ALBUMIN FORMULATION AND USE

Reference to a Sequence Listing

This application contains a Sequence Listing in computer readable form, which is incorporated herein by reference.

Background of the Invention

The invention relates to a new formulation of albumin and to uses of the albumin formulation.

Albumin is the most abundant protein in plasma. Albumin has been described and characterized from a large number of mammals and birds. Albumin is believed to have a role in maintaining correct osmotic pressure and it also has a role in transport of various compounds in the blood stream. Albumin is a protein which is used to treat patients with severe burns, shock or blood loss. It is also used as an excipient for pharmacologically active compounds, many of which need to be stabilized for example to reduce the formation of soluble aggregates and/or insoluble aggregates of albumin. Furthermore, albumin is used to supplement media used for growing higher eukaryotic cells, including stem cells. Albumin fusion proteins are a fusion of a protein to albumin, or to a variant or fragment thereof, and may increase or decrease the half-life of the protein, for example increased in vivo half-life. Conjugation partners, *e.g.* proteins or chemicals, can be conjugated to albumin to increase or decrease the half-life of the conjugation partner, for example increased in vivo half-life. At present albumin is obtained from blood products, such as serum, or produced recombinantly in microorganisms such as yeast (*e.g.* WO 96/37515, WO 2000/044772) or from transgenic plants or animals. Typically, albumin is purified from the production source in order to provide a product which is sufficiently pure to meet the user's needs and/or to achieve a high yield of product. In some technical areas, such as cell culture or pharmaceuticals, there is a desire for products to be substantially free or completely free of animal derived components.

Purified albumin in a final liquid form is relatively unstable (compared to albumin in solid form) and so in order to maximize its shelf life it is either lyophilized and/or stabilizers added to the final liquid formulation. However, lyophilization can add significantly to the overall cost of the preparation and can be inconvenient to the end user who would need to resuspend the lyophilized product if they need a liquid product. For the preferred liquid product, stabilizers that are commonly added to albumin are n-acetyl-tryptophan, octanoic acid (octanoate, caprylate) and/or polysorbate 80 (*e.g.* Tween®). The albumin of WO 2000/044772 is stabilized by octanoic

acid. Arakawa & Kita (2000) discloses stabilizing effects of caprylate and acetyltryptophanate on heat-induced aggregation of bovine serum albumin (*Biochimica et Biophysica Acta* 1479: 32-36). Hosseini *et al.* (2002) discloses a study of the heat-treated human albumin stabilization by caprylate and acetyltryptophanate (*Iranian Biomedical Journal* 6(4): 135-140).

The present inventors have identified that octanoic acid, can be deleterious to mammalian cell culture particularly to stem cell culture. Furthermore, polysorbate 80 (Tween®) can be deleterious to mammalian cell culture. What is required is a stable liquid formulation of albumin which is not deleterious to mammalian cell culture.

Summary of the Invention

The invention provides a liquid formulation of albumin with improved stability, where stability is shown, for example, as a reduced level of soluble aggregates of albumin or insoluble aggregates of albumin in the formulation. The invention also provides methods using the formulation and uses of the formulation, such as mammalian culture and particularly stem cell culture.

Brief Description of the Figures

Figure 1 shows the effect of pH and n-acetyl tryptophan concentration on the stability of albumin compositions (10 mg/mL), as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 Absorbance Units (AU), a measure of visible (insoluble) aggregates.

Figure 2 shows the effect of pH and phosphate concentration on the stability of albumin compositions (10 mg/mL), as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 3 shows the effect of pH and sodium concentration on the stability of albumin compositions (10 mg/mL), as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 4 shows the effect of pH and sodium concentration (for a wide range of sodium concentrations) on the stability of albumin compositions (10 mg/mL), as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 5 shows the effect of pH and sodium concentration on the stability of albumin compositions (50 mg/mL), as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 6 shows the effect of sodium concentration and albumin concentration on the stability of albumin compositions at pH 6.5, as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 7 shows the relationship between sodium concentration and relative monomer content (%) for albumin compositions incubated at 40°C for 14 days.

Figure 8 shows the relationship between sodium concentration and relative polymer content (%) for albumin compositions incubated at 40°C for 14 days.

Figure 9 shows a fatty acid profile of an albumin formulation according to the invention.

Figure 10 shows a metal ion profile, by ICP-OES, of an albumin formulation according to the invention.

Figure 11 shows the effect of sodium concentration and albumin concentration on albumin stability as determined by the remaining monomer content following incubation at 40°C for 4 weeks.

Figure 12 shows the effect of cation species and cation concentration on albumin stability as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.2 AU.

Figure 13 shows the effect of sodium ion concentration and anion species on albumin stability as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 14 shows the effect of sodium ion concentration and anion species on albumin stability as determined by the remaining monomer content following incubation at 65°C for 2 hours.

Figure 15 shows the effect of sodium ion concentration in the presence of different buffer anions on albumin stability wherein the contribution of sodium from both NaCl and the buffer is included, as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 16 shows the effect of sodium ion concentration in the presence of no buffering ion or 50 mM citrate as a buffering ion on albumin stability where the contribution of sodium ion from the sodium citrate buffer is ignored, as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 17 shows the effect of sodium ion concentration on the stability of different albumins and albumin variants as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 18 shows the effect of sodium ion concentration on the stability of mouse serum albumin as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 19 shows the effect of pH and sodium ion concentration on albumin stability as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 20 shows the effect of sodium ion concentration on albumin stability at pH 5.0 as determined by the time taken (seconds) for the absorbance (A350) to increase by 0.1 AU.

Figure 21 shows the effect of sodium ion concentration on albumin stability at pH 7.0, 7.5 and 8.0 as determined by the remaining monomer content following incubation at 65°C for 2 hours.

Detailed Description of the Invention

Definitions

The terms **"cell culture medium"**, **"culture medium"** and **"medium formulation"** refer to a nutritive solution for culturing or growing cells.

A **"serum-free"** medium is a medium that contains no serum (*e.g.*, fetal bovine serum (FBS), horse serum, goat serum, or any other animal-derived serum known to one skilled in the art).

The term **"basal medium"** refers to any medium which is capable of supporting growth of cells. The basal medium supplies standard inorganic salts, such as zinc, iron, magnesium, calcium and potassium, as well as trace elements, vitamins, an energy source, a buffer system, and essential amino acids. Suitable basal media include, but are not limited to Alpha Minimal Essential Medium (.alpha.MEM); Basal Medium Eagle (BME); Basal Medium Eagle with Earle's BSS; DME/F12; DMEM high Glucose with L-Glutamine; DMEM high glucose without L-Glutamine; DMEM:Fl2 1:1 with L-Glutamine; Dulbecco's Modified Eagle's Medium (DMEM); F-10; F-12; Glasgow's Minimal Essential Medium (G-MEM); G-MEM with L-glutamine; Grace's Complete Insect Medium; Grace's Insect Medium without FBS; Ham's F-10 with L-Glutamine; Ham's F-12 with L-Glutamine; IMDM with HEPES and L-Glutamine; IMDM with HEPES and without L-Glutamine; IPL-41 Insect Medium; Iscove's Modified Dulbecco's Medium.; L-15 (Leibovitz) without L-Glutamine; L-15 (Leibovitz)(2X) without L-Glutamine or Phenol Red; McCoy's 5A Modified Medium; Medium 199; MEM Eagle without L-Glutamine or Phenol Red (2X); MEM Eagle-Earle's BSS with L-glutamine; MEM Eagle-Earle's BSS without L-Glutamine; MEM Eagle-Hanks BSS without L-Glutamine; Minimal Essential Medium (MEM); Minimal Essential Medium-alpha. (MEM-alpha); NCTC-109 with L-Glutamine; Richter's CM Medium with L-Glutamine; RPMI 1640; RPMI 1640 with L-Glutamine; RPMI 1640 without L-Glutamine; RPMI

1640 with HEPES, L-Glutamine and/or Penicillin-Streptomycin; Schneider's Insect Medium; or any other media known to one skilled in the art. Preferred basal media for stem cell culture include MEF, DMEM, CTS, and DMEM/F-12.

The term "**albumin**" means a protein having the same and/or very similar tertiary structure as human serum albumin (HSA) or HSA domains and has similar properties of HSA or the relevant domains. Similar tertiary structures are for example the structures of the albumins from the species mentioned under parent albumin. Some of the major properties of albumin are i) its ability to regulate of plasma volume, ii) a long plasma half-life of around 19 days ± 5 days, iii) ligand-binding, *e.g.* binding of endogenous molecules such as acidic, lipophilic compounds including bilirubin fatty acids, hemin and thyroxine (see also Table 1 of Kragh-Hansen *et al*, 2002, Biol. Pharm. Bull. 25, 695, hereby incorporated by reference), iv) binding of small organic compounds with acidic or electronegative features *e.g.* drugs such as warfarin, diazepam, ibuprofen and paclitaxel (see also Table 1 of Kragh-Hansen *et al*, 2002, Biol. Pharm. Bull. 25, 695, hereby incorporated by reference). Not all of these properties need to be fulfilled to in order to characterize a protein or fragment as an albumin. If a fragment, for example, does not comprise a domain responsible for binding of certain ligands or organic compounds the variant of such a fragment will not be expected to have these properties either. The term albumin includes variants, and/or derivatives such as fusions and/or conjugations of an albumin or of an albumin variant.

The term "**variant**" means a polypeptide derived from a parent albumin comprising an alteration, *i.e.*, a substitution, insertion, and/or deletion, at one or more (several) positions. A substitution means a replacement of an amino acid occupying a position with a different amino acid; a deletion means removal of an amino acid occupying a position; and an insertion means adding 1-3 amino acids adjacent to an amino acid occupying a position. The altered polypeptide (variant) can be obtained through human intervention by modification of the polynucleotide sequence encoding the parental albumin. The variant albumin is preferably at least 70%, preferably at least 75%, more preferably at least 80%, more preferably at least 85%, even more preferably at least 90%, most preferably at least 95%, at least 96%, at least 97%, at least 98%, at least 99%, or 100% identical to SEQ ID NO: 2 and maintains at least one of the major properties of the parent albumin or a similar tertiary structure as HSA. For purposes of the present invention, the sequence identity between two amino acid sequences is determined using the Needleman-Wunsch algorithm (Needleman and Wunsch, 1970, *J. Mol. Biol.* 48: 443-453) as implemented in the Needle program of the EMBOSS package (EMBOSS: The European Molecular Biology Open Software Suite, Rice *et al.*, 2000, *Trends Genet.* 16: 276-

277), preferably version 5.0.0 or later. The parameters used are gap open penalty of 10, gap extension penalty of 0.5, and the EBLOSUM62 (EMBOSS version of BLOSUM62) substitution matrix. The output of Needle labeled "longest identity" (obtained using the –nobrief option) is used as the percent identity and is calculated as follows: (Identical Residues x 100)/(Length of Alignment – Total Number of Gaps in Alignment).

The variant may possess altered binding affinity to FcRn and/or an altered rate of transcytosis across endothelia, epithelia and/or mesothelia mono cell-layer when compared to the parent albumin. The variant polypeptide sequence is preferably one which is not found in nature. A variant includes a fragment, *e.g.* comprising or consisting of at least 100, 150, 200, 250, 300, 350, 450, 500, 550 contiguous amino acids of an albumin.

The term "**wild-type**" (WT) albumin means an albumin having the same amino acid sequence as the albumins naturally found in an animal or in a human being. SEQ ID NO: 2 is an example of a wild-type albumin from Homo sapiens.

The term "**parent**" or "**parent albumin**" means an albumin to which an alteration is made to produce the albumin variants which may be used in the present invention. The parent may be a naturally occurring (wild-type) polypeptide or an allele thereof or a variant thereof such as a variant described in PCT/EP2010/066572 or a variant or derivative described in PCT/EP2011/055577.

The term "**fusion**" means a genetic fusion of albumin (or a variant or fragment thereof) and a non-albumin protein. The non-albumin protein may be a therapeutic, prophylactic, or diagnostic protein. Examples of albumin fusions are provided in EP 624195, WO 2001/079271, WO 2003/059934, WO 2003/060071, WO 2011/051489, PCT/EP11/055577 and EP 11164955 (incorporated herein by reference in their entirety).

The term "**conjugation**" means an albumin (or a variant or fragment or fusion thereof) to which a non-albumin moiety is chemically conjugated. The non-albumin moiety may be a therapeutic, prophylactic, or diagnostic protein. Examples of albumin conjugations are provided in PCT/EP11/055577 and EP 11164955 (incorporated herein by reference in their entirety).

The term "**suspension culture**" refers to cells in culture in which the majority or all of cells in culture are present in suspension, and the minority or none of the cells in the culture vessel are attached to the vessel surface or to another surface within the vessel (adherent cells). The "suspension culture" can have greater than about 50%, 60%, 65%, 75%, 85%, or 95% of the cells in suspension, not attached to a surface on or in the culture vessel.

The term "**adherent culture**" refers to cells in culture in which the majority or all of cells in culture are present attached to the vessel surface or to another surface within the vessel, and

the minority or none of the cells in the culture vessel are in suspension. The "adherent culture" can have greater than 50%, 60%, 65%, 75%, 85%, or 95% of the cells adherent.

As used herein, the term "**mammal**" includes any human or non-human mammal, including but not limited to porcine, ovine, bovine, rodents, ungulates, pigs, sheep, lambs, goats, cattle, deer, mules, horses, primates (such as monkeys), dogs, cats, rats, and mice.

The term "**cell**' includes any cell such as, but not limited to, any human or non-human mammalian cell as described herein. A cell may be a normal cell or an abnormal cell (*e.g.* transformed cells, established cells, or cells derived from diseased tissue samples). The cell may be a somatic cell such as a fibroblast or keratinocyte. Preferred cells are stem cells such as, but not limited to, embryonic stem cells, fetal stem cells, adult stem cells and pluripotent stem cells such as induced pluripotent stem cells. Particularly preferred cells are human embryonic stem cells, human fetal stem cells, human adult stem cells and human pluripotent stem cells such as induced human pluripotent stem cells.

A first aspect of the invention provides a composition comprising albumin, a solvent, at least 175 mM cations, having a pH from about 5.0 to about 9.0 and wherein the composition comprises equal to or less than 30 mM octanoate. An advantage of such a composition is that this formulation provides an albumin which is sufficiently stable to have a useful shelf-life and is not deleterious to the health of mammalian cells (*e.g.* it is not toxic) when the composition is used in mammalian cell culture.

It is preferred that the composition contains anions to balance the cations.

The solvent may be an inorganic solvent such as water or an inorganic buffer such as a phosphate buffer such as sodium phosphate, potassium phosphate, or an organic buffer such as sodium acetate or sodium citrate. The buffer may stabilize pH. Sodium phosphate (*e.g.* NaH_2PO_4) is a preferred pH buffer, such as pH 5.0, 5.5., 6.0, 6.5, 7.0, 7.5, 8.0.

The inventors have observed that octanoate is deleterious to mammalian cells in cell culture. Therefore, the composition comprises low levels of octanoate. For example, it is preferred that the composition comprises less than 30 mM octanoate, more preferably less than about 28, 26, 24, 22, 20, 18, 16, 15, 14, 12, 10, 8 mM octanoate, even more preferably less than about 6, 5, 4, 3 mM octanoate, most preferably less than about 2, 1, 0.5, 0.4, 0.3, 0.2, 0.1, 0.01, or 0.001 mM octanoate. It is preferred that the composition is substantially free of octanoate. That is, it is preferred that the level of octanoate in the composition is not sufficient to cause a deleterious effect on cells during culture, for example mammalian cells (particularly

stem cells such as human stem cells) in cell culture such as *in vitro* cell culture. Most preferably the composition is free of octanoate (0 mM octanaote).

Preferred parameters for fatty acids are provided below. The fatty acid content is preferably an average of multiple samples, for example 2, 3, 4 or 5 samples:

Fatty Acid	**Preferred range (mM)**
C6:0	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C8:0	≤ 2.5 mM, more preferably ≤0.23 mM, most preferably 0 mM
C9:0	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C10:0	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C11:0	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C12:0	≤ 0.5 mM, more preferably ≤ 0.05 mM, most preferably 0 mM
C13:0	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C14:0	≤ 10 mM, more preferably 1 ≤ mM, most preferably 0 mM
C14:1	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C15:0	≤ 0.4 mM, more preferably ≤ 0.04 mM, most preferably 0 mM
C15:1	≤ 0.1, more preferably ≤0.01 mM, most preferably 0 mM
C16:0	≤ 34 mM, more preferably ≤ 3.38 mM, most preferably 0 mM
C16:1n7	≤ 0.9 mM, more preferably ≤ 0.09 mM, most preferably 0 mM
C16:2n4	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C16:3n4	≤ 0.5 mM, more preferably ≤ 0.05 mM, most preferably 0 mM
C17:0	≤ 0.5 mM, more preferably ≤ 0.05 mM, most preferably 0 mM
C17:1	≤ 0.1, more preferably ≤0.01 mM, most preferably 0 mM
C18:0	≤ 20 mM, more preferably ≤ 2.05 mM, most preferably 0 mM
C18:1n7	≤ 0.2 mM, more preferably ≤ 0.02 mM, most preferably 0 mM
C18:1n9c	≤ 8 mM, more preferably ≤ 0.8 mM, most preferably 0 mM
C18:1n9t	≤ 1.7 mM, more preferably ≤ 0.17 mM, most preferably 0 mM
C18:2n6c	≤ 4.2 mM, more preferably ≤ 042 mM, most preferably 0 mM
C18:2n6t	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C18:3n3	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C18:4n3	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C19:0	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C20:0	≤ 6 mM, more preferably ≤ 0.6 mM, most preferably 0 mM
C20:1n9	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM

Fatty Acid	Preferred range (mM)
C20:2n6	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C20:3n3	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C20:3n6	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C20:4n6	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C20:5n3	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C22:0	≤ 5.7 mM, more preferably ≤ 0.57 mM, most preferably 0 mM
C22:1n11	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C22:1n9	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM
C22:2n6	≤ 0.1 mM, more preferably ≤0.01 mM, most preferably 0 mM

It is also preferred that the overall fatty acid content of the composition is less than or equal to 20 mM, more preferably less than or equal to 15, 10, 5, 4, 3, 2 or 1 mM. It is more preferred that the composition is substantially free of fatty acids, more preferably free of fatty acids.

A fatty acid profile and a metal ion profile of an albumin formulation comprising 100 $g.L^{-1}$ albumin, ≤ 1 mM octanoate, 250 mM Na^+ and having a pH of about 6.5 are provided in Figures 9 and 10, respectively. These are particularly preferred profiles. The albumin composition may comply with one or both of the profiles of Fig 9 and Fig 10.

It is preferred that the cations are present from at least about 175 mM, for example from at least about 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 650, 700, 750, 800, 850, 900, 950, 1000 mM. Preferred maximum cation concentrations include 1000, 950, 900, 850, 800, 750, 700, 650, 600, 575, 550, 525, 500, 475, 450, 425, 400, 375, 350, 325, 300, 275 and 250 mM. Preferred cation concentrations include 200 to 500 mM. More preferred is a cation concentration of about 200 to 350 mM. Most preferred is a cation concentration of about 250 mM.

The pH of the composition may be between about 5.0 and about 9.0, for example from about 5.0, 5.25, 5.5, 5.75, 6.0, 6.25, 6.5, 6.75, 7.0, 7.25, 7.5, 7.75, 8.0, 8.25, or 8.5 to about 5.5, 5.75, 6.0, 6.25, 6.5, 6.75, 7.0, 7.25, 7.5, 7.75, 8.0, 8.25, 8.5, 8.75 or 9.0. It is preferred that pH is from about 5.0 to 8.0, such as from about 6.0 to about 8.0, more preferably from about 6.0 to about 7.0 or 6.0 to 6.5. Most preferred the pH is about 6.5.

The cations of the composition may be provided by any cation and may be provided by one or more (several) classes or species as described below. For example, the cations may be either mono or bivalent, monoatomic or polyatomic and may be provided by one or more

(several) of an alkali metal (such as sodium, potassium), an alkaline earth metal (such as calcium, magnesium) or ammonium. It is preferred that the cations are provided by sodium and/or potassium and/or magnesium, most preferably sodium or magnesium.

Cations may be provided by a salt of an inorganic acid (*e.g.* a group 1 or 2 metal or ammonium salt such as sodium chloride), a salt of a divalent acid (*e.g.* a group 1 or group 2 metal or ammonium sulphate or phosphate such as sodium sulphate) or a salt of an organic acid (*e.g.* a group 1 or group 2 metal or ammonium salt of acetate or citrate such as sodium acetate).

Cations and anions used to stabilize the albumin may be provided by (i) salts and/or (ii) pH buffers such as described herein. Therefore, there may be more than one (several) species of cation or anion, such as 2, or 3 species. There may be more than one (several) source of a single cation, for example Na which may be provided by both a pH buffer (such as sodium phosphate) and a salt (such as NaCl).

Anions useful to the invention include inorganic anions such as phosphate, and halides such as chloride, and organic anions such as acetate and citrate. Anions may be either mono or bivalent, monoatomic or polyatomic. Preferred anions include sulphate, acetate phosphate and chloride, particularly chloride, sulphate and acetate.

Therefore, the composition may comprise one or more (several) of an alkali metal phosphate or chloride (such as sodium phosphate, potassium phosphate, sodium chloride or potassium chloride), an alkaline earth metal phosphate (such as calcium phosphate, magnesium phosphate, calcium chloride, magnesium chloride) or ammonium phosphate or ammonium chloride.

The composition may have an overall ionic strength of at least 175 $mmol.L^{-1}$. For example, from about 175 to 1000 $mmol.L^{-1}$ such as from about 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 650, 700, 750, 800, 850, 900, 950, 1000 $mmol.L^{-1}$ to about 1000, 950, 900, 850, 800, 750, 700, 650, 600, 575, 550, 525, 500, 475, 450, 425, 400, 375, 350, 325, 300, 275, 250 $mmol.L^{-1}$. More preferred is an overall ionic strength of about 200 to 350 $mmol.L^{-1}$. Most preferred is an ionic strength of about 250 $mmol.L^{-1}$.

The inventors have realized that the presence of stabilizers such as detergents (*e.g.* polysorbate 80 ('Tween®')) can be deleterious to mammalian cells in cell culture. Therefore, it is preferred that the composition comprises less than 20 $mg.L^{-1}$ detergent (*e.g.* polysorbate 80), preferably less than 15, 10, 5, 4, 3, 2, 1, 0.5, 0.1, 0.01, 0.001 $mg.L^{-1}$ detergent (*e.g.* polysorbate 80). Even more preferably, the composition is substantially free of detergent (*e.g.* polysorbate

80). That is, it is preferred that the level of detergent (*e.g.* polysorbate 80) in the composition is not sufficient to cause a deleterious effect on cells during culture, for example mammalian cells (particularly stem cells such as human stem cells) in cell culture such as *in vitro* cell culture. Most preferably the composition is free of detergent (*e.g.* polysorbate 80). Detergent (*e.g.* polysorbate 80) levels can be assayed by techniques known to the skilled person for example, but not limited to, the assay disclosed in WO 2004/099234 (incorporated herein by reference).

For some cell media, it is preferred that the media is substantially free or free of tryptophan (*e.g.* tryptophan-free RPMI 1640 as disclosed by Lee *et al.*, 2002, *Immunology* 107(4): 452-460). An albumin composition may be added to a medium. Therefore, in order to maintain the tryptophan free character of a medium, an albumin composition which has low levels of amino acids (*e.g.* N-acetyl tryptophan), is substantially free of amino acids (*e.g.* N-acetyl tryptophan) or is free of amino acids (*e.g.* N-acetyl tryptophan) is useful. Therefore, it is preferred that the albumin composition comprises less than 5 mM amino acids (*e.g.* N-acetyl tryptophan), preferably less than 4, 3, 2, 1, 0.5, 0.1, 0.01, 0.005, 0.001 mM amino acids (*e.g.* N-acetyl tryptophan). Even more preferably, the composition is substantially free of amino acids (*e.g.* N-acetyl tryptophan). That is, it is preferred that the level of amino acids (*e.g.* N-acetyl tryptophan) in the composition is not sufficient to cause a deleterious effect on cells during culture, for example mammalian cells (particularly stem cells such as human stem cells) in cell culture such as *in vitro* cell culture. Most preferably the composition is free of amino acids (*e.g.* N-acetyl tryptophan).

It is even more preferred that the composition is substantially free of, or completely free of, octanoate, amino acids (*e.g.* N-acetyl tryptophan) and detergent (*e.g.* polysorbate 80).

In order to identify whether or not there is a deleterious or toxic effect of the albumin formulation on cell culture, a test may be carried out by preparing a first cell culture medium containing the albumin formulation of the invention and preparing one or more (several) control cell culture media and monitoring their effect on cell lines. A control cell culture medium is identical to the first cell culture medium except that the albumin formulation of the invention is replaced with another albumin formulation, *e.g.* an albumin formulation stabilized with octanoate, a detergent (*e.g.* polysorbate 80) and/or an amino acid (*e.g.* n-acetyl tryptophan). The test media and controls may be used to cultivate one or more (several) cell lines (*e.g.* a cell line as described herein) and the effect of the albumin on the cells monitored *e.g.* by monitoring cell growth, cell morphology and/or cell differentiation. It is preferred that the test is carried out over multiple passages of the cell line, *e.g.* at least 2, 3, 4, 5, 6, 7, 8, 9 or 10 passages. Suitable methods are known in the art. It is preferred that the albumin formulation of the present

invention is less toxic or deleterious to cells than an albumin stabilized with higher levels of octanoate, detergent or amino acids. For example, a medium comprising the albumin composition of the invention may show at least a 2-, 5-, 10-, 100-, 1000-, 10000-, or 100000-fold improvement over a control medium comprising another albumin formulation, *e.g.* an albumin formulation stabilized with octanoate, a detergent (*e.g.* polysorbate 80) and/or an amino acid (*e.g.* n-acetyl tryptophan). The 2, 5, 10, 100, 1000, 10000, or 100000-fold improvement may relate to viable cell numbers, correct or healthy cell morphology and/or to the number or relative number of differentiated cells, particularly cells showing differentiation to a desired cell class or type.

It is preferred that the stability of the albumin composition is higher than that of equivalent albumin in water or in 150 mM Na. One method to compare stability, particularly related to the formation of insoluble aggregates of albumin, is:

i) place an aliquot (*e.g.* 1 mL) of the albumin composition in a cuvette (*e.g.* a polystyrene cuvette, such as Sarstedt 10x4x45 mm);

ii) place the cuvette in a temperature controlled spectrophotometer that has been pre-equilibrated and controlled at a desired temperature, *e.g.* 65°C;

iii) Monitor / measure the absorbance of the composition at 350 nm, referenced against an empty cuvette over a desired time period (*e.g.* 2 hours) by taking a reading at defined intervals (*e.g.* every 18 seconds)

iv) Process the data by taking the first several (*e.g.* seven) data points, average the data point readings and subtract this data point from all data points in order to provide base absorbance values of around 0.

v) Determine and/or record the time taken for the processed absorbance values to increase by 0.1 AU (Absorbance Units) above this baseline.

It is preferred that stability analysis is performed in duplicate.

It is preferred that the stability of the albumin composition of the invention is sufficiently high so that the time taken for the measured absorbance to increase by 0.1 AU above the baseline (according to the above described test carried out at 65°C), compared to a control solution of albumin at the same concentration in a solvent such as 150 mM Na or water and measured under the same conditions is at least 10% better. It is more preferred that the stability is at least 20, 30, 40, 50, 60, 70, 80, 90 or 100% better.

An alternative or additional stability test, particularly for the formation of soluble aggregates of albumin, is to monitor the formation of soluble albumin polymer by GP-HPLC over time at a set temperature. One suitable stability study with measurement by GP HPLC includes:

i) Placing 10 mL sterilely (*e.g.* by filtration through a sterile 0.22 µm filter) of each sample to be investigated into sterile vials (*e.g.* baked 10 mL glass vials) which are then stoppered (*e.g.* with a sterile butyl rubber seal and optionally over-sealed).

ii) A T0 sample of ~200 µL is then taken and the vial is incubated at a specified temperature (*e.g.* placed in a water bath that is set at a specified temperature (*e.g.* at 40°C)).

iii) Samples (~200 µL) are then taken from each of the vials after certain time points (*e.g.* 14 days).

iv) injecting an aliquot (*e.g.* 25 µL) of the albumin sample taken out of the vial (at <50 mg/mL) onto a GP-HPLC column (*e.g.* 7.8mm id x 300 mm length TSK G3000SWXL column, (Tosoh Bioscience), with a 6.0 mm id x 40 mm length TSK SW guard column (Tosoh Bioscience));

v) chromatographing the aliquot in a suitable buffer (*e.g.* 25 mM sodium phosphate, 100 mM sodium sulphate, 0.05% (w/v) sodium azide, pH 7.0) at a suitable speed (*e.g.* 1 mL/min)

vi) monitoring the chromatograph procedure *e.g.* by UV detection at 280 nm;

vii) quantifying one or more (several), or all, of monomer, dimer, trimer and polymer content of the aliquot as % (w/w) by identifying their respective peak area relative to the total peak area.

It is preferred that the test is carried out in triplicate.

Therefore, the invention also provides an albumin composition having a stability as defined in one or both of the above mentioned tests, and a method for producing an albumin composition including one or both of the above mentioned tests.

Albumin has been described and characterized from a large number of mammals and birds (*e.g.* albumins listed in WO 2010/092135 (particularly Table 1) and PCT/EP11/055577 (particularly page 9 and SEQ ID NO: 2, 4-19 and 31), both incorporated herein by reference in their entirety).

The composition of the invention may comprise one or more (several) albumins. Preferably the composition comprises an albumin selected from human albumin (*e.g.* AAA98797 or P02768-1, SEQ ID NO: 2 (mature), SEQ ID NO: 3 (immature)), non-human primate albumin, (such as chimpanzee albumin (*e.g.* predicted sequence XP_517233.2 SEQ ID NO: 4), gorilla albumin or macaque albumin (*e.g.* NP_001182578, SEQ ID NO: 5), rodent albumin (such as hamster albumin (*e.g.* A6YF56, SEQ ID NO: 6), guinea pig albumin (*e.g.* Q6WDN9-1, SEQ ID NO: 7), mouse albumin (*e.g.* AAH49971 or P07724-1 Version 3, SEQ ID NO: 8, or the mature sequence SEQ ID NO: 19) and rat albumin (*e.g.* AAH85359 or P02770-1 Version 2, SEQ ID NO: 9))), bovine albumin (*e.g.* cow albumin P02769-1, SEQ ID NO: 10),

equine albumin such as horse albumin (*e.g.* P35747-1, SEQ ID NO: 11) or donkey albumin (*e.g.* Q5XLE4-1, SEQ ID NO: 12), rabbit albumin (*e.g.* P49065-1 Version 2, SEQ ID NO: 13), goat albumin (*e.g.* ACF10391, SEQ ID NO: 14), sheep albumin (*e.g.* P14639-1, SEQ ID NO: 15), dog albumin (*e.g.* P49822-1, SEQ ID NO: 16), chicken albumin (*e.g.* P19121-1 Version 2, SEQ ID NO: 17) and pig albumin (*e.g.* P08835-1 Version 2, SEQ ID NO: 18). Mature forms of albumin are particularly preferred and the skilled person is able to identify mature forms using publicly available information such as protein databanks and/or by using signal peptide recognition software such as SignalP (*e.g.*, SignalP (Nielsen *et al.*, 1997, *Protein Engineering* 10: 1-6)). SignalP Version 4.0 is preferred (Petersen *et al.*, 2011, *Nature Methods* (8): 785-786).

Human albumin as disclosed in SEQ ID NO: 2 or any naturally occurring allele thereof, is the preferred albumin of the albumin composition according to the invention. SEQ ID NO: 2 may be encoded by the nucleotide sequence of SEQ ID NO: 1.

The albumin, particularly the human albumin, may be a variant, or a derivative such as fusion of conjugation of an albumin or of an albumin variant. It is preferred that the albumin has at least 70% identity to HSA (SEQ ID NO: 2), more preferably at least 72, 73, 75, 80, 85, 90, 95, 96, 97, 98, 99, 99.5 % identity to HSA. The albumin variant may have one or more point (several) mutations, *e.g.* K573P, K573Y, K573W, K500A compared to a parent albumin such as those provided in the sequence listing, particularly SEQ ID NO: 2 (mutations are described in relation to SEQ ID NO: 2 and the skilled person can identify equivalent mutations in other albumins by aligning an albumin sequence against SEQ ID NO: 2 using the EMBOSS software described herein). For an albumin having about 70 to 80 % identity to SEQ ID NO: 2 (such as mouse albumin *e.g.* SEQ ID NO: 19), it is more preferred that the cation is present from at least 250 mM.

It is preferred that the albumin is present in the composition at a concentration of from about 1 $g.L^{-1}$ to about 400 $g.L^{-1}$. For example, the concentration may be from about 1, 5, 10, 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275 $g.L^{-1}$ to about 5, 10, 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375 or 400 $g.L^{-1}$. It is preferred that the concentration of albumin is from about 50 $g.L^{-1}$ to about 200 $g.L^{-1}$

Advantageously, the composition may comprise a recombinant albumin. That is, the albumin may be sourced from a recombinant organism such as a recombinant microorganism, recombinant plant or recombinant animal. Since some users prefer animal-free ingredients, it is more preferred that the albumin is sourced from a non-animal recombinant source, such as a recombinant microorganism or recombinant plant. Preferred microorganisms include prokaryotes and, more preferably, eukaryotes such as animals, plants, fungi or yeasts, for

example, but not limited to, the following species in which albumins have been successfully expressed as recombinant proteins:

- fungi (including but not limited to *Aspergillus* (WO 2006/066595), *Kluyveromyces* (Fleer, 1991, *Bio/technology* 9: 968-975), *Pichia* (Kobayashi, 1998, *Therapeutic Apheresis* 2: 257-262) and *Saccharomyces* (Sleep, 1990, *Bio/technology* 8: 42-46)), bacteria (Pandjaitab, 2000, *J. Allergy Clin. Immunol.* 105: 279-285)),
- animals (Barash, 1993, *Transgenic Research* 2: 266-276)
- plants (including but not limited to potato and tobacco (Sijmons, 1990, *Bio/technology* 8: 217 and Farran, 2002, *Transgenic Research* 11: 337-346) and rice *e.g. Oryza sativa*)
- mammalian cells such as CHO and HEK.

All citations are incorporated herein by reference in their entirety.

The albumin of the invention is preferably produced recombinantly in a suitable host cell. Non-animal host cells are preferred. A preferred host is yeast, preferably selected among *Pichia* or *Saccharomycacae*, more preferred *Saccharomyces cerevisiae*.

A preferred composition comprises 50 to 250 $g.L^{-1}$ albumin, 200 to 300 mM Na^+, 20 to 30 mM phosphate, comprises less than 2 mM octanoate and has a pH between about 6.0 and 7.0. A particularly preferred composition comprises 50 to 150 $g.L^{-1}$ albumin, 225 to 275 mM Na^+, 20 to 30 mM phosphate, comprises less than 1 mM octanoate and has a pH of about 6.5.

Another aspect of the invention provides a composition comprising albumin, a solvent, at least 175 mM cations, having a pH from about 5.0 to about 8.0 or 9.0. An advantage of such a composition is that this formulation provides an albumin which is sufficiently stable to have a useful shelf-life and is not deleterious to the health of mammalian cells when the composition is used in mammalian cell culture. Preferred parameters for the solvent, cations, ionic strength, and pH are the same as those disclosed in relation to the first aspect of the invention.

The albumin composition according to the invention may be provided in a flexible polymeric container, such as a bag. Suitable container volumes include from about 50 mL to about 10 000 mL, *e.g.* 50 mL, 1000 mL, 5000 mL and 10 000 mL. It is preferred that the container comprises one or more (several) inlets or outlets to allow filling of the container and/or dispensing from the bag. The albumin composition may be sterilized, *e.g.* prior to or after being filled in the container.

The production of recombinant albumin is known in the art and numerous hosts such as *Escherichia coli* (EP 73,646), yeast has been reported in WO 00/44772, EP 0683233 A2, and

US 5,612,196, and *Bacillus subtillis* (Saunders *et al.*, 1987, *J. Bacteriol.* 169: 2917-2925), Aspergillus. Production of albumin has been demonstrated in transgenic plants such as but not limited to tobacco, rice, and maize and in transgenic animals such as but not limited to chicken and bovine.

A second aspect of the invention provides a cell culture medium comprising a composition as described herein and a basal medium. The cell culture medium may, for example, be for the culture of mammalian cells such as human cells. The cell culture medium may, for example, be for the culture of stem cells or of gametes or of embryos for example cell culture for assisted reproductive technology (ART) purposes.

It is preferred that the cell culture medium is substantially free of animal-derived components. It is more preferred that the cell culture medium is free of animal-derived components. In this context, 'animal-derived' component means a component which has been obtained from an animal. It does not include a component which is identical or substantially identical to an animal-derived component but which, instead of being obtained from an animal, is obtained as a recombinant component from a non-animal. A non-animal includes a plant, such as rice, a microorganism such as a yeast or bacterium.

Examples of cell culture media in which the albumin formulation may be used include those described in WO 2008/009641 (incorporated herein by reference in its entirety).

A cell culture medium comprising the albumin formulation of the first aspect of the invention may or may not comprise one or more (several) fatty acids, such as provided by a fatty acid supplement. Fatty acid supplements are commercially available, *e.g.* F7050 Fatty Acid Supplement (Animal-component free, liquid, sterile-filtered, suitable for cell culture) available from Sigma-Aldrich.

A third aspect of the invention relates to use of an albumin formulation, composition or cell culture medium as described herein to culture cells, such as cells described with reference to the second aspect of the invention and or described below the fifth aspect of the invention.

A fourth aspect of the invention relates to a method of culturing cells comprising incubating cells in a culture medium as described herein. The cells may be the cells described with reference to the second aspect of the invention and or described below the fifth aspect of the invention.

A fifth aspect of the invention relates to use of the albumin formulation of the first aspect of the invention in pharmaceutical products. Therefore, the invention also provides a pharmaceutical composition comprising the albumin formulation and an active pharmaceutical ingredient (API).

A sixth aspect of the invention relates to the use of a high cation concentration to stabilize albumin, *e.g.* from at least 175 mM cations as described for the first aspect of the invention.

The compositions and media of the present invention may be used to culture a variety of cells. In one embodiment, the medium is used to culture eukaryotic cells such as plant and/or animal cells. The cells can be mammalian cells, fish cells, insect cells, amphibian cells or avian cells. The medium can be used to culture cells selected from the group consisting of MK2.7 cells, PER-C6 cells, NS0, GS-NS0, CHO cells, HEK 293 cells, COS cells and Sp2/0 cells.MK2.7 (ATCC Catalogue Number CRL 1909) is an anti-murine VCAM IgGl expressing Hybridoma cell line derived from the fusion of a rat splenocyte and a mouse Sp2/0 myeloma. MK2.7 is a non-adherent cell line that can be grown in serum-free media. Other types of cells can be selected from the group consisting of 5L8 hybridoma cells, Daudi cells, EL4 cells, HeLa cells, HL-60 cells, K562 cells, Jurkat cells, THP-1 cells, Sp2/0 cells; and/or the hybridoma cells listed in Table 2, WO 2005/070120 which is hereby incorporated by reference or any other cell type disclosed herein or known to one skilled in the art.

Preferred cells includes stem cells such as but not limited to, embryonic stem cells, fetal stem cells, adult stem cells and pleuripotent stem cells such as induced pleuripotent stem cells. Particularly preferred cells are human embryonic stem cells, human fetal stem cells, human adult stem cells and human pleuripotent stem cells such as induced human pleuripotent stem cells. The cell line may be derived from a blastocyst. The cell line may test positive for one or more (several) of the following cell markers: POU5F1 (OCT-4), SSEA-3, SSEA-4, TRA1-60, TRA1-81, ALPL, telomerase activity, and/or hES-Cellect™ (Cellartis AB, Gothenburg Sweden). The cell line may test negative for cell marker ALPL and/or SSEA-1. Particularly preferred cell lines include SA121 and SA181 (Cellartis AB, Gothenburg, Sweden).

Additional mammalian cell types can include, but are not limited to, including primary epithelial cells (*e.g.* keratinocytes, cervical epithelial cells, bronchial epithelial cells, tracheal epithelial cells, kidney epithelial cells and retinal epithelial cells) and established cell lines and their strains (*e.g.*, 293 embryonic kidney cells, BHK cells, HeLa cervical epithelial cells and

PER-C6 retinal cells, MDBK (NBL-1) cells, 91 1 cells, CRFK cells, MDCK cells, CHO cells, BeWo cells, Chang cells, Detroit 562 cells, HeLa 229 cells, HeLa S3 cells, Hep-2 cells, KB cells, LS 180 cells, LS 174T cells, NCI-H-548 cells, RPMI2650 cells, SW-13 cells, T24 cells, WI-28 VA13, 2RA cells, WISH cells, BS-C-I cells, LLC-PK.sub.2 cells, Clone M-3 cells, 1-10 cells, RAG cells, TCMK-1 cells, Y-1 cells, LLC-PK.sub.1 cells, PK(15) cells, GH.1 cells, GH3 cells, L2 cells, LLC-RC 256 cells, MH.sub.IC1 cells, XC cells, MDOK cells, VSW cells, and TH-I, B1 cells, or derivatives thereof), fibroblast cells from any tissue or organ (including but not limited to heart, liver, kidney, colon, intestines, esophagus, stomach, neural tissue (brain, spinal cord), lung, vascular tissue (artery, vein, capillary), lymphoid tissue (lymph gland, adenoid, tonsil, bone marrow, and blood), spleen, and fibroblast and fibroblast-like cell lines (*e.g.*, CHO cells, TRG-2 cells, IMR-33 cells, Don cells, GHK-2 1 cells, citrullinemia cells, Dempsey cells, Detroit 551 cells, Detroit 510 cells, Detroit 525 cells, Detroit 529 cells, Detroit 532 cells, Detroit 539 cells, Detroit 548 cells, Detroit 573 cells, HEL 299 cells, IMR-90 cells, MRC-5 cells, WI-38 cells, WI-26 cells, MiCl.sub.1 cells, CHO cells, CV-1 cells, COS-1 cells, COS-3 cells, COS-7 cells, Vero cells, DBS-FrhL-2 cells, BALB/3T3 cells, F9 cells, SV-T2 cells, M-MSV-BALB/3T3 cells, K-BALB cells, BLO-11 cells, NOR-10 cells, C3H/IOTI/2 cells, HSDM.sub.IC3 cells, KLN205 cells, McCoy cells, Mouse L cells, Strain 2071 (Mouse L) cells, L-M strain (Mouse L) cells, L-MTK (Mouse L) cells, NCTC clones 2472 and 2555, SCC-PSA1 cells, Swiss/3T3 cells, Indian muntjac cells, SIRC cells, CII cells, and Jensen cells, or derivatives thereof).

Cells include cancer cells such, but not limited to, the following cancer cell lines: human myeloma (*e.g.*, KMM-1, KMS-11, KMS-12-PE, KMS-12-BM, KMS-18, KMS-20, KMS-21-PE, U266, RPMI8226); human breast cancer (*e.g.*, KPL-1, KPL-4, MDA-MB-231, MCF-7, KPL-3C, T47D, SkBr3, HS578T, MDA4355, Hs 606 (CRL-7368), Hs 605.T (CRL-7365) HS 742.T (CRL-7482), BT-474, HBL-100, HCC202, HCC1419, HCC1954, MCF7, MDA-361 MDA-436, MDA-453, SK-BR-3, ZR-75-30, UACC-732, UACC-812, UACC-893, UACC-3133, MX-1 and EFM-192A); ductal (breast) carcinoma (*e.g.*, HS 57HT (HTB-126), HCC1008 (CRL-2320), HCC1954 (CRL-2338; HCC38 (CRL-2314), HCC1143 (CRL-2321), HCC1187 (CRL-2322), HCC1295 (CRL-2324), HCC1599 (CRL-2331), HCC1937 (CRL-2336), HCC2157 (CRL-2340), HCC2218 (CRL-2343), Hs574.T (CRL-7345), Hs 742.T (CRL-7482); skin cancer (*e.g.*, COLO 829 (CRL-1974), TE 354.T (CRL-7762), Hs 925.T (CIU-7677)); human prostate cancer (*e.g.*, MDA PCa 2a and MDA PCa 2b); bone cancer (*e.g.*, Hs 919.T (CRL-7672), Hs 821.T (CRL-7554), Hs 820.T (CRL-7552)y HS 704.T (CRL-7444), HS 707(A).T (CRL-7448), HS 735.T (CRL-7471), HS 860.T (CRL-7595)y HS 888.T.(CRL-7622); HS 889.T (CRL-7626); HS 890.T (CRL-7628), Hs 709.T (CRL-7453)); human lymphoma (*e.g.*, K562); human cervical carcinoma (*e.g.*, HeLA); lung

carcinoma cell lines (*e.g.*, H125, H522, H1299, NCI-H2126 (ATCC CCL-256), NCI-H1672 (ATCC CRL-5886), NCI-2171 (CRL-5929); NCI-H2195 (CRL05931); lung adenocarcinoma (*e.g.*, NCI-H1395 (CRL-5856), NCI-H1437 (CRL-5872), NCI-H2009 (CRL-5911), NCI-H2122 (CRL-5985), NCI-H2087 (CRL-5922); metastatic lung cancer (*e.g.*, bone) (*e.g.*, NCI-H209 (HTB-172); colon carcinoma cell lines (*e.g.*, LN235, DLD2, Colon A, LIM2537, LIM1215, LIM1863, LIM1899, LIM2405, LIM2412, SK-CO1 (ATCC HTB-77), HT29 (ATCC HTB38), LoVo (ATCC CCL-229), SW1222 (ATCC HB-11028), and SW480 (ATCC CCL-228); ovarian cancer (*e.g.*, OVCAR-3 (ATCC HTB-161) and SKOV-3 (ATCC HTB-77); mesothelioma (*e.g.*, NCI-h2052 (CRL-5915); neuroendocrine carcinoma (*e.g.*, HCI-H1770 (*e.g.*, CRL-5893); gastric cancer (*e.g.*, LIM1839); glioma (*e.g.*, T98, U251, LN235); head and neck squamous cell carcinoma cell lines (*e.g.*, SCC4, SCC9 and SCC25); medulloblastoma (*e.g.*, Daoy, D283 Med and D341 Med); testicular non-seminoma (*e.g.*, TERA1); prostate cancer (*e.g.*, 178-2BMA, Du145, LNCaP, and PC-3). Other cancer cell lines are well known in the art.

The media disclosed herein can be used to culture cells in suspension or adherent cells. The media of the present invention are suitable for adherent, monolayer or suspension culture, transfection, and/or cultivation of cells, and for expression of proteins or antibodies in cells in monolayer or suspension culture.

Cell culture can be performed using various culture devices, for example, a fermenter type tank culture device, an air lift type culture device, a culture flask type culture device, a spinner flask type culture device, a microcarrier type culture device, a fluidized bed type culture device, a hollow fiber type culture device, a roller bottle type culture device, a packed bed type culture device or any other suitable device known to one skilled in the art.

The present invention is further described by the following examples that should not be construed as limiting the scope of the invention.

Examples

Example 1: Effect of n-acetyl-tryptophan, phosphate concentration and sodium concentration on the stability of albumin.

Aim: Previous work indicated that monitoring the formation of insoluble aggregates at 65°C, through an increase in absorption at 350 nm, is a valid method for screening of the effect of different formulation (composition) parameters on the stability of albumin. Since octanoate and polysorbate 80 appear to be detrimental to stem cell growth, it is preferred that an albumin formulation is substantially free of these components. This Example analyzes the effect of pH,

sodium ion and buffer concentration on the stability of albumin. A common stabilizer for albumin is n-acetyl-tryptophan, therefore it is included in this Example as a test constituent.

Method: Albumin at 100 mg/mL in 145 mM NaCl (albumin batch 1401) was diluted to 10 mg/mL according to Table 3. The buffers used for dilution are shown in Tables 1 and 2.

Table 1	rHSA Conc (g/L)	Na Molarity (mM)	Tryptophan Molarity (mM)
rHSA solution (1401)	100	154	
5 M NaCl		5000	
Tryptophan		501	500

Table 2

Buffer Stock Solution	Phosphate (mM)	Na (mM)
0.5 M Phosphate pH 4	502	500
0.5 M Phosphate pH 5	500	518
0.5 M Phosphate pH 6	500	634
0.5 M Phosphate pH 7	500	851
0.5 M Phosphate pH 8	500	970
0.5 M Phosphate pH 9	500	992

Table 3	Stock Volumes to Add (mL)					
Sample	**rHSA**	**Sodium Phosphate**	**NaCl**	**Tryptophan**	**Water**	**Actual pH**
pH 4, 145 mM Sodium, 50 mM Phosphate	0.500	0.498	0.080	0.000	3.922	4.06
pH 5, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.078	0.000	3.922	5.03
pH 6, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.066	0.000	3.934	6.03
pH 7, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.045	0.000	3.956	7.04
pH 8, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.033	0.000	3.967	7.90
pH 9, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.030	0.000	3.970	8.84
pH 5.5, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.078	0.000	3.922	5.49
pH 6, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.066	0.000	3.934	5.97
pH 6.5, 145 mM Sodium, 50 mM Phosphate	0.500	0.500	0.066	0.000	3.934	6.48
pH 4, 145 mM Sodium, 50 mM Phosphate, 5 mM Tryptophan	0.500	0.498	0.075	0.050	3.877	3.98
pH 5, 145 mM Sodium, 50 mM Phosphate, 5 mM Tryptophan	0.500	0.500	0.073	0.050	3.877	5.00
pH 6, 145 mM Sodium, 50 mM Phosphate, 5 mM Tryptophan	0.500	0.500	0.061	0.050	3.889	6.00
pH 7, 145 mM Sodium, 50 mM Phosphate, 5 mM Tryptophan	0.500	0.500	0.039	0.050	3.911	7.08

Table 3	Stock Volumes to Add (mL)					
Sample	**rHSA**	**Sodium Phosphate**	**NaCl**	**Tryptophan**	**Water**	**Actual pH**
pH 8, 145 mM Sodium, 50 mM Phosphate, 5 mM Tryptophan	0.500	0.500	0.028	0.050	3.922	8.01
pH 9, 145 mM Sodium, 50 mM Phosphate, 5 mM Tryptophan	0.500	0.500	0.025	0.050	3.925	9.09
pH 4, 145 mM Sodium, 50 mM Phosphate, 2 mM Tryptophan	0.500	0.498	0.078	0.020	3.904	4.06
pH 5, 145 mM Sodium, 50 mM Phosphate, 2 mM Tryptophan	0.500	0.500	0.076	0.020	3.904	5.01
pH 6, 145 mM Sodium, 50 mM Phosphate, 2 mM Tryptophan	0.500	0.500	0.064	0.020	3.916	6.06
pH 7, 145 mM Sodium, 50 mM Phosphate, 2 mM Tryptophan	0.500	0.500	0.042	0.020	3.938	7.01
pH 8, 145 mM Sodium, 50 mM Phosphate, 2 mM Tryptophan	0.500	0.500	0.031	0.020	3.949	7.99
pH 9, 145 mM Sodium, 50 mM Phosphate, 2 mM Tryptophan	0.500	0.500	0.028	0.020	3.952	9.03
pH 4, 50 mM Sodium, 25 mM Phosphate	0.500	0.249	0.010	0.000	4.241	4.03
pH 5, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.009	0.000	4.241	5.02
pH 6, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.003	0.000	4.247	5.82

Table 3	Stock Volumes to Add (mL)					
Sample	**rHSA**	**Sodium Phosphate**	**NaCl**	**Tryptophan**	**Water**	**Actual pH**
pH 7, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.000	0.000	4.250	7.05
pH 8, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.000	0.000	4.250	7.97
pH 9, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.000	0.000	4.250	8.88
pH 5.5, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.009	0.000	4.241	5.48
pH 6, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.003	0.000	4.247	6.18
pH 6.5, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.003	0.000	4.247	6.60
pH 4, 300 mM Sodium, 25 mM Phosphate	0.500	0.249	0.260	0.000	3.991	4.03
pH 5, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.259	0.000	3.991	5.06
pH 6, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.253	0.000	3.997	6.06
pH 7, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.242	0.000	4.008	6.99
pH 8, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.236	0.000	4.014	8.02
pH 9, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.235	0.000	4.015	9.00
pH 5.5, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.259	0.000	3.991	5.61
pH 6, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.253	0.000	3.997	6.19
pH 6.5, 300 mM Sodium, 25 mM Phosphate	0.500	0.250	0.253	0.000	3.997	6.61

Table 3	Stock Volumes to Add (mL)					
Sample	**rHSA**	**Sodium Phosphate**	**NaCl**	**Tryptophan**	**Water**	**Actual pH**
pH 4, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	4.05
pH 5, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	5.02
pH 6, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	5.99
pH 7, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	6.97
pH 8, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	8.02
pH 9, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	9.02
pH 5.5, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	5.47
pH 6, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	6.30
pH 6.5, 145 mM Sodium, 0 mM Phosphate	0.500	0.000	0.130	0.000	4.370	6.65
pH 4, 145 mM Sodium, 100 mM Phosphate	0.500	0.996	0.030	0.000	3.474	3.98
pH 5, 145 mM Sodium, 100 mM Phosphate	0.500	1.000	0.026	0.000	3.474	4.91
pH 6, 145 mM Sodium, 100 mM Phosphate	0.500	0.999	0.003	0.000	3.498	5.98
pH 7, 145 mM Sodium, 100 mM Phosphate	0.500	1.000	-0.041	0.000	3.541	7.03
pH 8, 145 mM Sodium, 100 mM Phosphate	0.500	1.000	-0.064	0.000	3.564	8.10
pH 9, 145 mM Sodium, 100 mM Phosphate	0.500	0.999	-0.069	0.000	3.569	9.03

Table 3	Stock Volumes to Add (mL)					
Sample	**rHSA**	**Sodium Phosphate**	**NaCl**	**Tryptophan**	**Water**	**Actual pH**
pH 5.5, 145 mM Sodium, 100 mM Phosphate	0.500	0.999	0.026	0.000	3.474	5.58
pH 6, 145 mM Sodium, 100 mM Phosphate	0.500	0.999	0.003	0.000	3.498	6.22
pH 6.5, 145 mM Sodium, 100 mM Phosphate	0.500	0.999	0.003	0.000	3.498	6.60

Once diluted the samples were adjusted to their target pH with 1 M HCl, the volume of which was insignificant and does not alter the final albumin or constituent concentrations. An aliquot (1 mL) of the resulting solution was then placed in a polystyrene cuvette (Sarstedt 10x4x45 mm). The cuvette was then placed into a temperature controlled spectrophotometer that had been pre-equilibrated and controlled at 65°C. The absorbance at 350 nm, referenced against an empty cuvette, was then monitored over a 2 hour period with a reading being taken every 18 seconds. The data were processed by taking the first 7 data points, averaging them (calculating the mean) and then subtracting this from all data points in order to give base absorbance values of around 0. The time taken for this absorbance to then increase by 0.1 AU (Absorbance Units) above this baseline was then recorded for that particular formulation sample. Each formulation sample was performed in duplicate and the time for the absorbance to increase by 0.1 AU for each replicate averaged.

Results: The processed data with the time for each sample to increase by 0.1 AU, were plotted for time for absorbance increase against pH for each of the formulation constituents tested; n-acetyl-tryptophan, phosphate concentration and sodium concentration. Values above 7200 sec were extrapolated. The data are presented in Figs 1 (pH and n-acetyl tryptophan), 2 (pH and phosphate) and 3 (pH and sodium).

Conclusions:

- For all the data, except for 50 mM sodium, the optimum pH was between pH 6 and 7. For 50 mM sodium, although insoluble aggregates were not forming, it is possible that high levels of soluble oligomers were being generated and these were not coalescing to form insoluble aggregates. Soluble aggregates can be identified by GP-HPLC.

- For the phosphate buffer concentration, there was no significant difference between 50 and 100 mM. However, 0 mM phosphate did appear to be slightly more stable between pH 6 to 8. Although using no phosphate would be best in terms of stability, the use of a buffer aids pH control, for example because it reduces or eliminates the requirement to pH-adjust an albumin prior to formulation.
- Increasing sodium levels had a significant effect on stability with a large increase in stability between 145 and 300 mM sodium.

Example 2: Effect of increasing sodium concentration on albumin stability.

Aim: Example 1 indicated that increased levels of sodium had a beneficial effect on albumin stability. To investigate this further, increasing concentrations of sodium over a wider range than in Example 1 at the optimum pH range were investigated.

Method: Albumin at 100 mg/mL in 145 mM NaCl (albumin batch 1401) was diluted to 10 mg/mL according to the Table 6. The buffers used for dilution are shown in Tables 4 and 5.

Table 4	**rHSA Conc (g/L)**	**Na Molarity (mM)**	**Tryptophan Molarity (mM)**
rHSA solution (1401)	100	154	-
5 M NaCl	-	5000	-
Tryptophan	-	501	500

Table 5

Buffer Stock Solution	**Phosphate (mM)**	**Na (mM)**
0.5 M Phosphate pH 4	502	500
0.5 M Phosphate pH 5	500	518
0.5 M Phosphate pH 6	500	634
0.5 M Phosphate pH 7	500	851
0.5 M Phosphate pH 8	500	970
0.5 M Phosphate pH 9	500	992

Table 6:	Stock Volumes to Add (mL)			
Sample	**rHSA**	**Sodium Phosphate**	**NaCl**	**Water**
pH 6.5, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.003	4.247
pH 6.5, 100 mM Sodium, 25 mM Phosphate	0.500	0.250	0.053	4.197
pH 6.5, 150 mM Sodium, 25 mM Phosphate	0.500	0.250	0.103	4.147
pH 6.5, 200 mM Sodium, 25 mM Phosphate	0.500	0.250	0.153	4.097
pH 6.5, 250 mM Sodium, 25 mM Phosphate	0.500	0.250	0.203	4.047
pH 6.5, 400 mM Sodium, 25 mM Phosphate	0.500	0.250	0.353	3.897
pH 6.0, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.003	4.247
pH 6.0, 100 mM Sodium, 25 mM Phosphate	0.500	0.250	0.053	4.197
pH 6.0, 150 mM Sodium, 25 mM Phosphate	0.500	0.250	0.103	4.147
pH 6.0, 200 mM Sodium, 25 mM Phosphate	0.500	0.250	0.153	4.097
pH 6.0, 250 mM Sodium, 25 mM Phosphate	0.500	0.250	0.203	4.047
pH 6.0, 400 mM Sodium, 25 mM Phosphate	0.500	0.250	0.353	3.897
pH 7.0, 50 mM Sodium, 25 mM Phosphate	0.500	0.250	0.000	4.250
pH 7.0, 100 mM Sodium, 25 mM Phosphate	0.500	0.250	0.042	4.208
pH 7.0, 150 mM Sodium, 25 mM Phosphate	0.500	0.250	0.092	4.158
pH 7.0, 200 mM Sodium, 25 mM Phosphate	0.500	0.250	0.142	4.108
pH 7.0, 250 mM Sodium, 25 mM Phosphate	0.500	0.250	0.192	4.058
pH 7.0, 400 mM Sodium, 25 mM Phosphate	0.500	0.250	0.342	3.908

The dilution was performed by first mixing the albumin and buffer as a bulk and then adjusting it to the correct pH by the addition of 1 M HCl. This was then divided and water and 5 M NaCl added as appropriate. This ensured that all samples were at exactly the same pH. An aliquot (1 mL) of the resulting solution was then placed in a polystyrene cuvette (Sarstedt 10x4x45 mm). The cuvette was then placed into a temperature controlled spectrophotometer that had been pre-equilibrated and controlled at 65°C. The absorbance at 350 nm, referenced against an empty cuvette, was then monitored over a 2 hour period with a reading being taken every 18 seconds. The data were processed by taking the first 7 data points, averaging them (calculating the mean) and then subtracting this from all data points in order to give base absorbance values of around 0. The time taken for this absorbance to then increase by 0.1 AU above this baseline was then recorded for that particular formulation sample. Each formulation

sample was performed in duplicate and the time for the absorbance to increase by 0.1 AU for each replicate averaged.

Results: The processed data with the time for each sample to increase by 0.1 AU, were plotted for time for absorbance increase against Na concentration for each pH. Values above 7200 sec were extrapolated. The data are shown in Fig. 4.

Conclusion:

- Consistent with Example 1, increasing levels of sodium increased albumin stability. This was particularly the case around 200 mM where there was a sudden increase in stability. This was the case for all pHs, although it was less obvious at pH 6 since even at <200 mM increasing salt was still having a beneficial effect. The fact that the increase was around 200 mM maybe the reason that it has not been observed previously, since most other albumin formulations are 150 mM or lower in order to keep them approximately physiological. For an albumin used in cell culture media, this should not be an issue as the albumin will be diluted down into the media and the overall salt concentration of the media will be suitable for cell culture.
- pH 6 was slightly better than pH 6.5, both being significantly better than pH 7.

Example 3: Effect of sodium concentration on the stability of different concentrations of albumin.

Aim: Example 2 shows that sodium concentration is important to stability of albumin. Example 2 was done at an albumin concentration of 10 mg/mL. In order to confirm that this effect is also true at higher concentrations the effect of sodium at higher albumin concentrations was investigated.

Method: Albumin at 100 mg/mL in 145 mM NaCl (albumin batch 1401) was diluted to 50 or 90 mg/mL according to Table 9. The buffers used for dilution are shown in Tables 7 and 8.

Table 7	rHSA Conc (g/L)	Na Molarity (mM)	Tryptophan Molarity (mM)
rHSA solution (1401)	100	154	-
5 M NaCl	-	5000	-
Tryptophan	-	501	500

Table 8

Buffer Stock Solution	Phosphate (mM)	Na (mM)
0.5 M Phosphate pH 4	502	500
0.5 M Phosphate pH 5	500	518
0.5 M Phosphate pH 6	500	634
0.5 M Phosphate pH 7	500	851
0.5 M Phosphate pH 8	500	970
0.5 M Phosphate pH 9	500	992

Table 9	Sample rHSA conc (mg/mL)	Stock Volumes to Add (mL)			
Sample		rHSA	Sodium Phosphate	NaCl	H_2O
pH 6.5, 100 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.000	1.350
pH 6.5, 150 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.025	1.325
pH 6.5, 200 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.055	1.295
pH 6.5, 250 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.085	1.265
pH 6.5, 300 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.115	1.235
pH 6.5, 400 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.175	1.175
pH 6.0, 200 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.055	1.295
pH 6.0, 250 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.085	1.265
pH 6.0, 300 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.115	1.235
pH 7.0, 200 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.048	1.302
pH 7.0, 250 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.078	1.272
pH 7.0, 300 mM Sodium, 25 mM Phosphate	50	1.500	0.150	0.108	1.242
pH 6.5, 200 mM Sodium, 25 mM Phosphate	90	2.700	0.150	0.018	0.132
pH 6.5, 250 mM Sodium, 25 mM Phosphate	90	2.700	0.150	0.048	0.102
pH 6.5, 300 mM Sodium, 25 mM Phosphate	90	2.700	0.150	0.078	0.072
pH 6.5, 300 mM Sodium, 25 mM Phosphate	90	2.700	0.150	0.078	0.072
pH 6.5, 350 mM Sodium, 25 mM Phosphate	90	2.700	0.150	0.108	0.042
pH 6.5, 400 mM Sodium, 25 mM Phosphate	90	2.700	0.150	0.138	0.012

The dilution was performed by first mixing the albumin and buffer as a bulk and then adjusting it to the correct pH by the addition of 1 M HCl. This was then divided and water and 5 M NaCl added as appropriate. This ensured that all samples were at exactly the same pH.

An aliquot (1 mL) of the resulting solution was then placed in a polystyrene cuvette (Sarstedt 10x4x45 mm). The cuvette was then placed into a temperature controlled spectrophotometer that had been pre-equilibrated and controlled at 65°C. The absorbance at 350 nm, referenced against an empty cuvette, was then monitored over a 2 hour period with a reading being taken every 18 seconds. The data were processed by taking the first 7 data points, averaging them (calculating the mean) and then subtracting this from all data points in order to give base absorbance values of around 0. The time taken for this absorbance to then increase by 0.1 AU above this baseline was then recorded for that particular formulation sample. Each formulation sample was performed in duplicate and the time for the absorbance to increase by 0.1 AU for each replicate averaged.

Results: The processed data with the time for each sample to increase by 0.1 AU were plotted for time for absorbance increase against Na concentration for each pH (6.0, 6.5 and 7.0) at 50 mg/mL albumin and then for 3 different albumin concentrations (10, 50 and 90 mg/mL) at pH 6.5. The data are shown in Figs 5 and 6.

Conclusions:

- At 50 mg/mL albumin the trend of increasing sodium concentration improving albumin stability was confirmed at all 3 pHs. In this instance pH 6.5 was the best.
- At pH 6.5, the trend of increased sodium improving stability was again confirmed at all albumin concentrations. The trend was not as pronounced at 90 g/L, but it was still the case that sodium concentrations above 200 mM significantly improved the albumin stability.

Example 4: Effect of sodium concentration on the production of soluble aggregates in albumin.

Aim: Examples 1 to 3 show, using the formulation screening assay that measures insoluble aggregates, that increasing sodium concentrations improved albumin stability. In order to look at soluble aggregates (albumin polymer) GP-HPLC needs to be used as the measurement tool with polymer formation monitored in an accelerated stability trial at 40°C over a 2 week period. The tests were carried out at pH 6.5 because this was shown, by Examples 1 to 3, to be a preferred pH. A control of albumin in previous formulation conditions (pH 8.6, 150 mM Na) was

also used to confirm that a new formulation would be significantly beneficial. The actual albumin concentration was 90 mg/mL instead of the anticipated 100 mg/mL as this was the highest that could be used allowing for dilution into the various formulations. However, it is thought that observed trends at this slightly lower concentration will be the same at higher albumin concentrations.

Method: Albumin at 100 mg/mL in 145 mM NaCl (albumin batch 1401) was diluted to 90 mg/mL according to Table 12. The buffers used for dilution are shown in Tables 10 and 11.

Table 10	**rHSA Conc (g/L)**	**Na Molarity (mM)**
rHSA solution (1401)	100	154
5 M NaCl	-	5000

Table 11

Buffer Stock Solution	**Make up Vol (mL)**	**$NaH_2PO_4.2H_2O$ (g)**	**27% NaOH (mL)***	**Phosphate (mM)**	**Na (mM)**
0.5 M Phosphate pH 6	250	19.51	3.8	500	634

*27% w/w NaOH density = 1.3

Table 12	**Stock Volumes to Add (mL)**			
Sample	**rHSA**	**Sodium Phosphate**	**NaCl**	**H_2O**
pH 8.6, 150 mM Sodium	9.0	0.000	0.023	0.977
pH 6.5, 150 mM Sodium, 25 mM Phosphate	9.0	0.500	0.000	0.500
pH 6.5, 200 mM Sodium, 25 mM Phosphate	9.0	0.500	0.059	0.441
pH 6.5, 250 mM Sodium, 25 mM Phosphate	9.0	0.500	0.159	0.341
pH 6.5, 300 mM Sodium, 25 mM Phosphate	9.0	0.500	0.259	0.241
pH 6.5, 350 mM Sodium, 25 mM Phosphate	9.0	0.500	0.359	0.141

The dilution was performed by first mixing the albumin and buffer as a bulk and then adjusting it to the correct pH by the addition of 1 M HCl. This was then divided into appropriate

sized aliquots and water and 5 M NaCl added as required. This ensured that all samples were at exactly the same pH.

10 mL of each sample was then sterile filtered into a baked 10 mL glass vial stopped with a sterile butyl rubber seal and then over-sealed. A T0 sample of ~200 µL was then taken and the vial placed in a water bath that was set at 40°C. Samples (~200 µL) were then taken from each of the vials after 14 days, diluted 2 fold and injected in triplicate on the GP-HPLC system.

The GP-HPLC system was run, by injecting (25 µL) onto a 7.8 mm id x 300 mm length TSK G3000SW$_{XL}$ column (Tosoh Bioscience), with a 6.0 mm id x 40 mm length TSK SW guard column (Tosoh Bioscience). Samples were chromatographed in 25 mM sodium phosphate, 100 mM sodium sulphate, 0.05% (w/v) sodium azide, pH 7.0 at 1 mL/min and monitored by UV detection at 280 nm. Monomer, dimer, trimer and polymer content were quantified as % w/w by their respective peak area relative to the total peak area. Results from the triplicate injections were averaged to get a mean result for each sample.

Results: The data for the 14 day time point for monomer (Fig. 7) and polymer (Fig. 8) were plotted against sodium concentration.

Conclusions:

- The formulation at pH 6.5 was significantly better than that at pH 8.6 used for albumin batch 1401. The level of polymer significantly increased at pH 8.6, rising to approximately 20% after 2 weeks at 40°C compared to ~2% for the same sodium concentration at pH 6.5.
- The proposed trend of increasing sodium increasing albumin stability observed with the screening assay is confirmed here for soluble aggregates with a significant trend of reduced polymer formation with increasing sodium concentration. Going from 150 mM, a standard albumin concentration due to it being close to physiological conditions, to 200 mM sodium the level of polymer decreases by >2 fold with then a further decrease of ~2 fold going from 200 to 250 mM. Although the polymer decreases even further with higher salt concentrations up to 350 mM (and potentially beyond) the rate of decrease is slower. These results are matched in an increase in monomer remaining with increased sodium. Overall there is a > 4 fold decrease in polymer formation going from 150 to 250 mM sodium. Consequently, a preferred albumin formulation is 25 mM phosphate buffer pH 6.5, 250 mM sodium. The phosphate is present to aid pH control. Notably, sodium will come from both sodium chloride and sodium phosphate

(including any NaOH used to ensure the pH of the phosphate is correct) and therefore the buffer is not 250 mM NaCl.

- Although this work has all been performed with sodium, similar monovalent or bivalent metal ions are expected to have a similar effect. However, sodium is a preferred metal ion because it is known to be compatible with stem cell culture.

Example 5: Effect of albumin concentration and sodium ion concentration on stability of albumin

Method: A sample of purified albumin containing low octanoate (~0.2 mM octanotae, 100 g/L albumin) was diafiltered against a minimum of 10 continuous volumes of 25 mM phosphate, 50 mM sodium pH 6.5 and then concentrated to 338 g/L using a 10 KDa Pall Omega crossflow UF to generate a 50 mM sodium starting material. The sample was then diluted with water, 5 M NaCl and 0.5 M sodium phosphate pH 6.5 as shown in Table 13:

Table 13	**Sample details**		**Volume of stock required (mL)**			
Sample	**rHSA (mg/mL)**	**Na^+ (mM)**	**rHSA (338 g/L)**	**Sodium Phosphate (0.5 M, pH 6.5)**	**NaCl (5 M)**	**Water**
1	100	50	1.78	0.21	0.01	4.00
2	100	100	1.78	0.21	0.07	3.94
3	100	150	1.78	0.21	0.13	3.88
4	100	200	1.78	0.21	0.19	3.82
5	100	250	1.78	0.21	0.25	3.76
6	100	300	1.78	0.21	0.31	3.70
7	100	400	1.78	0.21	0.43	3.58
8	100	500	1.78	0.21	0.55	3.46
9	150	50	2.67	0.17	0.01	3.16
10	150	100	2.67	0.17	0.07	3.10
11	150	150	2.67	0.17	0.13	3.04
12	150	200	2.67	0.17	0.19	2.98
13	150	250	2.67	0.17	0.25	2.92
14	150	300	2.67	0.17	0.31	2.86
15	150	400	2.67	0.17	0.43	2.74
16	150	500	2.67	0.17	0.55	2.62

Table 13	Sample details		Volume of stock required (mL)			
Sample	rHSA (mg/mL)	Na^+ (mM)	rHSA (338 g/L)	Sodium Phosphate (0.5 M, pH 6.5)	NaCl (5 M)	Water
17	200	50	3.56	0.12	0.01	2.32
18	200	100	3.56	0.12	0.07	2.26
19	200	150	3.56	0.12	0.13	2.20
20	200	200	3.56	0.12	0.19	2.14
21	200	250	3.56	0.12	0.25	2.08
22	200	300	3.56	0.12	0.31	2.02
23	200	400	3.56	0.12	0.43	1.90
24	200	500	3.56	0.12	0.55	1.78
25	250	50	4.44	0.08	0.00	1.47
26	250	100	4.44	0.08	0.06	1.41
27	250	150	4.44	0.08	0.12	1.35
28	250	200	4.44	0.08	0.18	1.29
29	250	250	4.44	0.08	0.24	1.23
30	250	300	4.44	0.08	0.30	1.17
31	250	400	4.44	0.08	0.42	1.05
32	250	500	4.44	0.08	0.54	0.93

The samples were then aseptically filtered (0.22 µm filter) into sterile 5 mL glass vials and the vials placed in a 40°C incubator for 4 weeks. An aliquot from each sample was taken out at intervals, diluted to 40 g/L with water and assayed for soluble aggregates by GP-HPLC as per Example 4.

Results: Figure 11 shows monomer levels after a 4 week incubation. A higher monomer content shows better stability.

Conclusions:

- All points follow a trend apart from the 150 g/L albumin, 100 mM sodium sample. It is unclear why this sample is out of trend but is likely to be an outlier and does not detract from the overall conclusions of the experiment.

- For all albumin concentrations tested, there is a clear correlation of increasing monomer content *i.e.* increasing stability with increasing sodium content.
- The majority of the improved stability comes with increasing the sodium ion concentration up to ~200 mM. Above this concentration, although there is some further increase in stability it has mostly levelled off. Consequently the optimum sodium ion concentration is 200 mM or higher.

Example 6: Effect of different cations on stability of albumin

Method: A sample of purified albumin containing low octanoate (~0.2 mM @ 100 g/L albumin) was diluted initially to 50 mg/mL with water such that it contained 50 mg/mL albumin, 75 mM NaCl and no pH buffer constituent. The pH was adjusted with 0.5 M HCl to pH 6.43, the amount of HCl added was insignificant and would not have altered the albumin or other constituent concentrations. The samples were then diluted further to 10 mg/mL in UV transparent microtitre plate wells using 1 M cation stocks (KCl, NH_4Cl, $CaCl_2$, $MgCl_2$, NaCl) as shown in Table 14.

Table 14		**Sample parameters**			**Stock Volumes to Add (µL)**		
	Cation (mM)	**Final Vol (µL)**	**rHSA (mg/mL)**	**Na^+ (mM)**	**rHSA (50 g/L)**	**Cation (1 M)**	**Water**
A	50 mM	250	10	50	50.0	8.75	191.3
B	100 mM	250	10	100	50.0	21.25	178.8
C	150 mM	250	10	150	50.0	33.75	166.3
D	200 mM	250	10	200	50.0	46.25	153.8
E	250 mM	250	10	250	50.0	58.75	141.3
F	300 mM	250	10	300	50.0	71.25	128.8
G	400 mM	250	10	400	50.0	96.25	103.8
H	500 mM	250	10	500	50.0	121.25	78.8

Samples for each of KCl, NH_4Cl, $CaCl_2$, $MgCl_2$, NaCl were prepared according to Table 14. Therefore, in total, 40 different samples were prepared. Each sample was tested in duplicate on a microtitre plate.

The microtitre plate was gently rocked to mix the contents of each well, centrifuged to remove any air bubbles and placed in a Biotek Synergy Mx (Potton, UK) plate reader that had been pre-equilibrated and controlled at 65°C. The plate was then read at 350 nm every minute

over a total incubation time of 8 hours. Gen5 software (Biotek software for the plate reader version 2.00.18) was used to calculate the time taken for the A350nm absorbance to increase by 0.2 adsorption units above a base line. The base line was calculated from the mean of the first 5 data points.

Results: Figure 12 shows the time taken for the absorbance of samples to increase to 0.2 units above the baseline. A longer time shows better stability.

Conclusions:

- The control using NaCl shows the same trend as per the other examples *i.e.* increasing sodium levels improves the stability. This confirms that this microtitre plate method is suitable for testing stability effects.
- For all the different cations, both single and dual valency (group 1 metals and group 2 metals, respectively) there was a clear increase in albumin stability with increasing cation concentration up to 500 mM and probably beyond.
- These data indicate that while all cations improve stability albumin, $MgCl_2$ is very good.

Example 7: Effect of different anions on the stability of albumin

Method: A sample of purified albumin containing a low concentration of octanoate (~0.2 mM, 100 g/L albumin) was diluted initially to 50 mg/mL with water such that it contained 50 mg/mL albumin, 75 mM NaCl and no pH buffer constituent. The sample was pH adjusted with 0.5 M HCl to 6.43, the amount of HCl added was insignificant and would not have altered the albumin or constituent concentrations. 1 M sodium anion stock solutions were prepared according to Table 15.

Table 15: Anion stocks

Anion Stock Solution	MW* of chemical	Number of Na atoms in chemical	Components added to water to a final volume of 100 mL		Sodium ion (mM)
			Mass Chemical (g)	27% NaOH (mL)	
NaCl	58.44	1	5.84	0.0	1000
Na_2S0_4	142.04	2	7.12	0.0	1003
$NaH_2PO_4.2H_2O$	156.02	1	15.61	6.2	1545
Trisodium citrate	294.1	3	9.80	0.0	1000
Na Acetate	136.08	1	13.61	0.0	1000

*MW: molecular weight

The albumin and anion stocks were used as detailed below, being made to a final volume of 1 mL in a polystyrene cuvette (Sarstedt 10x4x45 mm). The samples were gently mixed prior to the cuvettes being placed into a temperature controlled spectrophotometer that had been pre-equilibrated and controlled at 65°C. The absorbance at 350 nm, referenced against an empty cuvette, was then monitored over a 2 hour period with a reading taken every 30 seconds. The data was processed by taking the first 9 data points (~ the first 4 minutes), calculating the mean (average) and then subtracting this from all data points in order to give a baseline absorbance. The time taken for the absorbance to increase by 0.1 AU above this baseline was recorded for that particular sample. If the absorbance did not go above 0.1 AU in 2 hours (7200 seconds), then the data was extrapolated in order to get an approximate time. Samples for which the absorbance does not go above 0.1 AU in 2 hours are significantly improved in stability compared to samples having lower cation concentrations.

A six cuvette holder in the spectrophotometer was used with the first sample always being a control and the other five samples using an increasing excipient (*i.e.* test material such as NaCl, Na_2SO_4) concentration. The control was always a pH 6.5 sample containing 250 mM NaCl, this needed to remain in solution with no insoluble aggregates over the full 2 hour 65°C incubation for the test to be considered to be valid.

Table 16:

Sample	Anion concentration and source	Sample parameters (final volume = 1000 µL)		Stock Volumes to Add (µL)		
		rHSA (mg/mL)	Na^+ (mM)	rHSA (50 mg/mL)	Anion * (1 M)	Water
1	50 mM NaCl	10	50	200	35.0	765.0
2	150 mM NaCl	10	150	200	135.0	665.0
3	200 mM NaCl	10	200	200	185.0	615.0
4	250 mM NaCl	10	250	200	235.0	565.0
5	300 mM NaCl	10	300	200	285.0	515.0
6	400 mM NaCl	10	400	200	385.0	415.0
7	50 mM Na_2SO_4	10	50	200	34.9	765.1
8	150 mM Na_2SO_4	10	150	200	134.7	665.3
9	200 mM Na_2SO_4	10	200	200	184.5	615.5
10	250 mM Na_2SO_4	10	250	200	234.4	565.6
11	400 mM Na_2SO4	10	400	200	384.0	416.0
12	70 mM NaH_2PO_4	10	69	200	35.0	765.0
13	220 mM NaH_2PO_4	10	223	200	134.7	665.3
14	300 mM NaH_2PO_4	10	300	200	184.5	615.5
15	380 mM NaH_2PO_4	10	377	200	234.4	565.6
16	600 mM NaH_2PO_4	10	608	200	384.0	416.0
17	50 mM Na Citrate	10	50	200	35.0	765.0
18	150 mM Na Citrate	10	150	200	135.0	665.0
19	200 mM Na Citrate	10	200	200	185.1	614.9
20	250 mM Na Citrate	10	250	200	235.1	564.9
21	400 mM Na Citrate	10	400	200	385.1	414.9
22	50 mM Na Acetate	10	50	200	35.0	765.0
23	150 mM Na Acetate	10	150	200	135.0	665.0
24	200 mM Na Acetate	10	200	200	185.0	615.0
25	250 mM Na Acetate	10	250	200	235.0	565.0
26	400 mM Na Acetate	10	400	200	384.9	415.1

*Anion stock solutions are described in Table 15

For the citrate samples, the stabilizing effect of the sodium was inconclusive when measuring the insoluble aggregates as detected by the A350nm absorbance increase. Therefore after the 2 hour, 65°C incubation in the spectrophotometer, the samples were removed, centrifuged to remove any large particles and the samples were analyzed for soluble aggregates by GP-HPLC (as per Example 4). The data was expressed as % monomeric albumin remaining (the higher the value the more stable the formulation). This was also done for the phosphate samples.

Results: All controls were valid. Figure 13 shows the effect of sodium ion concentration and anion species on the time taken for the A350 absorbance to increase to 0.1 AU above the base line. Figure 14 shows, the effect of citrate, phosphate and sodium on the stability of albumin following a 65°C, 2 hour incubation. A higher monomer level shows a higher stability. The results for the pH 6.5 controls (250 mM sodium) run at the same time gave a mean result of 81% monomer content.

Conclusions:

- Sodium chloride (sodium salt of an inorganic acid), sodium sulphate (sodium salt of a divalent acid) and sodium acetate (sodium salt of an organic acid) all gave a strong increase in albumin stability with increasing sodium concentration.
- For sodium dihydrogen phosphate the trend was not as strong as sodium chloride, sodium sulphate and sodium acetate. However, at 150 mM and above there is an increasing trend of stability with increasing sodium content. This trend was confirmed when the soluble aggregates were measured as shown by the strong trend of increasing monomer remaining with increasing sodium concentration.
- The trend of increasing stability with increasing sodium concentration for the sodium phosphate samples continued through to 600 mM sodium and would probably continue to higher sodium concentrations.
- For sodium citrate there was no obvious trend in albumin stability with sodium concentration as measured by the A350nm absorbance for the presence of insoluble aggregates. However, when the samples (after incubation at 65°C for 2 hours) were assessed for soluble aggregates through the measurement of % monomer content remaining by GP-HPLC then there was a trend. At 200 mM sodium and below, the monomer content was fairly flat but as the sodium content increased above 200 mM there was a definite trend of increasing monomer content and therefore albumin stability. Citrate is a chelating agent and therefore the

sodium present is chelated to the citrate and is unlikely to be as available to stabilize the albumin as the sodium provided, for example, by NaCl.

- Consequently, the inventors believe that any sodium salt (or any other mono or divalent anion based on the previous example) will impart stability on albumin, with a trend of increasing stability with increasing anion concentration.

Example 8: Effect of different buffers on albumin stability

Method: A sample of purified albumin containing a low concentration of octanoate (~0.2 mM, 100 g/L albumin) was diluted initially to 50 mg/mL with water such that it contained 50 mg/mL albumin, 75 mM NaCl and no buffer constituent. The sample was pH adjusted with 0.5 M HCl to pH 6.43, the amount of HCl added was insignificant and would not have altered the albumin or constituent concentrations.

An unbuffered stock of 1 M NaCl together with the following buffers (Table 17) pH adjusted to pH 6.43 as per the albumin stock (so that when added to the albumin the pH would not change) was prepared. For phosphate the pH was adjusted with 27% NaOH, for citrate it was adjusted with citric acid (citric acid powder) and for acetate it was adjusted with acetic acid (glacial acetic acid):

Table 17:

Anion Stock Solution	Final Vol (mL)	MW of chemical	Number of Na atoms in chemical	Mass Chemical (g)	27% NaOH (mL)	Na (mM)	Buffer Molarity (mM)
NaCl	100	58.44	1	5.84	0.0	1000	N/A
$NaH_2PO_4.2H_2O$	100	156.02	1	15.61	6.2	1545	1001
Na Citrate	100	294.1	3	9.80	0.0	1000	333
Na Acetate	100	136.08	1	13.61	0.0	1000	1000

The amount of acid added was insignificant and would not have altered the albumin or constituent concentrations.

The albumin and buffer stocks were used as detailed below, being made to a final volume of 1 mL in a polystyrene cuvette (Sarstedt 10x4x45 mm). The samples were gently mixed prior to the cuvettes being placed into a temperature controlled spectrophotometer that had been pre-equilibrated and controlled at 65°C. The absorbance at 350 nm, referenced against an empty cuvette, was then monitored over a 2 hour period with a reading taken every

30 seconds. The data was processed by taking the first 9 data points (~ the first 4 minutes), calculating the mean and then subtracting this from all data points in order to give a baseline absorbance. The time taken for the absorbance to increase by 0.1 AU above this baseline was recorded for that particular formulation sample. If the absorbance did not go above 0.1 AU in 2 hours (7200 seconds) then the data was extrapolated in order to get and approximate time.

A six cuvette holder in the spectrophotometer was used with the first sample always being a control and the other five samples using an increasing excipient concentration. The control was always a pH 6.5 sample containing 250 mM NaCl, this needed to remain in solution with no insoluble aggregates over the full 2 hour 65°C incubation for the test to be considered to be valid.

Table 18	**Sample parameters**			**Stock Volumes to Add (µL)**			
Sample (final volume = 1000 µL)	**rHSA (mg/mL)**	**Buffer (mM)**	**Na^+ (mM)**	**rHSA (50 mg/mL)**	**Buffer stock***	**NaCl (1 M)**	**Water**
pH 6.4, 50 mM NaCl	10	0	50	20	0.0	35.0	765.0
pH 6.4, 150 mM NaCl	10	0	150	20	0.0	135.0	665.0
pH 6.4, 200 mM NaCl	10	0	200	20	0.0	185.0	615.0
pH 6.4, 250 mM NaCl	10	0	250	200	0.0	235.0	565.0
pH 6.4, 300 mM NaCl	10	0	300	200	0.0	285.0	515.0
pH 6.4, 400 mM NaCl	10	0	400	200	0.0	385.0	415.0
pH 6.4, 50 mM NaH_2PO_4, 50 mM Na	10	50	92	200	50	0.0	750.0
pH 6.4, 50 mM NaH_2PO_4, 150 mM Na	10	50	150	200	50	57.8	692.2
pH 6.4, 50 mM NaH_2PO_4, 200 mM Na	10	50	200	200	50	107.8	642.2
pH 6.4, 50 mM NaH_2PO_4, 250 mM Na	10	50	250	200	50	157.8	592.2
pH 6.4, 50 mM NaH_2PO_4, 400 mM Na	10	50	400	200	50	307.8	442.2
pH 6.4, 50 mM Acetate, 50 mM Na	10	50	65	200	50	0	750.0
pH 6.4, 50 mM Acetate,	10	50	150	200	50	85.0	665.0

Table 18	Sample parameters			Stock Volumes to Add (µL)			
Sample (final volume = 1000 µL)	**rHSA (mg/mL)**	**Buffer (mM)**	**Na^+ (mM)**	**rHSA (50 mg/mL)**	**Buffer stock***	**NaCl (1 M)**	**Water**
150 mM Na							
pH 6.4, 50 mM Acetate, 200 mM Na	10	50	200	200	50	135.0	615.0
pH 6.4, 50 mM Acetate, 250 mM Na	10	50	250	200	50	185.0	565.0
pH 6.4, 50 mM Acetate, 400 mM Na	10	50	400	200	50	335.0	415.0
pH 6.4, 50 mM Citrate, 50 mM Na	10	50	165	200	150.1	0	649.9
pH 6.4, 50 mM Citrate, 150 mM Na	10	50	200	200	150.1	35.0	614.9
pH 6.4, 50 mM Citrate, 200 mM Na	10	50	250	200	150.1	85.0	564.9
pH 6.4, 50 mM Citrate, 250 mM Na	10	50	350	200	150.1	185.0	464.9
pH 6.4, 50 mM Citrate, 400 mM Na	10	50	500	200	150.1	335.0	314.9

*Buffer stocks were as per Table 17

Results: All controls were valid. For the samples, the time taken for the A350 absorbance to increase to 0.1 AU above the base line was plotted against the sodium concentration. Figure 15 shows that for all buffers, albumin stability increases as sodium ion concentration increases.

For the citrate samples the trend appears offset relative to the other samples. Consequently, the data for no buffer (sodium provided only by NaCl) was plotted together with the samples buffered with sodium citrate, but with the sodium concentration coming from the sodium citrate ignored (Figure 16).

Conclusions:

- For all buffers, and also with no buffer, there is a clear trend of increasing albumin stability with increasing sodium concentration.

- Even with citrate, which did not appear to be as good a sodium donator for albumin stability as NaCl, there was a trend of increasing stability within increasing sodium concentration but it was offset slightly. The reason for this offset is that, like for all the buffers, the sodium from the buffer was used in the calculation of the total sodium content. Consequently, if this sodium is not as effective (*e.g.* available) as sodium from sodium chloride (as shown in the previous examples) then there will be an offset. This was confirmed by Figure 16.
- Sodium phosphate is a good pH buffer, but as a donator for sodium for stabilization there are better donators and therefore it may be advantageous to combine sodium phosphate with another donator of cation (sodium or other cation) to stabilize albumin.
- Consequently, the inventors believe that the buffer in the formulation is not particularly important and any buffer, or no buffer, can be used. However, if the buffer is chelating then the anion present from the buffer should not be included in the calculation of the required concentration of anion.

Example 9: Effect of high salt concentration on stability of albumin variants

Method: Various albumins and variants (Table 19) were diluted with 0.5 M sodium phosphate buffer (pH 6.5).The variants were mature HSA (SEQ ID No: 2) with point mutations (K573P, K500A, K573Y, K573W) and mouse serum albumin (MSA, SEQ ID No: 19). The rHSA concentration and sodium ion concentration of the stock solutions of the albumin variants are provided in Table 20.

Table 19	**Stock Volumes Added (mL)**			**Sample details**			
Albumin Variant	**Albumin ****	**Phosphate (0.5 M, pH 6.5)*****	**Water**	**Albumin (mg/mL)**	**Phosphate (mM)**	**Na (mM)**	**Actual pH**
HSA-K573P	3.00	1.572	1.716	50.0	125	256	6.50
HSA-K500A	3.00	1.450	1.350	50.0	125	261	6.49
HSA-K573Y	4.50	1.710	0.650	50.0	125	281	6.49
HSA-K573W	4.50	1.520	0.073	50.0	125	293	6.51
HSA-K573H	4.00	1.750	1.250	50.0	125	269	6.50

Table 19	Stock Volumes Added (mL)			Sample details			
Albumin Variant	**Albumin **	**Phosphate (0.5 M, pH 6.5)*** **	**Water**	**Albumin (mg/mL)**	**Phosphate (mM)**	**Na (mM)**	**Actual pH**
HSA-K573F	4.00	1.640	0.900	50.0	125	276	6.50
HSA-wild-type*	2.50	1.250	1.250	50.0	125	263	6.50
MSA-wild-type	3.00	1.440	1.310	50.0	125	262	6.48

*HSA wild-type was spiked with 5 µL 2M octanoate (equivalent to 4 mM octanoate, 100 g/L)

**Albumin: see Table 20

***Phosphate (0.5 M, pH 6.5) is described in Table 20b

Table 20	rHSA Conc (mg/mL)	Na (mM)
K573P Stock	104.8	145
K500A Stock	96.7	145
K573Y Stock	76.2	145
K573W Stock	67.7	145
K573H Stock	87.5	145
K573F Stock	81.8	145
HSA Wild-type	100	150
Mouse	95.8	145

Table 20b Buffer Stock Solution	Make up Vol (mL)	$NaH_2PO_4.2H_2O$ (g)	27% NaOH (mL)	Sodium Phosphate (mM)	Na (mM)
0.5 M Sodium Phosphate pH 6.5	250	19.50	7.0	500	746

As all the variants had been purified slightly differently to the wild type human albumin, the levels of octanoate present would have been slightly different for each variant. From previous results, it was estimated that the octanoate present in the variants would have been equivalent to ~4 mM at 100 g/L albumin. As the wild-type stock had negligible levels of octanoate present, this stock was subsequently spiked with 5 µL of 2 M octanoate into the final

volume to give an approximately equivalent concentration of octanoate, relative to the variant albumins.

The albumin stocks and a 1 M NaCl stock were used according to Table 21, each sample being made to a final volume of 1 mL in a polystyrene cuvette (Sarstedt 10x4x45 mm). The samples were gently mixed prior to the cuvettes being placed into a temperature controlled spectrophotometer that had been pre-equilibrated and controlled at 65°C. The absorbance at 350 nm, referenced against an empty cuvette, was then monitored over a 2 hour period with a reading taken every 30 seconds. The data was processed by taking the first 9 data points (~ the first 4 minutes), calculating the mean (average) and then subtracting this from all data points in order to give a baseline absorbance. The time taken for the absorbance to then increase by 0.1 AU above this baseline was recorded for that particular formulation sample. If the absorbance did not go above 0.1 AU in 2 hours (7200 seconds) then the data was extrapolated in order to get and approximate time.

A six cuvette holder in the spectrophotometer was used with the first sample always a control and the other five samples using an increasing excipient concentration. The control was always a pH 6.5 sample containing 250 mM NaCl, this needed to remain in solution with no insoluble aggregates over the full 2 hour 65°C incubation for the test to be considered to be valid.

Table 21		**Actual concentration**			**Stock Volumes to Add (µL)**		
Sample	**Albumin Variant**	**rHSA (mg/mL)**	**Phosphate (mM)**	**Na (mM)**	**Albumin***	**NaCl (1 M)**	**Water**
1	K573P	10	25	51	200.0	0.0	800.0
2	K573P	10	25	150	200.0	98.9	701.1
3	K573P	10	25	200	200.0	148.9	651.1
4	K573P	10	25	250	200.0	198.9	601.1
5	K573P	10	25	400	200.0	348.9	451.1
6	K500A	10	25	52	199.9	0.0	800.1
7	K500A	10	25	150	199.9	97.7	702.3
8	K500A	10	25	200	199.9	147.7	652.3
9	K500A	10	25	250	199.9	197.7	602.3
10	K500A	10	25	400	199.9	347.7	452.3
11	K573Y	10	25	56	200.1	0.1	799.8

Table 21		Actual concentration			Stock Volumes to Add (µL)		
Sample	Albumin Variant	rHSA (mg/mL)	Phosphate (mM)	Na (mM)	Albumin*	NaCl (1 M)	Water
12	K573Y	10	25	150	200.1	93.8	706.2
13	K573Y	10	25	200	200.1	143.8	656.2
14	K573Y	10	25	250	200.1	193.8	606.2
15	K573Y	10	25	400	200.1	343.8	456.2
16	K573W	10	25	59	200.0	0.0	800.0
17	K573W	10	25	150	200.0	91.4	708.6
18	K573W	10	25	200	200.0	141.4	658.6
19	K573W	10	25	250	200.0	191.4	608.6
20	K573W	10	25	400	200.0	341.4	458.6
21	K573H	10	25	54	200.0	0.0	800.0
22	K573H	10	25	150	200.0	96.1	703.9
23	K573H	10	25	200	200.0	146.1	653.9
24	K573H	10	25	250	200.0	196.1	603.9
25	K573H	10	25	400	200.0	346.1	453.9
26	K573F	10	25	55	199.9	0.0	800.1
27	K573F	10	25	150	199.9	94.9	705.2
28	K573F	10	25	200	199.9	144.9	655.2
29	K573F	10	25	250	199.9	194.9	605.2
30	K573F	10	25	400	199.9	344.9	455.2
31	HSA Wild-type	10	25	53	200.0	0.0	800.0
32	HSA Wild-type	10	25	150	200.0	97.3	702.7
33	HSA Wild-type	10	25	200	200.0	147.3	652.7
34	HSA Wild-type	10	25	250	200.0	197.3	602.7
35	HSA Wild-type	10	25	400	200.0	347.3	452.7

Table 21		Actual concentration			Stock Volumes to Add (µL)		
Sample	Albumin Variant	rHSA (mg/mL)	Phosphate (mM)	Na (mM)	Albumin*	NaCl (1 M)	Water
36	Mouse	10	25	52	200.1	0.0	799.9
37	Mouse	10	25	150	200.1	97.5	702.4
38	Mouse	10	25	200	200.1	147.5	652.4
39	Mouse	10	25	250	200.1	197.5	602.4
40	Mouse	10	25	400	200.1	347.5	452.4

*Albumin concentration is provided in Table 20.

Results: All controls were valid. Figure 17 and 18 shows the effect of sodium ion concentration on the time taken for the A350 absorbance to increase by 0.1 AU above the base line.

Conclusions:

- All points follow a trend apart from the wild type albumin, 150 mM sodium sample. It is unclear why this point is out of trend but is likely to be an outlier and does not detract from the overall conclusions.
- For all albumin variants there is a clear trend of increasing albumin stability with increasing sodium concentration.
- Mature mouse serum albumin (SEQ ID No: 19) is 72.1% identical (using the algorithim described herein) to mature wild-type human serum albumin (SEQ ID NO: 2) and even though the overall stability was not as high as HSA, or HSA variants, there was still a clear trend of increasing stability with increasing sodium concentration at and above 200 mM.
- It is difficult to say whether or not there is a significant difference in stability between the different variants because it is difficult to compare the stabilities of the variants to the stability of wild type albumin since the base formulation with respect to the level of octanoate present was not absolutely controlled to be the same between each variant. However, within the data sets for each variant the level of octanoate will be the same and therefore the increase in stability can only be due to the increasing level of sodium.
- The one sample where the octanoate was known (wild type human serum albumin, equivalent to 4 mM at 100 g/L albumin) shows that the observed stability increase with sodium is also valid at this level of octanoate.

Example 10: Effect of pH on albumin stability

Method: A sample of purified albumin containing low octanoate (~0.2 mM, 100 g/L albumin) was diluted initially to 50 mg/mL according to Table 22, using phosphate stocks according to Table 23.

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Table 22		Stock Volumes Added (mL)			Final parameters of sample		
Sample	pH of phosphate buffer	rHSA (50 mg/mL)	Sodium Phosphate buffer (0.5 M)*	Water	rHSA Conc (mg/mL)	Sodium Phosphate (mM)	Na (mM)
1	pH 5.0	2.50	1.25	1.25	50.0	125	204
2	pH 6.5	2.50	1.25	1.25	50.0	125	261
3	pH 7.0	2.50	1.25	1.25	50.0	125	288
4	pH 8.0	2.50	1.25	1.25	50.0	125	318

*Sodium phosphate buffer stock solutions are described in Table 23

Table 23:

Buffer Stock Solution	Components (made up to a final volume of 250 mL with water)		Buffer parameters	
	$NaH_2PO_4.2H_2O$ (g)	27% NaOH (mL)	Phosphate (mM)	Na Molarity (mM)
0.5 M Phosphate pH 5	19.50	0.5	500	518
0.5 M Phosphate pH 6	19.51	3.8	500	634
0.5 M Phosphate pH 7	19.50	10.0	500	851
0.5 M Phosphate pH 8	19.50	13.4	500	970
0.5 M Phosphate pH 6.5	19.50	7.0	500	746

10 The samples were pH adjusted with 0.5 M HCl (*i.e.* no added sodium) to give final pHs of 5.02 and 5.55 using the pH 5 stock, pHs of 6.00 and 6.49 using the pH 6.5 stock, pH of 7.04

using the pH 7 stock and pHs of 7.55 and 7.98 using the pH 8 stock. The amount of HCl added was insignificant and would not have altered the albumin or constituent concentrations.

The stocks were used as detailed below (Table 24), being made to a final volume of 1 mL in a polystyrene cuvette (Sarstedt 10x4x45 mm). The samples were gently mixed prior to the cuvettes being placed into a temperature controlled spectrophotometer that had been pre-equilibrated to and controlled at 65°C. The absorbance at 350 nm, referenced against an empty cuvette, was then monitored over a 2 hour period with a reading taken every 30 seconds. The data was processed by taking the first 9 data points (~ the first 4 minutes), calculating the mean (average) and then subtracting this from all data points in order to give a baseline absorbance. The time taken for the absorbance to then increase by 0.1 AU above this baseline was recorded for that particular formulation sample. If the absorbance did not go above 0.1 AU in 2 hours (7200 seconds) then the data was extrapolated in order to get and approximate time.

A six cuvette holder in the spectrophotometer was used with the first sample always being a control and the other five samples using an increasing excipient concentration. The control was always a pH 6.5 sample containing 250 mM NaCl, this needed to remain in solution with no insoluble aggregates over the full 2 hour 65°C incubation for the test to be considered to be valid.

Table 24			**Actual**				**Stock Volumes to Add (µL)**		
Sample			**Final Vol (µL)**	**rHSA (mg/mL)**	**Phosphate (mM)**	**Na (mM)**	**rHSA (50 mg/mL)***	**NaCl (1 M)**	**Water**
Number	**pH**	**Na (mM)**							
1	6.49	50	1000	10	25	52	200.0	0.0	800.0
2	6.49	150	1000	10	25	150	200.0	97.7	702.3
3	6.49	200	1000	10	25	200	200.0	147.7	652.3
4	6.49	250	1000	10	25	250	200.0	197.7	602.3
5	6.49	400	1000	10	25	400	200.0	347.7	452.3
6	5.02	50	1000	10	25	50	200.0	9.1	790.9
7	5.02	150	1000	10	25	150	200.0	109.1	690.9
8	5.02	200	1000	10	25	200	200.0	159.1	640.9
9	5.02	250	1000	10	25	250	200.0	209.1	590.9

Table 24			Actual				Stock Volumes to Add (µL)		
Sample			Final Vol (µL)	rHSA (mg/mL)	Phosphate (mM)	Na (mM)	rHSA (50 mg/mL)*	NaCl (1 M)	Water
Number	pH	Na (mM)							
10	5.02	400	1000	10	25	400	200.0	359.1	440.9
11	5.55	50	1000	10	25	50	200.0	9.1	790.9
12	5.55	150	1000	10	25	150	200.0	109.1	690.9
13	5.55	200	1000	10	25	200	200.0	159.1	640.9
14	5.55	250	1000	10	25	250	200.0	209.1	590.9
15	5.55	400	1000	10	25	400	200.0	359.1	440.9
16	6.00	50	1000	10	25	52	200.0	0.0	800.0
17	6.00	150	1000	10	25	150	200.0	97.7	702.3
18	6.00	200	1000	10	25	200	200.0	147.7	652.3
19	6.00	250	1000	10	25	250	200.0	197.7	602.3
20	6.00	400	1000	10	25	400	200.0	347.7	452.3
21	7.04	50	1000	10	25	58	200.0	0.0	800.0
22	7.04,	150	1000	10	25	150	200.0	92.5	707.6
23	7.04	200	1000	10	25	200	200.0	142.5	657.6
24	7.04	250	1000	10	25	250	200.0	192.5	607.6
25	7.04	400	1000	10	25	400	200.0	342.5	457.6
26	7.55	50	1000	10	25	64	200.0	0.0	800.0
27	7.55	150	1000	10	25	150	200.0	86.5	713.5
28	7.55	200	1000	10	25	200	200.0	136.5	663.5
29	7.55	250	1000	10	25	250	200.0	186.5	613.5
30	7.55	400	1000	10	25	400	200.0	336.5	463.5
31	7.98	50	1000	10	25	64	200.0	0.0	800.0
32	7.98	150	1000	10	25	150	200.0	86.5	713.5
33	7.98	200	1000	10	25	200	200.0	136.5	663.5
34	7.98	250	1000	10	25	250	200.0	186.5	613.5
35	7.98	400	1000	10	25	400	200.0	336.5	463.5

*Albumin stocks are described in Table 23.

For the pH 7 (measure pH 7.04), 7.5 (measured pH 7.55) and 8 (measure pH 7.98) samples the stabilizing effect of the sodium was inconclusive when measuring insoluble aggregates as detected by the A350nm absorbance increase. Therefore after the 2 hour incubation at 65°C incubation in the spectrophotometer the samples were removed, centrifuged to remove any large particles and the samples analyzed for soluble aggregates by GP-HPLC (as per Example 4). The data was expressed as % monomeric albumin remaining (the higher the value the more stable the formulation).

Results: All controls were valid. Figures 19, 20 and 21 show the stability of albumin relative to sodium ion concentration. The results for the pH 6.5 controls run at the same time as the pH7, 7.5 and 8 samples gave a mean of 82% monomer content.

Conclusions:

- For all pHs from pH 5 to pH 6.5 it was clear that there was an increase in albumin stability with increasing albumin concentration as measured by the A350 absorbance increase (insoluble aggregates).
- At pHs 7, 7.5 and 8 the trend was not clear (Figure 19) with a possible dip in stability around 150 mM Na. However, when these samples were analyzed by GP-HPLC for soluble aggregates and % monomer remaining (Figure 21) there was a clear trend of increasing stability with increasing sodium. The reason that this trend was not observed for the insoluble aggregates may be due to the fact that these pHs are the furthest from the pI of albumin (5.2 for albumin) and therefore they are less likely to precipitate with the aggregates coming out of solution.
- The pH 6.5 controls had higher levels of monomer remaining at the same sodium ion concentration (250 mM) than any of the higher pHs showing that pH 6.5 is the more stable pH for albumin.
- Combining both the insoluble and soluble aggregate data shows that increasing sodium concentration increases albumin stability from pH 5 to pH 8.

Example 11: Effect of Octanoate on Stem Cell Cultures

Method: The effect of octanoate on stem cell culture was carried out by a contract research organization: Cellartis AB (Gothenburg, Sweden). Briefly, albumin at 100 g/L with varying levels of octanoate (0.2, 0.5, 1.0 and 8.0 mM) was used as the albumin supplement in standard stem

cell culture media. Human embryonic stem cells (cell lines SA121 and SA181 (Cellartis AB, cell lines deposited in the European Human Embryonic Stem Cell Registry)) were transferred from their standard media and grown through 5 passages in 6 well plates in the media supplemented with the albumin containing varying levels of octanoate. The cell growth over the 5 passages was assessed by monitoring the cell doubling times during consecutive passages in cell production. The doubling times of cultures should be within a range of 28-40 hours, and can be seen as a trend indicator. In order to determine the undifferentiation state of the cells after 5 passages in albumin supplemented media, antibodies against four different accepted markers for the undifferentiated state, namely Oct-4, SSEA-3, Tra-1 60 and hES-Cellect, were used for immunostaining.

Results: Table 25 shows data for the doubling time. The initial doubling times are quite high, probably due to cells needing to adjust to the new culture medium composition. However, the doubling times between passages 2 and 4 are all within expected range except for the sample containing 8 mM octanoate which failed to maintain acceptable cell attachment and could not be continued past passage 2 even with modified medium and coating conditions. Doubling times for passage 5 were highly variable and for some samples lay considerably outside the standard range. However, it is difficult to draw conclusions as cultures were not expanded further.

Table 25: Doubling time in hours for each of the cell lines over five passages. Doubling time is presented in hours, and formula used is Td(h) = T * LOG2/LOG(cells harvested/cells seeded). T = time in hours between passages

Cell line	Octanoate Present (mM)	Passage 1	Passage 2	Passage 3	Passage 4	Passage 5
SA121	0.2	45.6	31.7	35.8	33.8	56.1
	0.5	44.5	36.5	42.3	44.9	30.4
	1.0	65.5	33.4	31.2	30.4	38.7
	8.0	61.8	46.0	-	-	-
SA181	0.2	88.5	31.9	31.5	29.5	452
	0.5	144.0	34.3	37.3	29.0	134
	1.0	47.1	32.8	36.9	31.4	59.4
	8.0	117	89.7	-	-	-

Table 26 shows data for the immunocytochemical stainings for differentiation markers and shows that all the samples (except the sample containing 8 mM octanoate, since it did not

reach 5 passages) supported cultures to maintain an undifferentiated state for the 5 passages tested.

Table 26: Summary of immunocytochemical staining performed on cells stained using antibodies against Oct-4, Tra-1 60, SSEA-3, hES-Cellect™ and SSEA-1. (+++) represents good staining and easy to detect, while (-) represents no staining detectable.

Cell line	Octanoate Present (mM)	Oct-4	Tra-1 60	SSEA-3	hES-Cellect™	SSEA-1
SA121	0.2	+++	+++	+++	+++	-
	0.5	+++	+++	+++	+++	-
	1.0	+++	+++	+++	+++	-
SA181	0.2	+++	+++	+++	+++	-
	0.5	+++	+++	+++	+++	-
	1.0	+++	+++	+++	+++	-

Conclusions:

- The octanoate level present in the albumin is important for stem cell attachment, maintenance of undifferentiated cell growth. At 8 mM octanoate in 100 g/L albumin the octanoate is toxic to stem cells and does not allow their attachment to surfaces or cell growth.

The invention described and claimed herein is not to be limited in scope by the specific aspects herein disclosed, since these aspects are intended as illustrations of several aspects of the invention. Any equivalent aspects are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims. In the case of conflict, the present disclosure including definitions will control.

Claims

What is claimed is:

1. A composition comprising from 25 to 400 $g.L^{-1}$ albumin, a solvent, from 200 mM to 1000 mM cations, having a pH from about 5.0 to about 8.0 and wherein the composition comprises less than or equal to 5 mM octanoate, and wherein the albumin is human serum albumin (HSA) having the amino acid sequence of SEQ ID NO: 2 or a variant thereof having at least 80% sequence identity to SEQ ID NO: 2.

2. The composition according to claim 1 which comprises less than or equal to 1 mM octanoate.

3. The composition according to claim 2 wherein the cations are present at from 200 to 350 mM.

4. The composition according to any of claims 1 to 3 wherein the pH is from about 6.0 to about 7.0.

5. The composition according to any of claims 1 to 4 wherein the pH is about pH 6.5.

6. The composition according to any of claims 1 to 5 wherein the cations are selected from: sodium, potassium, calcium, magnesium, and ammonium.

7. The composition according to any of claims 1 to 6 wherein the cations are sodium ions.

8. The composition according to any of claims 1 to 7 which comprises:

   (a) less than 5 mM amino acids (such as N-acetyl tryptophan), preferably less than 1 mM amino acids; and/or

   (b) less than 20 $mg.L^{-1}$ detergent (such as polysorbate 80), preferably less than 5 $mg.L^{-1}$ detergent.

9. The composition according to claim 7 which is substantially free of amino acids (such as N-acetyl tryptophan) and/or substantially free of detergent (such as polysorbate 80).

10. A composition according to any of claims 1 to 9 wherein the albumin is HSA having the amino acid sequence of SEQ ID NO: 2.

11. The composition according to any of claims 1 to 10 wherein the albumin is at a concentration of from 50 g.L-1 to 400 g.L-1.

12. The composition according to any of claims 1 to 11 wherein the albumin is a recombinant albumin.

13. The composition according to claim 1 comprising:

(a) 50 to 250 $g.L^{-1}$ albumin;

(b) 225 to 275 mM Na^{+};

(c) 20 to 30 mM phosphate;

and having a pH of about 6.5, and wherein the composition comprises less than 2 mM octanoate.

14. The composition according to any of claims 1 to 13 which is substantially free of octanoate.

15. The composition according to any of claims 1 to 14 which is more stable than a control solution of albumin wherein the control solution is the same concentration in 150 mM Na or water.

16. A method for preparing a cell culture medium comprising supplementing a basal medium with the composition according to any preceding claim.

17. The method according to claim 16 wherein the cell culture medium is a stem cell culture medium.

18. The method according to claim 16 or 17 wherein the cell culture medium is substantially free of animal-derived components.

19. Use of a composition according to any of claims 1 to 15 to culture cells.

20. A method according to any of claims 16 to 18, further comprising incubating cells in the cell culture medium.

21. The use or method according to claim 19 or 20 in which the cells comprise stem cells.