REMOVAL OF SERINE PROTEASES BY TREATMENT WITH FINELY DIVIDED SILICON DIOXIDE

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority to AU Patent Application No. 2010202125, filed May 26, 2010 and issued as Australian Patent No. 2010202125, U.S. Patent Application Serial No. 12/789,365, filed May 27, 2010, and U.S. Patent Application Serial No. 12/842,944, filed July 23, 2010, the disclosures of which are hereby incorporated herein by reference in their entireties for all purposes.

BACKGROUND OF THE INVENTION

[0002] Plasma-derived blood products are used to treat not only a variety of blood disorders, but diseases of other origin. For example, immune globulin (IgG) products from human plasma were first used in 1952 to treat immune deficiency. Since then, IgG preparations have found widespread use in at least three main categories of medical conditions: (1) immune deficiencies such as X-linked agammaglobulinemia, hypogammaglobulinemia (primary immune deficiencies), and acquired compromised immunity conditions (secondary immune deficiencies), featuring low antibody levels; (2) inflammatory and autoimmune diseases; and (3) acute infections.

[0003] Likewise, Factor H has been implicated as a potential therapeutic agent for several human disease states, including age-related macular degeneration (AMD), hemolytic uremic syndrome (aHUS) and membranoproliferative glomerulonephritis (MPGN). Specifically, a causal relationship between the single nucleotide polymorphism (SNP) in complement control protein (CCP) module 7 of Factor H and age-related macular degeneration (AMD) has been characterized.

[0004] Studies have shown correlations between decreased plasma levels of Inter-alpha-Inhibitor proteins (IaIp) and mortality in patients with severe sepsis (Lim et al., J Infect Dis. (2003) Sep 15;188(6):919-26 and Opal et al., Crit Care Med. (2007) Feb;35(2):387-92). Furthermore, several studies have shown that the administration of IaIp reduces mortality associated with sepsis and septic shock (Jourdain et al., Am J Respir Crit Care Med. (1997)

Dec;156(6):1825-33; Yang et al., Crit Care Med. (2002) Mar;30(3):617-22; Lim et al., J Infect Dis. (2003) Sep 15;188(6):919-26; and Wu et al., Crit Care Med. (2004) Aug;32(8):1747-52; the disclosures of which are incorporated by reference herein in their entireties for all purposes).

[0005] Various safety precautions must be taken into consideration when manufacturing and formulating plasma-derived biologic therapies. These include methods for removing and/or inactivating blood borne pathogens (*e.g.*, viral and bacterial pathogens), anticomplement activity, and other unwanted contaminants arising from the use of donated plasma. Studies have suggested that administration of high levels of amidolytic activity may result in unwanted thromboembolic events (Wolberg AS *et al.*, Coagulation factor XI is a contaminant in intravenous immunoglobulin preparations. Am J Hematol 2000;65:30-34; and Alving BM *et al.*, Contact-activated factors: contaminants of immunoglobulins preparations with coagulant and vasoactive properties. J Lab Clin Med 1980; 96:334-346; the disclosures of which are hereby incorporated by reference in their entireties for all purposes). Highlighting this concern was the recent voluntary withdrawal of octagam® (Octapharma) in the US and suspension of marketing authorization for octagam® and octagam 10% by the European Commission following increased reports of thromboembolic events. It is likely that the increased thrombolic events were caused by high levels of amidolytic activity in the biologic, caused by serine protease and serine protease zymogen impurities, such as Factor XI, Factor XIa, Factor XII and Factor XIIa (FDA Notice: Voluntary Market Withdrawal – September 23, 2010 Octagam [Immune Globulin Intravenous (Human)] 5% Liquid Preparation; Octagam 50 mg/ml, solution pour perfusion - Octapharma France - Mise en quarantaine de tous les lots, published online September 9, 2010 by the AFSSAPS; and Questions and answers on the suspension of the marketing authorisations for Octagam (human normal immunoglobulin 5% and 10%), published online September 23, 2010 by the European Medicines Agency).

[0006] Dedicated serine proteases, generically known as coagulation factors, are integral components of both the contact activation and tissue factor pathways of the coagulation cascade. Upon a stimulus of the coagulation pathways, serine protease zymogens, which are inactive enzyme precursors, become activated proteases that catalyze the activation of the next protease zymogen, resulting in an activation cascade. This coagulation cascade culminates in the activation of Thrombin (Factor IIa) and Factor XIIIa, which function to convert Fibrinogen (Factor I) into Fibrin (Factor Ia) and cross-link fibrin to form a fibrin clot, respectively.

[0007] The contact activation pathway, also known as the intrinsic coagulation pathway, begins with the activation of Kallikrein and Factor XIIa (FXIIa) from Prekallikrein and Factor XII, respectively. The activated serine protease FXIIa cleaves Factor XI (FXI), converting the zymogen into Factor XIa (FXIa), an active serine protease which participates in the subsequent activation of Factor Xa (FXa).

[0008] Due to rising concerns over the presence of serine protease and serine protease zymogens in plasma-derived protein compositions, there remains a need in the art for methods for reducing the levels of these contaminants, and particularly FXI, FXIa, FXII, and FXIIa. The present invention fulfils these and other needs by providing such methods and plasma-derived protein compositions with reduced levels of serine protease and serine protease zymogen.

BRIEF SUMMARY OF THE INVENTION

[0009] In one aspect, the present invention is based on the surprising finding that serine proteases and serine protease zymogens, and specifically, FXI, FXIa, FXII, and FXIIa, can be removed from plasma-derived protein compositions by treatment with finely divided silicon dioxide (SiO_2). In this fashion the present invention provides methods for reducing the serine protease activity, serine protease content, and serine protease zymogen content of plasma-derived protein compositions. Also provided are therapeutic plasma-derived protein compositions having reduced serine protease activity, serine protease content, and serine protease zymogen content, as well as methods for treating or preventing disease by the administration of the same.

[0010] In a first aspect, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein composition, the method comprising the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO_2 from the composition to remove the bound serine protease. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), or Factor XII (FXII).

[0011] In certain embodiments, the method described above further comprises the step of performing a first target protein enrichment step to form a first enriched composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In one embodiment, the

first target protein enrichment step is a protein precipitation step. In a specific embodiment, the protein precipitation step is an alcohol fractionation step. In another embodiment, the first target protein enrichment step is an ultrafiltration/diafiltration step.

[0012] In other embodiments of the methods described above, the method further comprises the step of performing a second target protein enrichment step prior to contacting the enriched composition with finely divided silicon dioxide (SiO_2). In one embodiment, the second target protein enrichment step is a protein precipitation step. In a specific embodiment, the protein precipitation step is an alcohol fractionation step. In another embodiment, the second target protein enrichment step is an ultrafiltration/diafiltration step. In yet another embodiment, the second target protein enrichment step is a chromatographic enrichment step.

[0013] In other embodiments of the methods described above, the method further comprises the step of performing a third target protein enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2). In one embodiment, the third target protein enrichment step is a protein precipitation step. In a specific embodiment, the protein precipitation step is an alcohol fractionation step. In another embodiment, the third target protein enrichment step is an ultrafiltration/diafiltration step. In yet another embodiment, the third target protein enrichment step is a chromatographic enrichment step.

[0014] In certain embodiments of the methods described above, the chromatographic enrichment step comprises the sub-steps of: (i) contacting the plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind the plasma-derived target protein; and (ii) eluting the plasma-derived target protein from the chromatographic resin. In a specific embodiment, the impurity does not bind to the chromatographic resin in sub-step (i). In another specific embodiment, the impurity binds to the chromatographic resin in sub-step (i), but is not eluted from the chromatographic resin in sub-step (ii).

[0015] In other certain embodiments of the methods described above, the chromatographic enrichment step comprises the sub-steps of: (i) contacting the first enriched plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind at least one impurity; and (ii) separating the resin from the plasma-derived protein composition, wherein the plasma-derived target protein does not bind to the chromatographic resin in sub-step (i).

[0016] In certain embodiments of the methods comprising a chromatographic enrichment step described above, the chromatographic resin is selected from the group consisting of an anion exchange resin, a cation exchange resin, a hydrophobic interaction resin, a mixed mode resin, a hydroxyapatite resin, a ligand affinity resin, an immunoaffinity resin, and a size exclusion resin.

[0017] In other certain embodiments of the methods comprising a chromatographic enrichment step described above, the chromatographic enrichment step comprises separating at least one impurity from the target protein by size and/or shape using size exclusion chromatography.

[0018] In certain embodiments of the methods described above, the plasma-derived target protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI). In a specific embodiment, the protein of the complement system is selected from the group consisting of Factor H (FH), Factor D, complement protein C3, and C4 binding protein.

[0019] In yet another embodiment of the methods described above, the plasma-derived target protein composition is a manufacturing intermediate.

[0020] In a second aspect, the present invention provides a method for preparing a plasma-derived Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H and at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the composition; (c) eluting the serine protease or serine protease zymogen from the SiO_2 under a solution condition in which the Factor H remains bound; and (d) eluting the Factor H from the SiO_2.

[0021] In certain embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a pH greater than about 6.0. In another embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a pH greater than about 6.5. In another embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a pH greater than about 7.0. In yet another

embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a pH of at least about 7.5.

[0022] In certain embodiment of the methods described above, the solution condition comprises a pH of no more than 11.0. In another embodiment, the solution condition comprises a pH of no more than 10.0. In another embodiment, the solution condition comprises a pH of no more than 9.0.

[0023] In certain embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a conductivity of greater than about 10 mS/cm. In another embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a conductivity of greater than about 20 mS/cm. In another embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a conductivity of between about 10 mS/cm and about 50 mS/cm. In yet another embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and the Factor H remains bound comprises a conductivity between about 20 mS/cm and about 50 mS/cm.

[0024] In a third aspect, the present invention provides a method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H and at least one serine protease; (b) separating the SiO_2 from the composition; and (c) eluting the Factor H from the SiO_2 under conditions in which the serine protease or serine protease zymogen remains bound to the SiO_2.

[0025] In certain embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO_2 and the serine protease or serine protease zymogen remains bound comprises a pH greater than about 6.0. In another embodiment, the solution condition under which the Factor H is eluted from the SiO_2 and the serine protease or serine protease zymogen remains bound comprises a pH greater than about 6.5. In another embodiment, the solution condition under which the Factor H is eluted from the SiO_2 and the

serine protease or serine protease zymogen remains bound comprises a pH greater than about 7.0. In yet another embodiment, the solution condition under which the Factor H is eluted from the SiO_2 and the serine protease or serine protease zymogen remains bound comprises a pH of at least about 7.5.

[0026] In certain embodiment of the methods described above, the solution condition comprises a pH of no more than 11.0. In another embodiment, the solution condition comprises a pH of no more than 10.0. In another embodiment, the solution condition comprises a pH of no more than 9.0.

[0027] In certain embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO_2 and the serine protease or serine protease zymogen remains bound comprises a conductivity of less than about 20 mS/cm. In another embodiment, the solution condition under which the Factor H is eluted from the SiO_2 and the serine protease or serine protease zymogen remains bound comprises a conductivity of less than about 10 mS/cm. In another embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO_2 and the serine protease or serine protease zymogen remains bound comprises a conductivity between about 2 mS/cm and about 20 mS/cm. In yet another embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO_2 and the serine protease or serine protease zymogen remains bound comprises a conductivity between about 2 mS/cm and about 10 mS/cm.

[0028] In a fourth aspect, the present invention provides a method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H but not the at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the composition; and (c) eluting the Factor H from the SiO_2.

[0029] In certain embodiment of the methods described above, the solution condition under which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a pH greater than about 6.0. In another embodiment, the solution condition under which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a pH greater than about 6.5. In another embodiment, the solution condition under

which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a pH greater than about 7.0. In yet another embodiment, the solution condition under which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a pH of at least about 7.5.

[0030] In certain embodiment of the methods described above, the solution condition comprises a pH of no more than 11.0. In another embodiment, the solution condition comprises a pH of no more than 10.0. In another embodiment, the solution condition comprises a pH of no more than 9.0.

[0031] In certain embodiment of the methods described above, the solution condition under which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a conductivity of greater than about 10 mS/cm. In another embodiment of the methods described above, the solution condition under which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a conductivity of greater than about 20 mS/cm. In another embodiment of the methods described above, the solution condition under which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a conductivity between about 10 mS/cm and about 50 mS/cm. In yet another embodiment of the methods described above, the solution condition under which the Factor H binds to the SiO_2 and the serine protease or serine protease zymogen does not comprises a conductivity between about 20 mS/cm and about 50 mS/cm.

[0032] In a fifth aspect, the present invention provides a method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the at least one serine protease or serine protease zymogen but not the Factor H and (b) separating the SiO_2 from the composition.

[0033] In certain embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not comprises a pH greater than about 6.0. In another embodiment, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not comprises a pH greater than about 6.5. In another embodiment, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not

comprises a pH greater than about 7.0. In yet another embodiment, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not comprises a pH of at least about 7.5.

[0034] In certain embodiment of the methods described above, the solution condition comprises a pH of no more than 11.0. In another embodiment, the solution condition comprises a pH of no more than 10.0. In another embodiment, the solution condition comprises a pH of no more than 9.0.

[0035] In certain embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not comprises a conductivity of less than about 20 mS/cm. In another embodiment, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not comprises a conductivity of less than about 10 mS/cm. In another embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not comprises a conductivity between about 2 mS/cm and about 20 mS/cm. In yet another embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and the Factor H does not comprises a conductivity between about 2 mS/cm and about 10 mS/cm.

[0036] In a sixth aspect, the present invention provides a method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having reduced serine protease activity, the method comprising the steps of: (a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI and at least one serine protease; (b) separating the SiO_2 from the composition; (c) eluting the serine protease from the SiO_2 under conditions in which the IαI remains bound; and (d) eluting the IαI from the SiO_2.

[0037] In a seventh aspect, the present invention provides a method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having reduced serine protease activity, the method comprising the steps of: (a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI and at least one serine protease; (b) separating the SiO_2 from the composition; and (c) eluting the IαI from the SiO_2 under conditions in which the serine protease remains bound to the SiO_2.

[0038] In an eighth aspect, the present invention provides a method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having reduced serine protease activity, the method comprising the steps of: (a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI but not the least one serine protease; (b) separating the SiO_2 from the composition; and (c) eluting the IαI from the SiO_2.

[0039] In a ninth aspect, the present invention provides a method for preparing a inter-alpha-trypsin inhibitor (IαI) composition having reduced serine protease activity, the method comprising the steps of: (a) contacting a solution containing inter-alpha-trypsin inhibitor (IαI) and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the serine protease but not the inter-alpha-trypsin inhibitor (IαI); and (b) separating the SiO_2 from the composition.

[0040] In certain embodiments of the aspects described above, the composition is contacted with SiO_2 at a final concentration of at least 1 g SiO_2/g protein. In another embodiment of the aspects described above, the composition is contacted with SiO_2 at a final concentration of at least 2 g SiO_2/g protein. In another embodiment of the aspects described above, the composition is contacted with SiO_2 at a final concentration of at least 2.5 g SiO_2/g protein.

[0041] In certain embodiments of the aspects described above, the serine protease or serine protease zymogen is Factor XI. In another embodiment of the aspects described above, the serine protease or serine protease zymogen is Factor XIa. In another embodiment of the aspects described above, the serine protease or serine protease zymogen is Factor XII. In yet another embodiment of the aspects described above, the serine protease or serine protease zymogen is Factor XIIa.

[0042] In a tenth aspect, the present invention provides a plasma-derived protein composition prepared by a process comprising a method for reducing serine protease activity according to any one of the aspects described above. In one embodiment, the composition is formulated for administration to a subject. In a specific embodiment, the composition is formulated for intravenous, intramuscular, or subcutaneous administration. In one embodiment, the composition is aqueous. In another embodiment, the composition is lyophilized.

[0043] In an eleventh aspect, the present invention provides a method for treating a disease associated with aberrant activity of a plasma protein in a subject in need thereof, the method comprising administering a plasma-derived protein composition according to the aspect outlined above. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI).

[0044] In a twelfth aspect, the present invention provides a method for preparing a Factor H composition comprising the steps of (a) contacting a suspended plasma precipitate fraction containing Factor H with finely divided silicon dioxide (SiO_2), (b) washing the SiO_2 with a wash buffer comprising a low pH and a low conductivity, and (c) eluting Factor H from the SiO_2 with an elution buffer comprising a pH between 7.0 and 8.0 and a conductivity of at least 10 mS/cm. In specific embodiments, the plasma precipitate fraction containing Factor H is a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, or a Kistler/Nitschmann Precipitate B. In certain embodiments, the methods further comprises one or more additional steps selected from (d) precipitating and removing at least one impurity from the Factor H elution, (e) precipitating and recovering Factor H from the enriched composition, (f) further enriching Factor H by anion exchange chromatography, (g) further enriching Factor H by heparin affinity chromatography, (h) a dedicated viral inactivation step, and (i) concentrating the enriched Factor H composition by ultrafiltration/diafiltration.

[0045] In one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein composition, the method comprising the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO2 from the composition to remove the bound serine protease, wherein the at least one serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), or Factor XII (FXII).

[0046] In a specific embodiment of the methods described above, the method further comprises the step of performing a first target protein enrichment step to form a first enriched composition, prior to contacting the composition with finely divided silicon dioxide (SiO2). In one embodiment, the first target protein enrichment step is a protein precipitation step. In a

specific embodiment, the protein precipitation step is an alcohol fractionation step. In another specific embodiment, the first target protein enrichment step is an ultrafiltration/diafiltration step.

[0047] In a specific embodiment of the methods described above, the method further comprises the step of performing a second target protein enrichment step prior to contacting the enriched composition with finely divided silicon dioxide (SiO2). In one embodiment, the second target protein enrichment step is a protein precipitation step. In a specific embodiment, the protein precipitation step is an alcohol fractionation step. In one embodiment, the second target protein enrichment step is an ultrafiltration/diafiltration step. In one embodiment, the second target protein enrichment step is a chromatographic enrichment step.

[0048] In a specific embodiment of the methods described above, the method further comprises the step of performing a third target protein enrichment step after contacting the composition with finely divided silicon dioxide (SiO2). In one embodiment, the third target protein enrichment step is a protein precipitation step. In a specific embodiment, the protein precipitation step is an alcohol fractionation step. In one embodiment, the third target protein enrichment step is an ultrafiltration/diafiltration step. In one embodiment, the third target protein enrichment step is a chromatographic enrichment step.

[0049] In a specific embodiment of the methods described above, the chromatographic enrichment step comprises the sub-steps of: (i) contacting the plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind the plasma-derived target protein; and (ii) eluting the plasma-derived target protein from the chromatographic resin. In one specific embodiment, at least one impurity does not bind to the chromatographic resin in sub-step (i). In another specific embodiment, at least one impurity binds to the chromatographic resin in sub-step (i), but is not eluted from the chromatographic resin in sub-step (ii).

[0050] In a specific embodiment of the methods described above, the chromatographic enrichment step comprises the sub-steps of: (i) contacting the first enriched plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind at least one impurity; and (ii) separating the resin from the plasma-derived protein composition, wherein the plasma-derived target protein does not bind to the chromatographic resin in sub-step (i).

[0051] In a specific embodiment of the methods described above, the chromatographic resin is selected from the group consisting of an anion exchange resin, a cation exchange resin, a

hydrophobic interaction resin, a mixed mode resin, a hydroxyapatite resin, a ligand affinity resin, an immunoaffinity resin, and a size exclusion resin. In one embodiment, the chromatographic resin is an anion exchange resin. In one embodiment, the chromatographic resin is a cation exchange resin. In one embodiment, the chromatographic resin is a hydrophobic interaction resin. In one embodiment, the chromatographic resin is a mixed mode resin. In one embodiment, the chromatographic resin is a hydroxyapatite resin. In one embodiment, the chromatographic resin is a ligand affinity resin. In one embodiment, the chromatographic resin is an immunoaffinity resin. In one embodiment, the chromatographic enrichment step comprises separating at least one impurity from the target protein by size and/or shape using size exclusion chromatography.

[0052] In a specific embodiment of the methods described above, the plasma-derived target protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI). In one embodiment, the plasma-derived protein is an immunoglobulin (Ig). In one embodiment, the plasma-derived protein is albumin. In one embodiment, the plasma-derived protein is alpha-1-antitrypsin. In one embodiment, the plasma-derived protein is butyrylcholinesterase. In one embodiment, the plasma-derived protein is a protein of the complement system. In one embodiment, the protein of the complement system is selected from the group consisting of Factor H (FH), Factor D, complement protein C3, and C4 binding protein. In one embodiment, the plasma-derived protein is an inter-alpha-trypsin inhibitor.

[0053] In a specific embodiment of the methods described above, the plasma-derived target protein composition is a manufacturing intermediate.

[0054] In one embodiment, the present invention provides a method for preparing a plasma-derived Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO2) under conditions suitable to bind the Factor H and at least one serine protease or serine protease zymogen; (b) separating the SiO2 from the composition; (c) eluting the serine protease or serine protease zymogen from the SiO2 under a solution condition in which a substantial fraction of Factor H remains bound; and (d) eluting the Factor H from the SiO2.

[0055] In a specific embodiment of the methods described above, the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO2 comprises a pH below 7.0 and a conductivity of less than 11 mS/cm.

[0056] In a specific embodiment of the methods described above, the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO2 comprises a pH between 4.5 and 6.5 and a conductivity of less than 6 mS/cm.

[0057] In a specific embodiment of the methods described above, the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO2 comprises a pH between 4.5 and 6.5 and a conductivity between 0.5 mS/cm and 5 mS/cm.

[0058] In a specific embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO2 and a substantial fraction of the Factor H remains bound comprises a pH below 7.0 and a conductivity of less than 11 mS/cm.

[0059] In a specific embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO2 and a substantial fraction of the Factor H remains bound comprises a pH between 4.5 and 6.5 and a conductivity of less than 6 mS/cm.

[0060] In a specific embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO2 and a substantial fraction of the Factor H remains bound comprises a pH between 5.0 and 6.5 and a conductivity between 0.5 mS/cm and 5 mS/cm.

[0061] In a specific embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO2 comprises an ionic strength of at least 6 mS/cm.

[0062] In a specific embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO2 comprises an ionic strength of at least 11 mS/cm.

[0063] In a specific embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO2 comprises a pH between 5.0 and 7.0.

[0064] In a specific embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO2 comprises a pH between 7.0 and 8.0 and an ionic strength of between 4 mS/cm and 7 mS/cm.

[0065] In one embodiment, the present invention provides a method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO2) under conditions suitable to bind the Factor H and at least one serine protease; (b) separating the SiO2 from the composition; and (c) eluting the Factor H from the SiO2 under conditions in which a substantial fraction of the serine protease or serine protease zymogen remains bound to the SiO2.

[0066] In a specific embodiment of the methods described above, the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO2 comprises a pH below 7.0 and a conductivity of less than 11 mS/cm.

[0067] In a specific embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO2 and a substantial fraction of the Factor H remains bound comprises a pH between 4.5 and 6.5 and a conductivity of less than 6 mS/cm.

[0068] In a specific embodiment of the methods described above, the solution condition suitable to bind the Factor H and at least one serine protease or serine protease zymogen comprises a pH between 5.0 and 6.0 and a conductivity of between 0.5 mS/cm and 5.0 mS/cm.

[0069] In a specific embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO2 and a substantial fraction of the serine protease or serine protease zymogen remains bound comprises a pH between 5.0 and 7.0 and a conductivity of at least 11 mS/cm.

[0070] In a specific embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO2 and a substantial fraction of the serine protease or serine protease zymogen remains bound comprises a pH between 7.0 and 8.0 and a conductivity of between 2 mS/cm and 10 mS/cm.

[0071] In a specific embodiment of the methods described above, the conductivity of the solution condition is between 4 mS/cm and 7 mS/cm.

[0072] In a specific embodiment of the methods described above, the conductivity of the solution condition is between 5 mS/cm and 6 mS/cm.

[0073] In one embodiment, the present invention provides method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO2) under conditions suitable to bind the Factor H but not a substantial fraction of the at least one serine protease or serine protease zymogen; (b) separating the SiO2 from the composition; and

(c) eluting the Factor H from the SiO2.

[0074] In a specific embodiment of the methods described above, the solution condition under which the Factor H binds to the SiO2 and a substantial fraction of the serine protease or serine protease zymogen does not bind to the SiO2 comprises a pH of between 5.0 and 7.0 and a conductivity of no more than 14 mS/cm.

[0075] In a specific embodiment of the methods described above, the conductivity of the solution condition is between 9 mS/cm and 14 mS/cm.

[0076] In one embodiment, the present invention provides a method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO2) under conditions suitable to bind the at least one serine protease or serine protease zymogen but not a substantial fraction of the Factor H; and (b) separating the SiO2 from the composition.

[0077] In a specific embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to the SiO2 and a substantial fraction of the Factor H does not bind to the SiO2 comprises a pH between 5.0 and 7.0 and a conductivity of at least 11 mS/cm.

[0078] In a specific embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to the SiO2 and a substantial fraction of the Factor H does not bind to the SiO2 comprises a pH between 7.0 and 8.0 and a conductivity of between 2 mS/cm and 10 mS/cm.

[0079] In a specific embodiment of the methods described above, the conductivity of the solution condition is between 4 mS/cm and 7 mS/cm.

[0080] In a specific embodiment of the methods described above, the conductivity of the solution condition is between 5 mS/cm and 6 mS/cm.

[0081] In one embodiment, the present invention provides a method for preparing a Factor H composition, the method comprising the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO2) under conditions suitable to bind the Factor H; (b) washing the SiO2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm; and (c) eluting Factor H from the SiO2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm.

[0082] In a specific embodiment of the methods described above, the solution used to wash the SiO2 comprises a pH between 5.5 and 6.5.

[0083] In a specific embodiment of the methods described above, the solution used to wash the SiO2 comprises a pH between of 6.0±0.2.

[0084] In a specific embodiment of the methods described above, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm.

[0085] In a specific embodiment of the methods described above, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm.

[0086] In a specific embodiment of the methods described above, the starting composition containing Factor H is a suspended Cohn fraction II+III precipitate, or equivalent fraction thereof.

[0087] In a specific embodiment of the methods described above, the starting composition containing Factor H is a suspended Kistler/Nitschmann Precipitate A, or equivalent fraction thereof.

[0088] In a specific embodiment of the methods described above, the starting composition containing Factor H is a suspended Kistler/Nitschmann Precipitate B, or equivalent fraction thereof.

[0089] In a specific embodiment of the methods described above, the method further comprises the step of precipitating at least one impurity from the recovered Factor H solution, wherein Factor H is not precipitated.

[0090] In a specific embodiment of the methods described above, the precipitation step is PEG precipitation.

[0091] In a specific embodiment of the methods described above, the PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 3% and 7%.

[0092] In a specific embodiment of the methods described above, the final concentration of PEG 4000 is 5±0.5%.

[0093] In a specific embodiment of the methods described above, the method further comprises the step of precipitating Factor H from the recovered Factor H solution.

[0094] In a specific embodiment of the methods described above, the precipitation step is PEG precipitation.

[0095] In a specific embodiment of the methods described above, the PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 10% and 15%.

[0096] In a specific embodiment of the methods described above, the final concentration of PEG 4000 is 12±0.5%.

[0097] In a specific embodiment of the methods described above, the method further comprises a step of enriching Factor H by chromatography.

[0098] In a specific embodiment of the methods described above, the chromatographic enrichment step comprises anion exchange chromatography.

[0099] In a specific embodiment of the methods described above, the chromatographic enrichment step comprises heparin affinity chromatography.

[0100] In a specific embodiment of the methods described above, the chromatographic enrichment step comprises anion exchange chromatography followed by heparin affinity chromatography.

[0101] In a specific embodiment of the methods described above, the method further comprises at least one dedicated viral removal or inactivation step.

[0102] In a specific embodiment of the methods described above, the method comprises a nanofiltration step.

[0103] In a specific embodiment of the methods described above, the method further comprises a step of concentrating the Factor H composition comprising ultrafiltration/diafiltration.

[0104] In one embodiment, the present invention provides a method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO2) under conditions suitable to bind the IαI and at least one serine protease; (b) separating the SiO2 from the composition; (c) eluting the serine protease or serine protease zymogen from the SiO2 under conditions in which a substantial fraction of the IαI remains bound; and (d) eluting the IαI from the SiO2.

[0105] In one embodiment, the present invention provides a method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO2) under conditions suitable to bind the IαI and at least one serine protease; (b) separating the SiO2 from the composition; and (c) eluting the IαI from the SiO2 under conditions in which a substantial fraction of the serine protease or serine protease zymogen remains bound to the SiO2.

[0106] In one embodiment, the present invention provides a method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO2) under conditions suitable to bind the IαI but not a substantial fraction of the least one serine protease or

serine protease zymogen; (b) separating the SiO2 from the composition; and (c) eluting the IαI from the SiO2.

[0107] In one embodiment, the present invention provides a method for preparing a inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) contacting a solution containing inter-alpha-trypsin inhibitor (IαI) and at least one serine protease with finely divided silicon dioxide (SiO2) under conditions suitable to bind the serine protease or serine protease zymogen but not the inter-alpha-trypsin inhibitor (IαI); and (b) separating the SiO2 from the composition.

[0108] In one embodiment, the present invention provides a method for preparing an Immunoglobulin G (IgG) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of: (a) precipitating a cryo-poor plasmid fraction, in a first precipitation step, with between about 6% and about 10% alcohol at a pH of between about 7.0 and about 7.5 to obtain a first precipitate and a first supernatant; (b) precipitating IgG from the first supernatant, in a second precipitation step, with between about 20% and about 25% alcohol at a pH of between about 6.7 and about 7.3 to form a second precipitate; (c) re-suspending the second precipitate to form a suspension; (d) contacting the suspension with finely divided silicon dioxide (SiO2) under a solution condition suitable to bind a serine protease or serine protease zymogen; and (e) separating the SiO2 from the suspension to form a clarified suspension.

[0109] In a specific embodiment of the methods described above, the method further comprises the steps of: (f) precipitating IgG from the clarified suspension formed in step (e), in a third precipitation step, with between about 22% and about 28% alcohol at a pH of between about 6.7 and about 7.3 to form a third precipitate; (g) re-suspending the third precipitate to form a suspension; and (h) separating the soluble fraction from the suspension formed in step (e), thereby forming an enriched IgG composition.

[0110] In a specific embodiment of the methods described above, the method further comprises an anion exchange chromatography enrichment step.

[0111] In a specific embodiment of the methods described above, the method further comprises a cation exchange chromatography enrichment step.

[0112] In a specific embodiment of the methods described above, the method further comprises at least one dedicated viral inactivation or removal step.

[0113] In a specific embodiment of the methods described above, the method comprises a solvent/detergent (S/D) viral inactivation step.

[0114] In a specific embodiment of the methods described above, the method comprises a nanofiltration step.

[0115] In a specific embodiment of the methods described above, the method comprises an incubation step at low pH.

[0116] In a specific embodiment of the methods described above, step (b) comprises adjusting the ethanol concentration of the first supernatant formed in step (a) to about 25% (v/v) at a temperature between about -7°C and about -9°C.

[0117] In a specific embodiment of the methods described above, the temperature is about -9°C.

[0118] In a specific embodiment of the methods described above, step (c) comprises re-suspending the precipitate of step (b) with a buffer containing phosphate and acetate, wherein the pH of the buffer is adjusted with between 300 mL and 700 mL of glacial acetic acid per 1000 L of buffer.

[0119] In a specific embodiment of the methods described above, step (d) comprises the addition SiO2 to a final concentration of between about 0.02 grams per gram precipitate formed in step (b) and about 0.06 grams per gram precipitate formed in step (b).

[0120] In a specific embodiment of the methods described above, the solution condition suitable to bind a serine protease or serine protease zymogen comprises a pH between 4.5 and 6.0 and a conductivity of between 0.1 mS/cm and 3 mS/cm.

[0121] In a specific embodiment of the methods described above, the pH is between 4.9 and 5.3.

[0122] In a specific embodiment of the methods described above, the conductivity is between 0.5 mS/cm and 2 mS/cm.

[0123] In a specific embodiment of the methods described above, step (e) comprises the sub-steps of: (i) washing the filter press with at least 3 filter press dead volumes of a buffer containing phosphate and acetate, wherein the pH of the buffer is adjusted with between 50 mL and 200 mL of glacial acetic acid per 1000L of buffer, thereby forming a wash solution; and (ii) combining the filtrate of step (f) with the wash solution of step (g), thereby forming a solution.

[0124] In a specific embodiment of the methods described above, further comprising the sub-step of: (iii) treating the solution with a detergent.

[0125] In a specific embodiment of the methods described above, step (h) further comprises solvent and detergent (S/D) treatment of the enriched IgG composition.

[0126] In a specific embodiment of the methods described above, the enriched IgG composition obtained in step (h) contains at least 85% of the IgG content found in the cryo-poor plasma fraction used in step (a).

[0127] In a specific embodiment of the methods described above, the enriched IgG composition obtained in step (h) contains at least 90% of the IgG content found in the cryo-poor plasma fraction used in step (a).

[0128] In a specific embodiment of the methods described above, the amount of a serine protease or a serine protease zymogen has been reduced by at least 90%.

[0129] In a specific embodiment of the methods described above, the amount of a serine protease or a serine protease zymogen has been reduced by at least 95%.

[0130] In a specific embodiment of the methods described above, the amount of a serine protease or a serine protease zymogen has been reduced by at least 98%.

[0131] In a specific embodiment of the methods described above, the amount of a serine protease or a serine protease zymogen has been reduced by at least 99%.

[0132] In a specific embodiment of the methods described above, the serine protease or a serine protease zymogen is FXIa.

[0133] In a specific embodiment of the methods described above, the composition is contacted with SiO2 at a final concentration of at least 1 g SiO2/g protein.

[0134] In a specific embodiment of the methods described above, the composition is contacted with SiO2 at a final concentration of at least 2 g SiO2/g protein.

[0135] In a specific embodiment of the methods described above, the composition is contacted with SiO2 at a final concentration of at least 2.5 g SiO2/g protein.

[0136] In a specific embodiment of the methods described above, the serine protease or serine protease zymogen is Factor XI.

[0137] In a specific embodiment of the methods described above, the serine protease or serine protease zymogen is Factor XII.

[0138] In a specific embodiment of the methods described above, the serine protease or serine protease zymogen is Factor XIa.

[0139] In a specific embodiment of the methods described above, the serine protease or serine protease zymogen is Factor XIIa.

[0140] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a process comprising a method for reducing serine protease activity according to any one of the preceding claims.

[0141] In a specific embodiment of the compositions described above, the composition is formulated for administration to a subject.

[0142] In a specific embodiment of the compositions described above, the composition is formulated for intravenous, intramuscular, or subcutaneous administration.

[0143] In a specific embodiment of the compositions described above, the composition is aqueous.

[0144] In a specific embodiment of the compositions described above, the composition is lyophilized.

[0145] In one embodiment, the present invention provides a method for treating a disease associated with aberrant activity of a plasma protein in a subject in need thereof, the method comprising administering a plasma-derived protein composition according to any one of claims 124 to 128. In one embodiment, the composition comprises a plasma-derived protein is selected

from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI).

BRIEF DESCRIPTION OF THE DRAWINGS

[0146] **Figure 1.** Overview of an exemplary plasma fractionation scheme.

[0147] **Figure 2.** Factor H content in select fractions of an industrial-scale plasma protein fractionation, as measured by ELISA

[0148] **Figure 3.** Illustration of Factor H and amidolytic activity (as measured using substrate CS2166) eluted from SiO_2 under solution conditions with varying conductivities at pH 7.5.

DETAILED DESCRIPTION OF THE INVENTION

I. Introduction

[0149] Given the broad use of therapeutic plasma-derived blood protein compositions, such as immune globulin compositions, blood coagulation factors, coagulation factor inhibitors, and proteins of the complement system, ensuring the safety of these compositions is of paramount importance. Recent concerns over the amidolytic content of these compositions paired with the occurrence of thromboembolic events in patients being administered plasma-derived protein compositions, has highlighted a need in the art for method for reducing serine proteases (*e.g.*, FXIa and FXIIa) and serine protease zymogens (*e.g.*, FXI and FXII) during the manufacturing of these biologics. Advantageously, the present invention is based at least in part on the surprising finding that finely divided silicon dioxide (SiO_2) can be used to bind serine proteases and serine protease zymogens present in plasma-derived protein compositions. As such, methods are provided herein for reducing the concentration of serine proteases and serine protease zymogens during the manufacture of plasma-derived protein compositions.

[0150] In certain aspects, the present invention provides manufacturing methods based on the surprising finding that finely divided silicon dioxide (SiO_2) can be used to remove significant amounts of serine protease (*e.g.*, FXIa and FXIIa) and serine protease zymogen (*e.g.*, FXI and FXII) from plasma-derived protein solutions. As such, the methods provided herein may be easily integrated into existing manufacturing procedures, for example, the fractionation of pooled plasma samples, preferably human plasma samples, by ethanol in the cold (reviewed in Schultze

H E, Heremans J F; Molecular Biology of Human Proteins. Volume I: Nature and Metabolism of Extracellular Proteins 1966, Elsevier Publishing Company; p. 236-317). However, the methods provided herein are in no way limited in their use to manufacturing methods including ethanol fractionation. Other methodologies for the purification of plasma-derived proteins are also compatible with the methods provided herein, for example, polymer (*e.g.*, PEG) fractionation and chromatographic methodologies (*e.g.*, anion and/or cation exchange chromatography, affinity chromatography, immuno-affinity chromatography, size exclusion chromatography, hydrophobic interaction chromatography, mixed mode chromatography, and the like).

[0151] Furthermore, unlike other biologics that are produced via recombinant expression of DNA vectors in host cell lines, plasma-derived proteins are fractionated from human blood and plasma donations. Thus, the supply of these products cannot be increased by simply increasing the volume of production. Rather the level of commercially available blood products is limited by the available supply of blood and plasma donations. This dynamic results in a shortage in the availability of raw human plasma for the manufacture of new plasma-derived blood factors that have lesser established commercial markets, including Complement Factor H (CFH) and inter-alpha-trypsin inhibitor proteins (IαIp).

[0152] Due to the lack of plasma available for the manufacture of new plasma-derived products, their manufacture must be integrated into the existing framework of the established manufacturing processes for plasma-derived products such as immunoglobulins and albumin. Factor H, implicated as a potential therapeutic for AMD, aHUS, and MPGN, among other conditions, is one such plasma-derived blood product that is gaining the attention of physicians. However, due to the resources devoted to, for example, IgG gamma globulin manufacture, methods are needed for the manufacture of Factor H that can be introduced into the existing manufacturing schemes. Several methods have been suggested to achieve just this, however, many of these proposed solutions require modification of the existing manufacturing scheme for established products. Such changes will require new regulatory approvals for the established products and may even result in alterations of the characteristics of the established products.

[0153] For example, WO 2007/066017 describes methods for the production of Factor H preparations from the supernatant of a cryoprecipitate. The disclosed method consists of preparing a supernatant of a cryoprecipitate, submitting the supernatant to anion exchange chromatography (AEC), submitting the flow through from the AEC to heparin affinity

chromatography (HAC), submitting the relevant eluate from the HAC to strong cation exchange chromatography (CEC), submitting the relevant eluate from the CEC to strong anion exchange chromatography (sAEC) and eluting the Factor H from the sAEC. Disadvantageously, cryoprecipitate supernatants are common intermediate fractions in the manufacturing processes of many commercially important plasma-derived blood products, including IgG gamma globulins (IVIG and subcutaneous) and albumin. Submitting this fraction to chromatography steps will alter the cryoprecipitate supernatant and would require that the manufacturing processes of the established downstream blood products be adapted in unknown fashions. In addition to requiring a complete revalidation and possible redesign of these manufacturing processes, regulatory re-approval of the manufacturing procedures from key regulatory agencies is needed.

[0154] Likewise, WO 2008/113589 describes methods for the production of Factor H preparations from human plasma. Specifically, this publication describes the purification of Factor H from three known plasma processing fractions, namely a Cohn-Oncley Fraction I supernatant, a Cohn-Oncley Fraction III precipitate, and a Kistler/Nitschmann Precipitate B fraction. With respect to the first method, WO 2008/113589 discloses that Factor H can be removed from a Cohn-Oncley Fraction I supernatant by the addition of a heparin affinity chromatography step. Disadvantageously, the Cohn-Oncley Fraction I supernatant is a common intermediate fraction in the manufacturing processes of many commercially important plasma-derived blood products, including IgG gamma globulins (IVIG and subcutaneous) and albumin. Similarly, many immunoglobulin (e.g., IgG, IVIG, etc.) manufacturing processes do not rely on Cohn-Oncley Fraction III precipitation or Kistler/Nitschmann Precipitate B steps, for example Gammagard® Liquid and Kiovig (Baxter International Inc.). The disadvantage of the introduction of additional steps, such as a heparin affinity chromatography, Fraction III precipitation, or Precipitate B steps, into the manufacturing schemes of established blood products, as outlined above, is that it requires revalidation of the manufacturing procedure, regulatory re-approval of the manufacturing procedures from key regulatory agencies, and may further have unforeseen consequences for the yield and/or purity of the otherwise established product.

[0155] As such, a need remains in the art for methods of manufacturing Factor H that do not require the use of additional input plasma or the redesign and regulatory re-approval of existing manufacturing processes for commercially important plasma-derived blood products, such as

albumin and IgG gamma globulins for intravenous (IVIG) or subcutaneous administration. Advantageously, the present invention is based at least in part on the surprising discovery that Factor H, serine proteases, and serine protease zymogens can be simultaneously bound to finely divided silicon dioxide (SiO_2) thereby separating serine proteases and serine protease zymogen from a first protein of interest not bound to (*e.g.*, IgG) and then separated by differentially eluting Factor H and the serine protease and serine protease zymogens from the SiO_2. Similarly, the present invention is based at least in part on the surprising discovery that IαIp, serine proteases, and serine protease zymogens can be simultaneously bound to finely divided silicon dioxide (SiO_2) and then separated by differentially eluting IαIp and the serine protease and serine protease zymogens from the SiO_2.

II. Definitions

[0156] As used herein, "Factor H" refers to a protein component of the alternative pathway of complement encoded by the complement factor H gene (for example, CFH; NM000186; GeneID:3075; UniProt ID P08603; Ripoche et al., Biochem. J. 249:593-602(1988)). Factor H is translated as a 1,213 amino acid precursor polypeptide which is processed by removal of an 18 amino acid signal peptide, resulting in the mature Factor H protein (amino acids 19-1231). As used in the present invention, Factor H encompasses any natural variants, alternative sequences, isoforms or mutant proteins that can be found in a plasma sample, for example a human plasma sample. Examples of Factor H mutations found in the human population include, without limitation, Y402H; V62I; R78G; R127L; Δ224; Q400K; C431S; T493R; C536R; I551T; R567G; C630W; C673S; C673Y; E850K; S890I; H893R; C915S; E936D; Q950H; Y951H; T956M; C959Y; W978C; N997T; V1007I; V1007L; A1010T; T1017I; Y1021F; C1043R; N1050Y; I1059T; Q1076R; R1078S; D1119G; V1134G; Y1142D; Q1143E; W1157R; C1163W; W1183L; W1183R; T1184R; L1189R; S1191L; G1194D; V1197A; E1198A; F1199S; R1210C; R1215G; R1215Q; YPTCAKR1225:1231FQS; and P1226S. Many of the these mutations have been found to be associated with a variety of diseases and disorders, including, atypical haemolytic uremic syndrome (aHUS), age-related macular degeneration (AMD), membranoproliferative glomulonephritis type II (MPGNII), CFH deficiency, and basal laminar drusen. Factor H also includes proteins containing post-translational modifications. For example, Factor H is believed to be modified by N-acetylglucosamine (GlcNAc) at residues 529, 718, 802, 822, 882, 911, 1029, and 1095.

[0157] As used herein, "Inter-alpha-Inhibitor proteins" or "IaIp" refers to a family of plasma protease inhibitors comprised of polypeptides encoded by one or more of the Alpha-1-microglobulin/bikunin precursor gene (AMBP; UniGene ID:231948, bikunin polypeptide), Inter-alpha (globulin) inhibitor H1 gene (ITIH1; UniGene ID:224173, H1 polypeptide), Inter-alpha (globulin) inhibitor H2 gene (ITIH2; Unigene ID:139782, H2 polypeptide), Inter-alpha (globulin) inhibitor H3 gene (ITIH3; UniGene ID:140017, H3 polypeptide), or Inter-alpha (globulin) inhibitor H4 (plasma Kallikrein-sensitive glycoprotein, H4 polypeptide) gene (ITIH4; UniGene ID:3321613). Exemplary IaIp protease inhibitors include, without limitation, IaI (bikunin, H1, and H2 polypeptides); PaI (bikunin and H3 polypeptides), IaLI (bikunin and H2 polypeptides), IaIH4P (H4 polypeptide), and bikunin (Salier, J, et al., supra).

[0158] As used herein, "cryo-poor plasma" refers to the supernatant created after the removal of cryo-precipitate formed by thawing plasma or pooled plasma at temperatures near freezing, e.g., at temperatures below about 10°C, preferably at a temperature no higher than about 6°C. In the context of the present invention, plasma may refer interchangeably to recovered plasma (i.e., plasma that has been separated from whole blood ex vivo) or source plasma (i.e., plasma collected via plasmapheresis). Cryo-precipitation is commonly performed, for example, by thawing previously frozen pooled plasma, which has already been assayed for safety and quality considerations, although fresh plasma may also be used. After complete thawing of the frozen plasma at low temperature, separation of the solid cryo-precipitates from the liquid supernatant is performed in the cold (e.g., $\leq 6°C$) by centrifugation of filtration.

[0159] As used herein, a "Cohn pool" refers to the starting material used for the fractionation of a plasma sample or pool of plasma samples. Cohn pools include whole plasma, cryo-poor plasma samples, and pools of cryo-poor plasma samples that may or may not have been subjected to a pre-processing step. In certain embodiments, a Cohn pool is a cryo-poor plasma sample from which one or more blood factor have been removed in a pre-processing step, for example, adsorption onto a solid phase (e.g., aluminum hydroxide, finely divided silicon dioxide, etc.), or chromatographic step (e.g., ion exchange or heparin affinity chromatography). Various blood factors, including but not limited to Factor Eight Inhibitor Bypass Activity (FEIBA), Factor IX-complex, Factor VII-concentrate, or Antithrombin III-complex, may be isolated from the cryo-poor plasma sample to form a Cohn pool.

[0160] As used herein, a "Fraction II+III filter cake" refers to a solid phase recovered after the filtration or centrifugation of a Cohn-Oncley or equivalent Fraction II+III paste suspension. In a preferred embodiment, a Fraction II+III suspension will be treated with an adsorptive material, for example, finely divided silicon dioxide, to remove impurities such as lipids, fibrinogen, amidolytic activity, prekallikren activity, and lipoproteins. In another preferred embodiment, filter aid may be added to the Fraction II+III suspension prior to centrifugation or filtration. In a most preferred embodiment, a Fraction II+III suspension will be treated with both an adsorptive material and a filter aid prior to centrifugation or filtration. Upon separation of the clarified Fraction II+III suspension supernatant, the recovered solid phase material is referred to as the Fraction II+III filter cake.

[0161] As used herein, "finely divided silicon dioxide" or "finely divided silica" refers to an oxide of silicon having the formula SiO_2, manufactured in a fashion that allows for the adsorption of Factor H onto its surface. Exemplary forms of finely divided silicon dioxide suitable for use in the methods of the present invention include, without limitation, fumed silica, pyrogenic silica, Aerosil®, Cab-O-Sil™, colloidal silica, diatomaceous earth, and the like. In a preferred embodiment, a commercial hydrophilic fumed silica product is used for the methods provided herein. Non-limiting examples of these products include those marketed by Evonik Industries under the trade name Aerosil® (e.g., Aerosil 90, Aerosil 130, Aerosil 150, Aerosil 200, Aerosil 300, Aerosil 380, Aerosil OX 50, Aerosil EG 50, Aerosil TT 600, Aerosil 200 SP, Aerosil 300 SP, and Aerosil 300/30).

[0162] As used herein, a "disease or disorder associated with Factor H dysfunction" refers to any disease, disorder, or condition in a subject that is caused by, characterized by, or results in a reduced level of Factor H activity in the subject. For purposes of the present invention, Factor H activity may refer to the ability of Factor H to bind a protein or ligand, for example, C3b, C3bBb, C3b2Bb, csbC3b, complement factor B (CFB), C-reactive protein, endothelial cells, glycosaminoglycans (GAGs), or alternatively, may refer to its Factor I cofactor activity or its ability to accelerate the irreversible dissociation of C3bBb and C3b2Bb. In one embodiment, a disease or disorder associated with Factor H dysfunction results in a C3 deficiency and susceptibility to bacterial infections. In some instances, diseases or disorders associated with Factor H dysfunction include conditions that are caused by or linked to mutations and polymorphism in the CFH gene encoding Factor H (for review, see, Barlow et al., Adv Exp Med Biol. 2008;632:117-42, the disclosure of which is herein incorporated by reference in its entirety

for all purposes). Diseases that have been linked to mutations or polymorphisms in the CFH gene include, without limitation, Factor H deficiency, atypical haemolytic uremic syndrome (aHUS), age-related macular degeneration (AMD), membranoproliferative glomulonephritis type II (MPGNII; de Cordoba and de Jorge, Clinical and Experimental Immunology 151, 1–13 (2008)), myocardial infarction (Kardys et al., Journal of the American College of Cardiology 47, 1568–1575 (2006); Mooijaart et al., Experimental Gerontology 42, 1116–1122 (2007); Nicaud et al., Journal of Molecular Medicine 85, 771–775 (2007); Pai et al., European Heart Journal 28, 1297–1303 (2007); Stark et al., Clinical Science (Lond) 113, 213–218 (2007)), coronary heart disease/coronary artery disease (CAD/CHD; (Meng et al., BMC Medical Genetics 8, 62 (2007); Pulido et al., Mayo Clinic Proceedings 82, 301–307 (2007); Topol et al., Human Molecular Genetics 15 Spec No 2, R117–R123 (2006)), and Alzheimer's disease (Hamilton et al., Neuromolecular Medicine 9, 331–334 (2007); Zetterberg et al., American Journal of Ophthalmology 143, 1059–1060 (2007)). The disclosures of the forgoing references describing the associations between mutations and polymorphisms in the CFH gene and diseases associated with Factor H dysfunction are herein incorporated by reference in their entireties for all purposes.

[0163] As used herein, a "disease or disorder associated with abnormal alternative pathway complement activity" refers to a disease, disorder, or condition that results from uncontrolled or aberrant activation of the alternative pathway of complement. Generally, uncontrolled or aberrant activation of the alternative pathway of complement can result in bystander damage of host cells and tissues, as well as a depletion of C3 and corresponding susceptibility to pathogenic infections (e.g., fungal, bacterial, viral, and protistal). Examples of diseases and disorders associated with abnormal alternative pathway complement activity include, without limitation, various autoimmune diseases (such as rheumatoid arthritis, IgA nephropathy, asthma, systemic lupus erythematosus, multiple sclerosis, Anti-Phospholipid syndrome, ANCA-associated vasculitis, pemphigus, uveitis, myathemia gravis, Hashimoto's thyroiditis), Renal diseases (such as IgA nephropathy, hemolytic uremic syndrome, membranoproliferative glomerulonephritis) other disease such as asthma, Alzheimer disease, adult macular degeneration, proximal nocturnal hemoglobinuria, abdominal aortic aneurism, ischemia, and sepsis.

[0164] As used herein, the term "ultrafiltration (UF)" encompasses a variety of membrane filtration methods in which hydrostatic pressure forces a liquid against a semi-permeable membrane. Suspended solids and solutes of high molecular weight are retained, while water and

low molecular weight solutes pass through the membrane. This separation process is often used for purifying and concentrating macromolecular (10^3 - 10^6 Da) solutions, especially protein solutions. A number of ultrafiltration membranes are available depending on the size of the molecules they retain. Ultrafiltration is typically characterized by a membrane pore size between 1 and 1000 kDa and operating pressures between 0.01 and 10 bar.

[0165] As used herein, the term "diafiltration" is performed with the same or a similar membrane as ultrafiltration and is typically performed in a tangential flow filtration mode. During diafiltration, buffer is introduced into the recycle tank while filtrate is removed from the unit operation. In processes where the product is in the retentate (for example, Factor H), diafiltration is particularly useful for separating protein from small molecules like sugars and salts. In certain cases, diafiltration can be used to exchange the solution, buffer, or individual components of a buffering system.

[0166] As used herein, the term "mixing" describes an act of causing equal distribution of two or more distinct compounds or substances in a solution or suspension by any form of agitation. Complete equal distribution of all ingredients in a solution or suspension is not required as a result of "mixing" as the term is used in this application.

[0167] As used herein, the term "solvent" encompasses any liquid substance capable of dissolving or dispersing one or more other substances. A solvent may be inorganic in nature, such as water, or it may be an organic liquid, such as ethanol, acetone, methyl acetate, ethyl acetate, hexane, petrol ether, etc. As used in the term "solvent detergent treatment," solvent denotes an organic solvent (e.g., tri-N-butyl phosphate), which is part of the solvent detergent mixture used to inactivate lipid-enveloped viruses in solution.

[0168] As used herein, the term "detergent" is used in this application interchangeably with the term "surfactant" or "surface acting agent." Surfactants are typically organic compounds that are amphiphilic, i.e., containing both hydrophobic groups ("tails") and hydrophilic groups ("heads"), which render surfactants soluble in both organic solvents and water. A surfactant can be classified by the presence of formally charged groups in its head. A non-ionic surfactant has no charge groups in its head, whereas an ionic surfactant carries a net charge in its head. A zwitterionic surfactant contains a head with two oppositely charged groups. Some examples of common surfactants include: Anionic (based on sulfate, sulfonate or carboxylate anions): perfluorooctanoate (PFOA or PFO), perfluorooctanesulfonate (PFOS), sodium dodecyl sulfate

(SDS), ammonium lauryl sulfate, and other alkyl sulfate salts, sodium laureth sulfate (also known as sodium lauryl ether sulfate, or SLES), alkyl benzene sulfonate; cationic (based on quaternary ammonium cations): cetyl trimethylammonium bromide (CTAB) a.k.a. hexadecyl trimethyl ammonium bromide, and other alkyltrimethylammonium salts, cetylpyridinium chloride (CPC), polyethoxylated tallow amine (POEA), benzalkonium chloride (BAC), benzethonium chloride (BZT); Long chain fatty acids and their salts: including caprylate, caprylic acid, heptanoat, hexanoic acid, heptanoic acid, nanoic acid, decanoic acid, and the like; Zwitterionic (amphoteric): dodecyl betaine; cocamidopropyl betaine; coco ampho glycinate; nonionic: alkyl poly(ethylene oxide), alkylphenol poly(ethylene oxide), copolymers of poly(ethylene oxide) and poly(propylene oxide) (commercially known as Poloxamers or Poloxamines), alkyl polyglucosides, including octyl glucoside, decyl maltoside, fatty alcohols (e.g., cetyl alcohol and oleyl alcohol), cocamide MEA, cocamide DEA, polysorbates (Tween 20, Tween 80, etc.), Triton detergents, and dodecyl dimethylamine oxide.

[0169] As used herein, the term "therapeutically effective amount or dose" or "sufficient/effective amount or dose," refers to a dose that produces effects for which it is administered. The exact dose will depend on the purpose of the treatment, and will be ascertainable by one skilled in the art using known techniques (see, e.g., Lieberman, Pharmaceutical Dosage Forms (vols. 1-3, 1992); Lloyd, The Art, Science and Technology of Pharmaceutical Compounding (1999); Pickar, Dosage Calculations (1999); and Remington: The Science and Practice of Pharmacy, 20th Edition, 2003, Gennaro, Ed., Lippincott, Williams & Wilkins; the disclosures of which are herein incorporated by reference in their entireties for all purposes).

[0170] As used in this application, the term "spraying" refers to a means of delivering a liquid substance into a system, e.g., during an alcohol precipitation step, such as a Cohn fractionation I or II+III precipitation step, in the form of fine droplets or mist of the liquid substance. Spraying may be achieved by any pressurized device, such as a container (e.g., a spray bottle), that has a spray head or a nozzle and is operated manually or automatically to generate a fine mist from a liquid. Typically, spraying is performed while the system receiving the liquid substance is continuously stirred or otherwise mixed to ensure rapid and equal distribution of the liquid within the system.

[0171] As used herein, the term "about" denotes an approximate range of plus or minus 10% from a specified value. For instance, the language "about 20%" encompasses a range of 18-22%. As used herein, about also includes the exact amount. Hence "about 20%" means "about 20%" and also "20%." As used herein, "about" refers to a range of at or about the specified value.

[0172] The terms "dose" and "dosage" are used interchangeably herein. A dose refers to the amount of active ingredient given to an individual at each administration. The dose will vary depending on a number of factors, including frequency of administration; size and tolerance of the individual; severity of the condition; risk of side effects; and the route of administration. One of skill in the art will recognize that the dose can be modified depending on the above factors or based on therapeutic progress. The term "dosage form" refers to the particular format of the pharmaceutical, and depends on the route of administration. For example, a dosage form can be in a liquid, *e.g.*, a saline solution for injection.

[0173] As used herein, the term "prevent" refers to a decreased likelihood or reduced frequency of symptoms arising from a condition associated with the lack of function or disfunction of a blood protein.

[0174] As used herein, the term "therapy," "treatment," and "amelioration" refer to any reduction in the severity of symptoms arising from a condition associated with the lack of function or disfunction of a blood protein. As used herein, the terms "treat" and "prevent" are not intended to be absolute terms. Treatment can refer to any delay in onset, amelioration of symptoms, improvement in patient survival, increase in survival time or rate, *etc*. The effect of treatment can be compared to an individual or pool of individuals not receiving the treatment.

[0175] As used herein, the term "substantial fraction" refers to at least 10% of the population of a particular protein in a composition. For example, when referring to a substantial fraction of a serine protease in a composition, a substantial fraction of the serine protease corresponds to at least 10% of the serine protease present in the composition. In one embodiment, a substantial fraction refers to at least 25% of the population of a particular protein in a composition. In another embodiment, a substantial fraction refers to at least 50% of the population of a particular protein in a composition. In another embodiment, a substantial fraction refers to at least 75% of the population of a particular protein in a composition. In yet other embodiments, a substantial fraction refers to at least 10% of the population of a particular protein in a composition, or at

least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the population of a particular protein in a composition.

III. Reduction of Serine Protease and Serine Protease Zymogen Content

[0176] In a first aspect, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein composition by binding the serine protease and/or serine protease zymogen to finely divided silicon dioxide (SiO_2) and separating the SiO_2 from the composition.

[0177] In one embodiment, the method comprises the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII).

[0178] Accordingly, in one embodiment, the invention provides a method for reducing the amount of Factor XI in a plasma-derived protein composition, the method comprising the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind Factor XI; and (b) separating the SiO_2 from the composition to remove the bound Factor XI.

[0179] In another embodiment, the invention provides a method for reducing the amount of Factor XIa in a plasma-derived protein composition, the method comprising the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind Factor XIa; and (b) separating the SiO_2 from the composition to remove the bound Factor XIa.

[0180] In another embodiment, the invention provides a method for reducing the amount of Factor XII in a plasma-derived protein composition, the method comprising the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind Factor XII; and (b) separating the SiO_2 from the composition to remove the bound Factor XII.

[0181] In yet another embodiment, the invention provides a method for reducing the amount of Factor XIIa in a plasma-derived protein composition, the method comprising the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind Factor XIIa; and (b) separating the SiO_2 from the composition to remove the bound Factor XIIa.

[0182] In certain embodiments, the method described above further comprises the step of performing a first target protein enrichment step to form a first enriched composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first target protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0183] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein the method comprises the steps of: (a) forming a first enriched plasma-derived target protein composition by partially precipitating protein in a starting material derived from pooled plasma; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In one embodiment, the partial precipitation is achieved using alcohol. In a preferred embodiment, the alcohol is ethanol. In another preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII).

[0184] In another embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein the method comprises the steps of: (a) forming a first enriched plasma-derived target protein composition by ultrafiltering and/or diafiltering a starting material derived from pooled plasma; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII).

[0185] In yet another embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein the method comprises the steps of: (a) forming a first enriched plasma-derived target protein composition by contacting a starting material derived from pooled plasma with a chromatographic resin; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In certain embodiments, the chromatographic resin is selected from an anion exchange resin, a cation exchange resin, a hydrophobic interaction resin, a mixed mode resin, a hydroxyapatite resin, a ligand affinity resin, an immunoaffinity resin, and a size exclusion resin. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII).

[0186] In certain embodiments, the methods described above further comprises the step of performing a second target protein enrichment step to form a second enriched composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first target protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0187] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein the method comprises the steps of: (a) performing a first target protein enrichment step to form a first enriched plasma-derived target protein composition; (b) performing a second target protein enrichment step to form a second enriched plasma-derived target protein composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

Table 1. Exemplary embodiments for the combination of first and second enrichment steps.

		First Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Second Enrichment Step	Ppt	Var. 1	Var. 11	Var. 21	Var. 31	Var. 41	Var. 51	Var. 61	Var. 71	Var. 81	Var. 91
	UF/DF	Var. 2	Var. 12	Var. 22	Var. 32	Var. 42	Var. 52	Var. 62	Var. 72	Var. 82	Var. 92
	AEC	Var. 3	Var. 13	Var. 23	Var. 33	Var. 43	Var. 53	Var. 63	Var. 73	Var. 83	Var. 93
	CEC	Var. 4	Var. 14	Var. 24	Var. 34	Var. 44	Var. 54	Var. 64	Var. 74	Var. 84	Var. 94
	HIC	Var. 5	Var. 15	Var. 25	Var. 35	Var. 45	Var. 55	Var. 65	Var. 75	Var. 85	Var. 95
	HAC	Var. 6	Var. 16	Var. 26	Var. 36	Var. 46	Var. 56	Var. 66	Var. 76	Var. 86	Var. 96
	MMC	Var. 7	Var. 17	Var. 27	Var. 37	Var. 47	Var. 57	Var. 67	Var. 77	Var. 87	Var. 97
	LAC	Var. 8	Var. 18	Var. 28	Var. 38	Var. 48	Var. 58	Var. 68	Var. 78	Var. 88	Var. 98
	IAC	Var. 9	Var. 19	Var. 29	Var. 39	Var. 49	Var. 59	Var. 69	Var. 79	Var. 89	Var. 99
	SEC	Var. 10	Var. 20	Var. 30	Var. 40	Var. 50	Var. 60	Var. 70	Var. 80	Var. 90	Var. 100

* Ppt: Precipitation
UF/DF: Ultrafiltration/Diafiltration
AEC: Anion Exchange Chromatography
CEC: Cation Exchange Chromatography
HIC: Hydrophobic Interaction Chromatography
HAC: Hydroxyapatite Chromatography
MMC: Mixed Mode Chromatography
LAC: Ligand Affinity Chromatography
IAC: Immuno-Affinity Chromatography
SEC: Size Exclusion Chromatography

[0188] In certain embodiments, the methods described above further comprises the step of performing a target protein enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the target protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0189] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein the method comprises the steps of: (a) performing a first target protein enrichment step to form a first enriched plasma-derived target protein composition; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (c) separating the SiO_2 from the composition to

remove the bound serine protease or serine protease zymogen; and (d) performing a second target protein enrichment step to form a second enriched plasma-derived target protein composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0190] Likewise, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein the method comprises the steps of: (a) performing a first target protein enrichment step to form a first enriched plasma-derived target protein composition; (b) performing a second target protein enrichment step to form a second enriched plasma-derived target protein composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (e) performing a third target protein enrichment step to form a third enriched plasma-derived target protein composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 101 to Var. 1100, found in Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, or Table 11.

Table 2. Exemplary embodiments for the combination of a first precipitation enrichment step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment Step	Ppt	Var. 101	Var. 111	Var. 121	Var. 131	Var. 141	Var. 151	Var. 161	Var. 171	Var. 181	Var. 191
	UF/DF	Var. 102	Var. 112	Var. 122	Var. 132	Var. 142	Var. 152	Var. 162	Var. 172	Var. 182	Var. 192
	AEC	Var. 103	Var. 113	Var. 123	Var. 133	Var. 143	Var. 153	Var. 163	Var. 173	Var. 183	Var. 193
	CEC	Var. 104	Var. 114	Var. 124	Var. 134	Var. 144	Var. 154	Var. 164	Var. 174	Var. 184	Var. 194
	HIC	Var. 105	Var. 115	Var. 125	Var. 135	Var. 145	Var. 155	Var. 165	Var. 175	Var. 185	Var. 195
	HAC	Var. 106	Var. 116	Var. 126	Var. 136	Var. 146	Var. 156	Var. 166	Var. 176	Var. 186	Var. 196

	MMC	Var. 107	Var. 117	Var. 127	Var. 137	Var. 147	Var. 157	Var. 167	Var. 177	Var. 187	Var. 197
	LAC	Var. 108	Var. 118	Var. 128	Var. 138	Var. 148	Var. 158	Var. 168	Var. 178	Var. 188	Var. 198
	IAC	Var. 109	Var. 119	Var. 129	Var. 139	Var. 149	Var. 159	Var. 169	Var. 179	Var. 189	Var. 199
	SEC	Var. 110	Var. 120	Var. 130	Var. 140	Var. 150	Var. 160	Var. 170	Var. 180	Var. 190	Var. 200

* As per Table 1.

Table 3. Exemplary embodiments for the combination of a first Ultrafiltration/Diafiltration step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment Step	Ppt	Var. 201	Var. 211	Var. 221	Var. 231	Var. 241	Var. 251	Var. 261	Var. 271	Var. 281	Var. 291
	UF/DF	Var. 202	Var. 212	Var. 222	Var. 232	Var. 242	Var. 252	Var. 262	Var. 272	Var. 282	Var. 292
	AEC	Var. 203	Var. 213	Var. 223	Var. 233	Var. 243	Var. 253	Var. 263	Var. 273	Var. 283	Var. 293
	CEC	Var. 204	Var. 214	Var. 224	Var. 234	Var. 244	Var. 254	Var. 264	Var. 274	Var. 284	Var. 294
	HIC	Var. 205	Var. 215	Var. 225	Var. 235	Var. 245	Var. 255	Var. 265	Var. 275	Var. 285	Var. 295
	HAC	Var. 206	Var. 216	Var. 226	Var. 236	Var. 246	Var. 256	Var. 266	Var. 276	Var. 286	Var. 296
	MMC	Var. 207	Var. 217	Var. 227	Var. 237	Var. 247	Var. 257	Var. 267	Var. 277	Var. 287	Var. 297
	LAC	Var. 208	Var. 218	Var. 228	Var. 238	Var. 248	Var. 258	Var. 268	Var. 278	Var. 288	Var. 298
	IAC	Var. 209	Var. 219	Var. 229	Var. 239	Var. 249	Var. 259	Var. 269	Var. 279	Var. 289	Var. 299
	SEC	Var. 210	Var. 220	Var. 230	Var. 240	Var. 250	Var. 260	Var. 270	Var. 280	Var. 290	Var. 300

* As per Table 1.

Table 4. Exemplary embodiments for the combination of a first Anion Exchange Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment Step	Ppt	Var. 301	Var. 311	Var. 321	Var. 331	Var. 341	Var. 351	Var. 361	Var. 371	Var. 381	Var. 391
	UF/DF	Var. 302	Var. 312	Var. 322	Var. 332	Var. 342	Var. 352	Var. 362	Var. 372	Var. 382	Var. 392
	AEC	Var. 303	Var. 313	Var. 323	Var. 333	Var. 343	Var. 353	Var. 363	Var. 373	Var. 383	Var. 393
	CEC	Var. 304	Var. 314	Var. 324	Var. 334	Var. 344	Var. 354	Var. 364	Var. 374	Var. 384	Var. 394
	HIC	Var. 305	Var. 315	Var. 325	Var. 335	Var. 345	Var. 355	Var. 365	Var. 375	Var. 385	Var. 395

	HAC	Var. 306	Var. 316	Var. 326	Var. 336	Var. 346	Var. 356	Var. 366	Var. 376	Var. 386	Var. 396
	MMC	Var. 307	Var. 317	Var. 327	Var. 337	Var. 347	Var. 357	Var. 367	Var. 377	Var. 387	Var. 397
	LAC	Var. 308	Var. 318	Var. 328	Var. 338	Var. 348	Var. 358	Var. 368	Var. 378	Var. 388	Var. 398
	IAC	Var. 309	Var. 319	Var. 329	Var. 339	Var. 349	Var. 359	Var. 369	Var. 379	Var. 389	Var. 399
	SEC	Var. 310	Var. 320	Var. 330	Var. 340	Var. 350	Var. 360	Var. 370	Var. 380	Var. 390	Var. 400

* As per Table 1.

Table 5. Exemplary embodiments for the combination of a first Cation Exchange Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment Step	Ppt	Var. 401	Var. 411	Var. 421	Var. 431	Var. 441	Var. 451	Var. 461	Var. 471	Var. 481	Var. 491
	UF/DF	Var. 402	Var. 412	Var. 422	Var. 432	Var. 442	Var. 452	Var. 462	Var. 472	Var. 482	Var. 492
	AEC	Var. 403	Var. 413	Var. 423	Var. 433	Var. 443	Var. 453	Var. 463	Var. 473	Var. 483	Var. 493
	CEC	Var. 404	Var. 414	Var. 424	Var. 434	Var. 444	Var. 454	Var. 464	Var. 474	Var. 484	Var. 494
	HIC	Var. 405	Var. 415	Var. 425	Var. 435	Var. 445	Var. 455	Var. 465	Var. 475	Var. 485	Var. 495
	HAC	Var. 406	Var. 416	Var. 426	Var. 436	Var. 446	Var. 456	Var. 466	Var. 476	Var. 486	Var. 496
	MMC	Var. 407	Var. 417	Var. 427	Var. 437	Var. 447	Var. 457	Var. 467	Var. 477	Var. 487	Var. 497
	LAC	Var. 408	Var. 418	Var. 428	Var. 438	Var. 448	Var. 458	Var. 468	Var. 478	Var. 488	Var. 498
	IAC	Var. 409	Var. 419	Var. 429	Var. 439	Var. 449	Var. 459	Var. 469	Var. 479	Var. 489	Var. 499
	SEC	Var. 410	Var. 420	Var. 430	Var. 440	Var. 450	Var. 460	Var. 470	Var. 480	Var. 490	Var. 500

* As per Table 1.

Table 6. Exemplary embodiments for the combination of a first Hydrophobic Interaction Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment	Ppt	Var. 501	Var. 511	Var. 521	Var. 531	Var. 541	Var. 551	Var. 561	Var. 571	Var. 581	Var. 591
	UF/DF	Var. 502	Var. 512	Var. 522	Var. 532	Var. 542	Var. 552	Var. 562	Var. 572	Var. 582	Var. 592
	AEC	Var. 503	Var. 513	Var. 523	Var. 533	Var. 543	Var. 553	Var. 563	Var. 573	Var. 583	Var. 593
	CEC	Var. 504	Var. 514	Var. 524	Var. 534	Var. 544	Var. 554	Var. 564	Var. 574	Var. 584	Var. 594

	HIC	Var. 505	Var. 515	Var. 525	Var. 535	Var. 545	Var. 555	Var. 565	Var. 575	Var. 585	Var. 595
	HAC	Var. 506	Var. 516	Var. 526	Var. 536	Var. 546	Var. 556	Var. 566	Var. 576	Var. 586	Var. 596
	MMC	Var. 507	Var. 517	Var. 527	Var. 537	Var. 547	Var. 557	Var. 567	Var. 577	Var. 587	Var. 597
	LAC	Var. 508	Var. 518	Var. 528	Var. 538	Var. 548	Var. 558	Var. 568	Var. 578	Var. 588	Var. 598
	IAC	Var. 509	Var. 519	Var. 529	Var. 539	Var. 549	Var. 559	Var. 569	Var. 579	Var. 589	Var. 599
	SEC	Var. 510	Var. 520	Var. 530	Var. 540	Var. 550	Var. 560	Var. 570	Var. 580	Var. 590	Var. 600

* As per Table 1.

Table 7. Exemplary embodiments for the combination of a first Hydroxyapatite Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment Step	Ppt	Var. 601	Var. 611	Var. 621	Var. 631	Var. 641	Var. 651	Var. 661	Var. 671	Var. 681	Var. 691
	UF/DF	Var. 602	Var. 612	Var. 622	Var. 632	Var. 642	Var. 652	Var. 662	Var. 672	Var. 682	Var. 692
	AEC	Var. 603	Var. 613	Var. 623	Var. 633	Var. 643	Var. 653	Var. 663	Var. 673	Var. 683	Var. 693
	CEC	Var. 604	Var. 614	Var. 624	Var. 634	Var. 644	Var. 654	Var. 664	Var. 674	Var. 684	Var. 694
	HIC	Var. 605	Var. 615	Var. 625	Var. 635	Var. 645	Var. 655	Var. 665	Var. 675	Var. 685	Var. 695
	HAC	Var. 606	Var. 616	Var. 626	Var. 636	Var. 646	Var. 656	Var. 666	Var. 676	Var. 686	Var. 696
	MMC	Var. 607	Var. 617	Var. 627	Var. 637	Var. 647	Var. 657	Var. 667	Var. 677	Var. 687	Var. 697
	LAC	Var. 608	Var. 618	Var. 628	Var. 638	Var. 648	Var. 658	Var. 668	Var. 678	Var. 688	Var. 698
	IAC	Var. 609	Var. 619	Var. 629	Var. 639	Var. 649	Var. 659	Var. 669	Var. 679	Var. 689	Var. 699
	SEC	Var. 610	Var. 620	Var. 630	Var. 640	Var. 650	Var. 660	Var. 670	Var. 680	Var. 690	Var. 700

* As per Table 1.

Table 8. Exemplary embodiments for the combination of a first Mixed Mode Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichmen	Ppt	Var. 701	Var. 711	Var. 721	Var. 731	Var. 741	Var. 751	Var. 761	Var. 771	Var. 781	Var. 791
	UF/DF	Var. 702	Var. 712	Var. 722	Var. 732	Var. 742	Var. 752	Var. 762	Var. 772	Var. 782	Var. 792
	AEC	Var. 703	Var. 713	Var. 723	Var. 733	Var. 743	Var. 753	Var. 763	Var. 773	Var. 783	Var. 793

	CEC	Var. 704	Var. 714	Var. 724	Var. 734	Var. 744	Var. 754	Var. 764	Var. 774	Var. 784	Var. 794
	HIC	Var. 705	Var. 715	Var. 725	Var. 735	Var. 745	Var. 755	Var. 765	Var. 775	Var. 785	Var. 795
	HAC	Var. 706	Var. 716	Var. 726	Var. 736	Var. 746	Var. 756	Var. 766	Var. 776	Var. 786	Var. 796
	MMC	Var. 707	Var. 717	Var. 727	Var. 737	Var. 747	Var. 757	Var. 767	Var. 777	Var. 787	Var. 797
	LAC	Var. 708	Var. 718	Var. 728	Var. 738	Var. 748	Var. 758	Var. 768	Var. 778	Var. 788	Var. 798
	IAC	Var. 709	Var. 719	Var. 729	Var. 739	Var. 749	Var. 759	Var. 769	Var. 779	Var. 789	Var. 799
	SEC	Var. 710	Var. 720	Var. 730	Var. 740	Var. 750	Var. 760	Var. 770	Var. 780	Var. 790	Var. 800

* As per Table 1.

Table 9. Exemplary embodiments for the combination of a first Ligand Affinity Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment Step	Ppt	Var. 801	Var. 811	Var. 821	Var. 831	Var. 841	Var. 851	Var. 861	Var. 871	Var. 881	Var. 891
	UF/DF	Var. 802	Var. 812	Var. 822	Var. 832	Var. 842	Var. 852	Var. 862	Var. 872	Var. 882	Var. 892
	AEC	Var. 803	Var. 813	Var. 823	Var. 833	Var. 843	Var. 853	Var. 863	Var. 873	Var. 883	Var. 893
	CEC	Var. 804	Var. 814	Var. 824	Var. 834	Var. 844	Var. 854	Var. 864	Var. 874	Var. 884	Var. 894
	HIC	Var. 805	Var. 815	Var. 825	Var. 835	Var. 845	Var. 855	Var. 865	Var. 875	Var. 885	Var. 895
	HAC	Var. 806	Var. 816	Var. 826	Var. 836	Var. 846	Var. 856	Var. 866	Var. 876	Var. 886	Var. 896
	MMC	Var. 807	Var. 817	Var. 827	Var. 837	Var. 847	Var. 857	Var. 867	Var. 877	Var. 887	Var. 897
	LAC	Var. 808	Var. 818	Var. 828	Var. 838	Var. 848	Var. 858	Var. 868	Var. 878	Var. 888	Var. 898
	IAC	Var. 809	Var. 819	Var. 829	Var. 839	Var. 849	Var. 859	Var. 869	Var. 879	Var. 889	Var. 899
	SEC	Var. 810	Var. 820	Var. 830	Var. 840	Var. 850	Var. 860	Var. 870	Var. 880	Var. 890	Var. 900

* As per Table 1.

Table 10. Exemplary embodiments for the combination of a first Immuno-Affinity Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Enrichment	Ppt	Var. 901	Var. 911	Var. 921	Var. 931	Var. 941	Var. 951	Var. 961	Var. 971	Var. 981	Var. 991
	UF/DF	Var. 902	Var. 912	Var. 922	Var. 932	Var. 942	Var. 952	Var. 962	Var. 972	Var. 982	Var. 992

	AEC	Var. 903	Var. 913	Var. 923	Var. 933	Var. 943	Var. 953	Var. 963	Var. 973	Var. 983	Var. 993
	CEC	Var. 904	Var. 914	Var. 924	Var. 934	Var. 944	Var. 954	Var. 964	Var. 974	Var. 984	Var. 994
	HIC	Var. 905	Var. 915	Var. 925	Var. 935	Var. 945	Var. 955	Var. 965	Var. 975	Var. 985	Var. 995
	HAC	Var. 906	Var. 916	Var. 926	Var. 936	Var. 946	Var. 956	Var. 966	Var. 976	Var. 986	Var. 996
	MMC	Var. 907	Var. 917	Var. 927	Var. 937	Var. 947	Var. 957	Var. 967	Var. 977	Var. 987	Var. 997
	LAC	Var. 908	Var. 918	Var. 928	Var. 938	Var. 948	Var. 958	Var. 968	Var. 978	Var. 988	Var. 998
	IAC	Var. 909	Var. 919	Var. 929	Var. 939	Var. 949	Var. 959	Var. 969	Var. 979	Var. 989	Var. 999
	SEC	Var. 910	Var. 920	Var. 930	Var. 940	Var. 950	Var. 960	Var. 970	Var. 980	Var. 990	Var. 1000

* As per Table 1.

Table 11. Exemplary embodiments for the combination of a first Size Exclusion Chromatography step, a second, and a third enrichment step.

		Second Enrichment Step*									
		Ppt	UF/DF	AEC	CEC	HIC	HAC	MMC	LAC	IAC	SEC
Third Enrichment Step	Ppt	Var. 1001	Var. 1011	Var. 1021	Var. 1031	Var. 1041	Var. 1051	Var. 1061	Var. 1071	Var. 1081	Var. 1091
	UF/DF	Var. 1002	Var. 1012	Var. 1022	Var. 1032	Var. 1042	Var. 1052	Var. 1062	Var. 1072	Var. 1082	Var. 1092
	AEC	Var. 1003	Var. 1013	Var. 1023	Var. 1033	Var. 1043	Var. 1053	Var. 1063	Var. 1073	Var. 1083	Var. 1093
	CEC	Var. 1004	Var. 1014	Var. 1024	Var. 1034	Var. 1044	Var. 1054	Var. 1064	Var. 1074	Var. 1084	Var. 1094
	HIC	Var. 1005	Var. 1015	Var. 1025	Var. 1035	Var. 1045	Var. 1055	Var. 1065	Var. 1075	Var. 1085	Var. 1095
	HAC	Var. 1006	Var. 1016	Var. 1026	Var. 1036	Var. 1046	Var. 1056	Var. 1066	Var. 1076	Var. 1086	Var. 1096
	MMC	Var. 1007	Var. 1017	Var. 1027	Var. 1037	Var. 1047	Var. 1057	Var. 1067	Var. 1077	Var. 1087	Var. 1097
	LAC	Var. 1008	Var. 1018	Var. 1028	Var. 1038	Var. 1048	Var. 1058	Var. 1068	Var. 1078	Var. 1088	Var. 1098
	IAC	Var. 1009	Var. 1019	Var. 1029	Var. 1039	Var. 1049	Var. 1059	Var. 1069	Var. 1079	Var. 1089	Var. 1099
	SEC	Var. 1010	Var. 1020	Var. 1030	Var. 1040	Var. 1050	Var. 1060	Var. 1070	Var. 1080	Var. 1090	Var. 1100

* As per Table 1.

[0191] In certain embodiments of the methods described above, a chromatographic enrichment step comprises the sub-steps of: (i) contacting the plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind the plasma-derived target protein; and (ii) eluting the plasma-derived target protein from the chromatographic resin. In one specific embodiment, the impurity does not bind to the chromatographic resin in sub-step (i). In another

specific embodiment, the impurity binds to the chromatographic resin in sub-step (i), but is not eluted from the chromatographic resin in sub-step (ii).

[0192] In other certain embodiments of the methods described above, a chromatographic enrichment step comprises the sub-steps of: (i) contacting the first enriched plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind at least one impurity; and (ii) separating the resin from the plasma-derived protein composition, wherein the plasma-derived target protein does not bind to the chromatographic resin in sub-step (i).

[0193] In certain embodiments of the methods described above, the plasma-derived target protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, a protein of the complement system (*e.g.*, Factor H), and an inter-alpha-trypsin inhibitor (IαI). In a specific embodiment, the protein of the complement system is selected from the group consisting of Factor H (FH), Factor D, complement protein C3, and C4 binding protein. In a preferred embodiment, the protein composition is a manufacturing intermediate.

[0194] In certain embodiments of the methods provided herein, the amount of a particular serine protease or serine protease zymogen is reduced by at least 10%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 25%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 50%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 75%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 90%. In yet other embodiments, the amount of a particular serine protease or serine protease zymogen is reduced by at least 5%, or by at least 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or to levels below the detection limit of the test system.

[0195] Generally, the amount of finely divided silicon dioxide (SiO_2) required for the methods described herein will vary dependent on several factors, including without limitation, the total amount of protein present in the composition, the concentration of serine protease and serine protease zymogen (*e.g.*, FXI, FXIa, FXII, and FXIIa) in the composition, the target protein, and the solution conditions (*e.g.*, pH, conductivity, *etc.*). For example, SiO_2 may be added to a target composition at a concentration between about 0.01 g/g protein and about 10 g/g protein. In

another embodiment, SiO_2 may be added to a target composition at a concentration between about 1 g/g protein and about 5 g/g protein. In another embodiment, SiO_2 may be added to a target composition at a concentration between about 2 g/g protein and about 4 g/g protein. In one embodiment, SiO_2 is added at a final concentration of at least 1 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2.5 g per gram total protein. In another embodiment, SiO_2 may be added to a target composition at a concentration between about 0.01 g/g protein and about 5 g/g protein. In another embodiment, SiO_2 may be added to a target composition at a concentration between about 0.02 g/g protein and about 4 g/g protein. In one embodiment, SiO_2 is added at a final concentration of at least 0.1 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.25 g per gram total protein. In yet other specific embodiments, finely divided silicon dioxide is added at a concentration of at least 0.01 g/g total protein or at least 0.02 g, 0.03 g, 0.04 g, 0.05 g, 0.06 g, 0.07 g, 0.08 g, 0.09 g, 0.1 g, 0.2 g, 0.3 g, 0.4 g, 0.5 g, 0.6 g, 0.7 g, 0.8 g, 0.9 g, 1.0 g, 1.5 g, 2.0 g, 2.5 g, 3.0 g, 3.5 g, 4.0 g, 4.5 g, 5.0 g, 5.5 g, 6.0 g, 6.5 g, 7.0 g, 7.5 g, 8.0 g, 8.5 g, 9.0 g, 9.5 g, 10.0 g, or more g/g total protein.

[0196] In certain embodiments in which a target protein is extracted from a suspended plasma precipitate fraction, filter aid, for example Celpure C300 (Celpure) or Hyflo-Supper-Cel (World Minerals), will be added after the silica dioxide treatment, to facilitate depth filtration. Filter aid can be added at a final concentration of from about 0.01 kg/kg precipitate to about 1.0 kg/kg precipitate, or from about 0.02 kg/kg precipitate to about 0.8 kg/kg precipitate, or from about 0.03 kg/kg precipitate to about 0.7 kg/kg precipitate. In other embodiments, filter aid can be added at a final concentration of from about 0.01 kg/kg precipitate to about 0.07 kg/kg precipitate, or from about 0.02 kg/kg precipitate to about 0.06 kg/kg precipitate, or from about 0.03 kg/kg precipitate to about 0.05 kg/kg precipitate. In certain embodiments, the filter aid will be added at a final concentration of about 0.01 kg/kg precipitate, or about 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, or 1.0 kg/kg precipitate.

A. Immunoglobulins

[0197] In one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived immunoglobulin (Ig)

composition. In one specific embodiment, the method comprises the steps of: (a) contacting the Ig composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO_2 from the Ig composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In one embodiment, the Ig composition is an IgG composition. In other embodiments, the Ig composition is an IgA, IgM, IgG, or mixed composition thereof.

[0198] In one embodiment, the method further comprises the step of performing a first Ig protein enrichment step to form a first enriched Ig composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first Ig protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step. In one embodiment, the Ig composition is an IgG composition. In other embodiments, the Ig composition is an IgA, IgM, IgG, or mixed composition thereof.

[0199] In certain embodiments, the methods described above further comprises the step of performing a second Ig protein enrichment step to form a second enriched Ig composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first Ig protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0200] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived Ig composition, the method comprises the steps of: (a) performing a first Ig enrichment step to form a first enriched plasma-derived Ig composition; (b) performing a second Ig enrichment step to form a second enriched plasma-derived Ig composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI

(FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0201] In certain embodiments, the methods described above further comprises the step of performing an Ig enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the Ig enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0202] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived Ig composition the method comprises the steps of: (a) performing a first Ig enrichment step to form a first enriched plasma-derived Ig composition; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (d) performing a second Ig enrichment step to form a second enriched plasma-derived Ig composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0203] Likewise, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived Ig composition, the method comprising the steps of: (a) performing a first Ig enrichment step to form a first enriched plasma-derived Ig composition; (b) performing a second Ig enrichment step to form a second enriched plasma-derived Ig composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (e) performing a third Ig enrichment step to form a third enriched plasma-derived Ig composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 101 to Var. 1100, found in Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, or Table 11.

[0204] In a particular embodiment, the Ig composition is a manufacturing intermediate. For example, in certain embodiments, the Ig composition is an IgG manufacturing intermediate from a Cohn fractionation procedure (J. Am. Chem. Soc., 1946, 68(3): 459-475; J. Am. Chem. Soc. 72:465-474 (1950)), an Oncley fractionation procedure (J. Am. Chem. Soc., 1949, 71(2): 541-550), a Deutsch purification procedure (J. Biol. Chem. 164:109-118), a Hoppe purification procedure (Munch Med Wochenschr 1967 (34): 1749-1752), a Falksveden purification procedure (Swedish Patent No. 348942), a Falksveden and Lundblad purification procedure (Methods of Plasma Protein Fractionation 1980), a Lebing purification procedure (Vox Sang 2003 (84):193-201), a Tanaka purification procedure (Braz J Med Biol Res 2000 (33)37-30)), a Teschner purification procedure (Vox Sang, 2007 (92):42-55), a Nitschmann fractionation procedure (Helv. Chim. Acta 37:866-873), a Kistler/Nitschmann fractionation procedure (Vox Sang. 7:414-424 (1962)), a Barundern purification procedure (Vox Sang. 7:157-74 (1962)), a Koblet purification procedure (Vox Sang. 13:93-102 (1967)) a purification procedure disclosed in U.S. Patent Nos. 5,122,373 or 5,177,194, modified procedures thereof, and similar or equivalent purification procedures known in the art.

[0205] In one particular embodiment, the IgG composition is a cryo-poor Cohn pool. In another particular embodiment, the IgG composition is a Cohn Fraction I supernatant or equivalent fraction thereof. In another particular embodiment, the IgG composition is a re-suspended Cohn Fraction III precipitate, or equivalent fraction thereof. In another particular embodiment, the IgG composition is a re-suspended Cohn Fraction II+III precipitate, or equivalent fraction thereof. In another particular embodiment, the IgG composition is a re-suspended Cohn Fraction I+II+III precipitate, or equivalent fraction thereof. In another particular embodiment, the IgG composition is a re-suspended Precipitate G precipitate, or equivalent fraction thereof. In another particular embodiment, the IgG composition is a re-suspended Kistler/Nitschmann Precipitate B precipitate, or equivalent fraction thereof.

[0206] In a specific embodiment, the present invention provides a method for reducing the amount of serine protease and/or serine protease zymogen in a re-suspended IgG Fraction II+III precipitate. Advantageously, it has been found that the levels of Factor XI, Factor XII, Factor XIa, and/or Factor XIIa in a re-suspended IgG Fraction II+III precipitate can be greatly reduced by the addition of a pretreatment step prior to filtration/centrifugation. In one embodiment, this pretreatment step comprises addition of finely divided silica dioxide particles (*e.g.*, fumed silica, Aerosil®) followed by a 40 to 80 minute incubation period during which the suspension is

constantly mixed. In certain embodiments, the incubation period will be between about 50 minutes and about 70 minutes, or about 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, or more minutes. Generally, the treatment will be performed at between about 0°C and about 10°C, or between about 2°C and about 8°C. In certain embodiments, the treatment may be performed at about 0°C, 1°C, 2°C, 3°C, 4°C, 5°C, 6°C, 7°C, 8°C, 9°C, or 10°C. In a particular embodiment, the treatment is performed at between about 2°C and about 10°C.

[0207] The effect of the fumed silica treatment is exemplified by the results found in Examples 3, 6, and 7. In these examples, Fraction II+III precipitates are re-suspended and treated with varying amounts of finely divided silicon dioxide. As can be seen in Table 22, Table 27, Table 28, and

Table 29, Factor XI and XII serine protease activity and zymogen content can be reduced at least 90% by treating the suspension with SiO_2.

[0208] In certain embodiments, fumed silica is added at a concentration of between about 20 g/kg II+III paste and about 100 g/kg II+III paste (*i.e.*, for a Modified Fraction II+III precipitate that is extracted at a ratio of 1:15, fumed silica should be added at a concentration from about 20 g/16 kg II+III suspension to about 100 g/16 kg II+III suspension, or at a final concentration of about 0.125% (w/w) to about 0.625% (w/w)). In certain embodiments, the fumed silica may be added at a concentration of about 20 g/kg II+III paste, or about 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, or 100 g/kg II+III paste. In one specific embodiment, fumed silica (e.g., Aerosil 380 or equivalent) is added to the Modified Fraction II+III suspension to a final concentration of about 40 g/16 kg II+III. Mixing takes place at about 2 to 8°C for at least 50 to 70 minutes.

[0209] In certain embodiments, SiO_2 is added to a an IgG composition at a concentration between about 0.01 g/g protein and about 10 g/g protein. In another embodiment, SiO_2 is added to a an IgG composition at a concentration between about 0.01 g/g protein and about 5 g/g protein. In another embodiment, SiO_2 is added to an IgG composition at a concentration between about 0.02 g/g protein and about 4 g/g protein. In one embodiment, SiO_2 is added at a final concentration of at least 0.1 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.25 g per gram total protein. In other specific embodiments, fumed silica is added at a concentration of at least 1 g

per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2.5 g per gram total protein. In yet other specific embodiments, finely divided silicon dioxide is added at a concentration of at least 0.01 g/g total protein or at least 0.02 g, 0.03 g, 0.04 g, 0.05 g, 0.06 g, 0.07 g, 0.08 g, 0.09 g, 0.1 g, 0.2 g, 0.3 g, 0.4 g, 0.5 g, 0.6 g, 0.7 g, 0.8 g, 0.9 g, 1.0 g, 1.5 g, 2.0 g, 2.5 g, 3.0 g, 3.5 g, 4.0 g, 4.5 g, 5.0 g, 5.5 g, 6.0 g, 6.5 g, 7.0 g, 7.5 g, 8.0 g, 8.5 g, 9.0 g, 9.5 g, 10.0 g, or more per gram total protein.

[0210] In certain embodiments, filter aid, for example Celpure C300 (Celpure) or Hyflo-Supper-Cel (World Minerals), will be added after the silica dioxide treatment, to facilitate depth filtration. Filter aid can be added at a final concentration of from about 0.01 kg/kg II+III paste to about 1.0 kg/kg II+III paste, or from about 0.02 kg/kg II+III paste to about 0.8 kg/kg II+III paste, or from about 0.03 kg/kg II+III paste to about 0.7 kg/kg II+III paste. In other embodiments, filter aid can be added at a final concentration of from about 0.01 kg/kg II+III paste to about 0.07 kg/kg II+III paste, or from about 0.02 kg/kg II+III paste to about 0.06 kg/kg II+III paste, or from about 0.03 kg/kg II+III paste to about 0.05 kg/kg II+III paste. In certain embodiments, the filter aid will be added at a final concentration of about 0.01 kg/kg II+III paste, or about 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, or 1.0 kg/kg II+III paste.

[0211] In one embodiment, the process improvements are realized by inclusion of a fumed silica treatment prior to filtration or centrifugal clarification of a Fraction II+III suspension. In certain embodiments, the fumed silica treatment will include addition of from about 0.01 kg/kg II+III paste to about 0.07 kg/kg II+III paste, or from about 0.02 kg/kg II+III paste to about 0.06 kg/kg II+III paste, or from about 0.03 kg/kg II+III paste to about 0.05 kg/kg II+III paste, or about 0.02 kg/kg II+III paste, 0.03 kg/kg II+III paste, 0.04 kg/kg II+III paste, 0.05 kg/kg II+III paste, 0.06 kg/kg II+III paste, 0.07 kg/kg II+III paste, 0.08 kg/kg II+III paste, 0.09 kg/kg II+III paste, or 0.1 kg/kg II+III paste, and the mixture will be incubated for between about 50 minutes and about 70 minutes, or about 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, or more minutes at a temperature between about 2°C and about 8°C. In another embodiment, the process improvements are realized by inclusion of a fumed silica treatment which reduced the levels of residual fibrinogen, amidolytic activity, and/or prekallikrein activator activity. In a specific embodiment, the process improvements are realized by inclusion of a fumed silica treatment, which reduces the levels of FXI, FXIa, FXII, and FXIIa in the immunoglobulin preparation.

[0212] Generally, serine protease and/or serine protease zymogen removal from immunoglobulin compositions can be achieved by treating the immunoglobulin-containing solution with finely divided silicon dioxide (SiO_2) under pH and conductivity solution conditions in which the serine protease and/or serine protease zymogen binds to the SiO_2. As shown in the examples, suitable conditions include low pH and low conductivity.

[0213] Accordingly, in one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived immunoglobulin composition, the method comprising contacting the composition with SiO_2 at a pH between about 4.0 and about 7.0 to bind a serine protease or a serine protease zymogen and removing the SiO_2 from the composition. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 6.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 6.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 5.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 5.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 7.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 6.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 6.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 5.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 5.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 7.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 6.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 6.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 5.5. In yet another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.6 and about 5.6. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.7 and about 5.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.8 and about 5.4. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH

between about 4.9 and about 5.3. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 5.2. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH of about 5.1. In other embodiments, the method comprises contacting the composition with SiO_2 at a pH of about 4.0 or about 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, or no more than 7.0. In yet other embodiments, the method comprises contacting the composition with SiO_2 at a pH of no more than 4.0 or no more than 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, or no more than 7.0.

[0214] In one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived immunoglobulin composition, the method comprising contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 3.0 mS/cm to bind a serine protease or a serine protease zymogen and removing the SiO_2 from the composition. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.5 mS/cm and about 2.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 1.3 mS/cm and about 1.7 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.9 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.8 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.7 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.6 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.5 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.4 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.3 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.2 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.1 mS/cm. In another embodiment, the method comprises

contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 0.9 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 0.8 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.2 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.3 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 0.4 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.5 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.6 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.7 mS/cm and about 0.9 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength of about 0.8 mS/cm. In other embodiments, the method comprises contacting the composition with SiO_2 at an ionic strength of about 0.1 mS/cm or no more than 0.2 mS/cm, 0.3 mS/cm, 0.4 mS/cm, 0.5 mS/cm, 0.6 mS/cm, 0.7 mS/cm, 0.8 mS/cm, 0.9 mS/cm, 1.0 mS/cm, 1.1 mS/cm, 1.2 mS/cm, 1.3 mS/cm, 1.4 mS/cm, 1.5 mS/cm, 1.6 mS/cm, 1.7 mS/cm, 1.8 mS/cm, 1.9 mS/cm, 2.0 mS/cm, 2.1 mS/cm, 2.2 mS/cm, 2.3 mS/cm, 2.4 mS/cm, 2.5 mS/cm, 2.6 mS/cm, 2.7 mS/cm, 2.8 mS/cm, 2.9 mS/cm, or 3.0 mS/cm. In yet other embodiments, the method comprises contacting the composition with SiO_2 at an ionic strength of no more than 0.1 mS/cm or no more than 0.2 mS/cm, 0.3 mS/cm, 0.4 mS/cm, 0.5 mS/cm, 0.6 mS/cm, 0.7 mS/cm, 0.8 mS/cm, 0.9 mS/cm, 1.0 mS/cm, 1.1 mS/cm, 1.2 mS/cm, 1.3 mS/cm, 1.4 mS/cm, 1.5 mS/cm, 1.6 mS/cm, 1.7 mS/cm, 1.8 mS/cm, 1.9 mS/cm, 2.0 mS/cm, 2.1 mS/cm, 2.2 mS/cm, 2.3 mS/cm, 2.4 mS/cm, 2.5 mS/cm, 2.6 mS/cm, 2.7 mS/cm, 2.8 mS/cm, 2.9 mS/cm, or 3.0 mS/cm.

[0215] In certain embodiments, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived immunoglobulin composition, the method comprising contacting the composition with SiO_2 at a low pH and low ionic strength to bind a serine protease or a serine protease zymogen and removing the SiO_2 from the composition. In a particular embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.8 and about 5.4 at an ionic strength between about 0.6 mS/cm

and about 1.0 mS/cm. In a more particular embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.9 and about 5.3 at an ionic strength between about 0.7 mS/cm and about 0.9 mS/cm. In a yet more particular embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 5.2 at an ionic strength of about 0.8 mS/cm. In yet other embodiments, the method comprises contacting the composition with SiO_2 at a pH and ionic strength according to any one of variations Var. 1222 to 3041, as presented in **Table 12**, **Table 13**, **Table 14**, and **Table 15**.

Table 12. Exemplary embodiments of solution conditions useful for binding serine proteases and/or serine protease zymogens to SiO_2.

		pH								
		4.0-7.0	**4.5-5.0**	**4.5-5.0**	**4.5-5.0**	**4.5-5.0**	**4.5-5.0**	**4.5-5.0**	**4.5-5.0**	**4.5-5.0**
Ionic Strength (mS/cm)	**0.1-2.0**	Var. 1222	Var. 1638	Var. 1638	Var. 1638	Var. 1638	Var. 1638	Var. 1638	Var. 1638	Var. 1638
	0.1-1.9	Var. 1223	Var. 1639	Var. 1639	Var. 1639	Var. 1639	Var. 1639	Var. 1639	Var. 1639	Var. 1639
	0.1-1.8	Var. 1224	Var. 1640	Var. 1640	Var. 1640	Var. 1640	Var. 1640	Var. 1640	Var. 1640	Var. 1640
	0.1-1.7	Var. 1225	Var. 1641	Var. 1641	Var. 1641	Var. 1641	Var. 1641	Var. 1641	Var. 1641	Var. 1641
	0.1-1.6	Var. 1226	Var. 1642	Var. 1642	Var. 1642	Var. 1642	Var. 1642	Var. 1642	Var. 1642	Var. 1642
	0.1-1.5	Var. 1227	Var. 1643	Var. 1643	Var. 1643	Var. 1643	Var. 1643	Var. 1643	Var. 1643	Var. 1643
	0.1-1.4	Var. 1228	Var. 1644	Var. 1644	Var. 1644	Var. 1644	Var. 1644	Var. 1644	Var. 1644	Var. 1644
	0.1-1.3	Var. 1229	Var. 1645	Var. 1645	Var. 1645	Var. 1645	Var. 1645	Var. 1645	Var. 1645	Var. 1645
	0.1-1.2	Var. 1230	Var. 1646	Var. 1646	Var. 1646	Var. 1646	Var. 1646	Var. 1646	Var. 1646	Var. 1646
	0.1-1.1	Var. 1231	Var. 1647	Var. 1647	Var. 1647	Var. 1647	Var. 1647	Var. 1647	Var. 1647	Var. 1647
	0.1-1.0	Var. 1232	Var. 1648	Var. 1648	Var. 1648	Var. 1648	Var. 1648	Var. 1648	Var. 1648	Var. 1648
	0.1-0.9	Var. 1233	Var. 1649	Var. 1649	Var. 1649	Var. 1649	Var. 1649	Var. 1649	Var. 1649	Var. 1649
	0.1-0.8	Var. 1234	Var. 1650	Var. 1650	Var. 1650	Var. 1650	Var. 1650	Var. 1650	Var. 1650	Var. 1650
	0.2-2.0	Var. 1235	Var. 1651	Var. 1651	Var. 1651	Var. 1651	Var. 1651	Var. 1651	Var. 1651	Var. 1651
	0.2-1.5	Var. 1236	Var. 1652	Var. 1652	Var. 1652	Var. 1652	Var. 1652	Var. 1652	Var. 1652	Var. 1652
	0.2-1.0	Var. 1237	Var. 1653	Var. 1653	Var. 1653	Var. 1653	Var. 1653	Var. 1653	Var. 1653	Var. 1653
	0.2-0.9	Var. 1238	Var. 1654	Var. 1654	Var. 1654	Var. 1654	Var. 1654	Var. 1654	Var. 1654	Var. 1654
	0.2-0.8	Var. 1239	Var. 1655	Var. 1655	Var. 1655	Var. 1655	Var. 1655	Var. 1655	Var. 1655	Var. 1655
	0.3-1.0	Var. 1240	Var. 1656	Var. 1656	Var. 1656	Var. 1656	Var. 1656	Var. 1656	Var. 1656	Var. 1656
	0.3-0.9	Var. 1241	Var. 1657	Var. 1657	Var. 1657	Var. 1657	Var. 1657	Var. 1657	Var. 1657	Var. 1657
	0.3-0.8	Var. 1242	Var. 1658	Var. 1658	Var. 1658	Var. 1658	Var. 1658	Var. 1658	Var. 1658	Var. 1658
	0.4-1.0	Var. 1243	Var. 1659	Var. 1659	Var. 1659	Var. 1659	Var. 1659	Var. 1659	Var. 1659	Var. 1659
	0.4-0.9	Var. 1244	Var. 1660	Var. 1660	Var. 1660	Var. 1660	Var. 1660	Var. 1660	Var. 1660	Var. 1660
	0.4-0.8	Var. 1245	Var. 1661	Var. 1661	Var. 1661	Var. 1661	Var. 1661	Var. 1661	Var. 1661	Var. 1661
	0.5-1.0	Var. 1246	Var. 1662	Var. 1662	Var. 1662	Var. 1662	Var. 1662	Var. 1662	Var. 1662	Var. 1662
	0.5-0.9	Var. 1247	Var. 1663	Var. 1663	Var. 1663	Var. 1663	Var. 1663	Var. 1663	Var. 1663	Var. 1663
	0.5-0.8	Var. 1248	Var. 1664	Var. 1664	Var. 1664	Var. 1664	Var. 1664	Var. 1664	Var. 1664	Var. 1664
	0.6-1.0	Var. 1249	Var. 1665	Var. 1665	Var. 1665	Var. 1665	Var. 1665	Var. 1665	Var. 1665	Var. 1665
	0.6-0.9	Var. 1250	Var. 1666	Var. 1666	Var. 1666	Var. 1666	Var. 1666	Var. 1666	Var. 1666	Var. 1666
	0.6-0.8	Var. 1251	Var. 1667	Var. 1667	Var. 1667	Var. 1667	Var. 1667	Var. 1667	Var. 1667	Var. 1667
	0.7-1.0	Var. 1252	Var. 1668	Var. 1668	Var. 1668	Var. 1668	Var. 1668	Var. 1668	Var. 1668	Var. 1668
	0.7-0.9	Var. 1253	Var. 1669	Var. 1669	Var. 1669	Var. 1669	Var. 1669	Var. 1669	Var. 1669	Var. 1669
	0.1	Var. 1254	Var. 1670	Var. 1670	Var. 1670	Var. 1670	Var. 1670	Var. 1670	Var. 1670	Var. 1670
	0.2	Var. 1255	Var. 1671	Var. 1671	Var. 1671	Var. 1671	Var. 1671	Var. 1671	Var. 1671	Var. 1671
	0.3	Var. 1256	Var. 1672	Var. 1672	Var. 1672	Var. 1672	Var. 1672	Var. 1672	Var. 1672	Var. 1672
	0.4	Var. 1257	Var. 1673	Var. 1673	Var. 1673	Var. 1673	Var. 1673	Var. 1673	Var. 1673	Var. 1673
	0.5	Var. 1258	Var. 1674	Var. 1674	Var. 1674	Var. 1674	Var. 1674	Var. 1674	Var. 1674	Var. 1674
	0.6	Var. 1259	Var. 1675	Var. 1675	Var. 1675	Var. 1675	Var. 1675	Var. 1675	Var. 1675	Var. 1675
	0.7	Var. 1260	Var. 1676	Var. 1676	Var. 1676	Var. 1676	Var. 1676	Var. 1676	Var. 1676	Var. 1676
	0.8	Var. 1261	Var. 1677	Var. 1677	Var. 1677	Var. 1677	Var. 1677	Var. 1677	Var. 1677	Var. 1677
	0.9	Var. 1262	Var. 1678	Var. 1678	Var. 1678	Var. 1678	Var. 1678	Var. 1678	Var. 1678	Var. 1678
	1	Var. 1263	Var. 1679	Var. 1679	Var. 1679	Var. 1679	Var. 1679	Var. 1679	Var. 1679	Var. 1679
	1.1	Var. 1264	Var. 1680	Var. 1680	Var. 1680	Var. 1680	Var. 1680	Var. 1680	Var. 1680	Var. 1680
	1.2	Var. 1265	Var. 1681	Var. 1681	Var. 1681	Var. 1681	Var. 1681	Var. 1681	Var. 1681	Var. 1681
	1.3	Var. 1266	Var. 1682	Var. 1682	Var. 1682	Var. 1682	Var. 1682	Var. 1682	Var. 1682	Var. 1682

	1.4	Var. 1267	Var. 1683	Var. 1683	Var. 1683	Var. 1683	Var. 1683	Var. 1683	Var. 1683	Var. 1683
	1.5	Var. 1268	Var. 1684	Var. 1684	Var. 1684	Var. 1684	Var. 1684	Var. 1684	Var. 1684	Var. 1684
	1.6	Var. 1269	Var. 1685	Var. 1685	Var. 1685	Var. 1685	Var. 1685	Var. 1685	Var. 1685	Var. 1685
	1.7	Var. 1270	Var. 1686	Var. 1686	Var. 1686	Var. 1686	Var. 1686	Var. 1686	Var. 1686	Var. 1686
	1.8	Var. 1271	Var. 1687	Var. 1687	Var. 1687	Var. 1687	Var. 1687	Var. 1687	Var. 1687	Var. 1687
	1.9	Var. 1272	Var. 1688	Var. 1688	Var. 1688	Var. 1688	Var. 1688	Var. 1688	Var. 1688	Var. 1688
	2	Var. 1273	Var. 1689	Var. 1689	Var. 1689	Var. 1689	Var. 1689	Var. 1689	Var. 1689	Var. 1689

Table 13. Exemplary embodiments of solution conditions useful for binding serine proteases and/or serine protease zymogens to SiO_2.

		pH								
		5.0-7.0	**5.0-6.5**	**5.0-6.0**	**5.0-5.5**	**4.6-5.6**	**4.7-5.5**	**4.8-5.4**	**4.9-5.3**	**5.0-5.2**
Ionic Strength (mS/cm)	**0.1-2.0**	Var. 1690	Var. 1742	Var. 1794	Var. 1846	Var. 1898	Var. 1950	Var. 2002	Var. 2054	Var. 2106
	0.1-1.9	Var. 1691	Var. 1743	Var. 1795	Var. 1847	Var. 1899	Var. 1951	Var. 2003	Var. 2055	Var. 2107
	0.1-1.8	Var. 1692	Var. 1744	Var. 1796	Var. 1848	Var. 1900	Var. 1952	Var. 2004	Var. 2056	Var. 2108
	0.1-1.7	Var. 1693	Var. 1745	Var. 1797	Var. 1849	Var. 1901	Var. 1953	Var. 2005	Var. 2057	Var. 2109
	0.1-1.6	Var. 1694	Var. 1746	Var. 1798	Var. 1850	Var. 1902	Var. 1954	Var. 2006	Var. 2058	Var. 2110
	0.1-1.5	Var. 1695	Var. 1747	Var. 1799	Var. 1851	Var. 1903	Var. 1955	Var. 2007	Var. 2059	Var. 2111
	0.1-1.4	Var. 1696	Var. 1748	Var. 1800	Var. 1852	Var. 1904	Var. 1956	Var. 2008	Var. 2060	Var. 2112
	0.1-1.3	Var. 1697	Var. 1749	Var. 1801	Var. 1853	Var. 1905	Var. 1957	Var. 2009	Var. 2061	Var. 2113
	0.1-1.2	Var. 1698	Var. 1750	Var. 1802	Var. 1854	Var. 1906	Var. 1958	Var. 2010	Var. 2062	Var. 2114
	0.1-1.1	Var. 1699	Var. 1751	Var. 1803	Var. 1855	Var. 1907	Var. 1959	Var. 2011	Var. 2063	Var. 2115
	0.1-1.0	Var. 1700	Var. 1752	Var. 1804	Var. 1856	Var. 1908	Var. 1960	Var. 2012	Var. 2064	Var. 2116
	0.1-0.9	Var. 1701	Var. 1753	Var. 1805	Var. 1857	Var. 1909	Var. 1961	Var. 2013	Var. 2065	Var. 2117
	0.1-0.8	Var. 1702	Var. 1754	Var. 1806	Var. 1858	Var. 1910	Var. 1962	Var. 2014	Var. 2066	Var. 2118
	0.2-2.0	Var. 1703	Var. 1755	Var. 1807	Var. 1859	Var. 1911	Var. 1963	Var. 2015	Var. 2067	Var. 2119
	0.2-1.5	Var. 1704	Var. 1756	Var. 1808	Var. 1860	Var. 1912	Var. 1964	Var. 2016	Var. 2068	Var. 2120
	0.2-1.0	Var. 1705	Var. 1757	Var. 1809	Var. 1861	Var. 1913	Var. 1965	Var. 2017	Var. 2069	Var. 2121
	0.2-0.9	Var. 1706	Var. 1758	Var. 1810	Var. 1862	Var. 1914	Var. 1966	Var. 2018	Var. 2070	Var. 2122
	0.2-0.8	Var. 1707	Var. 1759	Var. 1811	Var. 1863	Var. 1915	Var. 1967	Var. 2019	Var. 2071	Var. 2123
	0.3-1.0	Var. 1708	Var. 1760	Var. 1812	Var. 1864	Var. 1916	Var. 1968	Var. 2020	Var. 2072	Var. 2124
	0.3-0.9	Var. 1709	Var. 1761	Var. 1813	Var. 1865	Var. 1917	Var. 1969	Var. 2021	Var. 2073	Var. 2125
	0.3-0.8	Var. 1710	Var. 1762	Var. 1814	Var. 1866	Var. 1918	Var. 1970	Var. 2022	Var. 2074	Var. 2126
	0.4-1.0	Var. 1711	Var. 1763	Var. 1815	Var. 1867	Var. 1919	Var. 1971	Var. 2023	Var. 2075	Var. 2127
	0.4-0.9	Var. 1712	Var. 1764	Var. 1816	Var. 1868	Var. 1920	Var. 1972	Var. 2024	Var. 2076	Var. 2128
	0.4-0.8	Var. 1713	Var. 1765	Var. 1817	Var. 1869	Var. 1921	Var. 1973	Var. 2025	Var. 2077	Var. 2129
	0.5-1.0	Var. 1714	Var. 1766	Var. 1818	Var. 1870	Var. 1922	Var. 1974	Var. 2026	Var. 2078	Var. 2130
	0.5-0.9	Var. 1715	Var. 1767	Var. 1819	Var. 1871	Var. 1923	Var. 1975	Var. 2027	Var. 2079	Var. 2131
	0.5-0.8	Var. 1716	Var. 1768	Var. 1820	Var. 1872	Var. 1924	Var. 1976	Var. 2028	Var. 2080	Var. 2132
	0.6-1.0	Var. 1717	Var. 1769	Var. 1821	Var. 1873	Var. 1925	Var. 1977	Var. 2029	Var. 2081	Var. 2133
	0.6-0.9	Var. 1718	Var. 1770	Var. 1822	Var. 1874	Var. 1926	Var. 1978	Var. 2030	Var. 2082	Var. 2134
	0.6-0.8	Var. 1719	Var. 1771	Var. 1823	Var. 1875	Var. 1927	Var. 1979	Var. 2031	Var. 2083	Var. 2135
	0.7-1.0	Var. 1720	Var. 1772	Var. 1824	Var. 1876	Var. 1928	Var. 1980	Var. 2032	Var. 2084	Var. 2136
	0.7-0.9	Var. 1721	Var. 1773	Var. 1825	Var. 1877	Var. 1929	Var. 1981	Var. 2033	Var. 2085	Var. 2137
	0.1	Var. 1722	Var. 1774	Var. 1826	Var. 1878	Var. 1930	Var. 1982	Var. 2034	Var. 2086	Var. 2138
	0.2	Var. 1723	Var. 1775	Var. 1827	Var. 1879	Var. 1931	Var. 1983	Var. 2035	Var. 2087	Var. 2139
	0.3	Var. 1724	Var. 1776	Var. 1828	Var. 1880	Var. 1932	Var. 1984	Var. 2036	Var. 2088	Var. 2140
	0.4	Var. 1725	Var. 1777	Var. 1829	Var. 1881	Var. 1933	Var. 1985	Var. 2037	Var. 2089	Var. 2141
	0.5	Var. 1726	Var. 1778	Var. 1830	Var. 1882	Var. 1934	Var. 1986	Var. 2038	Var. 2090	Var. 2142
	0.6	Var. 1727	Var. 1779	Var. 1831	Var. 1883	Var. 1935	Var. 1987	Var. 2039	Var. 2091	Var. 2143
	0.7	Var. 1728	Var. 1780	Var. 1832	Var. 1884	Var. 1936	Var. 1988	Var. 2040	Var. 2092	Var. 2144
	0.8	Var. 1729	Var. 1781	Var. 1833	Var. 1885	Var. 1937	Var. 1989	Var. 2041	Var. 2093	Var. 2145
	0.9	Var. 1730	Var. 1782	Var. 1834	Var. 1886	Var. 1938	Var. 1990	Var. 2042	Var. 2094	Var. 2146
	1	Var. 1731	Var. 1783	Var. 1835	Var. 1887	Var. 1939	Var. 1991	Var. 2043	Var. 2095	Var. 2147
	1.1	Var. 1732	Var. 1784	Var. 1836	Var. 1888	Var. 1940	Var. 1992	Var. 2044	Var. 2096	Var. 2148
	1.2	Var. 1733	Var. 1785	Var. 1837	Var. 1889	Var. 1941	Var. 1993	Var. 2045	Var. 2097	Var. 2149
	1.3	Var. 1734	Var. 1786	Var. 1838	Var. 1890	Var. 1942	Var. 1994	Var. 2046	Var. 2098	Var. 2150
	1.4	Var. 1735	Var. 1787	Var. 1839	Var. 1891	Var. 1943	Var. 1995	Var. 2047	Var. 2099	Var. 2151
	1.5	Var. 1736	Var. 1788	Var. 1840	Var. 1892	Var. 1944	Var. 1996	Var. 2048	Var. 2100	Var. 2152
	1.6	Var. 1737	Var. 1789	Var. 1841	Var. 1893	Var. 1945	Var. 1997	Var. 2049	Var. 2101	Var. 2153
	1.7	Var. 1738	Var. 1790	Var. 1842	Var. 1894	Var. 1946	Var. 1998	Var. 2050	Var. 2102	Var. 2154
	1.8	Var. 1739	Var. 1791	Var. 1843	Var. 1895	Var. 1947	Var. 1999	Var. 2051	Var. 2103	Var. 2155
	1.9	Var. 1740	Var. 1792	Var. 1844	Var. 1896	Var. 1948	Var. 2000	Var. 2052	Var. 2104	Var. 2156
	2	Var. 1741	Var. 1793	Var. 1845	Var. 1897	Var. 1949	Var. 2001	Var. 2053	Var. 2105	Var. 2157

Table 14. Exemplary embodiments of solution conditions useful for binding serine proteases and/or serine protease zymogens to SiO_2.

		pH								
		5.1	NMT 4.0	NMT 4.2	NMT 4.4	NMT 4.6	NMT 4.8	NMT 5.0	NMT 5.2	NMT 5.4
Ionic Strength (mS/cm)	0.1-2.0	Var. 2158	Var. 2210	Var. 2262	Var. 2314	Var. 2366	Var. 2418	Var. 2470	Var. 2522	Var. 2574
	0.1-1.9	Var. 2159	Var. 2211	Var. 2263	Var. 2315	Var. 2367	Var. 2419	Var. 2471	Var. 2523	Var. 2575
	0.1-1.8	Var. 2160	Var. 2212	Var. 2264	Var. 2316	Var. 2368	Var. 2420	Var. 2472	Var. 2524	Var. 2576
	0.1-1.7	Var. 2161	Var. 2213	Var. 2265	Var. 2317	Var. 2369	Var. 2421	Var. 2473	Var. 2525	Var. 2577
	0.1-1.6	Var. 2162	Var. 2214	Var. 2266	Var. 2318	Var. 2370	Var. 2422	Var. 2474	Var. 2526	Var. 2578
	0.1-1.5	Var. 2163	Var. 2215	Var. 2267	Var. 2319	Var. 2371	Var. 2423	Var. 2475	Var. 2527	Var. 2579
	0.1-1.4	Var. 2164	Var. 2216	Var. 2268	Var. 2320	Var. 2372	Var. 2424	Var. 2476	Var. 2528	Var. 2580
	0.1-1.3	Var. 2165	Var. 2217	Var. 2269	Var. 2321	Var. 2373	Var. 2425	Var. 2477	Var. 2529	Var. 2581
	0.1-1.2	Var. 2166	Var. 2218	Var. 2270	Var. 2322	Var. 2374	Var. 2426	Var. 2478	Var. 2530	Var. 2582
	0.1-1.1	Var. 2167	Var. 2219	Var. 2271	Var. 2323	Var. 2375	Var. 2427	Var. 2479	Var. 2531	Var. 2583
	0.1-1.0	Var. 2168	Var. 2220	Var. 2272	Var. 2324	Var. 2376	Var. 2428	Var. 2480	Var. 2532	Var. 2584
	0.1-0.9	Var. 2169	Var. 2221	Var. 2273	Var. 2325	Var. 2377	Var. 2429	Var. 2481	Var. 2533	Var. 2585
	0.1-0.8	Var. 2170	Var. 2222	Var. 2274	Var. 2326	Var. 2378	Var. 2430	Var. 2482	Var. 2534	Var. 2586
	0.2-2.0	Var. 2171	Var. 2223	Var. 2275	Var. 2327	Var. 2379	Var. 2431	Var. 2483	Var. 2535	Var. 2587
	0.2-1.5	Var. 2172	Var. 2224	Var. 2276	Var. 2328	Var. 2380	Var. 2432	Var. 2484	Var. 2536	Var. 2588
	0.2-1.0	Var. 2173	Var. 2225	Var. 2277	Var. 2329	Var. 2381	Var. 2433	Var. 2485	Var. 2537	Var. 2589
	0.2-0.9	Var. 2174	Var. 2226	Var. 2278	Var. 2330	Var. 2382	Var. 2434	Var. 2486	Var. 2538	Var. 2590
	0.2-0.8	Var. 2175	Var. 2227	Var. 2279	Var. 2331	Var. 2383	Var. 2435	Var. 2487	Var. 2539	Var. 2591
	0.3-1.0	Var. 2176	Var. 2228	Var. 2280	Var. 2332	Var. 2384	Var. 2436	Var. 2488	Var. 2540	Var. 2592
	0.3-0.9	Var. 2177	Var. 2229	Var. 2281	Var. 2333	Var. 2385	Var. 2437	Var. 2489	Var. 2541	Var. 2593
	0.3-0.8	Var. 2178	Var. 2230	Var. 2282	Var. 2334	Var. 2386	Var. 2438	Var. 2490	Var. 2542	Var. 2594
	0.4-1.0	Var. 2179	Var. 2231	Var. 2283	Var. 2335	Var. 2387	Var. 2439	Var. 2491	Var. 2543	Var. 2595
	0.4-0.9	Var. 2180	Var. 2232	Var. 2284	Var. 2336	Var. 2388	Var. 2440	Var. 2492	Var. 2544	Var. 2596
	0.4-0.8	Var. 2181	Var. 2233	Var. 2285	Var. 2337	Var. 2389	Var. 2441	Var. 2493	Var. 2545	Var. 2597
	0.5-1.0	Var. 2182	Var. 2234	Var. 2286	Var. 2338	Var. 2390	Var. 2442	Var. 2494	Var. 2546	Var. 2598
	0.5-0.9	Var. 2183	Var. 2235	Var. 2287	Var. 2339	Var. 2391	Var. 2443	Var. 2495	Var. 2547	Var. 2599
	0.5-0.8	Var. 2184	Var. 2236	Var. 2288	Var. 2340	Var. 2392	Var. 2444	Var. 2496	Var. 2548	Var. 2600
	0.6-1.0	Var. 2185	Var. 2237	Var. 2289	Var. 2341	Var. 2393	Var. 2445	Var. 2497	Var. 2549	Var. 2601
	0.6-0.9	Var. 2186	Var. 2238	Var. 2290	Var. 2342	Var. 2394	Var. 2446	Var. 2498	Var. 2550	Var. 2602
	0.6-0.8	Var. 2187	Var. 2239	Var. 2291	Var. 2343	Var. 2395	Var. 2447	Var. 2499	Var. 2551	Var. 2603
	0.7-1.0	Var. 2188	Var. 2240	Var. 2292	Var. 2344	Var. 2396	Var. 2448	Var. 2500	Var. 2552	Var. 2604
	0.7-0.9	Var. 2189	Var. 2241	Var. 2293	Var. 2345	Var. 2397	Var. 2449	Var. 2501	Var. 2553	Var. 2605
	0.1	Var. 2190	Var. 2242	Var. 2294	Var. 2346	Var. 2398	Var. 2450	Var. 2502	Var. 2554	Var. 2606
	0.2	Var. 2191	Var. 2243	Var. 2295	Var. 2347	Var. 2399	Var. 2451	Var. 2503	Var. 2555	Var. 2607
	0.3	Var. 2192	Var. 2244	Var. 2296	Var. 2348	Var. 2400	Var. 2452	Var. 2504	Var. 2556	Var. 2608
	0.4	Var. 2193	Var. 2245	Var. 2297	Var. 2349	Var. 2401	Var. 2453	Var. 2505	Var. 2557	Var. 2609
	0.5	Var. 2194	Var. 2246	Var. 2298	Var. 2350	Var. 2402	Var. 2454	Var. 2506	Var. 2558	Var. 2610
	0.6	Var. 2195	Var. 2247	Var. 2299	Var. 2351	Var. 2403	Var. 2455	Var. 2507	Var. 2559	Var. 2611
	0.7	Var. 2196	Var. 2248	Var. 2300	Var. 2352	Var. 2404	Var. 2456	Var. 2508	Var. 2560	Var. 2612
	0.8	Var. 2197	Var. 2249	Var. 2301	Var. 2353	Var. 2405	Var. 2457	Var. 2509	Var. 2561	Var. 2613
	0.9	Var. 2198	Var. 2250	Var. 2302	Var. 2354	Var. 2406	Var. 2458	Var. 2510	Var. 2562	Var. 2614
	1	Var. 2199	Var. 2251	Var. 2303	Var. 2355	Var. 2407	Var. 2459	Var. 2511	Var. 2563	Var. 2615
	1.1	Var. 2200	Var. 2252	Var. 2304	Var. 2356	Var. 2408	Var. 2460	Var. 2512	Var. 2564	Var. 2616
	1.2	Var. 2201	Var. 2253	Var. 2305	Var. 2357	Var. 2409	Var. 2461	Var. 2513	Var. 2565	Var. 2617
	1.3	Var. 2202	Var. 2254	Var. 2306	Var. 2358	Var. 2410	Var. 2462	Var. 2514	Var. 2566	Var. 2618
	1.4	Var. 2203	Var. 2255	Var. 2307	Var. 2359	Var. 2411	Var. 2463	Var. 2515	Var. 2567	Var. 2619
	1.5	Var. 2204	Var. 2256	Var. 2308	Var. 2360	Var. 2412	Var. 2464	Var. 2516	Var. 2568	Var. 2620
	1.6	Var. 2205	Var. 2257	Var. 2309	Var. 2361	Var. 2413	Var. 2465	Var. 2517	Var. 2569	Var. 2621
	1.7	Var. 2206	Var. 2258	Var. 2310	Var. 2362	Var. 2414	Var. 2466	Var. 2518	Var. 2570	Var. 2622
	1.8	Var. 2207	Var. 2259	Var. 2311	Var. 2363	Var. 2415	Var. 2467	Var. 2519	Var. 2571	Var. 2623
	1.9	Var. 2208	Var. 2260	Var. 2312	Var. 2364	Var. 2416	Var. 2468	Var. 2520	Var. 2572	Var. 2624
	2	Var. 2209	Var. 2261	Var. 2313	Var. 2365	Var. 2417	Var. 2469	Var. 2521	Var. 2573	Var. 2625

NMT = No More Than

Table 15. Exemplary embodiments of solution conditions useful for binding serine proteases and/or serine protease zymogens to SiO_2.

		pH							
		NMT 5.6	NMT 5.8	NMT 6.0	NMT 6.2	NMT 6.4	NMT 6.6	NMT 6.8	NMT 7.0
Ionic Strength (mS/cm)	0.1-2.0	Var. 2626	Var. 2678	Var. 2730	Var. 2782	Var. 2834	Var. 2886	Var. 2938	Var. 2990
	0.1-1.9	Var. 2627	Var. 2679	Var. 2731	Var. 2783	Var. 2835	Var. 2887	Var. 2939	Var. 2991
	0.1-1.8	Var. 2628	Var. 2680	Var. 2732	Var. 2784	Var. 2836	Var. 2888	Var. 2940	Var. 2992
	0.1-1.7	Var. 2629	Var. 2681	Var. 2733	Var. 2785	Var. 2837	Var. 2889	Var. 2941	Var. 2993
	0.1-1.6	Var. 2630	Var. 2682	Var. 2734	Var. 2786	Var. 2838	Var. 2890	Var. 2942	Var. 2994
	0.1-1.5	Var. 2631	Var. 2683	Var. 2735	Var. 2787	Var. 2839	Var. 2891	Var. 2943	Var. 2995
	0.1-1.4	Var. 2632	Var. 2684	Var. 2736	Var. 2788	Var. 2840	Var. 2892	Var. 2944	Var. 2996
	0.1-1.3	Var. 2633	Var. 2685	Var. 2737	Var. 2789	Var. 2841	Var. 2893	Var. 2945	Var. 2997
	0.1-1.2	Var. 2634	Var. 2686	Var. 2738	Var. 2790	Var. 2842	Var. 2894	Var. 2946	Var. 2998
	0.1-1.1	Var. 2635	Var. 2687	Var. 2739	Var. 2791	Var. 2843	Var. 2895	Var. 2947	Var. 2999
	0.1-1.0	Var. 2636	Var. 2688	Var. 2740	Var. 2792	Var. 2844	Var. 2896	Var. 2948	Var. 3000
	0.1-0.9	Var. 2637	Var. 2689	Var. 2741	Var. 2793	Var. 2845	Var. 2897	Var. 2949	Var. 3001
	0.1-0.8	Var. 2638	Var. 2690	Var. 2742	Var. 2794	Var. 2846	Var. 2898	Var. 2950	Var. 3002
	0.2-2.0	Var. 2639	Var. 2691	Var. 2743	Var. 2795	Var. 2847	Var. 2899	Var. 2951	Var. 3003
	0.2-1.5	Var. 2640	Var. 2692	Var. 2744	Var. 2796	Var. 2848	Var. 2900	Var. 2952	Var. 3004
	0.2-1.0	Var. 2641	Var. 2693	Var. 2745	Var. 2797	Var. 2849	Var. 2901	Var. 2953	Var. 3005
	0.2-0.9	Var. 2642	Var. 2694	Var. 2746	Var. 2798	Var. 2850	Var. 2902	Var. 2954	Var. 3006
	0.2-0.8	Var. 2643	Var. 2695	Var. 2747	Var. 2799	Var. 2851	Var. 2903	Var. 2955	Var. 3007
	0.3-1.0	Var. 2644	Var. 2696	Var. 2748	Var. 2800	Var. 2852	Var. 2904	Var. 2956	Var. 3008
	0.3-0.9	Var. 2645	Var. 2697	Var. 2749	Var. 2801	Var. 2853	Var. 2905	Var. 2957	Var. 3009
	0.3-0.8	Var. 2646	Var. 2698	Var. 2750	Var. 2802	Var. 2854	Var. 2906	Var. 2958	Var. 3010
	0.4-1.0	Var. 2647	Var. 2699	Var. 2751	Var. 2803	Var. 2855	Var. 2907	Var. 2959	Var. 3011
	0.4-0.9	Var. 2648	Var. 2700	Var. 2752	Var. 2804	Var. 2856	Var. 2908	Var. 2960	Var. 3012
	0.4-0.8	Var. 2649	Var. 2701	Var. 2753	Var. 2805	Var. 2857	Var. 2909	Var. 2961	Var. 3013
	0.5-1.0	Var. 2650	Var. 2702	Var. 2754	Var. 2806	Var. 2858	Var. 2910	Var. 2962	Var. 3014
	0.5-0.9	Var. 2651	Var. 2703	Var. 2755	Var. 2807	Var. 2859	Var. 2911	Var. 2963	Var. 3015
	0.5-0.8	Var. 2652	Var. 2704	Var. 2756	Var. 2808	Var. 2860	Var. 2912	Var. 2964	Var. 3016
	0.6-1.0	Var. 2653	Var. 2705	Var. 2757	Var. 2809	Var. 2861	Var. 2913	Var. 2965	Var. 3017
	0.6-0.9	Var. 2654	Var. 2706	Var. 2758	Var. 2810	Var. 2862	Var. 2914	Var. 2966	Var. 3018
	0.6-0.8	Var. 2655	Var. 2707	Var. 2759	Var. 2811	Var. 2863	Var. 2915	Var. 2967	Var. 3019
	0.7-1.0	Var. 2656	Var. 2708	Var. 2760	Var. 2812	Var. 2864	Var. 2916	Var. 2968	Var. 3020
	0.7-0.9	Var. 2657	Var. 2709	Var. 2761	Var. 2813	Var. 2865	Var. 2917	Var. 2969	Var. 3021
	0.1	Var. 2658	Var. 2710	Var. 2762	Var. 2814	Var. 2866	Var. 2918	Var. 2970	Var. 3022
	0.2	Var. 2659	Var. 2711	Var. 2763	Var. 2815	Var. 2867	Var. 2919	Var. 2971	Var. 3023
	0.3	Var. 2660	Var. 2712	Var. 2764	Var. 2816	Var. 2868	Var. 2920	Var. 2972	Var. 3024
	0.4	Var. 2661	Var. 2713	Var. 2765	Var. 2817	Var. 2869	Var. 2921	Var. 2973	Var. 3025
	0.5	Var. 2662	Var. 2714	Var. 2766	Var. 2818	Var. 2870	Var. 2922	Var. 2974	Var. 3026
	0.6	Var. 2663	Var. 2715	Var. 2767	Var. 2819	Var. 2871	Var. 2923	Var. 2975	Var. 3027
	0.7	Var. 2664	Var. 2716	Var. 2768	Var. 2820	Var. 2872	Var. 2924	Var. 2976	Var. 3028
	0.8	Var. 2665	Var. 2717	Var. 2769	Var. 2821	Var. 2873	Var. 2925	Var. 2977	Var. 3029
	0.9	Var. 2666	Var. 2718	Var. 2770	Var. 2822	Var. 2874	Var. 2926	Var. 2978	Var. 3030
	1	Var. 2667	Var. 2719	Var. 2771	Var. 2823	Var. 2875	Var. 2927	Var. 2979	Var. 3031
	1.1	Var. 2668	Var. 2720	Var. 2772	Var. 2824	Var. 2876	Var. 2928	Var. 2980	Var. 3032
	1.2	Var. 2669	Var. 2721	Var. 2773	Var. 2825	Var. 2877	Var. 2929	Var. 2981	Var. 3033
	1.3	Var. 2670	Var. 2722	Var. 2774	Var. 2826	Var. 2878	Var. 2930	Var. 2982	Var. 3034
	1.4	Var. 2671	Var. 2723	Var. 2775	Var. 2827	Var. 2879	Var. 2931	Var. 2983	Var. 3035
	1.5	Var. 2672	Var. 2724	Var. 2776	Var. 2828	Var. 2880	Var. 2932	Var. 2984	Var. 3036
	1.6	Var. 2673	Var. 2725	Var. 2777	Var. 2829	Var. 2881	Var. 2933	Var. 2985	Var. 3037
	1.7	Var. 2674	Var. 2726	Var. 2778	Var. 2830	Var. 2882	Var. 2934	Var. 2986	Var. 3038
	1.8	Var. 2675	Var. 2727	Var. 2779	Var. 2831	Var. 2883	Var. 2935	Var. 2987	Var. 3039
	1.9	Var. 2676	Var. 2728	Var. 2780	Var. 2832	Var. 2884	Var. 2936	Var. 2988	Var. 3040
	2	Var. 2677	Var. 2729	Var. 2781	Var. 2833	Var. 2885	Var. 2937	Var. 2989	Var. 3041

NMT = No More Than

A. Modified Alcohol Precipitation/Ion Exchange Chromatography Fractionation Methods

[0216] In one aspect, the present invention provides improved methods for the manufacture of IgG compositions suitable for use in IVIG therapy. Generally, these methods provide IgG preparations having higher yields and comparable if not higher purity than current methods employed for the production of commercial IVIG products.

[0217] In one specific aspect, the present invention provides a method for preparing a composition of concentrated IgG from plasma, *e.g.*, 10% IVIG, the method comprising performing at least one alcohol precipitation step and at least one ion exchange chromatography step. In particular, several steps in the improved upstream process are different from prior processes, *e.g.*, the use of 25% ethanol at lower temperatures, ethanol addition by spraying, pH adjustment by spraying, and the use of finely divided silica particles.

[0218] In a certain embodiment, the method comprises the steps of (a) precipitating a cryo-poor plasmid fraction, in a first precipitation step, with between about 6% and about 10% alcohol at a pH of between about 6.7 and about 7.3 to obtain a supernatant enriched in IgG, (b) precipitating IgG from the supernatant with between about 20% and about 30% alcohol at a lower temperature and at a pH of between about 6.7 and about 7.3 to form a first precipitate, (c) re-suspending the first precipitate formed in step (b) to form a suspension, (d) treating the suspension formed in step (c) with a detergent, (e) precipitating IgG from the suspension with between about 20% and about 30% alcohol at a pH of between about 6.7 and about 7.3 to form a second precipitate, (f) re-suspending the second precipitate formed in step (e) to form a suspension, (g) treating the suspension formed in step (f) with a solvent and/or detergent, and (h) performing at least one ion exchange chromatography fractionation thereby preparing a composition of concentrated IgG. In one embodiment, the method further comprises treating the suspension formed in step (c) with finely divided silica dioxide (SiO_2) and filtering the solution prior to step (d).

[0219] In one embodiment, a method for preparing a concentrated IgG composition from plasma is provided, the method comprising the steps of (a) adjusting the pH of a cryo-poor plasma fraction to about 7.0, (b) adjusting the ethanol concentration of the cryo-poor plasma

fraction of step (a) to at or about 25% (v/v) at a temperature between about -5°C and about -9°C, thereby forming a mixture, wherein the ethanol concentration may be adjusted by spraying, (c) separating liquid and precipitate from the mixture of step (b), (d) re-suspending the precipitate of step (c) with a buffer containing phosphate and acetate, wherein the pH of the buffer is adjusted with between about 400 and about 700 ml of glacial acetic acid per 1000L of buffer, thereby forming a suspension, (e) mixing finely divided silicon dioxide (SiO2) with the suspension from step (d) for at least about 30 minutes, (f) filtering the suspension with a filter press, thereby forming a filtrate, (g) washing the filter press with at least 3 filter press dead volumes of a buffer containing phosphate and acetate, wherein the pH of the buffer is adjusted with about 150 ml of glacial acetic acid per 1000L of buffer, thereby forming a wash solution, (h) combining the filtrate of step (f) with the wash solution of step (g), thereby forming a solution, and treating the solution with a detergent, (i) adjusting the pH of the solution of step (h) to about 7.0 and adding ethanol to a final concentration of at or about 25%, thereby forming a precipitate, wherein the ethanol concentration and/or pH may be adjusted by spraying (j) separating liquid and precipitate from the mixture of step (i), (k) dissolving the precipitate in an aqueous solution comprising a solvent or detergent and maintaining the solution for at least 60 minutes, (l) passing the solution after step (k) through a cation exchange chromatography column and eluting proteins absorbed on the column in an eluate, (m) passing the eluate from step (l) through an anion exchange chromatography column to generate an effluent (*i.e.*, flow-through), (n) passing the effluent from step (m) through a nanofilter to generate a nanofiltrate, (o) passing the nanofiltrate from step (n) through an ultrafiltration membrane to generate an ultrafiltrate, and (p) diafiltrating the ultrafiltrate from step (o) against a diafiltration buffer to generate a diafiltrate having a protein concentration between about 8% (w/v) and about 22% (w/v), thereby obtaining a composition of concentrated IgG. In one embodiment, the temperature of step (b) is at or about -7°C. In one specific embodiment, the suspension buffer in step (d) is adjusted with about 600 mL glacial acetic acid.

[0220] In certain embodiments, the diafiltrate will have a protein concentration between about 8% and about 12%, for example, about 8%, or about 9%, 10%, 11%, or 12%. In a preferred embodiment, the diafiltrate will have a protein concentration of at or about 10%. In another preferred embodiment, the diafiltrate will have a protein concentration of at or about 11%. In yet another preferred embodiment, the diafiltrate will have a protein concentration of at or about 12%. In other embodiments, the diafiltrate will have a protein concentration between about 13%

and about 17%, for example, about 13%, or about 14%, 15%, 16%, or 17%. In yet other embodiments, the diafiltrate will have a protein concentration between about 18% and about 22%, for example, about 18%, or about 19%, 20%, 21%, or 22%. In a preferred embodiment, the diafiltrate will have a protein concentration of at or about 20%. In another preferred embodiment, the diafiltrate will have a protein concentration of at or about 21%. In yet another preferred embodiment, the diafiltrate will have a protein concentration of at or about 22%.

[0221] In certain embodiments of the present invention, the methods provided herein may comprise improvements in two or more of the fractionation process steps described above. For example, embodiments may include improvements in the first precipitation step, the Modified Fraction II+III precipitation step, the Modified Fraction II+III dissolution step, and/or the Modified Fraction II+III suspension filtration step.

[0222] In one embodiment, the improvement made in the first precipitation step is the addition of alcohol by spraying. In another embodiment, the improvement made in the first precipitation step is the addition of a pH modifying agent by spraying. In yet embodiment, the improvement made in the first precipitation step is the adjustment of the pH of the solution after addition of the alcohol. In a related embodiment, the improvement made in the first precipitation step is the maintenance of the pH during the addition of the alcohol. In another related embodiment, the improvement made in the first precipitation step is the maintenance of the pH during the precipitation incubation time by continuously adjusting the pH of the solution. In certain embodiments, the first precipitation step may be improved by implementing more than one of these improvements. Further improvements that may be realized in this step will be evident from the section provided below discussing the first precipitation step – Modified Fractionation I. By implementing one or more of the improvements described above, a reduced amount of IgG is lost in the precipitate fraction of the first precipitation step and/or a reduced fraction of IgG is irreversibly denatured during the precipitation step.

[0223] In one embodiment, the improvement made in the Modified Fraction II+III precipitation step is the addition of alcohol by spraying. In another embodiment, the improvement made in the Modified Fraction II+III precipitation step is the addition of a pH modifying agent by spraying. In yet embodiment, the improvement made in the Modified Fraction II+III precipitation step is the adjustment of the pH of the solution after addition of the alcohol. In a related embodiment, the improvement made in the Modified Fraction II+III

precipitation step is the maintenance of the pH during the addition of the alcohol. In another related embodiment, the improvement made in the Modified Fraction II+III precipitation step is the maintenance of the pH during the precipitation incubation time by continuously adjusting the pH of the solution. In another aspect, the Modified Fraction II+III precipitation step is improved by increasing the concentration of alcohol to at or about 25%. In yet another embodiment, the Modified Fraction II+III precipitation step is improved by lowering the incubation temperature to between about -7°C and -9°C. In certain embodiments, the Modified Fraction II+III precipitation step may be improved by implementing more than one of these improvements. Further improvements that may be realized in this step will be evident from the section provided below discussing the second precipitation step – Modified Fractionation II+III.. By implementing one or more of the improvements described above, a reduced amount of IgG is lost in the supernatant fraction of the Modified Fraction II+III precipitation step and/or a reduced fraction of IgG is irreversibly denatured during the precipitation step.

[0224] In one embodiment, the improvement made in the Modified Fraction II+III dissolution step is achieved by increasing the glacial acetic acid content of the dissolution buffer to about 0.06%. In another embodiment, the improvement made in the Modified Fraction II+III dissolution step is achieved by maintaining the pH of the solution during the dissolution incubation time by continuously adjusting the pH of the solution. In another embodiment, the improvement made in the Modified Fraction II+III dissolution step is achieved by mixing finely divided silicon dioxide (SiO_2) with the Fraction II+III suspension prior to filtration. In certain embodiments, the Modified Fraction II+III dissolution step may be improved by implementing more than one of these improvements. Further improvements that may be realized in this step will be evident from the section provided below discussing the Modified Fraction II+III dissolution step – Extraction of the Modified Fraction II+III Precipitate. By implementing one or more of the improvements described above, an increased amount of IgG is recovered in the Fraction II+III suspension and/or the amount of impurities is reduced in the Fraction II+III suspension.

[0225] An exemplary improvement made in the Modified Fraction II+III suspension filtration step is realized by post-washing the filter with at least about 3.6 dead volumes of dissolution buffer containing at or about 150 mL glacial acetic acid per 1000 L. Further improvements that may be realized in this step will be evident from the section provided below discussing the Modified Fraction II+III suspension filtration step – Pretreatment and Filtration of the Modified

Fraction II+III Suspension. By implementing one or more of the improvements described above, a reduced amount of IgG is lost during the Modified Fraction II+III suspension filtration step.

[0226] In one embodiment, the method may comprise an improvement in the first precipitation step and the Modified Fraction II+III precipitation step.

[0227] In another embodiment, the method may comprise an improvement in the first precipitation step and the Modified Fraction II+III dissolution step.

[0228] In another embodiment, the method may comprise an improvement in the first precipitation step and the Modified Fraction II+III suspension filtration step.

[0229] In another embodiment, the method may comprise an improvement in the Modified Fraction II+III precipitation step and the Modified Fraction II+III dissolution step.

[0230] In another embodiment, the method may comprise an improvement in the Modified Fraction II+III precipitation step and the Modified Fraction II+III suspension filtration step.

[0231] In another embodiment, the method may comprise an improvement in the Modified Fraction II+III dissolution step and the Modified Fraction II+III suspension filtration step.

[0232] In another embodiment, the method may comprise an improvement in the first precipitation step, the Modified Fraction II+III precipitation step, and the Modified Fraction II+III dissolution step.

[0233] In another embodiment, the method may comprise an improvement in the first precipitation step, the Modified Fraction II+III precipitation step, and the Modified Fraction II+III suspension filtration step.

[0234] In another embodiment, the method may comprise an improvement in the first precipitation step, the Modified Fraction II+III dissolution step, and the Modified Fraction II+III suspension filtration step.

[0235] In another embodiment, the method may comprise an improvement in the Modified Fraction II+III precipitation step, the Modified Fraction II+III dissolution step, and the Modified Fraction II+III suspension filtration step.

[0236] In another embodiment, the method may comprise an improvement in all of the first precipitation step, the Modified Fraction II+III precipitation step, the Modified Fraction II+III dissolution step, and the Modified Fraction II+III suspension filtration step.

[0237] In certain embodiments, one process improvement in the IgG purification methods provided herein comprises the spray addition of one or more solutions that would otherwise be introduced into a plasma fraction by fluent addition. For example, in certain embodiments the process improvement comprises the addition of alcohol (*e.g.*, ethanol) into a plasma fraction for the purposes of precipitation of one or more protein species by spraying. In other embodiments, solutions that may be added to a plasma fraction by spraying include, without limitation, a pH modifying solution, a solvent solution, a detergent solution, a dilution buffer, a conductivity modifying solution, and the like. In a preferred embodiment, one or more alcohol precipitation steps is performed by the addition of alcohol to a plasma fraction by spraying. In a second preferred embodiment, one or more pH adjustment steps is performed by the addition of a pH modifying solution to a plasma fraction by spraying.

[0238] In certain embodiments, another process improvement, which may be combined with any other process improvement, comprises the adjustment of the pH of a plasma fraction being precipitated after and/or concomitant with the addition of the precipitating agent (*e.g.*, alcohol or polyethelene glycol). In some embodiments, a process improvement is provided in which the pH of a plasma fraction being actively precipitated is maintained throughout the entire precipitation incubation or hold step by continuous monitoring and adjustment of the pH. In preferred embodiments the adjustment of the pH is performed by the spray addition of a pH modifying solution.

[0239] In other embodiments, another process improvement, which may be combined with any other process improvement, comprises the use of a finely divided silica treatment step to remove impurities.

1. Preparation of Cryo-poor Plasma

[0240] The starting material used for the preparation of concentrated IgG compositions generally consists of either recovered plasma (*i.e.*, plasma that has been separated from whole blood *ex vivo*) or source plasma (*i.e.*, plasma collected via plasmapheresis). The purification process typically starts with thawing previously frozen pooled plasma, which has already been

assayed for safety and quality considerations. Thawing is typically carried out at a temperature no higher than 6°C. After complete thawing of the frozen plasma at low temperature, centrifugation is performed in the cold (*e.g.*, ≤ 6°C) to separate solid cryo-precipitates from the liquid supernatant. Alternatively, the separation step can be performed by filtration rather than centrifugation. The liquid supernatant (also referred to as "cryo-poor plasma," after cold-insoluble proteins removed by centrifugation from fresh thawed plasma) is then processed in the next step. Various additional steps can be taken at this juncture for the isolation of factor eight inhibitor bypass activity (FEIBA), Factor IX-complex, Factor VII-concentrate, or Antithrombin III-complex.

2. First Precipitation Event – Modified Fractionation I

[0241] In this step, cryo-poor plasma is typically cooled to about 0 ± 1°C and the pH is adjusted to between about 7.0 and about 7.5, preferably between about 7.1 and about 7.3, most preferably about 7.2. In one embodiment, the pH of the cryo-poor plasma is adjusted to a pH of at or about 7.2. Pre-cooled ethanol is then added while the plasma is stirred to a target concentration of ethanol at or about 8% v/v. At the same time the temperature is further lowered to between about -4 and about 0°C. In a preferred embodiment, the temperature is lowered to at or about -2°C, to precipitate contaminants such as α_2-macroglobulin, β_{1A}- and β_{1C}-globulin, fibrinogen, and Factor VIII. Typically, the precipitation event will include a hold time of at least about 1 hour, although shorter or longer hold times may also be employed. Subsequently, the supernatant (Supernatant I), ideally containing the entirety of the IgG content present in the cryo-poor plasma, is then collected by centrifugation, filtration, or another suitable method.

[0242] As compared to conventional methods employed as a first fractionation step for cryo-poor plasma (Cohn *et al.*, *supra*; Oncley *et al.*, *supra*), the present invention provides, in several embodiments, methods that result in improved IgG yields in the Supernatant I fraction. In one embodiment, the improved IgG yield is achieved by adding the alcohol by spraying. In another embodiment, the improved IgG yield is achieved by adding a pH modifying agent by spraying. In yet another embodiment, the improved IgG yield is achieved by adjusting the pH of the solution after addition of the alcohol. In a related embodiment, the improved IgG yield is achieved by adjusting the pH of the solution during the addition of the alcohol.

[0243] In one specific aspect, the improvement relates to a method in which a reduced amount of IgG is lost in the precipitate fraction of the first precipitation step. For example, in certain

embodiments, a reduced amount of IgG is lost in the precipitate fraction of the first precipitation step as compared to the amount of IgG lost in the first precipitation step of the Cohn method 6 protocol.

[0244] In certain embodiments, the process improvement is realized by adjusting the pH of the solution to between about 7.0 and about 7.5 after the addition of the precipitating alcohol. In other embodiments, the pH of the solution is adjusted to between about 7.1 and about 7.3 after addition of the precipitating alcohol. In yet other embodiments, the pH of the solution is adjusted to about 7.0 or about 7.1, 7.2, 7,3, 7.4, or 7.5 after addition of the precipitating alcohol. In a particular embodiment, the pH of the solution is adjusted to about 7.2 after addition of the precipitating alcohol. As such, in certain embodiments, a reduced amount of IgG is lost in the precipitate fraction of the first precipitation step as compared to an analogous precipitation step in which the pH of the solution is adjusted prior to but not after addition of the precipitating alcohol. In one embodiment, the pH is maintained at the desired pH during the precipitation hold or incubation time by continuously adjusting the pH of the solution. In one embodiment, the alcohol is ethanol.

[0245] In other certain embodiments, the process improvement is realized by adding the precipitating alcohol and/or the solution used to adjust the pH by spraying, rather than by fluent addition. As such, in certain embodiments, a reduced amount of IgG is lost in the precipitate fraction of the first precipitation step as compared to an analogous precipitation step in which the alcohol and/or solution used to adjust the pH is introduced by fluent addition. In one embodiment, the alcohol is ethanol.

[0246] In yet other certain embodiments, the improvement is realized by adjusting the pH of the solution to between about 7.0 and about 7.5. In a preferred embodiment, the pH of the solution is adjusted to between about 7.1 and about 7.3. In other embodiments, the pH of the solution is adjusted to at or about 7.0, 7.1, 7.2, 7.3, 7.4, or 7.5 after the addition of the precipitating alcohol and by adding the precipitating alcohol and/or the solution used to adjust the pH by spraying, rather than by fluent addition. In a particular embodiment, the pH of the solution is adjusted to at or about 7.2 after addition of the precipitating alcohol and by adding the precipitating alcohol and/or the solution used to adjust the pH by spraying, rather than by fluent addition. In one embodiment, the alcohol is ethanol.

3. Second Precipitation Event – Modified Fractionation II+III

[0247] To further enrich the IgG content and purity of the fractionation, Supernatant I is subjected to a second precipitation step, which is a modified Cohn-Oncley Fraction II+III fractionation. Generally, the pH of the solution is adjusted to a pH of between about 6.6 and about 6.8. In a preferred embodiment, the pH of the solution is adjusted to at or about 6.7. Alcohol, preferably ethanol, is then added to the solution while being stirred to a final concentration of between about 20% and about 25% (v/v) to precipitate the IgG in the fraction. In a preferred embodiment, alcohol is added to a final concentration of at or about 25% (v/v) to precipitate the IgG in the fraction. Generally, contaminants such as α_1-lipoprotein, α_1-antitrypsin, Gc-globulins, α_{1X}-glycoprotin, haptoglobulin, ceruloplasmin, transferrin, hemopexin, a fraction of the Christmas factor, thyroxin binding globulin, cholinesterase, hypertensinogen, and albumin will not be precipitated by these conditions.

[0248] Prior to or concomitant with alcohol addition, the solution is further cooled to between about -7°C and about -9°C. In a preferred embodiment, the solution is cooled to a temperature at or about -7°C. After completion of the alcohol addition, the pH of the solution is immediately adjusted to between about 6.8 and about 7.0. In a preferred embodiment, the pH of the solution is adjusted to at or about 6.9. Typically, the precipitation event will include a hold time of at least about 10 hours, although shorter or longer hold times may also be employed. Subsequently, the precipitate (Modified Fraction II+III), which ideally contains at least about 85%, preferably at least about 90%, more preferably at least about 95%, of the IgG content present in the cryo-poor plasma, is separated from the supernatant by centrifugation, filtration, or another suitable method and collected. As compared to conventional methods employed as a second fractionation step for cryo-poor plasma (Cohn *et al.*, *supra*; Oncley *et al.*, *supra*), the present invention provides, in several embodiments, methods that result in improved IgG yields in the Modified Fraction II+III precipitate. In a related embodiment, the present invention provides methods that result in a reduced loss of IgG in the Modified II+III supernatant.

[0249] As compared to conventional methods employed as a second fractionation step for cryo-poor plasma (Cohn *et al.*, *supra*; Oncley *et al.*, *supra*), the present invention provides, in several embodiments, methods that result in improved IgG yields in the Modified Fraction II+III precipitate. In one embodiment, the improvement is realized by the addition of alcohol by spraying. In another embodiment, the improvement is realized by the addition of a pH

modifying agent by spraying. In another embodiment, the improvement is realized by adjusting the pH of the solution after addition of the alcohol. In a related embodiment, the improvement is realized by adjusting the pH of the solution during addition of the alcohol. In another embodiment, the improvement is realized by increasing the concentration of alcohol (*e.g.*, ethanol) to about 25% (v/v). In another embodiment, the improvement is realized by lowering the temperature of the precipitation step to between about -7°C and -9°C. In a preferred embodiment, the improvement is realized by increasing the concentration of alcohol (*e.g.*, ethanol) to about 25% (v/v) and lowing the temperature to between about -7°C and -9°C. In comparison, both Cohn *et al.* and Oncley *et al.* perform precipitation at -5°C and Oncley *et al.* use 20% alcohol, in order to reduce the level of contaminants in the precipitate. Advantageously, the methods provided herein allow for maximal IgG yield without high levels of contamination in the final product.

[0250] It has been discovered that when the pH of the solution is adjusted to a pH of about 6.9 prior to addition of the precipitating alcohol, the pH of the solution shift from 6.9 to between about 7.4 and about 7.7, due in part to protein precipitation (*see*, Figure 8). As the pH of the solution shifts away from 6.9, precipitation of IgG becomes less favorable and the precipitation of certain contaminants becomes more favorable. Advantageously, the inventors have found that by adjusting the pH of the solution after addition of the precipitating alcohol, that a higher percentage of IgG is recovered in the Fraction II+III precipitate.

[0251] Accordingly, in one aspect, the improvement relates to a method in which a reduced amount of IgG is lost in the supernatant fraction of the modified Fraction II+III precipitation step. In other words, an increased percentage of the starting IgG is present in the Fraction II+III precipitate. In certain embodiments, the process improvement is realized by adjusting the pH of the solution to between about 6.7 and about 7.1 immediately after or during the addition of the precipitating alcohol. In another embodiment, the process improvement is realized by maintaining the pH of the solution to between about 6.7 and about 7.1 continuously during the precipitation incubation period. In other embodiments, the pH of the solution is adjusted to between about 6.8 and about 7.0 immediately after or during the addition of the precipitating alcohol, or to a pH of about 6.7, 6.8, 6.9, 7.0, or 7.1 immediately after or during the addition of the precipitating alcohol. In a particular embodiment, the pH of the solution is adjusted to about 6.9 immediately after or during the addition of the precipitating alcohol. In certain embodiments, the pH of the solution is maintained at between about 6.8 to about 7.0

continuously during the precipitation incubation period, or at a pH of about 6.9 continuously during the precipitation incubation period. As such, in certain embodiments, a reduced amount of IgG is lost in the supernatant fraction of the second precipitation step as compared to an analogous precipitation step in which the pH of the solution is adjusted prior to but not after addition of the precipitating alcohol or to an analogous precipitation step in which the pH of the solution is not maintained during the entirety of the precipitation incubation period. In one embodiment, the pH is maintained at the desired pH during the precipitation hold or incubation time by continuously adjusting the pH of the solution. In one embodiment, the alcohol is ethanol.

[0252] In another embodiment, the process improvement is realized by adding the precipitating alcohol and/or the solution used to adjust the pH by spraying, rather than by fluent addition. As such, in certain embodiments, a reduced amount of IgG is lost in the supernatant fraction of the second precipitation step as compared to an analogous precipitation step in which the alcohol and/or solution used to adjust the pH is introduced by fluent addition. In one embodiment, the alcohol is ethanol.

[0253] In another embodiment, the process improvement is realized by performing the precipitation step at a temperature between about -7°C and about -9°C. In one embodiment, the precipitation step is performed at a temperature of at or about -7°C. In another embodiment, the precipitation step is performed at a temperature of at or about -8°C. In another embodiment, the precipitation step is performed at a temperature of at or about -9°C. In certain embodiments, the alcohol concentration of the precipitation step is between about 23% and about 27%. In a preferred embodiment, the alcohol concentration is between about 24% and about 26%. In another preferred embodiment, the alcohol concentration is at or about 25%. In other embodiments, the alcohol concentration may be at or about 23%, 24%, 25%, 26%, or 27%. In a particular embodiment, the second precipitation step is performed at a temperature of at or about -7°C with an alcohol concentration of at or about 25%. In one embodiment, the alcohol is ethanol.

[0254] The effect of increasing the alcohol concentration of the second precipitation from 20%, as used in Oncley *et al., supra*, to 25% and lowering the temperature of the incubation from -5°C, as used in the Cohn and Oncley methods, to at or about -7°C is a 5 %to 6% increase in the IgG content of the modified Fraction II+III precipitate.

[0255] In another embodiment, the process improvement is realized by adjusting the pH of the solution to between about 6.7 and about 7.1, preferably at or about 6.9, immediately after or during the addition of the precipitating alcohol, maintaining the pH of the solution at a pH of between about 6.7 and about 7.1, preferably at or about 6.9, by continuously adjusting the pH during the precipitation incubation period, and by adding the precipitating alcohol and/or the solution used to adjust the pH by spraying, rather than by fluent addition. In another particular embodiment, the process improvement is realized by performing the precipitation step at a temperature between about -7°C and about -9°C, preferably at or about -7°C and by precipitating the IgG with an alcohol concentration of between about 23% and about 27%, preferably at or about 25%. In yet another particular embodiment, the process improvement is realized by incorporating all of the Modified Fraction II+III improvements provided above. In a preferred embodiment, the process improvement is realized by precipitating IgG at a temperature of at or about -7°C with at or about 25% ethanol added by spraying and then adjusting the pH of the solution to at or about 6.9 after addition of the precipitating alcohol. In yet another preferred embodiment, the pH of the solution is maintained at or about 6.9 for the entirety of the precipitation incubation or hold time.

4. Extraction of the Modified Fraction II+III Precipitate

[0256] In order to solubilize the IgG content of the modified Fraction II+III precipitate, a cold extraction buffer is used to re-suspend the Fractionation II+III precipitate at a typical ratio of 1 part precipitate to 15 parts of extraction buffer. Other suitable re-suspension ratios may be used, for example from about 1:8 to about 1:30, or from about 1:10 to about 1:20, or from about 1:12 to about 1:18, or from about 1:13 to about 1:17, or from about 1:14 to about 1:16. In certain embodiments, the re-suspension ratio may be about 1:8, 1:9, 1:10, 1:11, 1:12, 1:13, 1:14, 1:15, 1:16, 1:17, 1:18, 1:19, 1:20, 1:21, 1:22, 1:23, 1:24, 1:25, 1:26, 1:27, 1:28, 1:29, 1:30, or higher.

[0257] Suitable solutions for the extraction of the modified II+III precipitate will generally have a pH between about 4.0 and about 5.5. In certain embodiments, the solution will have a pH between about 4.5 and about 5.0, in other embodiments, the extraction solution will have a pH of about 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, or 5.5. In a preferred embodiment, the pH of the extraction buffer will be at or about 4.5. In another preferred embodiment, the pH of the extraction buffer will be at or about 4.7. In another preferred embodiment, the pH of the extraction buffer will be at or about 4.9. Generally, these pH

requirements can be met using a buffering agent selected from, for example, acetate, citrate, monobasic phosphate, dibasic phosphate, mixtures thereof, and the like. Suitable buffer concentrations typically range from about 5 to about 100 mM, or from about 10 to about 50 mM, or about 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, or 100 mM buffering agent.

[0258] The extraction buffer will preferably have a conductivity of from about 0.5 $mS \cdot cm^{-1}$ to about 2.0 $mS \cdot cm^{-1}$. For example, in certain embodiments, the conductivity of the extraction buffer will be about 0.5 $mS \cdot cm^{-1}$, or about 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or about 2.0 $mS \cdot cm^{-1}$. One of ordinary skill in the art will know how to generate extraction buffers having an appropriate conductivity.

[0259] In one particular embodiment, an exemplary extraction buffer may contain at or about 5 mM monobasic sodium phosphate and at or about 5 mM acetate at a pH of at or about 4.5 ± 0.2 and conductivity of at or about 0.7 to 0.9 mS/cm.

[0260] Generally, the extraction is performed at between about 0°C and about 10°C, or between about 2°C and about 8°C. In certain embodiments, the extraction may be performed at about 0°C, 1°C, 2°C, 3°C, 4°C, 5°C, 6°C, 7°C, 8°C, 9°C, or 10°C. In a particular embodiment, the extraction is performed at between about 2°C and about 10°C. Typically, the extraction process will proceed for between about 60 and about 300 minutes, or for between about 120 and 240 min, or for between about 150 and 210 minutes, while the suspension is continuously stirred. In certain embodiments, the extraction process will proceed for about 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, or about 300 minutes. In a preferred embodiment, the extraction process will proceed for at least 160 minutes with continuous stirring.

[0261] It has been found that employing an extraction buffer containing 5 mM monobasic sodium phosphate, 5 mM acetate, and 0.051% to 0.06% glacial acetic acid (v/v), a substantial increase in the yield increase in the final IgG composition can be obtained without jeopardizing the purity of the final product. The correlation of amount of acetic acid and extraction buffer pH is demonstrated in Figure 9. In a preferred embodiment, the Fraction II+III precipitate is extracted with a paste to buffer ration of at or about 1:15 at a pH of at or about 4.5 ± 0.2.

[0262] Advantageously, it has been found that compared to the current manufacturing process for GAMMAGARD® LIQUID (Baxter Healthcare), which employs an extraction buffer containing 5 mM monobasic sodium phosphate, 5 mM acetate, and 0.051% glacial acetic acid (v/v), that by increasing the glacial acetic acid content to at or about 0.06% (v/v), a substantial increase in the yield increase in the final IgG composition can be obtained. As compared to methods previously employed for the extraction of the precipitate formed by the second precipitation step (GAMMAGARD® LIQUID), the present invention provides, in several embodiments, methods that result in improved IgG yields in the Modified Fraction II+III suspension.

[0263] In one aspect, the improvement relates to a method in which a reduced amount of IgG is lost in the non-solubilized fraction of the Modified Fraction II+III precipitate. In one embodiment, the process improvement is realized by extracting the Modified Fraction II+III precipitate at a ratio of 1:15 (precipitate to buffer) with a solution containing 5 mM monobasic sodium phosphate, 5 mM acetate, and 0.06% glacial acetic acid (v/v). In another embodiment, the improvement is realized by maintaining the pH of the solution during the duration of the extraction process. In one embodiment, the pH of the solution is maintained at between about 4.1 and about 4.9 for the duration of the extraction process. In a preferred embodiment, the pH of the solution is maintained at between about 4.2 and about 4.8 for the duration of the extraction process. In a more preferred embodiment, the pH of the solution is maintained at between about 4.3 and about 4.7 for the duration of the extraction process. In another preferred embodiment, the pH of the solution is maintained at between about 4.4 and about 4.6 for the duration of the extraction process. In yet another preferred embodiment, the pH of the solution is maintained at or at about 4.5 for the duration of the extraction process.

[0264] In another aspect, the improvement relates to a method in which an increased amount of IgG is solubilized from the Fraction II+III precipitate in the Fraction II+III dissolution step. In one embodiment, the process improvement is realized by solubilizing the Fraction II+III precipitate in a dissolution buffer containing 600 mL glacial acetic acid per 1000 L. In another embodiment, the improvement relates to a method in which impurities are reduced after the IgG in the Fraction II+III precipitate is solubilized. In one embodiment, the process improvement is

realized by mixing finely divided silicon dioxide (SiO_2) with the Fraction II+III suspension for at least about 30 minutes.

5. Pretreatment and Filtration of the Modified Fraction II+III Suspension

[0265] In order to remove the non-solubilized fraction of the Modified Fraction II+III precipitate (*i.e.*, the Modified Fraction II+III filter cake), the suspension is filtered, typically using depth filtration. Depth filters that may be employed in the methods provided herein include, metallic, glass, ceramic, organic (such as diatomaceous earth) depth filters, and the like. Example of suitable filters include, without limitation, Cuno 50SA, Cuno 90SA, and Cuno VR06 filters (Cuno). Alternatively, the separation step can be performed by centrifugation rather than filtration.

[0266] Although the manufacturing process improvements described above minimize IgG losses in the initial steps of the purification process, critical impurities, including PKA activity, amidolytic activity, and fibrinogen content, are much higher when, for example, the II+III paste is extracted at pH 4.5 or 4.6, as compared to when the extraction occurs at a pH around 4.9 to 5.0 (*see*, Examples 2 to 5).

[0267] In order to counter act the impurities extracted in the methods provided herein, it has now been found that the purity of the IgG composition can be greatly enhanced by the addition of a pretreatment step prior to filtration/centrifugation. In one embodiment, this pretreatment step comprises addition of finely divided silica dioxide particles (*e.g.*, fumed silica, Aerosil®) followed by a 40 to 80 minute incubation period during which the suspension is constantly mixed. In certain embodiments, the incubation period will be between about 50 minutes and about 70 minutes, or about 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, or more minutes. Generally, the treatment will be performed at between about 0°C and about 10°C, or between about 2°C and about 8°C. In certain embodiments, the treatment may be performed at about 0°C, 1°C, 2°C, 3°C, 4°C, 5°C, 6°C, 7°C, 8°C, 9°C, or 10°C. In a particular embodiment, the treatment is performed at between about 2°C and about 10°C.

[0268] The effect of the fumed silica treatment is exemplified by the results found in Example 17. In this example, a Fraction II+III precipitate is suspended and split into two samples, one of which is clarified with filter aid only prior to filtration (Figure 7A) and one of which is treated

with fumed silica prior to addition of the filter aid and filtration (Figure 7B). As can be seen in the chromatographs and in the quantitated data, the filtrate sample pretreated with fumed silica had a much higher IgG purity than the sample only treated with filter aid (68.8% vs. 55.7%; compare Tables 17 and 18, respectively).

[0269] In certain embodiments, fumed silica is added at a concentration of between about 20 g/kg II+III paste and about 100 g/kg II+III paste (*i.e.*, for a Modified Fraction II+III precipitate that is extracted at a ratio of 1:15, fumed silica should be added at a concentration from about 20 g/16 kg II+III suspension to about 100 g/16 kg II+III suspension, or at a final concentration of about 0.125% (w/w) to about 0.625% (w/w)). In certain embodiments, the fumed silica may be added at a concentration of about 20 g/kg II+III paste, or about 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, or 100 g/kg II+III paste. In one specific embodiment, fumed silica (e.g., Aerosil 380 or equivalent) is added to the Modified Fraction II+III suspension to a final concentration of about 40 g/16 kg II+III. Mixing takes place at about 2 to 8°C for at least 50 to 70 minutes.

[0270] In certain embodiments, SiO_2 is added to a an IgG composition at a concentration between about 0.01 g/g protein and about 10 g/g protein. In another embodiment, SiO_2 is added to a an IgG composition at a concentration between about 0.01 g/g protein and about 5 g/g protein. In another embodiment, SiO_2 is added to an IgG composition at a concentration between about 0.02 g/g protein and about 4 g/g protein. In one embodiment, SiO_2 is added at a final concentration of at least 0.1 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.25 g per gram total protein. In other specific embodiments, fumed silica is added at a concentration of at least 1 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2.5 g per gram total protein. In yet other specific embodiments, finely divided silicon dioxide is added at a concentration of at least 0.01 g/g total protein or at least 0.02 g, 0.03 g, 0.04 g, 0.05 g, 0.06 g, 0.07 g, 0.08 g, 0.09 g, 0.1 g, 0.2 g, 0.3 g, 0.4 g, 0.5 g, 0.6 g, 0.7 g, 0.8 g, 0.9 g, 1.0 g, 1.5 g, 2.0 g, 2.5 g, 3.0 g, 3.5 g, 4.0 g, 4.5 g, 5.0 g, 5.5 g, 6.0 g, 6.5 g, 7.0 g, 7.5 g, 8.0 g, 8.5 g, 9.0 g, 9.5 g, 10.0 g, or more per gram total protein.

[0271] In certain embodiments, filter aid, for example Celpure C300 (Celpure) or Hyflo-Supper-Cel (World Minerals), will be added after the silica dioxide treatment, to facilitate depth filtration. Filter aid can be added at a final concentration of from about 0.01 kg/kg II+III paste to about 1.0 kg/kg II+III paste, or from about 0.02 kg/kg II+III paste to about 0.8 kg/kg II+III paste, or from about 0.03 kg/kg II+III paste to about 0.7 kg/kg II+III paste. In other embodiments, filter aid can be added at a final concentration of from about 0.01 kg/kg II+III paste to about 0.07 kg/kg II+III paste, or from about 0.02 kg/kg II+III paste to about 0.06 kg/kg II+III paste, or from about 0.03 kg/kg II+III paste to about 0.05 kg/kg II+III paste. In certain embodiments, the filter aid will be added at a final concentration of about 0.01 kg/kg II+III paste, or about 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, or 1.0 kg/kg II+III paste.

[0272] A significant fraction of IgG was being lost during the filtration step of the GAMMAGARD® LIQUID manufacturing process. It was found that the current methods of post-filtration wash, using 1.8 dead volumes of suspension buffer to purge the filter press frames and lines, were insufficient for maximal recovery of IgG at this step. Surprisingly, it was found that at least 3.0 dead volumes, preferably 3.6 dead volumes, of suspension buffer were required in order for efficient recovery of total IgG in the Modified Fraction II+III clarified suspension (*see*, Example 12 and Figure 1). In certain embodiments, the filter press may be washed with any suitable suspension buffer. In a particular embodiment, the wash buffer will comprise, for example, 5 mM monobasic sodium phosphate, 5 mM acetate, and 0.015% glacial acetic acid (v/v).

[0273] In one aspect, the improvement relates to a method in which a reduced amount of IgG is lost during the Fraction II+III suspension filtration step. In one embodiment, the process improvement is realized by post-washing the filter with at least about 3.6 dead volumes of dissolution buffer containing 150 mL glacial acetic acid per 1000 L. The relationship between the amount of glacial acetic acid and pH in the post-wash buffer is shown in Figure 10. In one embodiment, the pH of the post-wash extraction buffer is between about 4.6 and about 5.3. In a preferred embodiment, the pH of the post-wash buffer is between about 4.7 and about 5.2. In another preferred embodiment, the pH of the post-wash buffer is between about 4.8 and about 5.1. In yet another preferred embodiment, the pH of the post-wash buffer is between about 4.9 and about 5.0.

[0274] As compared to methods previously employed for the clarification of the suspension formed from the second precipitation step (GAMMAGARD® LIQUID), the present invention provides, in several embodiments, methods that result in improved IgG yields and purity in the clarified Fraction II+III suspension. In one aspect, the improvement relates to a method in which a reduced amount of IgG is lost in the Modified Fraction II+III filter cake. In other aspect, the improvement relates to a method in which a reduced amount of an impurity is found in the clarified Fraction II+III suspension.

[0275] In one embodiment, the process improvements are realized by inclusion of a fumed silica treatment prior to filtration or centrifugal clarification of a Fraction II+III suspension. In certain embodiments, the fumed silica treatment will include addition of from about 0.01 kg/kg II+III paste to about 0.07 kg/kg II+III paste, or from about 0.02 kg/kg II+III paste to about 0.06 kg/kg II+III paste, or from about 0.03 kg/kg II+III paste to about 0.05 kg/kg II+III paste, or about 0.02 kg/kg II+III paste, 0.03 kg/kg II+III paste, 0.04 kg/kg II+III paste, 0.05 kg/kg II+III paste, 0.06 kg/kg II+III paste, 0.07 kg/kg II+III paste, 0.08 kg/kg II+III paste, 0.09 kg/kg II+III paste, or 0.1 kg/kg II+III paste, and the mixture will be incubated for between about 50 minutes and about 70 minutes, or about 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, or more minutes at a temperature between about 2°C and about 8°C. In another embodiment, the process improvements are realized by inclusion of a fumed silica treatment which reduced the levels of residual fibrinogen, amidolytic activity, and/or prekallikrein activator activity. In a specific embodiment, the process improvements are realized by inclusion of a fumed silica treatment, which reduces the levels of FXI, FXIa, FXII, and FXIIa in the immunoglobulin preparation.

[0276] In another embodiment, the process improvements are realized by washing the depth filter with between about 3 and about 5 volumes of the filter dead volume after completing the Modified Fraction II+III suspension filtration step. In certain embodiments, the filter will be washed with between about 3.5 volumes and about 4.5 volumes, or at least about 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0 volumes of the filter dead volume. In a particular embodiment, the filter press will be washed with at least about 3.6 dead volumes of suspension buffer.

6. Detergent Treatment

[0277] In order to remove additional contaminants from the Modified Fraction II+III filtrate, the sample is next subjected to a detergent treatment. Methods for the detergent treatment of

plasma derived fractions are well known in the art. Generally, any standard non-ionic detergent treatment may be used in conjunction with the methods provided herein. For example, an exemplary protocol for a detergent treatment is provided below.

[0278] Briefly, polysorbate-80 is added to the Modified Fraction II+III filtrate at a final concentration of about 0.2% (w/v) with stirring and the sample is incubated for at least 30 minutes at a temperature between about 2 to 8°C. Sodium citrate dehydrate is then mixed into the solution at a final concentration of about 8 g/L and the sample is incubated for an additional 30 minutes, with continuous of stirring at a temperature between about 2 to 8°C.

[0279] In certain embodiments, any suitable non-ionic detergent can be used. Examples of suitable non-ionic detergents include, without limitation, Octylglucoside, Digitonin, C12E8, Lubrol, Triton X-100, Nonidet P-40, Tween-20 (*i.e.*, polysorbate-20), Tween-80 (*i.e.*, polysorbate-80), an alkyl poly(ethylene oxide), a Brij detergent, an alkylphenol poly(ethylene oxide), a poloxamer, octyl glucoside, decyl maltoside, and the like.

[0280] In one embodiment, a process improvement is realized by adding the detergent reagents (*e.g.*, polysorbate-80 and sodium citrate dehydrate) by spraying rather than by fluent addition. In other embodiments, the detergent reagents may be added as solids to the Modified Fraction II+III filtrate while the sample is being mixed to ensure rapid distribution of the additives. In certain embodiments, it is preferable to add solid reagents by sprinkling the solids over a delocalized surface area of the filtrate such that local overconcentration does not occur, such as in fluent addition.

7. Third Precipitation Event – Precipitation G

[0281] In order to remove several residual small proteins, such as albumin and transferrin, a third precipitation is performed at a concentration of 25% alcohol. Briefly, the pH of the detergent treated II+III filtrate is adjusted to between about 6.8 and 7.2, preferably between about 6.9 and about 7.1, most preferably about 7.0 with a suitable pH modifying solution (*e.g.*, 1M sodium hydroxide or 1M acetic acid). Cold alcohol is then added to the solution to a final concentration of about 25% (v/v) and the mixture is incubated while stirring at between about -6°C to about -10°C for at least 1 hour to form a third precipitate (*i.e.*, precipitate G). In one embodiment, the mixture is incubated for at lease 2 hours, or at least 3, 4, 5, 6, 7, 8, 9 ,10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, or more hours. In a preferred embodiment, the

mixture is incubated for at least 2 hours. In a more preferred embodiment, the mixture is incubated for at least 4 hours. In an even more preferred embodiment, the mixture is incubated for at least 8 hours.

[0282] In one aspect, a process improvement relates to a method in which a reduced amount of IgG is lost in the supernatant fraction of the third precipitation step. In certain embodiments, the process improvement is realized by adjusting the pH of the solution to between about 6.8 and about 7.2 immediately after or during the addition of the precipitating alcohol. In another embodiment, the process improvement is realized by maintaining the pH of the solution to between about 6.8 and about 7.2 continuously during the precipitation incubation period. In other embodiments, the pH of the solution is adjusted to between about 6.9 and about 7.1 immediately after or during the addition of the precipitating alcohol, or to a pH of about 6.8, 6.9, 7.0, 7.1, or 7.2 immediately after or during the addition of the precipitating alcohol. In a particular embodiment, the pH of the solution is adjusted to about 7.0 immediately after or during the addition of the precipitating alcohol. In certain embodiments, the pH of the solution is maintained at between about 6.9 to about 7.1 continuously during the precipitation incubation period, or at a pH of about 7.0 continuously during the precipitation incubation period. As such, in certain embodiments, a reduced amount of IgG is lost in the supernatant fraction of the third precipitation step as compared to an analogous precipitation step in which the pH of the solution is adjusted prior to but not after addition of the precipitating alcohol or to an analogous precipitation step in which the pH of the solution is not maintained during the entirety of the precipitation incubation period. In one embodiment, the pH is maintained at the desired pH during the precipitation hold or incubation time by continuously adjusting the pH of the solution. In one embodiment, the alcohol is ethanol.

[0283] In another embodiment, the process improvement is realized by adding the precipitating alcohol and/or the solution used to adjust the pH by spraying, rather than by fluent addition. As such, in certain embodiments, a reduced amount of IgG is lost in the supernatant fraction of the third precipitation step as compared to an analogous precipitation step in which the alcohol and/or solution used to adjust the pH is introduced by fluent addition. In one embodiment, the alcohol is ethanol.

8. Suspension and Filtration of Precipitate G (PptG)

[0284] In order to solubilize the IgG content of the precipitate G, a cold extraction buffer is used to re-suspend the PptG. Briefly, the precipitate G is dissolved 1 to 3.5 in Water for Injection (WFI) at between about 0°C and about 8°C to achieve an $AU_{280-320}$ value of between about 40 to 95. The final pH of the solution, which is stirred for at least 2 hours, is then adjusted to at or about 5.2 ± 0.2. In one embodiment, this pH adjustment is performed with 1M acetic acid. To increase the solubility of IgG, the conductivity of the suspension is increased to between about 2.5 and about 6.0 mS/cm. In one embodiment, the conductivity is increased by the addition of sodium chloride. The suspended PptG solution is then filtered with a suitable depth filter having a nominal pore size of between about 0.1 μm and about 0.4 μm in order to remove any undissolved particles. In one embodiment, the nominal pore size of the depth filter is about 0.2 μm (*e.g.*, Cuno VR06 filter or equivalent) to obtain a clarified filtrate. In another embodiment, the suspended PptG solution is centrifuged to recover a clarified supernatant. Post-wash of the filter is performed using a sodium chloride solution with a conductivity of between about 2.5 and about 6.0 mS/cm. Typically, suitable solutions for the extraction of precipitate G include, WFI and low conductivity buffers. In one embodiment, a low conductivity buffer has a conductivity of less than about 10 mS/cm. In a preferred embodiment, the low conductivity buffer has a conductivity of less than about 9, 8, 7, 6, 5, 4, 3, 2, or 1 mS/cm. In a preferred embodiment, the low conductivity buffer has a conductivity of less than about 6 mS/cm. In another preferred embodiment, the low conductivity buffer has a conductivity of less than about 4 mS/cm. In another preferred embodiment, the low conductivity buffer has a conductivity of less than about 2 mS/cm.

9. Solvent Detergent Treatment

[0285] In order to inactivate various viral contaminants which may be present in plasma-derived products, the clarified PptG filtrate is next subjected to a solvent detergent (S/D) treatment. Methods for the detergent treatment of plasma derived fractions are well known in the art (for review *see*, Pelletier JP *et al.*, *Best Pract Res Clin Haematol.* 2006;19(1):205-42). Generally, any standard S/D treatment may be used in conjunction with the methods provided herein. For example, an exemplary protocol for an S/D treatment is provided below.

[0286] Briefly, Triton X-100, Tween-20, and tri(n-butyl)phosphate (TNBP) are added to the clarified PptG filtrate at final concentrations of about 1.0%, 0.3%, and 0.3%, respectively. The mixture is then stirred at a temperature between about 18°C and about 25°C for at least about an hour.

[0287] In one embodiment, a process improvement is realized by adding the S/D reagents (*e.g.*, Triton X-100, Tween-20, and TNBP) by spraying rather than by fluent addition. In other embodiments, the detergent reagents may be added as solids to the clarified PptG filtrate, which is being mixed to ensure rapid distribution of the S/D components. In certain embodiments, it is preferable to add solid reagents by sprinkling the solids over a delocalized surface area of the filtrate such that local overconcentration does not occur, such as in fluent addition.

10. Ion Exchange Chromatography

[0288] In order to further purify and concentrate IgG from the S/D treated PptG filtrate, cation exchange and/or anion exchange chromatography can be employed. Methods for purifying and concentrating IgG using ion exchange chromatography are well known in the art. For example, U.S. Patent No. 5,886,154 describes a method in which a Fraction II+III precipitate is extracted at low pH (between about 3.8 and 4.5), followed by precipitation of IgG using caprylic acid, and finally implementation of two anion exchange chromatography steps. U.S. Patent No. 6,069,236 describes a chromatographic IgG purification scheme that does not rely on alcohol precipitation at all. PCT Publication No. WO 2005/073252 describes an IgG purification method involving the extraction of a Fraction II+III precipitate, caprylic acid treatment, PEG treatment, and a single anion exchange chromatography step. U.S. Patent No. 7,186,410 describes an IgG purification method involving the extraction of either a Fraction I+II+III or a Fraction II precipitate followed by a single anion exchange step performed at an alkaline pH. U.S. Patent No. 7,553,938 describes a method involving the extraction of either a Fraction I+II+III or a Fraction II+III precipitate, caprylate treatment, and either one or two anion exchange chromatography steps. U.S. Patent No. 6,093,324 describes a purification method comprising the use of a macroporous anion exchange resin operated at a pH between about 6.0 and about 6.6. U.S. Patent No. 6,835,379 describes a purification method that relies on cation exchange chromatography in the absence of alcohol fractionation. The disclosures of the above publications are hereby incorporated by reference in their entireties for all purposes

[0289] In one embodiment of the methods of the present invention, the S/D treated PptG filtrate may be subjected to both cation exchange chromatography and anion exchange chromatography. For example, in one embodiment, the S/D treated PptG filtrate is passed through a cation exchange column, which binds the IgG in the solution. The S/D reagents can then be washed away from the absorbed IgG, which is subsequently eluted off of the column with a high pH elution buffer having a pH between about 8.0 and 9.0. In this fashion, the cation exchange chromatography step can be used to remove the S/D reagents from the preparation, concentrate the IgG containing solution, or both. In certain embodiments, the pH elution buffer may have a pH between about 8.2 and about 8.8, or between about 8.4 and about 8.6, or a pH of about 8.0, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, or 9.0. In a preferred embodiment, the pH of the elution buffer is about 8.5 ± 0.1.

[0290] In certain embodiments, the eluate from the cation exchange column may be adjusted to a lower pH, for example between about 5.5 and about 6.5, and diluted with an appropriate buffer such that the conductivity of the solution is reduced. In certain embodiments, the pH of the cation exchange eluate may be adjusted to a pH between about 5.7 and about 6.3, or between about 5.9 and about 6.1, or a pH of about 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, or 6.5. In a preferred embodiment, the pH of the eluate is adjusted to a pH of about 6.0 ± 0.1. The eluate is then loaded onto an anion exchange column, which binds several contaminants found in the preparation. The column flow through, containing the IgG fraction, is collected during column loading and washing. In certain embodiments, the ion exchange chromatographic steps of the present invention can be performed in column mode, batch mode, or in a combination of the two.

[0291] In certain embodiments, a process improvement is realized by adding the solution used to adjust the pH by spraying, rather than by fluent addition.

11. Nanofiltration and Ultra/Diafiltration

[0292] In order to further reduce the viral load of the IgG composition provided herein, the anion exchange column effluent may be nanofiltered using a suitable nanofiltration device. In certain embodiments, the nanofiltration device will have a mean pore size of between about 15 nm and about 200 nm. Examples of nanofilters suitable for this use include, without limitation, DVD, DV 50, DV 20 (Pall), Viresolve NFP, Viresolve NFR (Millipore), Planova 15N, 20N, 35N, and 75N (Planova). In a specific embodiment, the nanofilter may have a mean pore size of between about 15 nm and about 72 nm, or between about 19 nm and about 35 nm, or of about 15

nm, 19nm, 35nm, or 72 nm. In a preferred embodiment, the nanofilter will have a mean pore size of about 35 nm, such as an Asahi PLANOVA 35N filter or equivalent thereof.

[0293] Optionally, ultrafiltration/diafiltration may performed to further concentrate the nanofiltrate. In one embodiment, an open channel membrane is used with a specifically designed post-wash and formulation near the end the production process render the resulting IgG compositions about twice as high in protein concentration (200mg/mL) compared to state of the art IVIGs (*e.g.*, GAMMAGARD® LIQUID) without affecting yield and storage stability. With most of the commercial available ultrafiltration membranes a concentration of 200mg/mL IgG cannot be reached without major protein losses. These membranes will be blocked early and therefore adequate post-wash is difficult to achieve. Therefore open channel membrane configurations have to be used. Even with open channel membranes, a specifically designed post-wash procedure has to be used to obtain the required concentration without significant protein loss (less than 2% loss). Even more surprising is the fact that the higher protein concentration of 200mg/mL does not effect the virus inactivation capacity of the low pH storage step.

[0294] Subsequent to nanofiltration, the filtrate may be further concentrated by ultrafiltration/diafiltration. In one embodiment, the nanofiltrate may be concentrated by ultrafiltration to a protein concentration of between about 2% and about 10% (w/v). In certain embodiments, the ultrafiltration is carried out in a cassette with an open channel screen and the ultrafiltration membrane has a nominal molecular weight cut off (NMWCO) of less than about 100 kDa or less than about 90, 80, 70, 60, 50, 40, 30, or fewer kDa. In a preferred embodiment, the ultrafiltration membrane has a NMWCO of no more than 50 kDa.

[0295] Upon completion of the ultrafiltration step, the concentrate may further be concentrated via diafiltration against a solution suitable for intravenous or intramuscular administration. In certain embodiments, the diafiltration solution may comprise a stabilizing and/or buffering agent. In a preferred embodiment, the stabilizing and buffering agent is glycine at an appropriate concentration, for example between about 0.20 M and about 0.30M, or between about 0.22M and about 0.28M, or between about 0.24M and about 0.26 mM, or at a concentration of about 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, or 3.0. In a preferred embodiment, the diafiltration buffer contains at or about 0.25 M glycine.

[0296] Typically, the minimum exchange volume is at least about 3 times the original concentrate volume or at least about 4, 5, 6, 7, 8, 9, or more times the original concentrate volume. The IgG solution may be concentrated to a final protein concentration of between about 5% and about 25% (w/v), or between about 6% and about 18% (w/v), or between about 7% and about 16% (w/v), or between about 8% and about 14% (w/v), or between about 9% and about 12%, or to a final concentration of about 5%, or 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%, 24%, 25% or higher. In one embodiment, a final protein concentration of at least about 23% is achieved without adding the post-wash fraction to the concentrated solution. In another embodiment, a final protein concentration of at least about 24% is achieved without adding the post-wash fraction to the concentrated solution. a final protein concentration of at least about 25% is achieved without adding the post-wash fraction to the concentrated solution. Typically, at the end of the concentration process, the pH of the solution will be between about 4.6 to 5.1.

[0297] In an exemplary embodiment, the pH of the IgG composition is adjusted to about 4.5 prior to ultrafiltration. The solution is concentrated to a protein concentration of 5 ± 2% w/v through ultrafiltration. The UF membrane has a nominal molecular weight cut off (NMWCO) of 50,000 Daltons or less (Millipore Pellicon Polyether sulfon membrane). The concentrate is diafiltered against ten volumes of 0.25 M glycine solution, pH 4.5 ± 0.2. Throughout the ultra-diafiltration operation the solution is maintained at a temperature of between about 2°C to about 8°C. After diafiltration, the solution is concentrated to a protein concentration of at least 11 % (w/v).

12. Formulation

[0298] Upon completion of the diafiltration step, the protein concentration of the solution is adjusted to with the diafiltration buffer to a final concentration of between about 5% and about 20% (w/v), or between about 6% and about 18% (w/v), or between about 7% and about 16% (w/v), or between about 8% and about 14% (w/v), or between about 9% and about 12%, or to a final concentration of about 5%, or 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, or 20%. In a preferred embodiment, the final protein concentration of the solution is between about 9% and about 11%, more preferably about 10%.

[0299] The formulated bulk solution is further sterilized by filtering through a membrane filter with an absolute pore size of no more than about 0.22 micron, for example about 0.2 micron.

Then the solution is aseptically dispensed into final containers for proper sealing, with samples taken for testing.

[0300] In one embodiment, the IgG composition is further adjusted to a concentration of about 10.2 ± 0.2% (w/v) with diafiltration buffer. The pH is adjusted to about 4.4 to about 4.9 if necessary. Finally, the solution is sterile filtered and incubated for three weeks at or about 30°C.

B. Factor H

[0301] In one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived Factor H composition. In one specific embodiment, the method comprises the steps of: (a) contacting the Factor H composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO_2 from the Factor H composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII).

[0302] In one embodiment, the method further comprises the step of performing a first Factor H protein enrichment step to form a first enriched Factor H composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first Factor H protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0303] In certain embodiments, the methods described above further comprises the step of performing a second Factor H protein enrichment step to form a second enriched Factor H composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first Factor H protein enrichment step is selected from a protein precipitation step (e.g., an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0304] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived Factor H composition, the method comprises the steps of: (a) performing a first Factor H enrichment step to form a first enriched plasma-derived Factor H composition; (b) performing a second Factor H enrichment step to form a second enriched plasma-derived Factor H composition; (c) contacting

the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0305] In certain embodiments, the methods described above further comprises the step of performing an Factor H enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the Factor H enrichment step is selected from a protein precipitation step (e.g., an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0306] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived Factor H composition the method comprises the steps of: (a) performing a first Factor H enrichment step to form a first enriched plasma-derived Factor H composition; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (d) performing a second Factor H enrichment step to form a second enriched plasma-derived Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0307] Likewise, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived Factor H composition, the method comprising the steps of: (a) performing a first Factor H enrichment step to form a first enriched plasma-derived Factor H composition; (b) performing a second Factor H enrichment step to form a second enriched plasma-derived Factor H composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (d) separating the SiO_2 from the

composition to remove the bound serine protease or serine protease zymogen; and (e) performing a third Factor H enrichment step to form a third enriched plasma-derived Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 101 to Var. 1100, found in Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, or Table 11.

1. Methods for the Manufacture of Plasma-Derived Factor H

[0308] Regarding production, the claimed processes starting from human plasma shall be based on the sub-fractionation of typical industrial intermediates obtained by, *e.g.*, the fractional precipitation by ethanol in the cold (reviewed in Schultze H E, Heremans J F; Molecular Biology of Human Proteins. Volume I: Nature and Metabolism of Extracellular Proteins 1966, Elsevier Publishing Company; p. 236-317). A preferred embodiment of such purification is the purification of functional Factor H from side fractions of industrial scale plasma fractionation in such a way that established and licensed manufacturing processes of plasma products, which are under control of pharmaceutical regulatory authorities, like immunoglobulins, are not affected. For example, the filter cake obtained after filtration of a Fraction II+III paste suspension (Teschner W *et al.*, Vox Sang. 2007 Jan;92(1):42-55), Fraction I precipitate (Cohn *et al.*, (1946) *supra*), Precipitate III (Schultze H E, Heremans J F; Molecular Biology of Human Proteins. Volume I: Nature and Metabolism of Extracellular Proteins 1966, Elsevier Publishing Company; p. 236-317 at p. 253) and precipitate B (method of Kistler and Nitschmann; supra at p. 253) are examples of such industrial sources for Factor H. Starting from those side fractions, purification procedures known in the art can be used to purify Factor H. They may be based on precipitation with polyethylene glycol (Nagasawa S, Stroud R M; Mol Immunol 1980; 17:1365-72), affinity chromatography via immobilized heparin (citation as before), ion exchange chromatography (Crossley L G, Porter R R; Biochem J 1980; 191:173-82) and hydrophobic interaction chromatography (Ripoche J, Al Salihi A, Rousseaux J, Fontaine M; Biochem J 1984; 221, 89-96).

[0309] In one embodiment, the starting material for the invention is prepared using Cohn fractions. This fractionation is a well known fractionation used for the preparation of immunoglobulin preparations can be prepared from donor serum or monoclonal or recombinant

immunoglobulins. In a typical example, blood is collected from healthy donors. Usually, the blood is collected from the same species of animal as the subject to which the immunoglobulin preparation will be administered (typically referred to as "homologous" immunoglobulins). The immunoglobulins are isolated from the blood by suitable procedures, such as, for example, Cohn fractionation, ultracentrifugation, electrophoretic preparation, ion exchange chromatography, affinity chromatography, immunoaffinity chromatography, polyethylene glycol fractionation, or the like. (See, e.g., Cohn et al., J. Am. Chem. Soc. 68:459-75 (1946); Oncley et al., J. Am. Chem. Soc. 71:541-50 (1949); Barundern et al., Vox Sang. 7:157-74 (1962); Koblet et al., Vox Sang. 13:93-102 (1967); U.S. Pat. Nos. 5,122,373 and 5,177,194; the disclosures of which are incorporated herein by reference in their entireties for all purposes.) In one embodiment, the present invention uses the discarded fractions from the preparation of immunoglobulins. In a particular embodiment, the present invention uses the fraction that is found in a SiO_2 filtration cake once the Fraction II+III extract is filtered.

[0310] Generally, Factor H preparations according to the present invention can be prepared from any suitable starting materials, for example, recovered plasma or source plasma. In a typical example, blood or plasma is collected from healthy donors. Usually, the blood is collected from the same species of animal as the subject to which the Factor H preparation will be administered (typically referred to as "homologous" Factor H). The Factor H is isolated from the blood or plasma by suitable procedures, such as, for example, precipitation (alcohol fractionation or polyethylene glycol fractionation), chromatographic methods (ion exchange chromatography, affinity chromatography, immunoaffinity chromatography, etc.) ultracentrifugation, and electrophoretic preparation, and the like. (See, e.g., Cohn et al., J. Am. Chem. Soc. 68:459-75 (1946); Deutsch et al., J. Biol. Chem. 164:109-118; Oncley et al., J. Am. Chem. Soc. 71:541-50 (1949); Cohn et al., J. Am. Chem. Soc. 72:465-474 (1950); Cohn et al., Blood Cells and Plasma Proteins: Their State in Nature (J.L. Tullis, ed), pp. 1-58, Academic Press, NewYork and London (1953); Nitschmann et al., Helv. Chim. Acta 37:866-873; Kistler and Nitschmann, Vox Sang. 7:414-424 (1962); Barundern et al., Vox Sang. 7:157-74 (1962); Koblet et al., Vox Sang. 13:93-102 (1967); U.S. Patent Nos. 5,122,373 and 5,177,194; the disclosures of which are hereby incorporated by reference in their entireties for all purposes).

[0311] In certain embodiments, Factor H is recovered from material otherwise discarded during the manufacture of other commercially important blood products by plasma fractionation. For example, in an exemplary embodiment, Factor H is extracted from a Fraction I precipitate

and/or extracted from a filter cake formed after centrifugation or filtration of a re-suspended Fraction II+III paste. Advantageously, according to the methods provided herein, industrial-scale preparation of Factor H can be achieved without the need for additional input plasma or the redesign and regulatory re-approval of existing manufacturing processes for other commercially important plasma-derived blood products, such as IgG gamma globulins for intravenous (IVIG) or subcutaneous administration.

[0312] In one aspect, the present invention provides a method for preparing an enriched Factor H composition having reduced serine protease and/or serine protease zymogen content from plasma by extracting Factor H from a plasma fraction and reducing the FXI, FXIa, FXII, and/or FXIIa content with a SiO_2 treatment method provided herein.

[0313] In one embodiment, a method is provided for preparing an enriched Factor H composition from plasma, the method comprising the steps of: (a) precipitating proteins from a cryo-poor plasma fraction, in a first precipitation step, with between about 6% and about 10% alcohol at a pH of between about 7.0 and about 7.5 to obtain a first precipitate and a first supernatant; (b) precipitating Factor H from the first supernatant, in a second precipitation step, with between about 20% and about 30% alcohol at a pH of between about 6.7 and about 7.3 to form a second precipitate; (c) re-suspending the second precipitate to form a suspension; (d) mixing finely divided silicon dioxide (SiO_2) with the suspension from step (c); (e) separating the suspension to form a filter cake and a supernatant; and (f) extracting Factor H from the SiO_2 filter cake under solution conditions that reduce the level of a serine protease or serine protease zymogen in the final composition. In a preferred embodiment, the filter cake is separated from the supernatant by filtering the suspension through a filter press containing a suitable filter. In one embodiment, Factor H can be extracted by re-circulating an extraction buffer through a filter press containing a filter cake.

[0314] In a second aspect, the present invention provides a method for preparing an enriched Factor H composition with reduced serine protease and/or serine protease zymogen content from plasma by extracting Factor H from a Fraction I precipitate.

[0315] In a preferred embodiment, a method is provided for preparing an enriched Factor H composition from plasma, the method comprising the steps of: (a) precipitating proteins from a cryo-poor plasma fraction, in a first precipitation step, with between about 6% and about 10% alcohol at a pH of between about 7.0 and about 7.5 to obtain a first precipitate and a first

supernatant; (b) extracting Factor H from the precipitate with a Factor H extraction buffer, and (c) reducing the level of a serine protease or serine protease zymogen by treating the composition with SiO_2, using a suitable method provided herein.

[0316] In one aspect, a method is provided for preparing an enriched Factor H composition from plasma, by extracting Factor H from a pool of two or more manufacturing byproduct fractions created by a process designed to provide a second blood protein, for example, IgG gamma globulins. In one embodiment, the method comprises pooling a Fraction I precipitate and a Fraction II+III filter cake formed during the manufacture of IgG gamma globulins (e.g., IVIG) and extracting Factor H from the pooled fractions.

[0317] In certain embodiments, an enriched Factor H composition having reduced serine protease and/or serine protease zymogen content may be further purified subsequent to extraction from a Fraction I precipitate and/or Fraction II+III filter cake. Various methods are available for further purifying Factor H, including without limitation, additional precipitation steps or fractionations, affinity chromatography, ion exchange chromatography, hydrophobic interaction chromatography, size exclusion chromatography, solvent/detergent (S/D) treatment, nanofiltration, ultrafiltration, diafiltration, and the like.

[0318] In one embodiment, the method further comprises precipitating impurities from an enriched Factor H composition. In certain embodiments, this step comprises precipitating at least one impurity, for example a lipid or protein, from the composition and then separating the precipitate from the supernatant containing Factor H. Optionally, Factor H can then be precipitated from the supernatant in a separate precipitation.

[0319] In a specific embodiment, a Factor H composition extracted from a plasma fraction (*e.g.*, fraction I precipitate, fraction II+III precipitate, Precipitate B precipitate, *etc.*) is further enriched by precipitating at least one impurity out of the solution using PEG at a final concentration of between about 2.5% and about 7.5%. In another embodiment, PEG is used at a final concentration of between about 3% and about 7%. In another embodiment, PEG is used at a final concentration of between about 4% and about 6%. In yet another embodiment, PEG is used at a final concentration of about 5%.

[0320] In another specific embodiment, a Factor H composition extracted from a plasma fraction (*e.g.*, fraction I precipitate, fraction II+III precipitate, Precipitate B precipitate, *etc.*) is

further enriched by precipitating Factor H out of the solution using PEG at a final concentration of between about 9% and about 15%. In another embodiment, PEG is used at a final concentration of between about 10% and about 14%. In another embodiment, PEG is used at a final concentration of between about 11% and about 13%. In yet another embodiment, PEG is used at a final concentration of about 12%.

[0321] In another specific embodiment, a Factor H composition extracted from a plasma fraction (*e.g.*, fraction I precipitate, fraction II+III precipitate, Precipitate B precipitate, *etc.*) is further enriched by (a) precipitating at least one impurity out of the solution; (b) precipitating Factor H out of the solution; and (c) recovering the precipitate containing Factor H. In certain embodiments, the precipitation steps are performed with alcohol (*e.g.*, methanol or ethanol), PEG, or a combination thereof. In a particular embodiment, the precipitation steps are performed with PEG. In certain embodiments, the PEG concentration of the first precipitation step is between about 2.5% and about 7.5% and the PEG concentration of the second precipitation step is between about 9% and about 15%. In a specific embodiment, the PEG concentration of the first step is between about 4% and about 6% and the PEG concentration of the second step is between about 11% and about 13%. In a more specific embodiment, the PEG concentration of the first precipitation step is about 5% and the PEG concentration of the second precipitation step is about 12%. In yet other embodiments, the PEG concentration of the first and second precipitation steps is selected from variations Var. 1101 and Var. 1221 listed in **Table 16**.

Table 16. PEG concentrations for enrichment of Factor H compositions.

		PEG Concentration – First Precipitation										
		2.5%	3.0%	3.5%	4.0%	4.5%	5.0%	5.5%	6.0%	6.5%	7.0%	7.5%
PEG Concentration – Second Precipitation	2.5%	Var. 1101	Var. 1112	Var. 1123	Var. 1134	Var. 1145	Var. 1156	Var. 1167	Var. 1178	Var. 1189	Var. 1200	Var. 1211
	3.0%	Var. 1102	Var. 1113	Var. 1124	Var. 1135	Var. 1146	Var. 1157	Var. 1168	Var. 1179	Var. 1190	Var. 1201	Var. 1212
	3.5%	Var. 1103	Var. 1114	Var. 1125	Var. 1136	Var. 1147	Var. 1158	Var. 1169	Var. 1180	Var. 1191	Var. 1202	Var. 1213
	4.0%	Var. 1104	Var. 1115	Var. 1126	Var. 1137	Var. 1148	Var. 1159	Var. 1170	Var. 1181	Var. 1192	Var. 1203	Var. 1214
	4.5%	Var. 1105	Var. 1116	Var. 1127	Var. 1138	Var. 1149	Var. 1160	Var. 1171	Var. 1182	Var. 1193	Var. 1204	Var. 1215

	5.0%	Var. 1106	Var. 1117	Var. 1128	Var. 1139	Var. 1150	Var. 1161	Var. 1172	Var. 1183	Var. 1194	Var. 1205	Var. 1216
	5.5%	Var. 1107	Var. 1118	Var. 1129	Var. 1140	Var. 1151	Var. 1162	Var. 1173	Var. 1184	Var. 1195	Var. 1206	Var. 1217
	6.0%	Var. 1108	Var. 1119	Var. 1130	Var. 1141	Var. 1152	Var. 1163	Var. 1174	Var. 1185	Var. 1196	Var. 1207	Var. 1218
	6.5%	Var. 1109	Var. 1120	Var. 1131	Var. 1142	Var. 1153	Var. 1164	Var. 1175	Var. 1186	Var. 1197	Var. 1208	Var. 1219
	7.0%	Var. 1110	Var. 1121	Var. 1132	Var. 1143	Var. 1154	Var. 1165	Var. 1176	Var. 1187	Var. 1198	Var. 1209	Var. 1220
	7.5%	Var. 1111	Var. 1122	Var. 1133	Var. 1144	Var. 1155	Var. 1166	Var. 1177	Var. 1188	Var. 1199	Var. 1210	Var. 1221

[0322] In certain embodiments, the method for preparing an enriched Factor H composition further comprises at least one, preferably two, chromatographic steps to further enrich the purity of the composition. Generally, any suitable chromatographic method may be employed to further enrich the Factor H composition, for example, extracted from a Fraction I precipitate or Fraction II+III filter cake. In certain embodiments, prior to chromatographic enrichment, the extracted Factor H composition will be subjected one or more additional precipitation steps, as described above, to reduce the impurities present in the composition, reduce the load volume for the chromatographic step, and/or exchange the buffer of the composition.

[0323] In certain embodiments, a Factor H composition may be further enriched by a chromatographic step comprising anion exchange chromatography (AEC), cation exchange chromatography (CEC), heparin affinity chromatography, hydrophobic exchange chromatography (HIC), hydroxyapatite chromatography (HAP), immunoaffinity chromatography, size exclusion chromatography (i.e., gel filtration), or other suitable chromatographic step. Chromatographic steps may be performed in either batch or column mode.

[0324] In a preferred embodiment, the method comprises the use of anion exchange chromatography and heparin affinity chromatography.

[0325] In certain embodiments, the methods provided herein for the preparation of an enriched Factor H composition will further include at least one, preferably at least two, most preferably at least three, viral inactivation or removal steps. Non-limiting examples of viral inactivation or removal steps that may be employed with the methods provided herein include, solvent detergent treatment (Horowitz *et al.*, Blood Coagul Fibrinolysis 1994 (5 Suppl 3):S21-S28 and Kreil et al.,

Transfusion 2003 (43):1023-1028, both of which are herein expressly incorporated by reference in their entirety for all purposes), nanofiltration (Hamamoto *et al.*, Vox Sang 1989 (56)230-236 and Yuasa *et al.*, J Gen Virol. 1991 (72 (pt 8)):2021-2024, both of which are herein expressly incorporated by reference in their entirety for all purposes), low pH incubation at high temperatures (Kempf *et al.*, Transfusion 1991 (31)423-427 and Louie *et al.*, Biologicals 1994 (22):13-19), and heat treatment of lyophilized Factor H compositions (Piszkiewicz *et al.*, Thromb Res. 1987 Jul 15;47(2):235-41; Piszkiewicz *et al.*, Curr Stud Hematol Blood Transfus. 1989;(56):44-54; Epstein and Fricke, Arch Pathol Lab Med. 1990 Mar;114(3):335-40).

[0326] In a preferred embodiment, the present invention provides a method of preparing a virally safe enriched Factor H composition having reduced serine protease and/or serine protease zymogen content comprising (i) extracting Factor H from a Fraction II+III filter cake using SiO_2, (ii) performing a first precipitation step to precipitate at least one impurity from the Factor H composition, (iii) performing a second precipitation step to precipitate Factor H from the composition, and (iv) performing at least one viral inactivation or removal step, thereby preparing a virally safe enriched Factor H composition. In one embodiment, the precipitation steps comprise PEG precipitation. In a specific embodiment, the PEG concentration of the first and second precipitation steps is selected from variations Var. 1101 and Var. 1221 listed in **Table 16**.

2. Co-Binding and Differential Elution

[0327] In one aspect, the present invention provides a method for preparing a plasma-derived Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising co-extracting Factor H and a serine protease and/or serine protease zymogen from a composition derived from pooled plasma by binding the proteins to finely divided silicon dioxide (SiO_2), eluting the serine protease and/or serine protease zymogen from the SiO_2 under a first solution condition, and subsequently eluting Factor H from the SiO_2 under a second solution condition. In a preferred embodiment, the starting composition is a re-suspended Fraction II+III precipitate or equivalent precipitate thereof.

[0328] In a specific embodiment, the method comprises the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H and at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the

composition; (c) eluting the serine protease or serine protease zymogen from the SiO_2 under a solution condition in which the Factor H remains bound; and (d) eluting the Factor H from the SiO_2.

[0329] In certain embodiments, a solution condition in which the Factor H remains bound refers to a condition that preferentially elutes the serine protease or serine protease zymogen, while a substantial fraction of Factor H remains bound to the SiO_2. In one embodiment, a substantial fraction refers to at least 10% of the Factor H bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 25% of the Factor H bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 50% of the Factor H bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 75% of the Factor H bound to the SiO_2. In yet other embodiments, a substantial fraction refers to at least 10% of the Factor H bound to the SiO_2, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the Factor H bound to the SiO_2.

[0330] In certain embodiments, differential elution of the serine protease or serine protease zymogen and Factor H is achieved by sequentially contacting (*i.e.*, step-wise elution) the SiO_2 with a first solution condition (*e.g.*, a first elution buffer) suitable to elute the majority of the serine protease or serine protease zymogen but not a substantial fraction of the bound Factor H, and a second solution condition (*e.g.*, a second elution buffer) suitable to elute the substantial fraction of bound Factor H from the SiO_2.

[0331] In other embodiments, differential elution of the serine protease or serine protease zymogen and Factor H is achieved by gradually changing the solution conditions (*i.e.*, with an elution gradient) from a first solution condition suitable to elute the majority of the serine protease or serine protease zymogen but not a substantial fraction of the bound Factor H to a second solution condition suitable to elute the substantial fraction of bound Factor H from the SiO_2. In this fashion, the serine protease or serine protease zymogen and Factor H content eluted off of the SiO_2 may be partially overlapping. By fractionating the elution and characterizing the individual fractions, a Factor H pool may be created from fractions having high Factor H content and low serine protease or serine protease zymogen content.

[0332] Solution conditions that may be varied to achieve a desired result from a method described above include, without limitation, the pH of the solution, the conductivity of the solution, the temperature of the solution, the concentration of Factor H in the composition, and

the concentration of SiO_2 used in the method. Generally, suitable pH ranges for methods of reducing serine protease and/or serine protease zymogen content in a Factor H enriched composition range from about 3 to about 11. Suitable conductivities for the methods described above range from about 0.1 mS/cm to about 100 mS/cm. Suitable temperatures for performing the methods described above range from about -10°C to about 90°C. Finely divided silicon dioxide may be used at a final concentration ranging from about 0.01 g/g protein to about 10 g/g protein. Finally, Factor H compositions may vary in concentration from about 0.001 mg/mL to about 100 mg/mL.

[0333] In one embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a pH between about 5.0 and about 11.0. In another embodiment, the pH is between about 6.0 and about 1.0. In another embodiment, the pH is between about 7.0 and about 9.0. In another embodiment, the pH is between about 7.5 and about 8.5. In yet another embodiment, the pH is between about 7.0 and about 8.0.

[0334] In a particular embodiment ,the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a pH of about 7.0. In another specific embodiment, the pH is about 7.5. In another embodiment, the pH is about 8.0. In yet other embodiments, the pH is about 3.0 or about 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.0, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8.0, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9.0, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10.0, 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, or 11.0.

[0335] In one embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a pH of at least 6.0. In another embodiment, the pH is at least 6.5. In another embodiment, the pH is at least 7.0. In yet another embodiment, the pH is at least 7.5. In yet other embodiments, the pH of the solution is at least 3.0 or at least 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, or higher.

[0336] In another embodiment, of any of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a pH of no greater than about 11.0.

In another embodiment, the pH is no greater about 10.0. In another embodiment, the pH is no greater about 9.0. In another embodiment, the pH is no greater about 8.0. In yet other embodiments, the pH is no greater than about 11.0, or 10.5, 10.0, 9.5, 9.0, 8.5, 8.0, 7.5, 7.0, 6.5, 6.0, 5.5, 5.0, 4.5, 4.0, 3.5, or lower.

[0337] In one embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a conductivity of at least 10 mS/cm. In another embodiment, the conductivity is at least 20 mS/cm. In yet other embodiments, the conductivity of the solution condition is at least 2 mS/cm, or at least 3 mS/cm, 4 mS/cm, 5 mS/cm, 6 mS/cm, 7 mS/cm, 8 mS/cm, 9 mS/cm, 10 mS/cm, 11 mS/cm, 12 mS/cm, 13 mS/cm, 14 mS/cm, 15 mS/cm, 16 mS/cm, 17 mS/cm, 18 mS/cm, 19 mS/cm, 20 mS/cm, 21 mS/cm, 22 mS/cm, 23 mS/cm, 24 mS/cm, 25 mS/cm, 26 mS/cm, 27 mS/cm, 28 mS/cm, 29 mS/cm, 30 mS/cm, 31 mS/cm, 32 mS/cm, 33 mS/cm, 34 mS/cm, 35 mS/cm, 36 mS/cm, 37 mS/cm, 38 mS/cm, 39 mS/cm, 40 mS/cm, 41 mS/cm, 42 mS/cm, 43 mS/cm, 44 mS/cm, 45 mS/cm, 46 mS/cm, 47 mS/cm, 48 mS/cm, 49 mS/cm, 50 mS/cm, 55 mS/cm, 60 mS/cm, 65 mS/cm, 70 mS/cm, 75 mS/cm, 80 mS/cm, 85 mS/cm, 90 mS/cm, 95 mS/cm, 100 mS/cm, or greater.

[0338] In one embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a conductivity between about 10 mS/cm and about 100 mS/cm. In another embodiment, the conductivity is between about 10 mS/cm and about 50 mS/cm. In another embodiment, the conductivity is between about 20 mS/cm and about 100 mS/cm. In yet another embodiment, the conductivity is between about 20 mS/cm and about 50 mS/cm.

[0339] As shown in Example 5 and illustrated in Figure 3, it was found that the use of solution conditions having a pH greater than 6.0 (*e.g.*, 7.5) and increasing conductivity (*e.g.*, greater than 6.0 mS/cm), results in increased elution of serine proteases and/or serine protease zymogens from SiO_2, and decreased elution of Factor H from SiO_2. Advantageously, these findings can be used to provide methods for reducing the levels of serine protease and serine protease zymogen present in Factor H compositions. In a particular embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a conductivity of at least about 10 mS/cm and a pH of at least 7.0. In another particular embodiment, the solution

condition comprises a conductivity of at least 10 mS/cm and a pH of at least 7.5. In another embodiment, the solution condition comprises a conductivity of at least 20 mS/cm and a pH of at least 7.0. In yet another embodiment, the solution condition comprises a conductivity of at least 20 mS/cm and a pH of at least 7.5.

3. Co-Binding and Preferential Factor H Elution

[0340] In one aspect, the present invention provides a method for preparing a plasma-derived Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising co-extracting Factor H and a serine protease and/or serine protease zymogen from a composition derived from pooled plasma by binding the proteins to finely divided silicon dioxide (SiO_2), and eluting the Factor H from the SiO_2 under conditions in which a substantial fraction of the bound serine protease and/or serine protease zymogen remains bound to the SiO_2. In a preferred embodiment, the starting composition is a re-suspended Fraction II+III precipitate or equivalent precipitate thereof.

[0341] In a specific embodiment, the method comprises the steps of: (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H and at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the composition; and (c) eluting the Factor H from the SiO_2 under a solution condition in which the serine protease or serine protease zymogen remains bound.

[0342] In certain embodiments, a solution condition in which the serine protease or serine protease zymogen remains bound refers to a condition that preferentially elutes the Factor H, while a substantial fraction of the serine protease or serine protease zymogen remains bound to the SiO_2. In one embodiment, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 25% of the serine protease or serine protease zymogen bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 50% of the serine protease or serine protease zymogen bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 75% of the serine protease or serine protease zymogen bound to the SiO_2. In yet other embodiments, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen bound to the SiO_2, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85,

90, 95, 96, 97, 98, 99, or more of the serine protease or serine protease zymogen bound to the SiO_2.

[0343] Solution conditions that may be varied to achieve a desired result from a method described above include, without limitation, the pH of the solution, the conductivity of the solution, the temperature of the solution, the concentration of Factor H in the composition, and the concentration of SiO_2 used in the method. Generally, suitable pH ranges for methods of reducing serine protease and/or serine protease zymogen content in a Factor H enriched composition range from about 3 to about 11. Suitable conductivities for the methods described above range from about 0.1 mS/cm to about 100 mS/cm. Suitable temperatures for performing the methods described above range from about -10°C to about 90°C. Finely divided silicon dioxide may be used at a final concentration ranging from about 0.01 g/g protein to about 10 g/g protein. Finally, Factor H compositions may vary in concentration from about 0.001 mg/mL to about 100 mg/mL.

[0344] In one embodiment, the solution condition under which the Factor H is eluted from the SiO_2 and a significant fraction of the serine protease or serine protease zymogen remains bound comprises a pH between about 5.0 and about 11.0. In another embodiment, the pH is between about 6.0 and about 1.0. In another embodiment, the pH is between about 7.0 and about 9.0. In another embodiment, the pH is between about 7.5 and about 8.5. In yet another embodiment, the pH is between about 7.0 and about 8.0.

[0345] In a particular embodiment ,the solution condition under which the Factor H is eluted from the SiO_2 and a significant fraction of the serine protease or serine protease zymogen remains bound comprises a pH of about 7.0. In another specific embodiment, the pH is about 7.5. In another embodiment, the pH is about 8.0. In yet other embodiments, the pH is about 3.0 or about 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.0, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8.0, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9.0, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10.0, 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, or 11.0.

[0346] In one embodiment, the solution condition under which the Factor H is eluted from the SiO_2 and a significant fraction of the serine protease or serine protease zymogen remains bound comprises a pH of at least 6.0. In another embodiment, the pH is at least 6.5. In another embodiment, the pH is at least 7.0. In yet another embodiment, the pH is at least 7.5. In yet

other embodiments, the pH of the solution is at least 3.0 or at least 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, or higher.

[0347] In another embodiment, of any of the methods described above, the solution condition under which the Factor H is eluted from the SiO_2 and a significant fraction of the serine protease or serine protease zymogen remains bound comprises a pH of no greater than about 11.0. In another embodiment, the pH is no greater about 10.0. In another embodiment, the pH is no greater about 9.0. In another embodiment, the pH is no greater about 8.0. In yet other embodiments, the pH is no greater than about 11.0, or 10.5, 10.0, 9.5, 9.0, 8.5, 8.0, 7.5, 7.0, 6.5, 6.0, 5.5, 5.0, 4.5, 4.0, 3.5, or lower.

[0348] In one embodiment, the solution condition under which the Factor H is eluted from the SiO_2 and a significant fraction of the serine protease or serine protease zymogen remains bound comprises a conductivity of no more than about 20 mS/cm. In another embodiment, the conductivity is no more than about 10 mS/cm. In yet other embodiments, the conductivity of the solution condition is no more than about 20 mS/cm, or no more than about 19 mS/cm, 18 mS/cm, 17 mS/cm, 16 mS/cm, 15 mS/cm, 14 mS/cm, 13 mS/cm, 12 mS/cm, 11 mS/cm, 10 mS/cm, 9 mS/cm, 8 mS/cm, 7 mS/cm, 6 mS/cm, 5 mS/cm, 4 mS/cm, 3 mS/cm, 2 mS/cm, or less.

[0349] In one embodiment, the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a significant fraction of the Factor H remains bound comprises a conductivity between about 2 mS/cm and about 20 mS/cm. In another embodiment, the conductivity is between about 2 mS/cm and about 10 mS/cm. In another embodiment, the conductivity is between about 20 mS/cm and about 6 mS/cm. In yet another embodiment, the conductivity is between about 10 mS/cm and about 6 mS/cm.

[0350] As shown in Example 5 and illustrated in Figure 3, it was found that the use of solution conditions having a pH greater than 6.0 (*e.g.*, 7.5) and decreasing conductivity (*e.g.*, less than 20 mS/cm), results in increased elution of Factor H from SiO_2, and decreased elution of serine proteases and/or serine protease zymogens from SiO_2. Advantageously, these findings can be used to provide methods for reducing the levels of serine protease and serine protease zymogen present in Factor H compositions. In a particular embodiment of the methods described above, the solution condition under which the Factor H is eluted from the SiO_2 and a significant fraction of the serine protease or serine protease zymogen remains bound comprises a conductivity of at no more than about 20 mS/cm and a pH of at least 7.0. In another particular embodiment, the

solution condition comprises a conductivity of no more than about 10 mS/cm and a pH of at least 7.5. In another embodiment, the solution condition comprises a conductivity between about 10 mS/cm and about 2 mS/cm and a pH of at least 7.0. In yet another embodiment, the solution condition comprises a conductivity between about 10 mS/cm and about 2 mS/cm and a pH of at least 7.5.

4. Preferential binding of Factor H

[0351] In one aspect, the present invention provides a method for preparing a plasma-derived Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H but not the at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the composition; and (c) eluting the Factor H from the SiO_2.

[0352] In certain embodiments, a solution condition in which the serine protease or serine protease zymogen does not bind to the SiO_2 refers to a condition that preferentially allows Factor H binding to the SiO_2, while a substantial fraction of the serine protease or serine protease zymogen remains unbound in the solution. In one embodiment, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen in the starting composition. In another embodiment, a substantial fraction refers to at least 25% of the serine protease or serine protease zymogen in the starting composition. In another embodiment, a substantial fraction refers to at least 50% of the serine protease or serine protease zymogen in the starting composition. In another embodiment, a substantial fraction refers to at least 75% of the serine protease or serine protease zymogen in the starting composition. In yet other embodiments, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen in the starting composition, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the serine protease or serine protease zymogen in the starting composition.

[0353] Solution conditions that may be varied to achieve a desired result from a method described above include, without limitation, the pH of the solution, the conductivity of the solution, the temperature of the solution, the concentration of Factor H in the composition, and the concentration of SiO_2 used in the method. Generally, suitable pH ranges for methods of

reducing serine protease and/or serine protease zymogen content in a Factor H enriched composition range from about 3 to about 11. Suitable conductivities for the methods described above range from about 0.1 mS/cm to about 100 mS/cm. Suitable temperatures for performing the methods described above range from about -10°C to about 90°C. Finely divided silicon dioxide may be used at a final concentration ranging from about 0.01 g/g protein to about 10 g/g protein. Finally, Factor H compositions may vary in concentration from about 0.001 mg/mL to about 100 mg/mL.

[0354] In one embodiment, the solution condition under which Factor H binds to SiO_2 and a significant fraction of the serine protease or serine protease zymogen does not bind comprises a pH between about 5.0 and about 11.0. In another embodiment, the pH is between about 6.0 and about 1.0. In another embodiment, the pH is between about 7.0 and about 9.0. In another embodiment, the pH is between about 7.5 and about 8.5. In yet another embodiment, the pH is between about 7.0 and about 8.0.

[0355] In a particular embodiment ,the solution condition under which Factor H binds to SiO_2 and a significant fraction of the serine protease or serine protease zymogen does not bind comprises a pH of about 7.0. In another specific embodiment, the pH is about 7.5. In another embodiment, the pH is about 8.0. In yet other embodiments, the pH is about 3.0 or about 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.0, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8.0, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9.0, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10.0, 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, or 11.0.

[0356] In one embodiment, the solution condition under which Factor H binds to SiO_2 and a significant fraction of the serine protease or serine protease zymogen does not bind comprises a pH of at least 6.0. In another embodiment, the pH is at least 6.5. In another embodiment, the pH is at least 7.0. In yet another embodiment, the pH is at least 7.5. In yet other embodiments, the pH of the solution is at least 3.0 or at least 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, or higher.

[0357] In another embodiment, of any of the methods described above, the solution condition under which Factor H binds to SiO_2 and a significant fraction of the serine protease or serine protease zymogen does not bind comprises a pH of no greater than about 11.0. In another embodiment, the pH is no greater about 10.0. In another embodiment, the pH is no greater about

9.0. In another embodiment, the pH is no greater about 8.0. In yet other embodiments, the pH is no greater than about 11.0, or 10.5, 10.0, 9.5, 9.0, 8.5, 8.0, 7.5, 7.0, 6.5, 6.0, 5.5, 5.0, 4.5, 4.0, 3.5, or lower.

[0358] In one embodiment, the solution condition under which Factor H binds to SiO_2 and a significant fraction of the serine protease or serine protease zymogen does not bind comprises a conductivity of at least 10 mS/cm. In another embodiment, the conductivity is at least 20 mS/cm. In yet other embodiments, the conductivity of the solution condition is at least 2 mS/cm, or at least 3 mS/cm, 4 mS/cm, 5 mS/cm, 6 mS/cm, 7 mS/cm, 8 mS/cm, 9 mS/cm, 10 mS/cm, 11 mS/cm, 12 mS/cm, 13 mS/cm, 14 mS/cm, 15 mS/cm, 16 mS/cm, 17 mS/cm, 18 mS/cm, 19 mS/cm, 20 mS/cm, 21 mS/cm, 22 mS/cm, 23 mS/cm, 24 mS/cm, 25 mS/cm, 26 mS/cm, 27 mS/cm, 28 mS/cm, 29 mS/cm, 30 mS/cm, 31 mS/cm, 32 mS/cm, 33 mS/cm, 34 mS/cm, 35 mS/cm, 36 mS/cm, 37 mS/cm, 38 mS/cm, 39 mS/cm, 40 mS/cm, 41 mS/cm, 42 mS/cm, 43 mS/cm, 44 mS/cm, 45 mS/cm, 46 mS/cm, 47 mS/cm, 48 mS/cm, 49 mS/cm, 50 mS/cm, 55 mS/cm, 60 mS/cm, 65 mS/cm, 70 mS/cm, 75 mS/cm, 80 mS/cm, 85 mS/cm, 90 mS/cm, 95 mS/cm, 100 mS/cm, or greater.

[0359] In one embodiment, the solution condition under which Factor H binds to SiO_2 and a significant fraction of the serine protease or serine protease zymogen does not bind comprises a conductivity between about 10 mS/cm and about 100 mS/cm. In another embodiment, the conductivity is between about 10 mS/cm and about 50 mS/cm. In another embodiment, the conductivity is between about 20 mS/cm and about 100 mS/cm. In yet another embodiment, the conductivity is between about 20 mS/cm and about 50 mS/cm.

[0360] As shown in Example 5 and illustrated in Figure 3, it was found that the use of solution conditions having a pH greater than 6.0 (*e.g.*, 7.5) and increasing conductivity (*e.g.*, greater than 6.0 mS/cm), results in a decreased affinity of serine proteases and/or serine protease zymogens for SiO_2, and increased affinity of Factor H for SiO_2. Advantageously, these findings can be used to provide methods for reducing the levels of serine protease and serine protease zymogen present in Factor H compositions. In a particular embodiment of the methods described above, the solution condition under which Factor H binds to SiO_2 and a significant fraction of the serine protease or serine protease zymogen does not bind comprises a conductivity of at least about 10 mS/cm and a pH of at least 7.0. In another particular embodiment, the solution condition comprises a conductivity of at least 10 mS/cm and a pH of at least 7.5. In another embodiment,

the solution condition comprises a conductivity of at least 20 mS/cm and a pH of at least 7.0. In yet another embodiment, the solution condition comprises a conductivity of at least 20 mS/cm and a pH of at least 7.5.

5. Preferential binding of Serine Protease or Serine Protease Zymogen

[0361] In one aspect, the present invention provides a method for preparing a plasma-derived Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising (a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the serine protease and/or serine protease zymogen but not the Factor H; and (b) separating the SiO_2 from the composition.

[0362] In certain embodiments, a solution condition in which the Factor H does not bind to the SiO_2 refers to a condition that preferentially allows serine protease or serine protease zymogen binding to the SiO_2, while a substantial fraction of the Factor H remains unbound in the solution. In one embodiment, a substantial fraction refers to at least 10% of the Factor H in the starting composition. In another embodiment, a substantial fraction refers to at least 25% of the Factor H in the starting composition. In another embodiment, a substantial fraction refers to at least 50% of the Factor H in the starting composition. In another embodiment, a substantial fraction refers to at least 75% of the Factor H in the starting composition. In yet other embodiments, a substantial fraction refers to at least 10% of the Factor H in the starting composition, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the Factor H in the starting composition.

[0363] Solution conditions that may be varied to achieve a desired result from a method described above include, without limitation, the pH of the solution, the conductivity of the solution, the temperature of the solution, the concentration of Factor H in the composition, and the concentration of SiO_2 used in the method. Generally, suitable pH ranges for methods of reducing serine protease and/or serine protease zymogen content in a Factor H enriched composition range from about 3 to about 11. Suitable conductivities for the methods described above range from about 0.1 mS/cm to about 100 mS/cm. Suitable temperatures for performing the methods described above range from about -10°C to about 90°C. Finely divided silicon dioxide may be used at a final concentration ranging from about 0.01 g/g protein to about 10 g/g

protein. Finally, Factor H compositions may vary in concentration from about 0.001 mg/mL to about 100 mg/mL.

[0364] In one embodiment, the solution condition under which the serine protease or serine protease zymogen binds to SiO_2 and a significant fraction of the Factor H does not bind comprises a pH between about 5.0 and about 11.0. In another embodiment, the pH is between about 6.0 and about 1.0. In another embodiment, the pH is between about 7.0 and about 9.0. In another embodiment, the pH is between about 7.5 and about 8.5. In yet another embodiment, the pH is between about 7.0 and about 8.0.

[0365] In a particular embodiment ,the solution condition under which the serine protease or serine protease zymogen binds to SiO_2 and a significant fraction of the Factor H does not bind comprises a pH of about 7.0. In another specific embodiment, the pH is about 7.5. In another embodiment, the pH is about 8.0. In yet other embodiments, the pH is about 3.0 or about 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.0, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8.0, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9.0, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10.0, 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, or 11.0.

[0366] In one embodiment, the solution condition under which the serine protease or serine protease zymogen binds to SiO_2 and a significant fraction of the Factor H does not bind comprises a pH of at least 6.0. In another embodiment, the pH is at least 6.5. In another embodiment, the pH is at least 7.0. In yet another embodiment, the pH is at least 7.5. In yet other embodiments, the pH of the solution is at least 3.0 or at least 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, or higher.

[0367] In another embodiment, of any of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to SiO_2 and a significant fraction of the Factor H does not bind comprises a pH of no greater than about 11.0. In another embodiment, the pH is no greater about 10.0. In another embodiment, the pH is no greater about 9.0. In another embodiment, the pH is no greater about 8.0. In yet other embodiments, the pH is no greater than about 11.0, or 10.5, 10.0, 9.5, 9.0, 8.5, 8.0, 7.5, 7.0, 6.5, 6.0, 5.5, 5.0, 4.5, 4.0, 3.5, or lower.

[0368] In one embodiment, the solution condition under which the serine protease or serine protease zymogen binds to SiO_2 and a significant fraction of the Factor H does not bind comprises a conductivity of no more than about 20 mS/cm. In another embodiment, the conductivity is no more than about 10 mS/cm. In yet other embodiments, the conductivity of the solution condition is no more than about 20 mS/cm, or no more than about 19 mS/cm, 18 mS/cm, 17 mS/cm, 16 mS/cm, 15 mS/cm, 14 mS/cm, 13 mS/cm, 12 mS/cm, 11 mS/cm, 10 mS/cm, 9 mS/cm, 8 mS/cm, 7 mS/cm, 6 mS/cm, 5 mS/cm, 4 mS/cm, 3 mS/cm, 2 mS/cm, or less.

[0369] In one embodiment, the solution condition under which the serine protease or serine protease zymogen binds to SiO_2 and a significant fraction of the Factor H does not bind comprises a conductivity between about 2 mS/cm and about 20 mS/cm. In another embodiment, the conductivity is between about 2 mS/cm and about 10 mS/cm. In another embodiment, the conductivity is between about 20 mS/cm and about 6 mS/cm. In yet another embodiment, the conductivity is between about 10 mS/cm and about 6 mS/cm.

[0370] As shown in Example 5 and illustrated in Figure 3, it was found that the use of solution conditions having a pH greater than 6.0 (*e.g.*, 7.5) and decreasing conductivity (*e.g.*, less than 20 mS/cm), results in increased affinity of Factor H for SiO_2, and decreased affinity of serine proteases and/or serine protease zymogens from SiO_2. Advantageously, these findings can be used to provide methods for reducing the levels of serine protease and serine protease zymogen present in Factor H compositions. In a particular embodiment of the methods described above, the solution condition under which the serine protease or serine protease zymogen binds to SiO_2 and a significant fraction of the Factor H does not bind comprises a conductivity of at no more than about 20 mS/cm and a pH of at least 7.0. In another particular embodiment, the solution condition comprises a conductivity of no more than about 10 mS/cm and a pH of at least 7.5. In another embodiment, the solution condition comprises a conductivity between about 10 mS/cm and about 2 mS/cm and a pH of at least 7.0. In yet another embodiment, the solution condition comprises a conductivity between about 10 mS/cm and about 2 mS/cm and a pH of at least 7.5.

6. Method for Factor H Extraction from a Plasma Precipitate

[0371] In one aspect, the present invention provides a method for preparing a Factor H composition, the method comprising the steps of: (a) contacting a suspended plasma precipitate composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H, (b)

washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm, and (c) eluting the Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm, thereby providing an enriched Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is one or more of FXI, FXIa, FXII, and FXIIa. In certain embodiments, the plasma precipitate is a Cohn fraction I precipitate, a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, a Kistler/Nitschmann Precipitate B, or an equivalent fraction thereof. In one embodiment, the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5. In a specific embodiment, the solution used to wash the SiO_2 comprises a pH of 6.0±0.2. In one embodiment, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm. In a specific embodiment, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm.

[0372] In certain embodiments, the method described above further comprises an enrichment step comprising precipitating at least one impurity from the enriched Factor H composition, wherein Factor H is not co-precipitated. In a specific embodiment, the method comprises the steps of (a) contacting a suspended plasma precipitate composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H, (b) washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm, (c) eluting the Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm, and (d) precipitating at least one impurity from the Factor H elution, wherein Factor H is not precipitated, thereby providing an enriched Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is one or more of FXI, FXIa, FXII, and FXIIa. In certain embodiments, the plasma precipitate is a Cohn fraction I precipitate, a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, a Kistler/Nitschmann Precipitate B, or an equivalent fraction thereof. In one embodiment, the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5. In a specific embodiment, the solution used to wash the SiO_2 comprises a pH of 6.0±0.2. In one embodiment, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm. In a specific embodiment, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm. In one embodiment, the impurity precipitation step is PEG precipitation. In a specific embodiment, the impurity PEG precipitation comprises precipitation

with PEG 4000 at a final concentration between 3% and 7%. In a more specific embodiment, the final concentration of PEG 4000 in the impurity precipitation step is 5±0.5%.

[0373] In certain embodiments, the methods described above further comprises an enrichment step comprising precipitating Factor H from an enriched Factor H composition. In a specific embodiment, the method comprises the steps of (a) contacting a suspended plasma precipitate composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H, (b) washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm, (c) eluting the Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm, (d) precipitating at least one impurity from the Factor H elution, to form a supernatant comprising Factor H, and (e) precipitating Factor H from the supernatant, thereby providing an enriched Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is one or more of FXI, FXIa, FXII, and FXIIa. In certain embodiments, the plasma precipitate is a Cohn fraction I precipitate, a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, a Kistler/Nitschmann Precipitate B, or an equivalent fraction thereof. In one embodiment, the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5. In a specific embodiment, the solution used to wash the SiO_2 comprises a pH of 6.0±0.2. In one embodiment, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm. In a specific embodiment, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm. In one embodiment, the impurity precipitation step is PEG precipitation. In a specific embodiment, the impurity PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 3% and 7%. In a more specific embodiment, the final concentration of PEG 4000 in the impurity precipitation step is 5±0.5%. In one embodiment, the Factor H precipitation step is PEG precipitation. In a specific embodiment, the Factor H PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 10% and 15%. In a more specific embodiment, the final concentration of PEG 4000 is 12±0.5% in the Factor H precipitation step.

[0374] In certain embodiments, the methods described above further comprises an enrichment step comprising performing anion exchange chromatography with an enriched Factor H composition. In a specific embodiment, the method comprises the steps of (a) contacting a suspended plasma precipitate composition containing Factor H and at least one serine protease or

serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H, (b) washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm, (c) eluting the Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm, (d) precipitating at least one impurity from the Factor H elution, to form a supernatant comprising Factor H, (e) precipitating Factor H from the supernatant, (f) re-suspending the precipitate comprising Factor H, (g) binding Factor H present in the re-suspended precipitate to an anion exchange resin, and (h) eluting Factor H from the anion exchange resin, thereby providing an enriched Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is one or more of FXI, FXIa, FXII, and FXIIa. In certain embodiments, the plasma precipitate is a Cohn fraction I precipitate, a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, a Kistler/Nitschmann Precipitate B, or an equivalent fraction thereof. In one embodiment, the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5. In a specific embodiment, the solution used to wash the SiO_2 comprises a pH of 6.0±0.2. In one embodiment, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm. In a specific embodiment, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm. In one embodiment, the impurity precipitation step is PEG precipitation. In a specific embodiment, the impurity PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 3% and 7%. In a more specific embodiment, the final concentration of PEG 4000 in the impurity precipitation step is 5±0.5%. In one embodiment, the Factor H precipitation step is PEG precipitation. In a specific embodiment, the Factor H PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 10% and 15%. In a more specific embodiment, the final concentration of PEG 4000 is 12±0.5% in the Factor H precipitation step.

[0375] In certain embodiments, the methods described above further comprises an enrichment step comprising performing heparin affinity chromatography with an enriched Factor H composition. In a specific embodiment, the method comprises the steps of (a) contacting a suspended plasma precipitate composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H, (b) washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm, (c) eluting the Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm, (d) precipitating

at least one impurity from the Factor H elution, to form a supernatant comprising Factor H, (e) precipitating Factor H from the supernatant, (f) re-suspending the precipitate comprising Factor H, (g) binding Factor H present in the re-suspended precipitate to an anion exchange resin, (h) eluting Factor H from the anion exchange resin, (i) binding Factor H present in the anion exchange eluate to a heparin affinity resin, and (j) eluting Factor H from the heparin affinity resin, thereby providing an enriched Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is one or more of FXI, FXIa, FXII, and FXIIa. In certain embodiments, the plasma precipitate is a Cohn fraction I precipitate, a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, a Kistler/Nitschmann Precipitate B, or an equivalent fraction thereof. In one embodiment, the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5. In a specific embodiment, the solution used to wash the SiO_2 comprises a pH of 6.0±0.2. In one embodiment, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm. In a specific embodiment, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm. In one embodiment, the impurity precipitation step is PEG precipitation. In a specific embodiment, the impurity PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 3% and 7%. In a more specific embodiment, the final concentration of PEG 4000 in the impurity precipitation step is 5±0.5%. In one embodiment, the Factor H precipitation step is PEG precipitation. In a specific embodiment, the Factor H PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 10% and 15%. In a more specific embodiment, the final concentration of PEG 4000 is 12±0.5% in the Factor H precipitation step.

[0376] In certain embodiments, the methods described above further comprises subjecting a Factor H composition to a dedicated viral removal and/or inactivation step. In a specific embodiment, the method comprises the steps of (a) contacting a suspended plasma precipitate composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H, (b) washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm, (c) eluting the Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm, (d) precipitating at least one impurity from the Factor H elution, to form a supernatant comprising Factor H, (e) precipitating Factor H from the supernatant, (f) re-suspending the precipitate comprising Factor H, (g) binding Factor H

present in the re-suspended precipitate to an anion exchange resin, (h) eluting Factor H from the anion exchange resin, (i) binding Factor H present in the anion exchange eluate to a heparin affinity resin, (j) eluting Factor H from the heparin affinity resin, and (k) performing a dedicated viral removal and/or inactivation step selected from nanofiltration, solvent/detergent (S/D) treatment, heat treatment, and incubation at low pH, thereby providing an enriched Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is one or more of FXI, FXIa, FXII, and FXIIa. In certain embodiments, the plasma precipitate is a Cohn fraction I precipitate, a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, a Kistler/Nitschmann Precipitate B, or an equivalent fraction thereof. In one embodiment, the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5. In a specific embodiment, the solution used to wash the SiO_2 comprises a pH of 6.0±0.2. In one embodiment, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm. In a specific embodiment, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm. In one embodiment, the impurity precipitation step is PEG precipitation. In a specific embodiment, the impurity PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 3% and 7%. In a more specific embodiment, the final concentration of PEG 4000 in the impurity precipitation step is 5±0.5%. In one embodiment, the Factor H precipitation step is PEG precipitation. In a specific embodiment, the Factor H PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 10% and 15%. In a more specific embodiment, the final concentration of PEG 4000 is 12±0.5% in the Factor H precipitation step.

[0377] In certain embodiments, the methods described above further comprises a step of concentrating an enriched Factor H composition by ultrafiltration/diafiltration. In a specific embodiment, the method comprises the steps of (a) contacting a suspended plasma precipitate composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H, (b) washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm, (c) eluting the Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm, (d) precipitating at least one impurity from the Factor H elution, to form a supernatant comprising Factor H, (e) precipitating Factor H from the supernatant, (f) re-suspending the precipitate comprising Factor H, (g) binding Factor H present in the re-suspended precipitate to an anion exchange resin, (h) eluting Factor H from the

anion exchange resin, (i) binding Factor H present in the anion exchange eluate to a heparin affinity resin, (j) eluting Factor H from the heparin affinity resin, (k) performing a dedicated viral removal and/or inactivation step selected from nanofiltration, solvent/detergent (S/D) treatment, heat treatment, and incubation at low pH, and (l) concentrating Factor H by ultrafiltration/diafiltration, thereby providing an enriched Factor H composition. In a preferred embodiment, the serine protease or serine protease zymogen is one or more of FXI, FXIa, FXII, and FXIIa. In certain embodiments, the plasma precipitate is a Cohn fraction I precipitate, a Cohn fraction II+III precipitate, a Cohn fraction I+II+III precipitate, a Kistler/Nitschmann Precipitate A, a Kistler/Nitschmann Precipitate B, or an equivalent fraction thereof. In one embodiment, the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5. In a specific embodiment, the solution used to wash the SiO_2 comprises a pH of 6.0±0.2. In one embodiment, the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm. In a specific embodiment, the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm. In one embodiment, the impurity precipitation step is PEG precipitation. In a specific embodiment, the impurity PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 3% and 7%. In a more specific embodiment, the final concentration of PEG 4000 in the impurity precipitation step is 5±0.5%. In one embodiment, the Factor H precipitation step is PEG precipitation. In a specific embodiment, the Factor H PEG precipitation comprises precipitation with PEG 4000 at a final concentration between 10% and 15%. In a more specific embodiment, the final concentration of PEG 4000 is 12±0.5% in the Factor H precipitation step.

C. Inter-alpha-Trypsin Inhibitor (IαI)

[0378] In one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived IαI composition. In one specific embodiment, the method comprises the steps of: (a) contacting the IαI composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO_2 from the IαI composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII).

[0379] In one embodiment, the method further comprises the step of performing a first IαI protein enrichment step to form a first enriched IαI composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first IαI protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0380] In certain embodiments, the methods described above further comprises the step of performing a second IαI protein enrichment step to form a second enriched IαI composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first IαI protein enrichment step is selected from a protein precipitation step (e.g., an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0381] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived IαI composition, the method comprises the steps of: (a) performing a first IαI enrichment step to form a first enriched plasma-derived IαI composition; (b) performing a second IαI enrichment step to form a second enriched plasma-derived IαI composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0382] In certain embodiments, the methods described above further comprises the step of performing an IαI enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the IαI enrichment step is selected from a protein precipitation step (e.g., an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0383] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived IαI composition the method comprises the steps of: (a) performing a first IαI enrichment step to form a first enriched plasma-derived IαI composition; (b) contacting the first enriched composition with

finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (d) performing a second IαI enrichment step to form a second enriched plasma-derived IαI composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0384] Likewise, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived IαI composition, the method comprising the steps of: (a) performing a first IαI enrichment step to form a first enriched plasma-derived IαI composition; (b) performing a second IαI enrichment step to form a second enriched plasma-derived IαI composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (e) performing a third IαI enrichment step to form a third enriched plasma-derived IαI composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 101 to Var. 1100, found in Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, or Table 11.

1. Co-Binding and Differential Elution

[0385] In one aspect, the present invention provides a method for preparing a plasma-derived IαI composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising co-extracting IαI and a serine protease and/or serine protease zymogen from a composition derived from pooled plasma by binding the proteins to finely divided silicon dioxide (SiO_2), eluting the serine protease and/or serine protease zymogen from the SiO_2 under a first solution condition, and subsequently eluting IαI from the SiO_2 under a second solution condition. In a preferred embodiment, the starting composition is a re-suspended Fraction II+III precipitate or equivalent precipitate thereof.

[0386] In a specific embodiment, the method comprises the steps of: (a) contacting a composition containing IαI and at least one serine protease or serine protease zymogen with

finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI and at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the composition; (c) eluting the serine protease or serine protease zymogen from the SiO_2 under a solution condition in which the IαI remains bound; and (d) eluting the IαI from the SiO_2.

[0387] In certain embodiments, a solution condition in which the IαI remains bound refers to a condition that preferentially elutes the serine protease or serine protease zymogen, while a substantial fraction of IαI remains bound to the SiO_2. In one embodiment, a substantial fraction refers to at least 10% of the IαI bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 25% of the IαI bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 50% of the IαI bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 75% of the IαI bound to the SiO_2. In yet other embodiments, a substantial fraction refers to at least 10% of the IαI bound to the SiO_2, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the IαI bound to the SiO_2.

[0388] In certain embodiments, differential elution of the serine protease or serine protease zymogen and IαI is achieved by sequentially contacting (*i.e.*, step-wise elution) the SiO_2 with a first solution condition (*e.g.*, a first elution buffer) suitable to elute the majority of the serine protease or serine protease zymogen but not a substantial fraction of the bound IαI, and a second solution condition (*e.g.*, a second elution buffer) suitable to elute the substantial fraction of bound IαI from the SiO_2.

[0389] In other embodiments, differential elution of the serine protease or serine protease zymogen and IαI is achieved by gradually changing the solution conditions (*i.e.*, with an elution gradient) from a first solution condition suitable to elute the majority of the serine protease or serine protease zymogen but not a substantial fraction of the bound IαI to a second solution condition suitable to elute the substantial fraction of bound IαI from the SiO_2. In this fashion, the serine protease or serine protease zymogen and IαI content eluted off of the SiO_2 may be partially overlapping. By fractionating the elution and characterizing the individual fractions, a IαI pool may be created from fractions having high IαI content and low serine protease or serine protease zymogen content.

2. Co-Binding and Preferential IαI Elution

[0390] In one aspect, the present invention provides a method for preparing a plasma-derived IαI composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising co-extracting IαI and a serine protease and/or serine protease zymogen from a composition derived from pooled plasma by binding the proteins to finely divided silicon dioxide (SiO_2), and eluting the IαI from the SiO_2 under conditions in which a substantial fraction of the bound serine protease and/or serine protease zymogen remains bound to the SiO_2. In a preferred embodiment, the starting composition is a re-suspended Fraction II+III precipitate or equivalent precipitate thereof.

[0391] In a specific embodiment, the method comprises the steps of: (a) contacting a composition containing IαI and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI and at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the composition; and (c) eluting the IαI from the SiO_2 under a solution condition in which the serine protease or serine protease zymogen remains bound.

[0392] In certain embodiments, a solution condition in which the serine protease or serine protease zymogen remains bound refers to a condition that preferentially elutes the IαI, while a substantial fraction of the serine protease or serine protease zymogen remains bound to the SiO_2. In one embodiment, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 25% of the serine protease or serine protease zymogen bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 50% of the serine protease or serine protease zymogen bound to the SiO_2. In another embodiment, a substantial fraction refers to at least 75% of the serine protease or serine protease zymogen bound to the SiO_2. In yet other embodiments, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen bound to the SiO_2, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the serine protease or serine protease zymogen bound to the SiO_2.

3. Preferential binding of IαI

[0393] In one aspect, the present invention provides a method for preparing a plasma-derived IαI composition having a reduced amount of a serine protease or a serine protease zymogen, the

method comprising (a) contacting a composition containing IαI and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI but not the at least one serine protease or serine protease zymogen; (b) separating the SiO_2 from the composition; and (c) eluting the IαI from the SiO_2.

[0394] In certain embodiments, a solution condition in which the serine protease or serine protease zymogen does not bind to the SiO_2 refers to a condition that preferentially allows IαI binding to the SiO_2, while a substantial fraction of the serine protease or serine protease zymogen remains unbound in the solution. In one embodiment, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen in the starting composition. In another embodiment, a substantial fraction refers to at least 25% of the serine protease or serine protease zymogen in the starting composition. In another embodiment, a substantial fraction refers to at least 50% of the serine protease or serine protease zymogen in the starting composition. In another embodiment, a substantial fraction refers to at least 75% of the serine protease or serine protease zymogen in the starting composition. In yet other embodiments, a substantial fraction refers to at least 10% of the serine protease or serine protease zymogen in the starting composition, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the serine protease or serine protease zymogen in the starting composition.

4. Preferential binding of Serine Protease or Serine Protease Zymogen

[0395] In one aspect, the present invention provides a method for preparing a plasma-derived IαI composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising (a) contacting a composition containing IαI and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the serine protease and/or serine protease zymogen but not the IαI; and (b) separating the SiO_2 from the composition.

[0396] In certain embodiments, a solution condition in which the IαI does not bind to the SiO_2 refers to a condition that preferentially allows serine protease or serine protease zymogen binding to the SiO_2, while a substantial fraction of the IαI remains unbound in the solution. In one embodiment, a substantial fraction refers to at least 10% of the IαI in the starting composition. In another embodiment, a substantial fraction refers to at least 25% of the IαI in the starting composition. In another embodiment, a substantial fraction refers to at least 50% of the IαI in the starting composition. In another embodiment, a substantial fraction refers to at

least 75% of the IαI in the starting composition. In yet other embodiments, a substantial fraction refers to at least 10% of the IαI in the starting composition, or at least 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, or more of the IαI in the starting composition.

D. Alpha-1-Antitrypsin (A1PI)

[0397] In one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived alpha-1-antitrypsin (A1PI) composition. In one specific embodiment, the method comprises the steps of: (a) contacting an A1PI composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO_2 from the A1PI composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII).

[0398] In one embodiment, the method further comprises the step of performing a first A1PI protein enrichment step to form a first enriched A1PI composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first A1PI protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0399] In certain embodiments, the methods described above further comprises the step of performing a second A1PI protein enrichment step to form a second enriched A1PI composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first A1PI protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0400] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived A1PI composition, the method comprises the steps of: (a) performing a first A1PI enrichment step to form a first enriched plasma-derived A1PI composition; (b) performing a second A1PI enrichment step to form a second enriched plasma-derived A1PI composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least

one serine protease or serine protease zymogen; and (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0401] In certain embodiments, the methods described above further comprises the step of performing an A1PI enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the A1PI enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0402] Accordingly, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived A1PI composition the method comprises the steps of: (a) performing a first A1PI enrichment step to form a first enriched plasma-derived A1PI composition; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (d) performing a second A1PI enrichment step to form a second enriched plasma-derived A1PI composition. In a preferred embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1.

[0403] Likewise, in one embodiment, the invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived A1PI composition, the method comprising the steps of: (a) performing a first A1PI enrichment step to form a first enriched plasma-derived A1PI composition; (b) performing a second A1PI enrichment step to form a second enriched plasma-derived Ig composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (e) performing a third A1PI enrichment step to form a third enriched plasma-derived A1PI composition. In a preferred

embodiment, the serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), and/or Factor XII (FXII). In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 101 to Var. 1100, found in Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, or Table 11.

[0404] In a particular embodiment, the A1PI composition is a manufacturing intermediate. For example, in certain embodiments, the A1PI composition is a manufacturing intermediate from a Cohn fractionation procedure (J. Am. Chem. Soc., 1946, 68(3): 459-475; J. Am. Chem. Soc. 72:465-474 (1950)), an Oncley fractionation procedure (J. Am. Chem. Soc., 1949, 71(2): 541-550), a Kistler/Nitschmann fractionation procedure (Vox Sang. 7:414-424 (1962)), a purification procedure disclosed in U.S. Patent Nos. 6,974,792 or 7,807,435, modified procedures thereof, and similar or equivalent purification procedures known in the art. The aforementioned references are hereby incorporated by reference in their entireties for all purposes.

[0405] For example, a number of production methods for A1PI are known which comprise the fractionated precipitation of plasma with polyethylene glycol 4000, but also the processing of various plasma fractions (Cohn fraction IV-1-precipitate or Kistler and Nitschmann Supernatant A or A+1) (Feldman and Winkelman, Blood Separation and Plasma Fractionation (1991), Wiley-Liss, Inc., pp. 341-383). In more elaborate purifications, the respective blood fractions have been purified by means of DEAE cellulose, e.g. (Basis et al. (Vopr. Med. Khim. 33 (1) (1987), 54-59)), treated with affinity chromatographic materials or with cation exchanger chromatographic materials (EP 0 698 615 A1). U.S. Patent No. 6,974,792 describes a purification process yielding A1PI with high specific activity utilizing a Cohn fraction V precipitate. U.S. Patent No. 7,807,435 describes a purification process providing higher yields of A1PI, utilizing a Cohn fraction IV-1 and/or fraction IV-4 precipitate.

[0406] In one particular embodiment, the A1PI composition is a cryo-poor Cohn pool. In another particular embodiment, the A1PI composition is a re-suspended Cohn Fraction V precipitate or equivalent fraction thereof. In another particular embodiment, the A1PI composition is a re-suspended Cohn Fraction IV-1 precipitate, or equivalent fraction thereof. In another particular embodiment, the A1PI composition is a re-suspended Cohn Fraction IV-4 precipitate, or equivalent fraction thereof. In another particular embodiment, the A1PI composition is a Kistler/Nitschmann Supernatant A, or equivalent fraction thereof.

[0407] Generally, serine protease and/or serine protease zymogen removal from A1PI compositions can be achieved by treating the A1PI-containing composition with finely divided silicon dioxide (SiO_2) under pH and conductivity solution conditions in which the serine protease and/or serine protease zymogen binds to the SiO_2.

[0408] In one embodiment, the process improvements are realized by inclusion of a fumed silica treatment prior to filtration or centrifugal clarification of a plasma precipitate comprising A1PI. In one embodiment, the SiO_2 treatment step comprises addition of finely divided silica dioxide particles (*e.g.*, fumed silica, Aerosil®) followed by a 40 minute to 16 hour incubation period during which the suspension is constantly mixed. In certain embodiments, the incubation period will be between about 50 minutes and about 70 minutes, or about 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, or more minutes. In other embodiments, the incubation period will be at least 1 hour, or at least 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 7 hours, 8 hours, 9 hours, 10 hours, 11 hours, 12 hours, 13 hours, 14 hours, 15 hours, 16 hours, or more hours. In a particular embodiment, the incubation period will be at least 15 hours. Generally, the treatment will be performed at between about 0°C and about 25°C, or between about 2°C and about 8°C. In certain embodiments, the treatment may be performed at about 0°C, 1°C, 2°C, 3°C, 4°C, 5°C, 6°C, 7°C, 8°C, 9°C, 10°C, 11°C, 12°C, 13°C, 14°C, 15°C, 16°C, 17°C, 18°C, 19°C, 20°C, 21°C, 22°C, 23°C, 24°C, or 25°C. In a particular embodiment, the treatment is performed at between about 2°C and about 25°C. In a specific embodiment, the process improvements are realized by inclusion of a fumed silica treatment, which reduces the levels of FXI, FXIa, FXII, and FXIIa in the immunoglobulin preparation.

[0409] In certain embodiments, fumed silica is added at a concentration of between about 20 g/kg precipitate and about 100 g/kg precipitate. In certain embodiments, the fumed silica may be added at a concentration of about 20 g/kg precipitate, or about 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, or 100 g/kg precipitate. In one specific embodiment, fumed silica (e.g., Aerosil 380 or equivalent) is added to the precipitate re-suspension to a final concentration of about 40 g/kg precipitate.

[0410] In certain embodiments, SiO_2 is added to an A1PI composition at a concentration between about 0.01 g/g protein and about 10 g/g protein. In another embodiment, SiO_2 is added to an A1PI composition at a concentration between about 0.01 g/g protein and about 5 g/g protein. In another embodiment, SiO_2 is added to an A1PI composition at a concentration

between about 0.02 g/g protein and about 4 g/g protein. In one embodiment, SiO_2 is added to an A1PI composition at a final concentration of at least 0.1 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 0.25 g per gram total protein. In other specific embodiments, fumed silica is added at a concentration of at least 1 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2 g per gram total protein. In another specific embodiment, fumed silica is added at a concentration of at least 2.5 g per gram total protein. In yet other specific embodiments, finely divided silicon dioxide is added at a concentration of at least 0.01 g/g total protein or at least 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, or more g/g total protein.

[0411] In certain embodiments, filter aid, for example Celpure C300 (Celpure) or Hyflo-Supper-Cel (World Minerals), will be added after the silica dioxide treatment, to facilitate depth filtration. Filter aid can be added at a final concentration of from about 0.01 kg/kg precipitate to about 1.0 kg/kg precipitate, or from about 0.02 kg/kg precipitate to about 0.8 kg/kg precipitate, or from about 0.03 kg/kg precipitate to about 0.7 kg/kg precipitate. In certain embodiments, the filter aid will be added at a final concentration of at least 0.01 kg/kg precipitate, or at least 0.02 kg/kg, 0.03 kg/kg, 0.04 kg/kg, 0.05 kg/kg, 0.06 kg/kg, 0.07 kg/kg, 0.08 kg/kg, 0.09 kg/kg, 0.1 kg/kg, 0.2 kg/kg, 0.3 kg/kg, 0.4 kg/kg, 0.5 kg/kg, 0.6 kg/kg, 0.7 kg/kg, 0.8 kg/kg, 0.9 kg/kg, or 1.0 kg/kg precipitate. In certain embodiments, the filter aid will be added at a final concentration of about 0.01 kg/kg precipitate, or about 0.02 kg/kg, 0.03 kg/kg, 0.04 kg/kg, 0.05 kg/kg, 0.06 kg/kg, 0.07 kg/kg, 0.08 kg/kg, 0.09 kg/kg, 0.1 kg/kg, 0.2 kg/kg, 0.3 kg/kg, 0.4 kg/kg, 0.5 kg/kg, 0.6 kg/kg, 0.7 kg/kg, 0.8 kg/kg, 0.9 kg/kg, or 1.0 kg/kg precipitate.

[0412] Accordingly, in one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived A1PI composition, the method comprising contacting the composition with SiO_2 at a pH between about 4.0 and about 7.0 to bind a serine protease or a serine protease zymogen. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 6.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 6.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 5.5. In

another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.0 and about 5.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 7.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 6.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 6.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 5.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.5 and about 5.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 7.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 6.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 6.0. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 5.5. In yet another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.6 and about 5.6. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.7 and about 5.5. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.8 and about 5.4. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.9 and about 5.3. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 5.2. In another embodiment, the method comprises contacting the composition with SiO_2 at a pH of about 5.1. In other embodiments, the method comprises contacting the composition with SiO_2 at a pH of about 4.0 or about 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, or no more than 7.0. In yet other embodiments, the method comprises contacting the composition with SiO_2 at a pH of no more than 4.0 or no more than 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, or no more than 7.0.

[0413] In one embodiment, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived A1PI composition, the method comprising contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 2.0 mS/cm to bind a serine protease or a serine protease zymogen. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength

between about 0.1 mS/cm and about 1.9 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.8 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.7 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.6 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.5 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.4 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.3 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.2 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.1 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 0.9 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 0.8 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.2 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.3 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.1 mS/cm and about 0.4 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.5 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.6 mS/cm and about 1.0 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength between about 0.7 mS/cm and about 0.9 mS/cm. In another embodiment, the method comprises contacting the composition with SiO_2 at an ionic strength of about 0.8 mS/cm. In other embodiments, the method comprises contacting the composition with SiO_2 at an ionic strength of about 0.1 mS/cm or no more than 0.2 mS/cm, 0.3 mS/cm, 0.4 mS/cm, 0.5 mS/cm, 0.6 mS/cm, 0.7 mS/cm, 0.8 mS/cm, 0.9 mS/cm, 1.0 mS/cm,

1.1 mS/cm, 1.2 mS/cm, 1.3 mS/cm, 1.4 mS/cm, 1.5 mS/cm, 1.6 mS/cm, 1.7 mS/cm, 1.8 mS/cm, 1.9 mS/cm, 2.0 mS/cm, 2.1 mS/cm, 2.2 mS/cm, 2.3 mS/cm, 2.4 mS/cm, 2.5 mS/cm, 2.6 mS/cm, 2.7 mS/cm, 2.8 mS/cm, 2.9 mS/cm, or 3.0 mS/cm. In yet other embodiments, the method comprises contacting the composition with SiO_2 at an ionic strength of no more than 0.1 mS/cm or no more than 0.2 mS/cm, 0.3 mS/cm, 0.4 mS/cm, 0.5 mS/cm, 0.6 mS/cm, 0.7 mS/cm, 0.8 mS/cm, 0.9 mS/cm, 1.0 mS/cm, 1.1 mS/cm, 1.2 mS/cm, 1.3 mS/cm, 1.4 mS/cm, 1.5 mS/cm, 1.6 mS/cm, 1.7 mS/cm, 1.8 mS/cm, 1.9 mS/cm, 2.0 mS/cm, 2.1 mS/cm, 2.2 mS/cm, 2.3 mS/cm, 2.4 mS/cm, 2.5 mS/cm, 2.6 mS/cm, 2.7 mS/cm, 2.8 mS/cm, 2.9 mS/cm, or 3.0 mS/cm.

[0414] In certain embodiments, the present invention provides a method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived A1PI composition, the method comprising contacting the composition with SiO_2 at a low pH and low ionic strength to bind a serine protease or a serine protease zymogen. In a particular embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.8 and about 5.4 at an ionic strength between about 0.6 mS/cm and about 1.0 mS/cm. In a more particular embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 4.9 and about 5.3 at an ionic strength between about 0.7 mS/cm and about 0.9 mS/cm. In a yet more particular embodiment, the method comprises contacting the composition with SiO_2 at a pH between about 5.0 and about 5.2 at an ionic strength of about 0.8 mS/cm. In yet other embodiments, the method comprises contacting the composition with SiO_2 at a pH and ionic strength according to any one of variations Var. 1222 to 3041, as presented in **Table 12**, **Table 13**, **Table 14**, and **Table 15**.

1. Binding and Elution of Serine Proteases or Serine Protease Zymogens

[0415] In one aspect, the present invention provides a method for reducing the amount of serine protease and/or serine protease zymogen in a re-suspended plasma precipitate comprising A1PI. Generally, the precipitate may be any precipitated during the fractionation of pooled plasma, preferably human plasma In one embodiment, the method comprises contacting a re-suspended plasma precipitate comprising A1PI in an insoluble state with finely divided silicon dioxide (SiO_2) under a first low pH solution condition to bind the serine protease and/or serine protease zymogen and to maintain the A1PI in an insoluble state, separating the soluble and insoluble portions of the suspension, eluting the serine and/or serine protease zymogen from SiO_2 under a second low pH solution condition suitable to maintain a substantial fraction of the

A1PI in an insoluble state, separating the soluble and insoluble portions of the suspension, and extracting the A1PI from the insoluble portion. In one embodiment, the SiO_2 is admixed prior to or during the precipitation reaction and recovered along with the precipitate. In a specific embodiment, the precipitate is a Cohn fraction IV-1 precipitate. In another embodiment, the precipitate is a Cohn fraction IV-4 precipitate. In another embodiment, the precipitate is a Cohn fraction V precipitate. In another embodiment, the precipitate is a Kistler/Nitschmann precipitate IV. In yet another embodiment, the precipitate is a Kistler/Nitschmann precipitate C.

[0416] In one embodiment of the methods provided above, the first low pH solution condition comprises a pH of between 4.0 and 7.0 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 7.0 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.0 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 5.0 mS/cm. In a specific embodiment, the solution condition comprises a pH of 5.5±0.2 and an ionic strength of less than about 5.0 mS/cm. In another specific embodiment, the solution condition comprises a pH of 6.0±0.2 and an ionic strength of less than about 5.0 mS/cm.

[0417] In another embodiment of the methods provided above, the first low pH solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 3.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 2.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 1.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 0.5 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 3.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 2.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 1.0

mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 0.5 mS/cm. In a specific embodiment, the solution conditions comprises a pH of 5.5±0.2 and an ionic strength of less than about 3.0 mS/cm. In another specific embodiment, the solution condition comprises a pH of 6.0±0.2 and an ionic strength of less than about 3.0 mS/cm. In yet other embodiments, the first low pH solution condition comprises a pH and ionic strength according to any one of variations Var. 1222 to 3041, as presented in **Table 12**, **Table 13**, **Table 14**, and **Table 15**.

[0418] In one embodiment of the methods provided above, the second low pH solution condition comprises a pH of between 4.0 and 7.0 and an ionic strength of greater than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 7.0 and an ionic strength of greater than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of greater than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.0 and an ionic strength of greater than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of greater than about 5.0 mS/cm. In a specific embodiment, the solution condition comprises a pH of 5.5±0.2 and an ionic strength of greater than about 5.0 mS/cm. In another specific embodiment, the solution conditions comprises a pH of 6.0±0.2 and an ionic strength of greater than about 5.0 mS/cm.

[0419] In another embodiment of the methods provided above, the second low pH solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of greater than about 3.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of greater than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of greater than about 6.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of greater than about 7.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of greater than about 10 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of greater than about 3.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of greater than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of greater than about 6.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of greater than about 7.0

mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of greater than about 10 mS/cm. In a specific embodiment, the solution conditions comprises a pH of 5.5±0.2 and an ionic strength of greater than about 10 mS/cm. In another specific embodiment, the solution condition comprises a pH of 6.0±0.2 and an ionic strength of greater than about 10 mS/cm.

[0420] In one specific embodiment, the present invention provides a method for reducing the amount of serine protease and/or serine protease zymogen in a re-suspended plasma precipitate comprising A1PI, comprising the steps of contacting a re-suspended plasma precipitate comprising A1PI in an insoluble state with finely divided silicon dioxide (SiO_2) under a first low pH solution condition comprising a pH between about 5.0 and about 6.5 and an ionic strength of less than 5.0 mS to bind the serine protease and/or serine protease zymogen and to maintain the A1PI in an insoluble state, separating the soluble and insoluble portions of the suspension, eluting the serine and/or serine protease zymogen from SiO_2 under a second low pH solution condition comprising a pH between about 5.0 and about 6.5 and an ionic strength of greater than 5.0 mS to maintain a substantial fraction of the A1PI in an insoluble state, separating the soluble and insoluble portions of the suspension, and extracting the A1PI from the insoluble portion. In one embodiment, the SiO_2 is admixed prior to or during the precipitation reaction and recovered along with the precipitate. In a specific embodiment, the precipitate is a Cohn fraction IV-1 precipitate. In another embodiment, the precipitate is a Cohn fraction IV-4 precipitate. In another embodiment, the precipitate is a Cohn fraction V precipitate. In another embodiment, the precipitate is a Kistler/Nitschmann precipitate IV. In yet another embodiment, the precipitate is a Kistler/Nitschmann precipitate C.

2. Binding of Serine Proteases or Serine Protease Zymogens and Extraction of A1PI

[0421] In another aspect, the present invention provides a method for reducing the amount of serine protease and/or serine protease zymogen in a re-suspended plasma precipitate comprising A1PI. Generally, the precipitate may be any precipitated during the fractionation of pooled plasma, preferably human plasma In one embodiment, the method comprises contacting a re-suspended plasma precipitate comprising A1PI in an insoluble state with finely divided silicon dioxide (SiO_2) under a first solution condition comprising low pH to bind the serine protease and/or serine protease zymogen and to maintain the A1PI in an insoluble state, separating the

soluble and insoluble portions of the suspension, extracting the A1PI from the insoluble portion under a second solution condition comprising high pH, and separating the soluble portion from the insoluble portion, wherein a substantial fraction of the serine protease and/or serine protease zymogen remains bound to the SiO_2 during the extraction of A1PI from the insoluble portion. In one embodiment, the SiO_2 is admixed prior to or during the precipitation reaction and recovered along with the precipitate. In a specific embodiment, the precipitate is a Cohn fraction IV-1 precipitate. In another embodiment, the precipitate is a Cohn fraction IV-4 precipitate. In another embodiment, the precipitate is a Cohn fraction V precipitate. In another embodiment, the precipitate is a Kistler/Nitschmann precipitate IV. In yet another embodiment, the precipitate is a Kistler/Nitschmann precipitate C.

[0422] In one embodiment of the methods provided above, the first solution condition comprises a pH of between 4.0 and 7.0 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 7.0 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.0 and an ionic strength of less than about 5.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 5.0 mS/cm. In a specific embodiment, the solution condition comprises a pH of 5.5±0.2 and an ionic strength of less than about 5.0 mS/cm. In another specific embodiment, the solution condition comprises a pH of 6.0±0.2 and an ionic strength of less than about 5.0 mS/cm.

[0423] In another embodiment of the methods provided above, the first solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 3.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 2.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 1.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.0 and 6.5 and an ionic strength of less than about 0.5 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 3.0 mS/cm. In another embodiment, the solution

condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 2.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 1.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 5.5 and 6.0 and an ionic strength of less than about 0.5 mS/cm. In a specific embodiment, the solution conditions comprises a pH of 5.5±0.2 and an ionic strength of less than about 3.0 mS/cm. In another specific embodiment, the solution condition comprises a pH of 6.0±0.2 and an ionic strength of less than about 3.0 mS/cm. In yet other embodiments, the first low pH solution condition comprises a pH and ionic strength according to any one of variations Var. 1222 to 3041, as presented in **Table 12**, **Table 13**, **Table 14**, and **Table 15**.

[0424] In one embodiment of the methods provided above, the second solution condition comprises a pH of between 7.0 and 10.0 and an ionic strength of less than about 10.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 9.0 and an ionic strength of less than about 10.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 10.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.5 and an ionic strength of less than about 10.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 10.0 mS/cm. In a specific embodiment, the solution condition comprises a pH of 7.5±0.2 and an ionic strength of less than about 10.0 mS/cm. In another specific embodiment, the solution condition comprises a pH of 8.0±0.2 and an ionic strength of less than about 10.0 mS/cm.

[0425] In another embodiment of the methods provided above, the second solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 9.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 8.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 7.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 6.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 5 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 3.0 mS/cm. In another embodiment, the solution

condition comprises a pH of between 7.0 and 8.5 and an ionic strength of less than about 2 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.0 and 8.5 and an ionic strength of between 2 mS/cm and 10 mS/cm.

[0426] In another embodiment of the methods provided above, the second solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 9.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 8.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 7.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 6.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 5 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 4.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 3.0 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.0 and an ionic strength of less than about 2 mS/cm. In another embodiment, the solution condition comprises a pH of between 7.5 and 8.5 and an ionic strength of between 2 mS/cm and 10 mS/cm. In a specific embodiment, the solution condition comprises a pH of 7.5±0.2 and an ionic strength of between 2 mS/cm and 10 mS/cm. In another specific embodiment, the solution condition comprises a pH of 8.0±0.2 and an ionic strength of between 2 mS/cm and 10 mS/cm.

IV. Pharmaceutical Compositions

[0427] In one aspect, the present invention provides compositions of plasma-derived proteins having reduced levels of serine protease and/or serine protease zymogen, which are prepared according to any of the methods described herein. In certain embodiments, these compositions will be formulated for pharmaceutical administration (*i.e.*, pharmaceutical compositions). Generally, the plasma-derived blood protein compositions prepared according to the methods provided herein will have reduced amidolytic activity and will provide better safety profiles than existing plasma-derived biologics currently available. In a preferred embodiment, the compositions provided herein will have reduced Factor XI, Factor XIa, Factor XII, and/or Factor XIIa content.

[0428] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a method comprising the steps of: (a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (b) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In one embodiment, the composition is formulated for pharmaceutical administration. In a specific embodiment, the composition is formulated for intravenous administration. In another specific embodiment, the composition is formulated for intramuscular administration. In another embodiment, the composition is formulated for subcutaneous administration. In yet another embodiment, the composition is formulated for intraocular administration. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0429] In certain embodiments, the compositions described above are prepared by a method further comprising the step of performing a first target protein enrichment step to form a first enriched composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first target protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0430] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a method comprising the steps of: (a) forming a first enriched plasma-derived target protein composition by partially precipitating protein in a starting material derived from pooled plasma; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In one embodiment, the partial precipitation is achieved using alcohol. In one embodiment, the composition is formulated for pharmaceutical administration. In a specific embodiment, the composition is formulated for intravenous administration. In another specific embodiment, the composition is formulated for intramuscular administration. In another embodiment, the composition is formulated for subcutaneous administration. In yet another embodiment, the composition is formulated for intraocular administration. In certain embodiments, the composition comprises a plasma-derived protein is selected from an

immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0431] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a method comprising the steps of: (a) forming a first enriched plasma-derived target protein composition by ultrafiltering and/or diafiltering a starting material derived from pooled plasma; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In one embodiment, the partial precipitation is achieved using alcohol. In one embodiment, the composition is formulated for pharmaceutical administration. In a specific embodiment, the composition is formulated for intravenous administration. In another specific embodiment, the composition is formulated for intramuscular administration. In another embodiment, the composition is formulated for subcutaneous administration. In yet another embodiment, the composition is formulated for intraocular administration. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0432] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a method comprising the steps of: (a) forming a first enriched plasma-derived target protein composition by contacting a starting material derived from pooled plasma with a chromatographic resin; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In one embodiment, the partial precipitation is achieved using alcohol. In one embodiment, the composition is formulated for pharmaceutical administration. In a specific embodiment, the composition is formulated for intravenous administration. In another specific embodiment, the composition is formulated for intramuscular administration. In another embodiment, the composition is formulated for subcutaneous administration. In yet another embodiment, the composition is formulated for intraocular administration. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI),

butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0433] In certain embodiments, the compositions described above are prepared by a method further comprising the step of performing a second target protein enrichment step to form a second enriched composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the first target protein enrichment step is selected from a protein precipitation step (*e.g.*, an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0434] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a method comprising the steps of: (a) performing a first target protein enrichment step to form a first enriched plasma-derived target protein composition; (b) performing a second target protein enrichment step to form a second enriched plasma-derived target protein composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen. In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1. In one embodiment, the composition is formulated for pharmaceutical administration. In a specific embodiment, the composition is formulated for intravenous administration. In another specific embodiment, the composition is formulated for intramuscular administration. In another embodiment, the composition is formulated for subcutaneous administration. In yet another embodiment, the composition is formulated for intraocular administration. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0435] In certain embodiments, the compositions described above are prepared by a method further comprising the step of performing a target protein enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2). In certain embodiments, the target protein enrichment step is selected from a protein precipitation step (e.g., an alcohol fractionation step), an ultrafiltration/diafiltration step, and a chromatographic step.

[0436] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a method comprising the steps of: (a) performing a first target protein enrichment step to form a first enriched plasma-derived target protein composition; (b) contacting the first enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (c) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (d) performing a second target protein enrichment step to form a second enriched plasma-derived target protein composition. In certain embodiments, the combination of first and second enrichment steps is selected from any one of variations Var. 1 to Var. 100, found in Table 1. In one embodiment, the composition is formulated for pharmaceutical administration. In a specific embodiment, the composition is formulated for intravenous administration. In another specific embodiment, the composition is formulated for intramuscular administration. In another embodiment, the composition is formulated for subcutaneous administration. In yet another embodiment, the composition is formulated for intraocular administration. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0437] In one aspect, the present invention provides a plasma-derived protein composition having reduced levels of serine protease and/or serine protease zymogen for use in the treatment of a condition associated with a blood protein deficiency or dysfunction. In certain embodiments, the plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0438] In one embodiment, the present invention provides a plasma-derived protein composition prepared by a method comprising the steps of: (a) performing a first target protein enrichment step to form a first enriched plasma-derived target protein composition; (b) performing a second target protein enrichment step to form a second enriched plasma-derived target protein composition; (c) contacting the second enriched composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; (d) separating the SiO_2 from the composition to remove the bound serine protease or serine protease zymogen; and (e) performing a third target protein enrichment step to form a third enriched plasma-derived target protein composition. In certain embodiments, the

combination of first and second enrichment steps is selected from any one of variations Var. 101 to Var. 1100, found in Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, or Table 11. In one embodiment, the composition is formulated for pharmaceutical administration. In a specific embodiment, the composition is formulated for intravenous administration. In another specific embodiment, the composition is formulated for intramuscular administration. In another embodiment, the composition is formulated for subcutaneous administration. In yet another embodiment, the composition is formulated for intraocular administration. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0439] In certain embodiments of the compositions described above, a chromatographic enrichment step comprises the sub-steps of: (i) contacting the plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind the plasma-derived target protein; and (ii) eluting the plasma-derived target protein from the chromatographic resin. In one specific embodiment, the impurity does not bind to the chromatographic resin in sub-step (i). In another specific embodiment, the impurity binds to the chromatographic resin in sub-step (i), but is not eluted from the chromatographic resin in sub-step (ii).

[0440] In other certain embodiments of the compositions described above, a chromatographic enrichment step comprises the sub-steps of: (i) contacting the first enriched plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind at least one impurity; and (ii) separating the resin from the plasma-derived protein composition, wherein the plasma-derived target protein does not bind to the chromatographic resin in sub-step (i).

[0441] In certain embodiments of the compositions provided herein, the amount of a particular serine protease or serine protease zymogen is reduced by at least 10%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 25%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 50%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 75%. In another embodiment, the amount of a particular serine protease or serine protease zymogen is reduced by at least 90%. In yet other embodiments, the amount of a particular serine protease or serine protease zymogen is reduced

by at least 5%, or by at least 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99%. In one embodiment, the reduction of serine protease or serine protease zymogen refers to the reduction achieved within the individual SiO_2 treatment step. In another embodiment, the reduction of serine protease or serine protease zymogen refers to the level of the contaminant in the final composition, as compared to a composition prepared in a similar fashion excluding a SiO_2 treatment step.

[0442] In one embodiment, the pharmaceutical compositions provided herein are prepared by formulating a plasma-derived protein composition isolated using a method provided herein. Generally, the formulated composition will have been subjected to at least one, preferably at least two, most preferably at least three, viral inactivation or removal steps. Non-limiting examples of viral inactivation or removal steps that may be employed with the methods provided herein include, solvent detergent treatment (Horowitz et al., Blood Coagul Fibrinolysis 1994 (5 Suppl 3):S21-S28 and Kreil et al., Transfusion 2003 (43):1023-1028, both of which are herein expressly incorporated by reference in their entirety for all purposes), nanofiltration (Hamamoto et al., Vox Sang 1989 (56)230-236 and Yuasa et al., J Gen Virol. 1991 (72 (pt 8)):2021-2024, both of which are herein expressly incorporated by reference in their entirety for all purposes), and low pH incubation at high temperatures (Kempf et al., Transfusion 1991 (31)423-427 and Louie et al., Biologicals 1994 (22):13-19). In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0443] In one embodiment, the pharmaceutical compositions provided herein will comprise one or more buffering agents or pH stabilizing agents suitable for intravenous, subcutaneous, intramuscular, and/or intraocular administration. Non-limiting examples of buffering agents suitable for formulating a plasma-derived protein composition provided herein include glycine, citrate, phosphate, acetate, glutamate, tartrate, benzoate, lactate, histidine or other amino acids, gluconate, malate, succinate, formate, propionate, carbonate, or any combination thereof adjusted to an appropriate pH. Generally, the buffering agent will be sufficient to maintain a suitable pH in the formulation for an extended period of time. In a preferred embodiment, the buffering agent is glycine. In certain embodiments, the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI),

butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0444] In some embodiments, the pharmaceutical compositions provided herein may optionally further comprise an agent for adjusting the osmolarity of the composition. Non-limiting examples of osmolarity agents include mannitol, sorbitol, glycerol, sucrose, glucose, dextrose, levulose, fructose, lactose, polyethylene glycols, phosphates, sodium chloride, potassium chloride, calcium chloride, calcium gluconoglucoheptonate, dimethyl sulfone, and the like.

[0445] Typically, the formulations provided herein will have osmolarities that are comparable to physiologic osmolarity, about 285 to 295 mOsmol/kg (Lacy et al., Drug Information Handbook – Lexi-Comp 1999:1254. In certain embodiments, the osmolarity of the formulation will be between about 200 mOsmol/kg and about 350 mOsmol/kg, preferably between about 240 and about 300 mOsmol/kg. In particular embodiments, the osmolarity of the formulation will be about 200 mOsmol/kg, or 210 mOsmol/kg, 220 mOsmol/kg, 230 mOsmol/kg, 240 mOsmol/kg, 245 mOsmol/kg, 250 mOsmol/kg, 255 mOsmol/kg, 260 mOsmol/kg, 265 mOsmol/kg, 270 mOsmol/kg, 275 mOsmol/kg, 280 mOsmol/kg, 285 mOsmol/kg, 290 mOsmol/kg, 295 mOsmol/kg, 300 mOsmol/kg, 310 mOsmol/kg, 320 mOsmol/kg, 330 mOsmol/kg, 340 mOsmol/kg, 340 mOsmol/kg, or 350 mOsmol/kg.

[0446] The plasma-derived formulations provided herein are generally stable in liquid form for an extended period of time. In certain embodiments, the formulations are stable for at least about 3 months at room temperature, or at least about 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, or 24 months at room temperature. The formulation will also generally be stable 6 or at least about 18 months under refrigerated conditions (typically between about 2°C and about 8°C), or for at least about 21, 24, 27, 30, 33, 36, 39, 42, or 45 months under refrigerated conditions.

V. Methods of Treatment

[0447] In one aspect, the present invention provides methods for treating a disease or disorder associated with a blood protein deficiency or dysfunction in a subject in need thereof by administering a therapeutically effective dose of a plasma-derived protein composition having reduced levels of serine protease and/or serine protease zymogen prepared according to a method provided herein. In certain embodiments, the composition comprises a plasma-derived protein is

selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

[0448] In one aspect, the present invention provides the use of a plasma-derived protein composition having reduced levels of serine protease and/or serine protease zymogen for the manufacture of a medicament for use in the treatment of a condition associated with a blood protein deficiency or dysfunction. In certain embodiments, the plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, Factor H, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI) protein.

A. Immunoglobulins

[0449] As routinely practiced in the modern medicine, sterilized preparations of concentrated immunoglobulins (especially IgGs) are used for treating medical conditions that fall into these three main classes: immune deficiencies, inflammatory and autoimmune diseases, and acute infections. These IgG preparations may also be useful for treating multiple sclerosis (especially relapsing-remitting multiple sclerosis or RRMS), Alzheimer's disease, and Parkinson's disease. The purified IgG preparation of this invention is suitable for these purposes, as well as other clinically accepted uses of IgG preparations.

[0450] The FDA has approved the use of IVIG to treat various indications, including allogeneic bone marrow transplant, chronic lymphocytic leukemia, idiopathic thrombocytopenic purpura (ITP), pediatric HIV, primary immunodeficiencies, Kawasaki disease, chronic inflammatory demyelinating polyneuropathy (CIDP), and kidney transplant with a high antibody recipient or with an ABO incompatible donor. In certain embodiments, the IVIG compositions provided herein are useful for the treatment or management of these diseases and conditions.

[0451] Furthermore, off-label uses for IVIG are commonly provided to patients for the treatment or management of various indications, for example, chronic fatigue syndrome, clostridium difficile colitis, dermatomyositis and polymyositis, Graves' ophthalmopathy, Guillain-Barré syndrome, muscular dystrophy, inclusion body myositis, Lambert-Eaton syndrome, Lupus erythematosus, multifocal motor neuropathy, multiple sclerosis (MS), myasthenia gravis, neonatal alloimmune thrombocytopenia, Parvovirus B19 infection,

pemphigus, post-transfusion purpura, renal transplant rejection, spontaneous Abortion/Miscarriage, stiff person syndrome, opsoclonus Myoclonus, severe sepsis and septic shock in critically ill adults, toxic epidermal necrolysis, chronic lymphocytic leukemia, multiple myeloma, X-linked agammaglobulinemia, and hypogammaglobulinemia. In certain embodiments, the IVIG compositions provided herein are useful for the treatment or management of these diseases and conditions.

[0452] Finally, experimental use of IVIG for the treatment or management of diseases including primary immune deficiency, RRMS, Alzheimer's disease, and Parkinson's disease has been proposed (U.S. Patent Application Publication No. U.S. 2009/0148463, which is herein incorporated by reference in its entirety for all purposes). In certain embodiments, the IVIG compositions provided herein are useful for the treatment or management of primary immune deficiency, RRMS, Alzheimer's disease, or Parkinson's disease. In certain embodiments comprising daily administration, an effective amount to be administered to the subject can be determined by a physician with consideration of individual differences in age, weight, disease severity, route of administration (*e.g.*, intravenous v. subcutaneous) and response to the therapy. In certain embodiments, an immunoglobulin preparation of this invention can be administered to a subject at about 5 mg/kilogram to about 2000 mg/kilogram each day. In additional embodiments, the immunoglobulin preparation can be administered in amounts of at least about 10 mg/kilogram, at last 15 mg/kilogram, at least 20 mg/kilogram, at least 25 mg/kilogram, at least 30 mg/kilogram, or at least 50 mg/kilogram. In additional embodiments, the immunoglobulin preparation can be administered to a subject at doses up to about 100 mg/kilogram, to about 150 mg/kilogram, to about 200 mg/kilogram, to about 250 mg/kilogram, to about 300 mg/kilogram, to about 400 mg/kilogram each day. In other embodiments, the doses of the immunoglobulin preparation can be greater or less. Further, the immunoglobulin preparations can be administered in one or more doses per day. Clinicians familiar with the diseases treated by IgG preparations can determine the appropriate dose for a patient according to criteria known in the art.

[0453] In accordance with the present invention, the time needed to complete a course of the treatment can be determined by a physician and may range from as short as one day to more than a month. In certain embodiments, a course of treatment can be from 1 to 6 months.

[0454] An effective amount of an IVIG preparation is administered to the subject by intravenous means. The term "effective amount" refers to an amount of an IVIG preparation that results in an improvement or remediation of disease or condition in the subject. An effective amount to be administered to the subject can be determined by a physician with consideration of individual differences in age, weight, the disease or condition being treated, disease severity and response to the therapy. In certain embodiments, an IVIG preparation can be administered to a subject at dose of about 5 mg/kilogram to about 2000 mg/kilogram per administration. In certain embodiments, the dose may be at least about 5 mg/kg, or at least about 10 mg/kg, or at least about 20 mg/kg, 30 mg/kg, 40 mg/kg, 50 mg/kg, 60 mg/kg, 70 mg/kg, 80 mg/kg, 90 mg/kg, 100 mg/kg, 125 mg/kg, 150 mg/kg, 175 mg/kg, 200 mg/kg, 250 mg/kg, 300 mg/kg, 350 mg/kg, 400 mg/kg, 450 mg/kg, 500 mg/kg, 550 mg/kg, 600 mg/kg, 650 mg/kg, 700 mg/kg, 750 mg/kg, 800 mg/kg, 850 mg/kg, 900 mg/kg, 950 mg/kg, 1000 mg/kg, 1100 mg/kg, 1200 mg/kg, 1300 mg/kg, 1400 mg/kg, 1500 mg/kg, 1600 mg/kg, 1700 mg/kg, 1800 mg/kg,, 1900 mg/kg,, or at least about 2000 mg/kg.

[0455] The dosage and frequency of IVIG treatment will depend upon, among other factors. the disease or condition being treated and the severity of the disease or condition in the patient. Generally, for primary immune dysfunction a dose of between about 100 mg/kg and about 400 mg/kg body weight will be administered about every 3 to 4 weeks. For neurological and autoimmune diseases, up to 2 g/kg body weight is implemented for three to six months over a five day course once a month. This is generally supplemented with maintenance therapy comprising the administration of between about 100 mg/kg and about 400 mg/kg body weight about once every 3 to 4 weeks. Generally, a patient will receive a dose or treatment about once every 14 to 35 days, or about every 21 to 28 days. The frequency of treatment will depend upon, among other factors. the disease or condition being treated and the severity of the disease or condition in the patient.

[0456] In a preferred embodiment, a method of treating an immunodeficiency, autoimmune disease, or acute infection in a human in need thereof is provided, the method comprising administering a pharmaceutical IVIG composition of the present invention. In a related embodiment, the present invention provides IVIG compositions manufactured according to a method provided herein for the treatment of an immunodeficiency, autoimmune disease, or acute infection in a human in need thereof.

[0457] In certain embodiments, the immunodeficiency, autoimmune disease, or acute infection is selected from allogeneic bone marrow transplant, chronic lymphocytic leukemia, idiopathic thrombocytopenic purpura (ITP), pediatric HIV, primary immunodeficiencies, Kawasaki disease, chronic inflammatory demyelinating polyneuropathy (CIDP), kidney transplant with a high antibody recipient or with an ABO incompatible donor, chronic fatigue syndrome, clostridium difficile colitis, dermatomyositis and polymyositis, Graves' ophthalmopathy, Guillain-Barré syndrome, muscular dystrophy, inclusion body myositis, Lambert-Eaton syndrome, Lupus erythematosus, multifocal motor neuropathy, multiple sclerosis (MS), myasthenia gravis, neonatal alloimmune thrombocytopenia, Parvovirus B19 infection, pemphigus, post-transfusion purpura, renal transplant rejection, spontaneous Abortion/Miscarriage, stiff person syndrome, opsoclonus Myoclonus, severe sepsis and septic shock in critically ill adults, toxic epidermal necrolysis, chronic lymphocytic leukemia, multiple myeloma, X-linked agammaglobulinemia, hypogammaglobulinemia, primary immune deficiency, RRMS, Alzheimer's disease, and Parkinson's disease.

B. Factor H

[0458] In one aspect, the present invention provides methods for treating a disease or disorder associated with a Factor H dysfunction or abnormal alternative pathway complement activity in a subject in need thereof by administering a therapeutically effective dose of a Factor H composition prepared according to a method provided herein. In one embodiment, the Factor H composition is prepared by extracting Factor H from a Fraction I precipitate. In another embodiment, the Factor H composition is prepared by extracting Factor H from a Fraction II+III filter cake.

[0459] In certain embodiments, the disease or disorder associated with a Factor H dysfunction is selected from atypical haemolytic uremic syndrome (aHUS), age-related macular degeneration (AMD), membranoproliferative glomulonephritis type II (MPGNII), myocardial infarction, coronary heart disease/coronary artery disease (CAD/CHD), and Alzheimer's disease. In one particular embodiment, the disease is atypical haemolytic uremic syndrome (aHUS). In another particular embodiment, the disease is age-related macular degeneration (AMD). In yet another particular embodiment, the disease is membranoproliferative glomulonephritis type II (MPGNII).

[0460] In certain embodiments, a method is provided for treating a disease or disorder associated with a abnormal alternative pathway complement activity in a subject in need thereof by administering to the subject a therapeutically effective dose of a Factor H composition provided herein. In one embodiment, the Factor H composition is prepared by extracting Factor H from a Fraction I precipitate. In another embodiment, the Factor H composition is prepared by extracting Factor H from a Fraction II+III filter cake.

[0461] In certain embodiments, the disease or disorder associated with abnormal alternative pathway complement activity is selected from an autoimmune disease (such as rheumatoid arthritis, IgA nephropathy, asthma, systemic lupus erythematosus, multiple sclerosis, Anti-Phospholipid syndrome, ANCA-associated vasculitis, pemphigus, uveitis, myathemia gravis, Hashimoto's thyroiditis), a renal disease (such as IgA nephropathy, hemolytic uremic syndrome, membranoproliferative glomerulonephritis) asthma, Alzheimer disease, adult macular degeneration, proximal nocturnal hemoglobinuria, abdominal aortic aneurism, ischemia reperfusion injury, and sepsis.

[0462] The pharmaceutical compositions provided by the invention may be administered alone or in conjunction with other therapeutic agents. These agents may be incorporated as part of the same pharmaceutical.

1. Administration

[0463] In accordance with the present invention, the time needed to complete a course of the treatment can be determined by a physician and may range from as short as one day to more than a month. In certain embodiments, a course of treatment can be from 1 to 6 months.

[0464] An effective amount of a Factor H preparation is administered to the subject by any suitable means to treat the disease or disorder. For example, in certain embodiments, Factor H may be administered by intravenous, intraocular, subcutaneous, and/or intramuscular means. In a preferred embodiment, a method for treating age-related macular degeneration in a subject in need thereof is provided comprising the intraocular administration of a Factor H composition to the patient.

[0465] In certain embodiments, the Factor H compositions provided herein can be administered either systemically or locally. Systemic administration includes: oral, transdermal, subdermal, intraperitioneal, subcutaneous, transnasal, sublingual, or rectal. The most preferred

systemic route of administration is oral. Local administration for ocular administration includes: topical, intravitreal, periocular, transcleral, retrobulbar, juxtascleral, sub-tenon, or via an intraocular device. Preferred methods for local delivery include transscleral delivery to the macula by posterior juxtascleral administration; via intravitreal injection; or via cannula, such as that described in U.S. Pat. No. 6,413,245, the disclosure of which is incorporated by reference herein in its entirety for all purposes. Alternatively, the inhibitors may be delivered via a sustained delivery device implanted intravitreally or transsclerally, or by other known means of local ocular delivery.

[0466] In certain embodiments, the term "effective amount" refers to an amount of a Factor H preparation that results in an improvement or remediation of disease or condition in the subject. An effective amount to be administered to the subject can be determined by a physician with consideration of individual differences in age, weight, the disease or condition being treated, disease severity and response to the therapy. In certain embodiments, an Factor H preparation can be administered to a subject at dose of at or about between 5 mg/kilogram and 2000 mg/kilogram per administration. In certain embodiments, the dose may be at least at or about 5 mg/kg, or at least at or about 10 mg/kg, or at least at or about 20 mg/kg, 30 mg/kg, 40 mg/kg, 50 mg/kg, 60 mg/kg, 70 mg/kg, 80 mg/kg, 90 mg/kg, 100 mg/kg, 125 mg/kg, 150 mg/kg, 175 mg/kg, 200 mg/kg, 250 mg/kg, 300 mg/kg, 350 mg/kg, 400 mg/kg, 450 mg/kg, 500 mg/kg, 550 mg/kg, 600 mg/kg, 650 mg/kg, 700 mg/kg, 750 mg/kg, 800 mg/kg, 850 mg/kg, 900 mg/kg, 950 mg/kg, 1000 mg/kg, 1100 mg/kg, 1200 mg/kg, 1300 mg/kg, 1400 mg/kg, 1500 mg/kg, 1600 mg/kg, 1700 mg/kg, 1800 mg/kg,, 1900 mg/kg, or 2000 mg/kg. The dosage and frequency of Factor H treatment will depend upon, among other factors, the disease or condition being treated and the severity of the disease or condition in the patient.

2. Age-Related Macular Degeneration (AMD)

[0467] In a preferred embodiment, the present invention provides a method of treating age-related macular degeneration in a subject in need thereof by administering to the subject a therapeutically effective dose of a Factor H composition provided herein.

[0468] Age-related macular degeneration (AMD) is the number one cause of blindness for the elderly population over 60 years of age. Today, it is estimated that 35-40% of those over 75 years of age have some degree of AMD. It has been estimated that approximately 50 million people are affected world-wide, with 10 million in the US alone. Currently, about 155,000 new

diagnoses of AMD are made every year. As the worldwide population continues to age, the number of annual diagnoses are expected to triple by the year 2020. It is a devastating disease that destroys central vision in the affected individuals, robbing them of their ability to perform activities necessary for everyday life such as reading and driving.

[0469] AMD is a slow, progressive disease that involves cells of the outer retinal layers (including photoreceptors and the retinal pigment epithelial (RPE) cells that support the photoreceptors), as well as cells in the adjacent vascular layer of the eye known as the choroid. Macular degeneration is characterized by the breakdown of the macula, a small portion of the central retina (about 2 mm in diameter) responsible for high-acuity vision. Late-onset macular degeneration (*i.e.*, AMD) is generally defined as either "dry" or "wet." The wet ("exudative") neovascular form of AMD affects approximately 10% of those with the disease, and is characterized by abnormal blood vessels growing from the choriocapillaris through the RPE, typically resulting in hemorrhage, exudation, scarring, and/or serous retinal detachment. Approximately 90% of patients with AMD have the non-neovascular, or dry form of the disease, which is characterized by atrophy of the RPE and loss of macular photoreceptors.

[0470] AMD is characterized by the presence of deposits of debris-like material, termed "drusen," that accumulate on Bruch's membrane, a multilayered composite of extracellular matrix components separating the RPE (the outermost layer of the retina) from the underlying choroid. Drusen can be observed by funduscopic eye examination. These deposits have been extensively characterized in microscopic studies of donor eyes from patients with AMD. The deposits observed in the living eye upon clinical examination are classified as either soft drusen or hard drusen, according to several criteria including relative size, abundance, and shape of the deposits. Histochemical and immunocytochemical studies have shown that drusen contain a variety of lipids, polysaccharides, glycosaminoglycans and proteins.

[0471] Presently, there no known cure for AMD, although several types of treatments has been shown to be effective at managing the disease. Laser photocoagulation of abnormal vessels in the wet form of the disease is the standard treatment. This treatment is limited by the fact that only well-delineated neovascular lesions can be treated in this way and that 50% of patients will suffer recurrence of the leakage from the vessels (Fine *et al.*, 2000). Because of the energy of the laser required for this treatment, the photoreceptors in the treated area will also die, and the patient will also often suffer central blindness immediately after the treatment. New neovascular

lesions will eventually develop, requiring repeated treatments. Other interventions include changing lifestyles by cessation of smoking and beginning therapy with antioxidants. Antiangiogenic treatments using VEGF inhibitors *e.g.*, intravitrial injection of ranibizumab or bevacizumab also have been suggested.

[0472] Recently it was discovered that about 35% of individuals carry at an at-risk single nucleotide polymorphism (SNP) in one or both copies of their Factor H gene. Homozygous individuals have an approximately sevenfold increased chance of developing age-related macular degeneration, while heterozygotes have a two-to-threefold increased likelihood of developing the disease. This SNP, located in CCP module 7 of Factor H, has been shown to affect the interactions between Factor H and both C-reactive protein and heparin indicating a causal relationship between the SNP and disease. The polymorphism is a Y420H polymorphism.

[0473] In one embodiment of a method for limiting complement activation resulting in delayed progression or onset of the development of age related macular degeneration (AMD) in a subject, the subject does not have any symptoms of AMD.

[0474] In another embodiment of a method for limiting complement activation resulting in delayed progression or onset of the development of age related macular degeneration (AMD) in a subject, the subject has drusen.

[0475] In another embodiment of a method for limiting complement activation resulting in delayed progression or onset of the development of age related macular degeneration (AMD) in a subject, the subject is at increased risk of developing AMD.

[0476] In another embodiment of a method for limiting complement activation resulting in delayed progression or onset of the development of age related macular degeneration (AMD) in a subject, the administration is intravenous.

[0477] In another embodiment of a method for limiting complement activation resulting in delayed progression or onset of the development of age related macular degeneration (AMD) in a subject, the method further comprises treating a subject having signs and/or symptoms of AMD.

[0478] In another embodiment of a method for limiting complement activation resulting in delayed progression or onset of the development of age related macular degeneration (AMD) in a subject, the subject has been diagnosed with AMD.

[0479] In another aspect, the present invention provides a method of treating a human subject judged to be at risk for the development of age related macular degeneration, comprising the step of administering to the subject a prophylactically or therapeutically effective amount of a Factor H preparation provided herein, and periodically repeating said administration.

[0480] In one embodiment of a method of treating a human subject judged to be at risk for the development of age related macular degeneration, the administration is repeated for a time effective to delay the progression or onset of the development of macular degeneration in said subject.

[0481] In another embodiment of a method of treating a human subject judged to be at risk for the development of age related macular degeneration, the human subject is judged to be at risk for the development of age-related macular degeneration as identified based on the presence of one or more genetic markers associated with development of age-related macular degeneration.

[0482] In another embodiment of a method of treating a human subject judged to be at risk for the development of age related macular degeneration, the genetic marker is a polymorphism.

[0483] In another embodiment of a method for limiting complement activation resulting in delayed progression or onset of the development of age related macular degeneration (AMD) in a subject, the subject is not diagnosed with AMD.

C. Inter-alpha-Trypsin Inhibitor (IαI)

[0484] In yet other aspects, it is an object of the invention to provide methods for treating disorders and diseases associated with reduced IaIp function or IaIp dysfunction by administering a therapeutically effective amount of an IaIp composition provided herein. In one embodiment, the disease or disorder associated with reduced IaIp function or IaIp dysfunction is sepsis.

[0485] In one embodiment, the present invention provides a therapeutically effective dose of an IaIp composition prepared by a method disclosed herein for use in a method for treating a disease or disorder associated with reduced IaIp function or IaIp dysfunction in a subject in need thereof. In one embodiment, the disease or disorder associated with reduced IaIp function or IaIp dysfunction is sepsis.

[0486] In another aspect, it is an object of the invention to provide methods for treating diseases and disorders associated with increased plasma serine protease activity by administering a therapeutically effective amount of an IaIp composition provided herein. In one embodiment, the disease or disorder associated increased plasma serine protease activity is selected from sepsis, septic shock, endotoxic shock, disseminated intravascular coagulation, fibroproliferation, anthrax intoxication, cancer metastasis, tissue injury during surgery, kidney disease, vascular disease, coagulation, diabetes, and systemic inflammation.

[0487] In one embodiment, the present invention provides a therapeutically effective dose of an IaIp composition prepared by a method disclosed herein for use in a method for treating a disease or disorder associated with increased plasma serine protease activity in a subject in need thereof. In one embodiment, the disease or disorder associated increased plasma serine protease activity is selected from sepsis, septic shock, endotoxic shock, disseminated intravascular coagulation, fibroproliferation, anthrax intoxication, cancer metastasis, tissue injury during surgery, kidney disease, vascular disease, coagulation, diabetes, and systemic inflammation.

A. Administration

[0488] In accordance with the present invention, the time needed to complete a course of the treatment can be determined by a physician and may range from as short as one day to more than a month. In certain embodiments, a course of treatment can be from 1 to 6 months.

[0489] An effective amount of an IaIp preparation is administered to the subject by any suitable means to treat the disease or disorder. For example, in certain embodiments, IaIp may be administered by intravenous, subcutaneous, and/or intramuscular means. In a preferred embodiment, a method for treating sepsis in a subject in need thereof is provided comprising the intravenous (IV) administration of an IaIp composition to the patient.

[0490] In certain embodiments, the IaIp compositions provided herein can be administered either systemically or locally. Systemic administration includes: oral, subdermal, intraperitioneal, subcutaneous, transnasal, sublingual, or rectal routes of administration. Local administration includes: topical, subcutaneous, intramuscular, and intraperitoneal routes of administration.

[0491] In certain embodiments, the term "effective amount" refers to an amount of a IaIp preparation that results in an improvement or remediation of disease or condition in the subject. An effective amount to be administered to the subject can be determined by a physician with

consideration of individual differences in age, weight, the disease or condition being treated, disease severity and response to the therapy. In certain embodiments, an IaIp preparation can be administered to a subject at dose of about 5 mg/kilogram to about 2000 mg/kilogram per administration. In certain embodiments, the dose may be at least about 5 mg/kg, or at least about 10 mg/kg, or at least about 20 mg/kg, 30 mg/kg, 40 mg/kg, 50 mg/kg, 60 mg/kg, 70 mg/kg, 80 mg/kg, 90 mg/kg, 100 mg/kg, 125 mg/kg, 150 mg/kg, 175 mg/kg, 200 mg/kg, 250 mg/kg, 300 mg/kg, 350 mg/kg, 400 mg/kg, 450 mg/kg, 500 mg/kg, 550 mg/kg, 600 mg/kg, 650 mg/kg, 700 mg/kg, 750 mg/kg, 800 mg/kg, 850 mg/kg, 900 mg/kg, 950 mg/kg, 1000 mg/kg, 1100 mg/kg, 1200 mg/kg, 1300 mg/kg, 1400 mg/kg, 1500 mg/kg, 1600 mg/kg, 1700 mg/kg, 1800 mg/kg,, 1900 mg/kg,, or at least about 2000 mg/kg. The dosage and frequency of IaIp treatment will depend upon, among other factors, the disease or condition being treated and the severity of the disease or condition in the patient.

VI. Examples

Example 1

[0492] In order to determine the residual serine protease content and activity present in plasma-derived protein compositions, the amidolytic activity profile was determined for two commercially available IgG preparations that were manufactured without the use of SiO_2 treatment: OCTAGAM® (5% Intravenous Immune Globulin; Octapharma) and Subcuvia (16% Subcutaneous Immune Globulin; Baxter); two lots of a commercially available IgG preparation manufactured using SiO_2 treatment: Gammagard Liquid (10% Intravenous Immune Globulin; Baxter), and a Factor H purification method currently in development. Notably, the Factor H composition was purified as described above, by binding and subsequently eluting Factor H from finely divided SiO_2.

[0493] Briefly, the amidolytic activity profile for each of the plasma-derived protein compositions was determined by assaying with the following chromogenic substrates with different enzyme specificities: PL-1 (broad spectrum), S-2288 (broad spectrum), S-2266 (FXIa, glandular kallikreins), S-2222 (FXa, trypsin), S-2251 (Plasmin), and S-2302 (Kallikrein, FXIa, and FXIIa). Pre-kallikrein activator activity (PKKA) and amount of Factor XIa Units was also determined. As shown in Table 17, the plasma-derived IgG compositions manufactured without the use of an SiO_2 adsorption step contained significant levels of amidolytic activity and FXIa content. In contrast, both tested lots of the Gammagard Liquid contained minimal amidolytic

activity and FXIa content. Consistent with these results, the Factor H composition prepared by binding and eluting from finely divided SiO_2, contains extremely high levels of amidolytic activity and FXIa content.

Table 17. Amidolytic activity of various plasma-derived protein compositions.

		Factor H	Commercially available IGIV preparations			IGSC
Specificity	Chromogenic substrate	Sample FH012 FC steril	Octagam 5% (Octa-pharma) #B842A8432	Gammagard Liquid 10% lot 1 (Baxter) #LE12G142AD	Gammagard Liquid 10% lot 2 (Baxter) #LE12HE76	Subcuvia 16% (Baxter) #VNG1H020
		Hydrolysis rate [nmol/ml x min]				
Broad spectrum	PL-1	73.7	18.3	<10	<10	22.1
Broad spectrum	S-2288	241	29	<5	<5	46
FXIa, glandular kallikreins	S-2266	171	27.1	<5	<5	34.2
FXa, Trypsin	S-2222	8.3	<5	<5	<5	<5
Plasmin	S-2251	7.3	<5	<5	<5	<5
Kallikrein, FXIa, FXIIa	S-2302	563	70.1	<5	7,6	99.6
PKKA	IE/mL	9.5	<4	<4	<4	<4
F-XIa	mU/mL	510.8	1.37	<0.04	<0.04	0.79

Example 2

[0494] To determine an economically beneficial scheme for the manufacture of Factor H from a plasma sample, which allows for the recovery of additional blood factors from the same plasma sample, a lot of pooled human plasma was subjected to fractionation according to the scheme outlined in the flow-diagram shown in Figure 1. As shown in Figure 2, the majority of Factor H (about 90%) present in a human plasma cryo-poor Cohn pool can be found in the fraction II+III precipitate. A smaller, yet significant, amount of Factor H (about 10%) can also be found in the fraction I precipitate. This is consistent with the results shown in PCT Publication No. WO 2011/011753, the contents of which are hereby incorporated by reference in their entirety for all purposes.

[0495] Factor H was extracted from the finely divided SiO_2 filter cake byproduct formed as a result of filtering the "Aerosil Treatment" composition directly upstream of composition 6, the "Fraction II+III Filtrate," by re-circulating a Factor H extraction buffer through the filter press.

Salts and various impurities were then removed from the filter cake extract by a first precipitation step performed at pH 8.0 via addition of ethanol to a final concentration of 15% and incubation at -6°C for a minimum of four hours. The pH of the precipitation reaction was readjusted to 8.0 after 1 hour of incubation time. The precipitate was then removed from the supernatant by centrifugation. Factor H was further enriched by a second precipitation step performed at pH 6.0 via addition of ethanol to a final concentration of 25% and incubation at -10°C for a minimum of 8 hours. The precipitate containing Factor H was then recovered by centrifugation.

[0496] The precipitate formed by the second precipitation step was dissolved at a ratio of 1:9 in a low ionic strength dissolution buffer and S/D treated to inactivate lipid enveloped viruses. Factor H was subsequently enriched by anion exchange chromatography using a DEAE-Sepharose FF resin. Briefly, Factor H was bound to DEAE-Sepharose resin under low ionic strength conditions and eluted by increasing the ionic strength of the solution. The conductivity of the DEAE-Sepharose eluate was then reduced and Factor H was further enriched by Heparin-affinity chromatography. Briefly, Factor H was bound to Heparin-Sepharose FF resin under low ionic strength conditions and eluted by increasing the ionic strength of the solution. As shown in Table 18, the majority of Factor H bound to the DEAE and Heparin resins.

Table 18. Binding of Factor H to chromatographic resins.

	1. DEAE-Sepharose FF		2. Heparin-Sepharose FF	
LOT	FH006	FH012	FH006	FH012
Loading (Protein)	**30.6 mg/ml**	**28.0 mg/ml**	**3.3 mg/ml**	**2.1 mg/ml**
FH binding to resine	**87.4 %**	**96.3 %**	**100 %**	**99.4 %**

[0497] Factor H eluted from the Heparin resin was then subjected to ultrafiltration/diafiltration according to standard procedures, followed by size exclusion chromatography on a Superdex 200 column. Factor H recovered from the size exclusion chromatography was then concentrated by

ultrafiltration, sterile filtered, and formulated at a final protein concentration of 50 mg/mL in PBS-buffer.

[0498] The final Factor H composition (FH012) was then characterized for homogeneity, impurities, and amidolytic activity. The monodispersity of the Factor H composition was characterized by size exclusion chromatography. As shown in Table 19, the majority of the protein present in the Factor H final composition migrated with an estimated size of 400 kDa when loaded onto an HP-SEC column.

Table 19. Molecular size distribution of final FH012 composition as determined by HP-SEC.

	Peak 1	Peak 2	Peak 3
sample	>450 kDa	400 kDa	160 kDa
	% area		
FC FH012	0.3	97.6	2.1

[0499] The level of endotoxins, pH, visual appearance, and final protein concentration was then determined for the final Factor H composition. As shown in Table 20, the composition had low endotoxin levels (<0.5 EU/mL) as determined by limulus amebocyte lysate (LAL) assay.

Table 20. LAL, pH, visual appearance, and protein content of the final FH012 composition.

LAL	<0.5 EU/mL (pyrogen free)
pH	7.1
Visual Appearance	Colorless and free of visual particles
Protein Concentration	4.54%

[0500] The level of various protein impurities in the final Factor H composition was then determined. As shown in Table 21, complement proteins and IgG immunoglobulins accounted for less than 1% of the final protein concentration in the Factor H composition.

Table 21. Impurities in the final FH012 composition.

Impurity	**Concentration**	**Percentage of Total Protein**
IgG	51 µg/mL	0.11%
C3	321.5 µg/mL	0.71%
C3a	17.5 µg/mL	0.04%
C5a	3.7 ng/mL	<0.01%
C4	1.94 µg/mL	<0.01%

EDTA	72 µg/mL	

[0501] Finally, the level of amidolytic activity and protease content was determined as reported in Example 1. As shown in Table 17, plasma-derived Factor H purified according to the scheme outlined in this example contained high levels of amidolytic activity and FXIa content.

Example 3

[0502] In order to show the capability of removing amidolytic activity from a plasma-derived protein composition, re-suspended Cohn Fraction II+III precipitates were treated with finely divided silicon dioxide (SiO_2). Briefly, pooled cryo-poor human plasma was fractionated according to the IgG purification scheme described herein, to provide a Fraction II+III precipitate. The fraction II+III precipitate was re-suspended in low conductivity extraction buffer (pH 5.1±0.2; ~0.8 mS/cm) at a temperature maintained between 0°C and 8°C. Aerosil® 380 (Evonik Industries AG) was added to a final concentration of between 40 and 60 g/kg II+III precipitate. After the additional of CELPURE® C300 filter aid (Advanced Minerals Corporation) to a final concentration of 0.5 kg/kg II+III precipitate, the suspension was filtered using a depth filter. The immunoglobulin composition in the filtrate was then tested for FXI zymogen content. As shown in Table 22, treatment of the fraction II+III suspension with finely divided SiO_2 resulted in nearly 90% reduction in the Factor XI zymogen content of the composition.

Table 22. Impurities in the final FH012 composition.

	Fraction II+III Re-suspension					Fraction II+III Extract Cuno Filtrate				
Lot	**Fr. II+III paste, (kg)**	**Fr. II+III dissolved (L)**	**F-XI zymogen (U/mL)**	**F-XI zymogen (1000s of U)**	**F-XI zymogen (%)**	**Fr. II+III Filtrate volume, (L)**	**F-XI zymogen (U/mL)**	**F-XI zymogen (1000s of U)**	**F-XI zymogen (% of II+III re-suspension)**	**% Removal**
1	117	469	5.25	2460	100	2250	0.11	247	10.1%	89.9%
2	118	475	5.13	2435	100	2290	0.11	251	10.3%	89.7%
3	119	479	4.51	2162	100	2300	0.12	276	12.8%	87.2%

Example 4

[0503] To evaluate the elution of serine proteases from a finely divided SiO_2 filter cake, as prepared in Example 3, elution buffers containing varying concentrations of phosphate buffer (100, 50, 25, and 5 mM) were used to elute proteins from the SiO_2 at two different pH (6.0, 7.5). Briefly, the filtercake was dissolved at a ratio of 1:5 in the appropriate buffer system and filtrated through depth filters (Cuno 50 SA). The amidolytic activity and Factor H composition of each

eluate was then determined (Table 23 and Table 24). As shown in Table 23, at lower conductivity and pH (*i.e.*, 6.0), the elution of amidolytic activity measured with the substrate CS2166 (FXIa, activated Protein C) was reduced.

[0504] Under elution conditions at pH 7.5 (Table 24), Factor H elution decreased with increasing conductivity, while serine protease elution increased with increasing conductivity. Surprisingly, at extremely low conductivity (5 mM phosphate; 0.882 mS/cm), serine protease elution increased substantially, while Factor H elution decreased. The data obtained for elution at pH 7.5 is shown graphically in Figure 3.

Table 23. Elution of Factor H and serine protease activity from finely divided SiO_2 at pH 6.0.

		Substrate: CS2166	**Factor H**	**Protein**
Buffer System: pH = 6.0	**Sample**	**total nmol*min**	**[g/l Plasma]**	**[nmol/g]**
100 mM Phosphate buffer; Cond. 11.88 mS/cm	Filtrate	72745	0.27	61944
50 mM Phosphate buffer; Cond. 6.55 mS/cm	Filtrate	65055	0.19	64600
25 mM Phosphate buffer; Cond. 3.48 mS/cm	Filtrate	28591	0.05	63694
5 mM Phosphate buffer: Cond. 0.882 mS/cm	Filtrate	4816	0.0003	57331

Table 24. Elution of Factor H and serine protease activity from finely divided SiO_2 at pH 7.5.

		Substrate: CS2166	**Factor H**	**Protein**
Buffer System: pH = 7.5	**Sample**	**total nmol*min**	**[g/l Plasma]**	**[nmol/g]**
100 mM Phosphate buffer; Cond. 18.81 mS/cm	Filtrate	236456	0.21	156718
50 mM Phosphate Buffer; Cond. 10.91 mS/cm	Filtrate	147829	0.29	109228
25 mM Phosphate buffer; Cond. 6.08 mS/cm	Filtrate	84622	0.39	57892
5 mM Phosphate buffer: Cond. 1.524 mS/cm	Filtrate	176685	0.33	134051

Example 5

[0505] In order to demonstrate the ability to differentially elute serine proteases and Factor H co-bound to SiO_2, a two step elution procedure was developed. Briefly, a fraction II+III filter cake formed after SiO_2 treatment was prepared as before. The filter cake was then subjected to a first elution under solution conditions comprising an ionic strength between 0.882 mS/cm and

11.88 mS/cm at pH 6.0. As demonstrated in Example 4, treatment of bound SiO_2 at low pH (pH 6.0) and low ionic strength (less than 6.5 mS/cm) results in elution of serine proteases (*e.g.*, FXIa), while a substantial fraction of Factor H remains bound. Subsequent treatment at high pH (pH 7.5) and high ionic strength results in the elution of Factor H from the SiO_2 (**Table 25**). Furthermore, consistent with the results provided in Example 4, initial treatment of SiO_2 at high pH (7.5) results in elution of Factor H (**Table 26**). As shown, an initial elution at lower conductivity and pH 6.0 could be used to partially reduce amidolytic activity from the filter cake and then Factor H can be eluted at 100 mM phosphate concentration, 150 mM NaCl, pH 7.6. This procedure resulted in a filtrate, Factor H yield of 0.31 g/l plasma, with reduced amidolytic activity (CS2166) for further processing.

Table 25. Two-step differential elution of serine protease and Factor H from SiO_2 at pH 6.0/7.6.

First Elution buffer System pH 6.0	**Second Elution buffer**	**Sample**	**Factor H [g/l Plasma]**
100 mM Phosphate buffer; Cond. 11.88 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.06
50 mM Phosphate buffer; Cond. 6.55 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.11
25 mM Phosphate buffer; Cond. 3.48 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.25
5 mM Phosphate buffer: Cond. 0.882 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.31

Table 26. Two-step differential elution of serine protease and Factor H from SiO_2 at pH 7.5/7.6.

First Elution buffer System pH 7.5	**Second Elution buffer**	**Sample**	**Factor H [g/l Plasma]**
100 mM Phosphate buffer; Cond. 11.88 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.05
50 mM Phosphate buffer; Cond. 6.55 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.06
25 mM Phosphate buffer; Cond. 3.48 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.06

5 mM Phosphate buffer: Cond. 0.882 mS/cm	100mM Phosphate buffer + 150 mM NaCl, pH 7.6	Filtrate second elution	0.07

Example 6

[0506] To determine the amount of finely divided SiO_2 required for efficient removal of serine proteases and serine protease zymogens from a plasma-derived protein composition, a fraction II+III precipitate (*i.e.*, II+III filtercake) was dissolved, filtered, treated with SiO_2, filter aid was admixed, and subjected to a second filtration. Briefly, the fraction II+III filtercake was first dissolved in 0.1 M phosphate buffer containing 150 mM sodium chloride (pH 7.5; 30 mS/cm). This suspension was then filtered through a Cuno 50 SA filter and the filtrate collected. Aerosil 380 was admixed with the filtrate at a final concentration of either 1.0 or 2.5 g/g protein and then incubated for at least 50 minutes. CELPURE filter aid was added and filtration was performed using a Cuno 50 SA filter. The resulting filtrate was then characterized for amidolytic activity, as reported in Table 27. Significantly, the results show that addition of Aerosil at a final concentration of 2.5 g/g protein reduced the amidolytic activity of Kallikrein, FXIa, and FXIIa in the composition by greater than 90%, as compared to the sample treated with Aerosil at a final concentration of 1.0 g/g protein.

Table 27. Amidolytic activity present in re-suspended Fraction II+III precipitate after treatment with finely divided silicon dioxide.

Kallikrein, FXIa, FXIIa	**Substrate: S-2302**	**Reduction by increased Aerosil addition**
sample	total: nmol*min	[%]
FH027 Cuno filtrate, after addition of 1 g Aerosil per g Protein	83347	-
FH027 Cuno filtrate, after addition of 2.5 g Aerosil per g Protein	6227	92.5

Example 7

[0507] To evaluate the efficiency of SiO_2 treatment for the removal of Factor XI zymogen during the industrial-scale manufacture of plasma-derived protein compositions, the FXI zymogen content of six industrial-scale manufacturing batches was characterized. Table 28 and Table **29** show the average FXI zymogen content of each upstream process step from three purifications performed at the same manufacturing site. The data in Table 28 and

Table **29** demonstrate that SiO_2 treatment of manufacturing-scale purifications can reduce the FXI zymogen content of the composition by at least 90%. Notably, manufacturing sites 1 admixed Aerosil at a final concentration of 50 g/kg II+III precipitate, while site 2 used Aerosil at a final concentration of 40 g/kg II+III precipitate. Surprisingly, this small difference in the amount of aerosil used resulted in a significant difference in the Factor XI zymogen content of the filtrate after aerosil treatment (8.1% of Cohn starting pool for site 2 vs. 2.8% of Cohn starting pool for site 1).

Table 28. Mean value of Factor XI zymogen content in each fraction of three large-scale manufacturing batches processed at site 1.

Sample	Volume	F-XI zymogen		
		(U/mL)	(U)	(% of Cohn pool)
Cohn pool	3379	1.25	4233923	100.0
Supernatant I	3632	1.01	3669081	87.2
Supernatant II+II	3927	0.21	812077	19.1
II+III paste*	2302	1.31	3026261	71.6
Filtrate after Aerosil	2993	0.04	119107	2.8
Ppt G dissolved	248	0.31	77300	1.8

Table 29. Mean value of Factor XI zymogen content in each fraction of three large-scale manufacturing batches processed at site 2.

Sample	Volume	F-XI zymogen		
		(U/mL)	(U)	(% of Cohn pool)
Cohn pool	2885	1.11	3193460	100.0
Supernatant I	3076	1.04	3208517	100.5
Supernatant II+II	3376	0.29	968120	30.2
II+III paste*	474.3	4.96	2352714	74.0
Filtrate after Aerosil	2280	0.11	258466.7	8.1
Ppt G dissolved	238.1	1.07	253912.33	8.0

[0508] It is understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application

and scope of the appended claims. All publications, patents, and patent applications cited herein are hereby incorporated by reference in their entirety for all purposes.

WHAT IS CLAIMED IS:

1. A method for reducing the amount of a serine protease or a serine protease zymogen in a plasma-derived target protein composition, the method comprising the steps of:

(a) contacting the composition with finely divided silicon dioxide (SiO_2) under conditions suitable to bind at least one serine protease or serine protease zymogen; and

(b) separating the SiO_2 from the composition to remove the bound serine protease,

wherein the at least one serine protease or serine protease zymogen is Factor XIa (FXIa), Factor XIIa (FXIIa), Factor XI (FXI), or Factor XII (FXII).

2. The method of claim 1, wherein the method further comprises the step of performing a first target protein enrichment step to form a first enriched composition, prior to contacting the composition with finely divided silicon dioxide (SiO_2).

3. The method of claim 2, wherein the first target protein enrichment step is a protein precipitation step.

4. The method of claim 3, wherein the protein precipitation step is an alcohol fractionation step.

5. The method of claim 2, wherein the first target protein enrichment step is an ultrafiltration/diafiltration step.

6. The method according to any one of claims 2 to 5, wherein the method further comprises the step of performing a second target protein enrichment step prior to contacting the enriched composition with finely divided silicon dioxide (SiO_2).

7. The method of claim 6, wherein the second target protein enrichment step is a protein precipitation step.

8. The method of claim 7, wherein the protein precipitation step is an alcohol fractionation step.

9. The method of claim 6, wherein the second target protein enrichment step is an ultrafiltration/diafiltration step.

10. The method of claim 6, wherein the second target protein enrichment step is a chromatographic enrichment step.

11. The method according to any one of claims 1 to 10, wherein the method further comprises the step of performing a third target protein enrichment step after contacting the composition with finely divided silicon dioxide (SiO_2).

12. The method of claim 11, wherein the third target protein enrichment step is a protein precipitation step.

13. The method of claim 12, wherein the protein precipitation step is an alcohol fractionation step.

14. The method of claim 12, wherein the third target protein enrichment step is an ultrafiltration/diafiltration step.

15. The method of claim 12, wherein the third target protein enrichment step is a chromatographic enrichment step.

16. The method of claim 10 or 15, wherein the chromatographic enrichment step comprises the sub-steps of:

(i) contacting the plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind the plasma-derived target protein; and

(ii) eluting the plasma-derived target protein from the chromatographic resin.

17. The method of claim 16, wherein at least one impurity does not bind to the chromatographic resin in sub-step (i).

18. The method of claim 16, wherein at least one impurity binds to the chromatographic resin in sub-step (i), but is not eluted from the chromatographic resin in sub-step (ii).

19. The method of claim 10 or 15, wherein the chromatographic enrichment step comprises the sub-steps of:

(i) contacting the first enriched plasma-derived target protein composition with a chromatographic resin under conditions suitable to bind at least one impurity; and

(ii) separating the resin from the plasma-derived protein composition,

wherein the plasma-derived target protein does not bind to the chromatographic resin in sub-step (i).

20. The method according to any one of claims 15 to 19, wherein the chromatographic resin is selected from the group consisting of an anion exchange resin, a cation exchange resin, a hydrophobic interaction resin, a mixed mode resin, a hydroxyapatite resin, a ligand affinity resin, an immunoaffinity resin, and a size exclusion resin.

21. The method of claim 20, wherein the chromatographic resin is an anion exchange resin.

22. The method of claim 20, wherein the chromatographic resin is a cation exchange resin.

23. The method of claim 20, wherein the chromatographic resin is a hydrophobic interaction resin.

24. The method of claim 20, wherein the chromatographic resin is a mixed mode resin.

25. The method of claim 20, wherein the chromatographic resin is a hydroxyapatite resin.

26. The method of claim 20, wherein the chromatographic resin is a ligand affinity resin.

27. The method of claim 20, wherein the chromatographic resin is an immunoaffinity resin.

28. The method of claim 10 or 15, wherein the chromatographic enrichment step comprises separating at least one impurity from the target protein by size and/or shape using size exclusion chromatography.

29. The method according to any one of claims 1 to 28, wherein the plasma-derived target protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin

(A1PI), butyrylcholinesterase, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI).

30. The method of claim 29, wherein the plasma-derived protein is an immunoglobulin (Ig).

31. The method of claim 29, wherein the plasma-derived protein is albumin.

32. The method of claim 29, wherein the plasma-derived protein is alpha-1-antitrypsin.

33. The method of claim 29, wherein the plasma-derived protein is butyrylcholinesterase.

34. The method of claim 29, wherein the plasma-derived protein is a protein of the complement system.

35. The method of claim 34, wherein the protein of the complement system is selected from the group consisting of Factor H (FH), Factor D, complement protein C3, and C4 binding protein.

36. The method of claim 29, wherein the plasma-derived protein is an inter-alpha-trypsin inhibitor.

37. The method according to any one of claims 1 to 36, wherein the plasma-derived target protein composition is a manufacturing intermediate.

38. A method for preparing a plasma-derived Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H and at least one serine protease or serine protease zymogen;

(b) separating the SiO_2 from the composition;

(c) eluting the serine protease or serine protease zymogen from the SiO_2 under a solution condition in which a substantial fraction of Factor H remains bound; and

(d) eluting the Factor H from the SiO_2.

39. The method of claim 38, wherein the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO_2 comprises a pH below 7.0 and a conductivity of less than 11 mS/cm.

40. The method of claim 38 or 39, wherein the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO_2 comprises a pH between 4.5 and 6.5 and a conductivity of less than 6 mS/cm.

41. The method of claim 40, wherein the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO_2 comprises a pH between 4.5 and 6.5 and a conductivity between 0.5 mS/cm and 5 mS/cm.

42. The method according to any one of claims 38 to 41, wherein the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a substantial fraction of the Factor H remains bound comprises a pH below 7.0 and a conductivity of less than 11 mS/cm.

43. The method of claim 42, wherein the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a substantial fraction of the Factor H remains bound comprises a pH between 4.5 and 6.5 and a conductivity of less than 6 mS/cm.

44. The method of claim 42, wherein the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a substantial fraction of the Factor H remains bound comprises a pH between 5.0 and 6.5 and a conductivity between 0.5 mS/cm and 5 mS/cm.

45. The method according to any one of claims 38 to 44, wherein the solution condition under which the Factor H is eluted from the SiO_2 comprises an ionic strength of at least 6 mS/cm.

46. The method according to any one of claims 38 to 45, wherein the solution condition under which the Factor H is eluted from the SiO_2 comprises an ionic strength of at least 11 mS/cm.

47. The method according to any one of claims 38 to 46, wherein the solution condition under which the Factor H is eluted from the SiO_2 comprises a pH between 5.0 and 7.0.

48. The method according to any one of claims 38 to 44, wherein the solution condition under which the Factor H is eluted from the SiO_2 comprises a pH between 7.0 and 8.0 and an ionic strength of between 4 mS/cm and 7 mS/cm.

49. A method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H and at least one serine protease;

(b) separating the SiO_2 from the composition; and

(c) eluting the Factor H from the SiO_2 under conditions in which a substantial fraction of the serine protease or serine protease zymogen remains bound to the SiO_2.

50. The method of claim 49, wherein the solution condition under which the Factor H and at least one serine protease or serine protease zymogen bind the SiO_2 comprises a pH below 7.0 and a conductivity of less than 11 mS/cm.

51. The method of claim 49 or 50, wherein the solution condition under which the serine protease or serine protease zymogen is eluted from the SiO_2 and a substantial fraction of the Factor H remains bound comprises a pH between 4.5 and 6.5 and a conductivity of less than 6 mS/cm.

52. The method of claim 49, wherein the solution condition suitable to bind the Factor H and at least one serine protease or serine protease zymogen comprises a pH between 5.0 and 6.0 and a conductivity of between 0.5 mS/cm and 5.0 mS/cm.

53. The method according to any one of claims 49 to 52, wherein the solution condition under which the Factor H is eluted from the SiO_2 and a substantial fraction of the serine protease or serine protease zymogen remains bound comprises a pH between 5.0 and 7.0 and a conductivity of at least 11 mS/cm.

54. The method according to any one of claims 49 to 52, wherein the solution condition under which the Factor H is eluted from the SiO_2 and a substantial fraction of the serine protease or serine protease zymogen remains bound comprises a pH between 7.0 and 8.0 and a conductivity of between 2 mS/cm and 10 mS/cm.

55. The method of claim 54, wherein the conductivity of the solution condition is between 4 mS/cm and 7 mS/cm.

56. The method of claim 54, wherein the conductivity of the solution condition is between 5 mS/cm and 6 mS/cm.

57. A method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H but not a substantial fraction of the at least one serine protease or serine protease zymogen;

(b) separating the SiO_2 from the composition; and

(c) eluting the Factor H from the SiO_2.

58. The method of claim 57, wherein the solution condition under which the Factor H binds to the SiO_2 and a substantial fraction of the serine protease or serine protease zymogen does not bind to the SiO_2 comprises a pH of between 5.0 and 7.0 and a conductivity of no more than 14 mS/cm.

59. The method of claim 58, wherein the conductivity of the solution condition is between 9 mS/cm and 14 mS/cm.

60. A method for preparing a Factor H composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the at least one serine protease or serine protease zymogen but not a substantial fraction of the Factor H; and

(b) separating the SiO_2 from the composition.

61. The method of claim 60, wherein the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and a substantial fraction of the Factor H does not bind to the SiO_2 comprises a pH between 5.0 and 7.0 and a conductivity of at least 11 mS/cm.

62. The method of claim 60, wherein the solution condition under which the serine protease or serine protease zymogen binds to the SiO_2 and a substantial fraction of the Factor H does not bind to the SiO_2 comprises a pH between 7.0 and 8.0 and a conductivity of between 2 mS/cm and 10 mS/cm.

63. The method of claim 62, wherein the conductivity of the solution condition is between 4 mS/cm and 7 mS/cm.

64. The method of claim 62, wherein the conductivity of the solution condition is between 5 mS/cm and 6 mS/cm.

65. A method for preparing a Factor H composition, the method comprising the steps of:

(a) contacting a composition containing Factor H and at least one serine protease or serine protease zymogen with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the Factor H;

(b) washing the SiO_2 with a solution comprising a pH between 5.0 and 7.0 and a conductivity of less than 4 mS/cm; and

(c) eluting Factor H from the SiO_2 with a solution comprising a pH between 7.0 and 8.0 and a conductivity greater than 10 mS/cm.

66. The method of claim 65, wherein the solution used to wash the SiO_2 comprises a pH between 5.5 and 6.5.

67. The method of claim 65, wherein the solution used to wash the SiO_2 comprises a pH between of 6.0 ± 0.2.

68. The method according to any one of claims of claims 65 to 67, wherein the solution used to elute Factor H comprises a conductivity of at least 20 mS/cm.

69. The method of claim 68, wherein the solution used to elute Factor H comprises a conductivity of between 25 mS/cm and 40 mS/cm.

70. The method according to any one of claims of claims 38 to 69, wherein the starting composition containing Factor H is a suspended Cohn fraction II+III precipitate, or equivalent fraction thereof.

71. The method according to any one of claims of claims 38 to 69, wherein the starting composition containing Factor H is a suspended Kistler/Nitschmann Precipitate A, or equivalent fraction thereof.

72. The method according to any one of claims of claims 38 to 69, wherein the starting composition containing Factor H is a suspended Kistler/Nitschmann Precipitate B, or equivalent fraction thereof.

73. A method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI and at least one serine protease;

(b) separating the SiO_2 from the composition;

(c) eluting the serine protease or serine protease zymogen from the SiO_2 under conditions in which a substantial fraction of the IαI remains bound; and

(d) eluting the IαI from the SiO_2.

74. A method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI and at least one serine protease;

(b) separating the SiO_2 from the composition; and

(c) eluting the IαI from the SiO_2 under conditions in which a substantial fraction of the serine protease or serine protease zymogen remains bound to the SiO_2.

75. A method for preparing an inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a solution containing IαI and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the IαI but not a substantial fraction of the least one serine protease or serine protease zymogen;

(b) separating the SiO_2 from the composition; and

(c) eluting the IαI from the SiO_2.

76. A method for preparing a inter-alpha-trypsin inhibitor (IαI) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) contacting a solution containing inter-alpha-trypsin inhibitor (IαI) and at least one serine protease with finely divided silicon dioxide (SiO_2) under conditions suitable to bind the serine protease or serine protease zymogen but not the inter-alpha-trypsin inhibitor (IαI); and

(b) separating the SiO_2 from the composition.

77. A method for preparing an Immunoglobulin G (IgG) composition having a reduced amount of a serine protease or a serine protease zymogen, the method comprising the steps of:

(a) precipitating a cryo-poor plasmid fraction, in a first precipitation step, with between about 6% and about 10% alcohol at a pH of between about 7.0 and about 7.5 to obtain a first precipitate and a first supernatant;

(b) precipitating IgG from the first supernatant, in a second precipitation step, with between about 20% and about 25% alcohol at a pH of between about 6.7 and about 7.3 to form a second precipitate;

(c) re-suspending the second precipitate to form a suspension;

(d) contacting the suspension with finely divided silicon dioxide (SiO_2) under a solution condition suitable to bind a serine protease or serine protease zymogen; and

(e) separating the SiO_2 from the suspension to form a clarified suspension.

78. The method of claim 77, wherein the method further comprises the steps of:

(f) precipitating IgG from the clarified suspension formed in step (e), in a third precipitation step, with between about 22% and about 28% alcohol at a pH of between about 6.7 and about 7.3 to form a third precipitate;

(g) re-suspending the third precipitate to form a suspension; and

(h) separating the soluble fraction from the suspension formed in step (e), thereby forming an enriched IgG composition.

79. The method of claim 77 or 78, wherein the method further comprises an anion exchange chromatography enrichment step.

80. The method according to any one of claims 77 to 79, wherein the method further comprises a cation exchange chromatography enrichment step.

81. The method according to any one of claims 77 to 80, wherein the method further comprises at least one dedicated viral inactivation or removal step.

82. The method of claim 81, wherein the method comprises a solvent/detergent (S/D) viral inactivation step.

83. The method of claim 81 or 82, wherein the method comprises a nanofiltration step.

84. The method according to any one of claims 81 to 83, wherein the method comprises an incubation step at low pH.

85. The method according to any one of claims 78 to 84, wherein step (b) comprises adjusting the ethanol concentration of the first supernatant formed in step (a) to about 25% (v/v) at a temperature between about -7°C and about -9°C.

86. The method of claim 85, wherein the temperature is about -9°C.

87. The method according to any one of claims 78 to 86, wherein step (c) comprises re-suspending the precipitate of step (b) with a buffer containing phosphate and

acetate, wherein the pH of the buffer is adjusted with between 300 mL and 700 mL of glacial acetic acid per 1000 L of buffer.

88. The method according to any one of claims 78 to 87, wherein step (d) comprises the addition SiO_2 to a final concentration of between about 0.02 grams per gram precipitate formed in step (b) and about 0.06 grams per gram precipitate formed in step (b).

89. The method according to any one of claims 78 to 88, wherein the solution condition suitable to bind a serine protease or serine protease zymogen comprises a pH between 4.5 and 6.0 and a conductivity of between 0.1 mS/cm and 3 mS/cm.

90. The method of claim 89, wherein the pH is between 4.9 and 5.3.

91. The method of claim 89 or 90, wherein the conductivity is between 0.5 mS/cm and 2 mS/cm.

92. The method according to any one of claims 78 to 91, wherein step (e) comprises the sub-steps of:

(i) washing the filter press with at least 3 filter press dead volumes of a buffer containing phosphate and acetate, wherein the pH of the buffer is adjusted with between 50 mL and 200 mL of glacial acetic acid per 1000L of buffer, thereby forming a wash solution; and

(ii) combining the filtrate of step (f) with the wash solution of step (g), thereby forming a solution.

93. The method of claim 92, further comprising the sub-step of:

(iii) treating the solution with a detergent.

94. The method according to any one of claims 78 to 93, wherein step (h) further comprises solvent and detergent (S/D) treatment of the enriched IgG composition.

95. The method according to any one of claims 78 to 93, wherein the enriched IgG composition obtained in step (h) contains at least 85% of the IgG content found in the cryo-poor plasma fraction used in step (a).

96. The method of claim 95, wherein the enriched IgG composition obtained in step (h) contains at least 90% of the IgG content found in the cryo-poor plasma fraction used in step (a).

97. The method according to any one of claims 77 to 96, wherein the amount of a serine protease or a serine protease zymogen has been reduced by at least 90%.

98. The method of claim 97, wherein the amount of a serine protease or a serine protease zymogen has been reduced by at least 95%.

99. The method of claim 97, wherein the amount of a serine protease or a serine protease zymogen has been reduced by at least 98%.

100. The method of claim 97, wherein the amount of a serine protease or a serine protease zymogen has been reduced by at least 99%.

101. The method according to any one of claims 97 to 100, wherein the serine protease or a serine protease zymogen is FXIa.

102. The method according to any one of the preceding claims, wherein the composition is contacted with SiO_2 at a final concentration of at least 1 g SiO_2/g protein.

103. The method of claim 102, wherein the composition is contacted with SiO_2 at a final concentration of at least 2 g SiO_2/g protein.

104. The method of claim 102, wherein the composition is contacted with SiO_2 at a final concentration of at least 2.5 g SiO_2/g protein.

105. The method according to any one of the preceding claims, wherein the serine protease or serine protease zymogen is Factor XI.

106. The method according to any one of the preceding claims, wherein the serine protease or serine protease zymogen is Factor XII.

107. The method according to any one of the preceding claims, wherein the serine protease or serine protease zymogen is Factor XIa.

108. The method according to any one of the preceding claims, wherein the serine protease or serine protease zymogen is Factor XIIa.

109. A plasma-derived protein composition prepared by a process comprising a method for reducing serine protease activity according to any one of the preceding claims.

110. The plasma-derived protein composition of claim 109, wherein the composition is formulated for administration to a subject.

111. The plasma-derived protein composition of claim 109, wherein the composition is formulated for intravenous, intramuscular, or subcutaneous administration.

112. The plasma-derived protein composition according to any one of claims 109 to 111, wherein the composition is aqueous.

113. The plasma-derived protein composition according to any one of claims 109 to 111, wherein the composition is lyophilized.

114. A method for treating a disease associated with aberrant activity of a plasma protein in a subject in need thereof, the method comprising administering a plasma-derived protein composition according to any one of claims 109 to 113.

115. The method of claim 114, wherein the composition comprises a plasma-derived protein is selected from an immunoglobulin (Ig), albumin, alpha-1-antitrypsin (A1PI), butyrylcholinesterase, a protein of the complement system, and an inter-alpha-trypsin inhibitor (IαI).