

LAYERED CELL CULTURE PARTICLES AND METHODS OF MAKING THEREOF**CROSS-REFERENCE**

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application no. 62/272,828, filed 30 December, 2015. The entire content of the aforementioned application is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates to dry cell culture media, feeds, supplements, or concentrates comprising layered particles useful in culturing cells and other such applications. The invention relates to processes for preparing such layered compositions and methods of making cell culture compositions that are stable, for e.g., thermally, photo-chemically and/or to gamma irradiation. The invention also relates to the use of such layered particle preparations to produce proteins and polypeptides, and to increase cell growth and protein titers thereby.

BRIEF SUMMARY OF THE INVENTION

[0003] The invention is directed in part to methods of making a media or a feed composition for culturing cells, comprising: i) subjecting a dry powder to suspension in a moving column of a gas in a fluid bed apparatus; ii) introducing at least one solvent using a sprayer into the dry powder of step (i) to form a layered base particle; and iii) drying the layered base particle.

[0004] The invention is also directed in part to methods of making a media or a feed composition for culturing cells, comprising: i) subjecting a dry powder to suspension in a moving column of a gas in a fluid bed apparatus; ii) introducing a first solvent using a first sprayer onto the dry powder of step (i) to form a base granule; iii) introducing at least one second solvent using a second sprayer onto the base granule of step (ii) to form a layered base granule; iv) drying the layered base granule.

[0005] In accordance with the above first aspects of the invention, the dry powder may be a basal media powder, a complete media powder, a cell culture feed, a cell culture supplement, a cell culture media or feed concentrate or an amino acid mixture.

[0006] In a second aspect, the first sprayer may be selected from the group consisting of: a top sprayer, a bottom sprayer and a tangential sprayer. Alternately, the first or the second sprayer may be selected from

the group consisting of: a top sprayer, a bottom sprayer and a tangential sprayer. In a preferred embodiment, the second sprayer may be a bottom sprayer.

[0007] In a third aspect, the second sprayer may spray a plurality of solvents on to the base granule to form a multilayered base granule or multilayered base particle respectively. Alternately, the second sprayer may spray the plurality of solvents sequentially, such that there are intermittent drying steps between each spraying step. And alternately, the second sprayer may spray the plurality of solvents sequentially without any intermittent drying steps between each spraying step.

[0008] In a fourth aspect, each solvent in the plurality of solvents may have one component; or, the same components; or, each solvent may have different components. For example, each solvent may have a mixture of components. In a further aspect, the solvent comprises a reactive species. In another aspect, the solvent comprises a sensitive species.

[0009] In a fifth aspect, the components to be sprayed through the solvent are segregated into reactive species and into sensitive species.

[0010] In a further aspect, the reactive species and the sensitive species are sprayed separately to give a layered granule. In a particular aspect, the reactive species may be selected from the group consisting of one or more trace elements, one or more reactive amino acids, one or more reactive amino acids, one or more metal salts, one or more acid soluble reactive groups, one or more alcohol soluble reactive groups and one or more pH modifier groups.

[0011] In another further aspect, the sensitive species may be selected from the group consisting of one or more polyamines, one or more vitamins, one or more growth factor and one or more labile amino acids.

[0012] In a sixth aspect, an inlet gas is used in the methods which may be at about temperature 20° C to 30° C. In a further aspect the inlet gas used in the method may be at about temperature 25° C.

[0013] In a seventh aspect, the vitamins that may be sensitive are selected from the group consisting of: vitamin B12, biotin, choline, folic acid, niacinamide, pyridoxine, riboflavin, thiamine, ascorbic acid and para-aminobenzoic acid (PABA).

[0014] In an eighth aspect, the drying step may be at about temperature 50° C to 60° C.

[0015] In a ninth aspect, the base particle or the base granule may be dried to a moisture content of about 0.5% to 10%.

[0016] In yet another further aspect, the solvent additionally comprises at least one antioxidant, or at least one neutral species, or both.

[0017] In a tenth aspect, the layered base particle or the layered base granule is obtained through any of the methods described above.

[0018] In a eleventh aspect, the methods are directed to producing a nutritive medium layered particle, a nutritive medium supplement layered particle, a nutritive medium subgroup layered particle, the method comprising making a layered media particle according to any of the methods described above and wherein at least one layer on the base particle or base granule comprises a reactive species and/or at least one layer on the base particle or base granule comprises a sensitive species. In a further aspect, the reactive species may be selected from the group consisting of one or more trace elements, one or more reactive amino acids, one or more reactive amino acids, one or more metal salts, one or more acid soluble reactive groups, one or more alcohol soluble reactive groups and one or more pH modifier groups. Alternately, the sensitive species may be selected from the group consisting of one or more polyamines, one or more vitamins, one or more growth factor and one or more labile amino acids. In some embodiments, the dry powder may be selected from the group consisting of vitamins, bulk inorganic salts and sugars.

[0019] In a twelfth aspect, the methods are directed to culturing a cell in a liquid reconstituted from the layered media made as described above, the method comprising: i) reconstituting the layered media particle in a suitable liquid or buffer; wherein said layered media particle may be a cell culture medium, feed, supplement or concentrate; and ii) culturing the cell may be the reconstituted liquid under conditions favorable for the growth of the cell. In a further aspect, the culturing of the cell may be used to produce increased amount of a polypeptide. In yet a further aspect, the polypeptide may be a recombinant polypeptide. Alternately, the culturing increases product production, increasing cell growth, as compared to a culture with liquid media not made from the layered media particles.

[0020] A thirteenth aspect provides a kit comprising: i) a first container comprising a layered particle or granule according any one of the above claims; wherein said layered particle or granule may be a cell culture medium, feed, supplement or concentrate; and ii) instructions for using the layered particle or granule for cell culture.

[0021] A fourteenth aspect provides a system comprising: a liquid medium reconstituted from a layered media particles according to the methods described above, and a cell. In a further aspect, the reconstituted liquid medium may be used to cultivate a cell that produces a recombinant polypeptide, a virus, a secreted protein, or to cultivate a cell in suspension or a cell that may be attached.

[0022] A fifteenth aspect provides methods of making a media or a feed composition for culturing cells as described above, or, a kit as described above, or, a system as described above, wherein amino acids are used and the amino acids are selected from one or more of the twenty amino acids, their salts or derivatives thereof. In a further aspect, the amino acids are selected from one or more of glycine, alanine, arginine, aspartic acid, glutamic acid, histidine, isoleucine, methionine, phenylalanine, proline, hydroxyproline, serine, threonine, tryptophan, valine, tyrosine, cysteine and lysine.

[0023] A sixteenth aspect provides layered particles or granules obtained through the methods described above used for culturing a cell. In a further aspect, the cell may be a mammalian cell. In a particular aspect, the cell may be selected from the group consisting of CHO, BHK, HEK, 293, and VERO cells. In another aspect, the cell may be a plant cell, an animal cell, a eukaryotic cell, a eukaryotic cell, an algal cell, a fungal cell, and a bacterial cell.

INCORPORATION BY REFERENCE

[0024] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0026] Figure 1: Schematic of Process for Making Culture Media Layered Granule Formulations. Bottom spray coating was performed with a GPCG 1.1 with a 6" Wurster Insert, 2 Liter Granulator/Dryer/Coater. Bottom Spray Layering- Layer composition varies for each granulation.

[0027] Figure 1a: Schematic diagram of exemplary single layer, single ingredient cell culture media layered granules – Layered Granule Prototype A.

[0028] Figure 1b: Schematic diagram of exemplary multi-layer, single ingredient in each layer cell culture media layered granules – Layered Granule Prototype B.

[0029] Figure 2a: SEM images of cell culture media layered granules Prototype A (Single Layer, Single Ingredient).

[0030] Figure 2b: SEM images of cell culture media layered granules Prototype-B (Multi-Layered, Single Ingredient).

[0031] Figure 3a: Prototype A Layered Feed Cell Viability Assay.

[0032] Figure 3b: Prototype A Layered Feed Cell Growth Assay.

[0033] Figure 4: Exemplary Process for the Production of Layered Media/ Feed Granules for Cell Culture.

[0034] Figure 5a: Schematic diagram of Formulation 1 Cell Culture Media Layered Granules.

[0035] Figure 5b: Schematic diagram of Formulation 2 Cell Culture Media Layered Granules.

[0036] Figure 6a: Formulation 1 Particle size analysis of non-coated, non-layered granules (blue bars) and coated (layered) granules (red bars).

[0037] Figure 6b: Formulation 2 Particle size analysis of non-coated, non-layered granules (blue bars); and the coated (layered) granules (red bars).

[0038] Figure 7a: Formulation 1 Cumulative Particle Size (sieve) Analysis before and after bottom spray coating: Sieve Fraction analysis of the granulated base powder before layering step. Particle size analysis of non-coated, non-layered granules (blue squares) and coated, layered granules (red diamonds).

[0039] Figure 7b: Formulation 2 Cumulative Particle Size (sieve) Analysis before and after bottom spray coating: Sieve Fraction analysis of the granulated base powder before layering step.

[0040] Figure 8a: Formulation 1 SEM images of coated (layered) granules of formulation 1 (F1) at magnifications Left panel: Top View 100x; Right panel: Cross-Section 1500x.

[0041] Figure 8b: Formulation 2 SEM images of coated (layered) granules of formulation 2 (F2) at magnifications Left panel: Top View 100x; Right panel: Cross-Section 1500x.

[0042] Figure 9a: Formulations 1, 2, 3: Granulated Base Powders Particle Size Analysis. Cumulative Sieve Fraction analysis. Sieve analysis of base powder granulation was performed with 3-5 grams of granulated material using 3-inch sieves.

[0043] Figure 9b: Formulations 1, 2, 3: Granulated Base Powders Particle Size Analysis. Sieve analysis of base powder granulation was performed with 3-5 grams of granulated material using 3-inch sieves.

[0044] Fig 10a: Formulations 1, 2, 3: Milled Granulated Base Powders Particle Size Analysis. Cumulative Sieve Fraction analysis for the base powder that was milled post-granulation.

[0045] Fig 10b: Formulations 1, 2, 3: Milled Granulated Base Powders Particle Size Analysis Bar Graph. Sieve analysis of base powder (milled post- granulation) was performed with 95-105 grams of material using 8-inch sieves.

[0046] Figure 11: Radiation Induced Nutrient Degradation in Layered Granulations. As seen from the figures, layering strategies when applied to gamma irradiated dry format medium (dose range 20kGy-70kGy) improved the stability of sensitive and/or reactive components compared to that of un-irradiated (0kGy) control medium.

DETAILED DESCRIPTION OF THE INVENTION

[0047] The invention relates to methods of producing a dry powder media composition comprising layered base particles or layered base granules. Dry powder media when mentioned in this disclosure may refer to dry powder media (basal media or complete media), dry concentrated cell culture media, dry powder feeds or supplements, dry powder concentrated feeds or supplements, dry buffer powders, which may be used in combination, or in part, or by itself (when it may be a complete medium) to culture a cell. Generally, culturing refers to culturing a cell *in vitro*. A production method for making layered media or feed particles or granules will be described hereinafter.

[0048] Cell culture media, feed or supplement formulations may contain chemicals that become unstable over time (i.e., degrade, oxidize, etc.), or unstable due to adverse interactions between sensitive and reactive components in the formulation itself. For example, glucose may react with some amino acids or with polyamines to form undesirable Maillard reaction products that precipitate out when dissolved in solution, and such reactions may be further enhanced in the presence of one or more of the following: high-energy or ionizing radiations, thermal damage, light, environmental chemicals, long term storage, mechanical shaking, etc. Thus cell culture media must be stored or shipped at lower temperatures, which increases cost of goods and may be cumbersome. To overcome such challenges, a method is needed to protect cell culture media components that would otherwise interact adversely, and this may be achieved through segregating or grouping cell culture ingredients, for example, reactive components may be spatially separated from sensitive components through layering them in separate layers, and in some embodiments, by mixing the sensitive component layer and/or the reactive components with quenchers of

free radicals or of reactive species; quenching components like anti-oxidants, and/or with neutral components (for example, see the Table in Example 3 below). A desirable solution to the above problem would therefore be to provide a cell culture medium or a feed (basal or complete) for supplementation in a cell culture system, such that the sensitive components in the formulation and/or the reactive components of the formulation are separated spatially from one another through layering. Optionally, inert components and/or quenchers such as anti-oxidants may be mixed with the sensitive components, and/or, the reactive components, or, the inert components and/or quenchers such as anti-oxidants may be layered in between the reactive and the sensitive layer. The application of such layered, powdered cell culture media may prolong the stability of the product, and/or increase stability, for e.g., to thermal, irradiation, or photochemical radiations.

[0049] To prepare a layered granule of a multi-component cell culture medium, feed or supplement can be challenging because complete media for example, comprises 80 to 100 components, each needed in precise amounts to maintain viable cell growth and maintain robust protein titers.

[0050] To prepare a layered granule a sprayer, for e.g., a bottom sprayer may be used, to spray a solvent onto an un-granulated base powder or a granulated or agglomerated base powder. A wide range of particle sizes can be layered. Exemplary granulated powders include but are not limited to those made by spray/wet granulation, fluid bed spray drying, (see Srivastava et al.; International Journal of Pharmaceutical Sciences and Drug Research 2010; 2(4): 236-246; hereby incorporated by reference in its entirety). Thus, a first layer may be formed on the granule. The solvent may contain one or more chemicals /components, or a microsuspension of one or more chemicals / components. In certain embodiments, different chemical layers of controlled thickness can be created on a granule. In a particular embodiment, binders are not used in the solvent or at any stage to form or to layer the granule. In other words, the formulation of a cell culture medium, feed or concentrate need not be altered due to the addition of binders or additional components for granule formation. The granule may be layered using components already present in the formulation. Instead, the formulation's components are segregated or group as described below.

[0051] Segregation of chemicals/ components and Layering: Chemicals / components in the layered granule may be segregated or grouped according to, for e.g., their chemical reactivity/ properties; their susceptibility to thermal damage or radiation damage, or photochemical damage, or according to their solvent solubility, etc.

[0052] For example, the core of the granule (also referred to as the base granule) may comprise one or more sensitive components (sometimes called inner core/layer). In other instances, the base granule may comprise a mixture of sensitive and anti-oxidant components. In yet other instances, the base granule may comprise a mixture of sensitive components, anti-oxidant and/or neutral components. For example, in a particular embodiment, the core of the granule may comprise the most sensitive component or a mixture of the most sensitive components, and, a mixture of one or more neutral (inert) components and/or one or more anti-oxidant components. In other instances, the base granule itself maybe layered such that the sensitive components, and/or neutral chemicals, and/or anti-oxidant components may be layered one by one, one on top of each other. For example, the most sensitive component may form the central core of the base granule, followed by the next sensitive component in the next layer, and so on, intermingled or followed by the neutral/ inert component(s) and/or, the anti-oxidant layer as the outermost layer of the base granule. Alternately, the neutral component may be at the core followed by sensitive components, or vice versa. The sensitive/ neutral / anti-oxidant layering of the granule may follow any order, according to the ingredients of the cell culture media, feed or concentrate and as determined by the skilled artisan based on the properties of cell culture media or feed components.

[0053] Next, the reactive chemicals may be applied over the sensitive component base granules (inner core or layer). In some examples, the reactive chemicals may be mixed together and applied as one layer over the base granule. This separation can provide some sort of spatial separation between the sensitive and the reactive chemicals within the same granule. In other instances, the reactive chemicals may be applied one by one, one layer over another, with the least reactive chemical being in contact with the (sensitive) base granule, and the most reactive chemical being spatially distant from the base granule (outermost layer). Alternately, an intervening, neutral/inert chemical layer may separate the inner, sensitive layer from the outer reactive layer/ layers of the granule.

[0054] In a preferred embodiment, AGT agglomerated cell culture media may be produced using a fluid bed granulation method. To a given base particle, an additional fluid bed coating technique may be applied, for example, using a bottom -spray layering method like the Wurster method. In an AGT cell culture formulation, the bottom spray method could allow chemical groups to be added in specific order to form controlled layers around bulk granulation components (i.e., called active layering) in order to separate/segregate reactive chemical components in the final AGT product. In some aspects, the coated particle can be modified for slow release of components, and in other aspects, the active layered AGT could provide protection of formulation components that are unstable to gamma irradiation, environmental degradation, degradation due to moisture, and so on. The reactive chemical components may be mixed with anti-oxidants to provide a protective effect. One or more active layers may be sprayed

on an AGT particle to complete the formulation. Each layer may or may not comprise one or more antioxidants for additional stability. This method has potential to provide a terminally sterilized complete AGT medium (i.e., single-part, dry format) without the need for secondary processing conditions (e.g., spray drying, microencapsulation). Stability testing can be done after 1 week, 3 weeks, or more with storage of the layered particle media @ 37C, RT, 4°C, 0C, etc. Analytical testing against irradiation and/or environmental degradation, temperature variation, or weeks of stability was done by assaying for preservation of sensitive components such as vitamins, ethanolamine, etc. using routine assays.

[0055] Exemplary sensitive or less stable chemicals /components include but are not limited to, vitamins, polyamines, growth factors, hormones, etc. Exemplary reactive chemicals/ components include but are not limited to trace metals or salts, some reactive amino acids, some sugars (for e.g., glucose which may form adducts with other components including certain amino acids, polyamines), metal ions, etc. Exemplary neutral chemicals/ components include but are not limited to neutral amino acids, neutral sugars, etc.

[0056] Definitions

[0057] The term "powder" or "dry powder" as used herein refers to media powders or powdered media compositions for cell culture that are present in dry form, whose gross appearance may be free flowing. The term "powder" includes agglomerated powders. The term "base powder" or "dry base powder" or "dry powder" may be used interchangeably, and as used herein generally refers to a starting dry powder composition before it may be layered. The term "base powder" or "dry base powder" or "dry powder" may be granulated by any means, for example, in a fluid-bed processor to produce a "base granule" or an "agglomerated granule" that can then be layered by further "layering" with solvents. But that does not mean that a layered particle (or granule) must start from a base granule. The layered particle can begin with a simple un-granulated powdered that may be layered using spraying techniques as well. For the sake of convenience, a granulated or agglomerated start particle before layering may be referred to as "a base granule". Correspondingly, a dry powder, un-granulated start particle may be sometimes referred to as "a base particle" before layering. It may not mean that any starting material may be completely free of dry powder or agglomerated granules. The starting material may sometimes have a mixture of dry powder and agglomerated granules before layering with a solvent. The dry or the agglomerated powder (as applicable) may be a basal media powder, a complete media powder, a cell culture feed, a cell culture supplement, a cell culture media or feed concentrate or an amino acid mixture.

[0058] The term “cell culture media compositions” or “powdered media composition” or “media powders” or “dry powder formulations” or “media formulations” may be used interchangeably and broadly include, *e.g.* a media, media supplement, media subgroup or buffer of the invention and may not be limited to, basal media, complete media, media feeds, media supplements, media additives, concentrated media, concentrated supplements and feeds, amino acids or groups of amino acids, short peptides, vitamins, buffers, salts, trace components, etc. These terms generally refer to components added during cell culture, and the skilled artisan would clearly understand when or how these terms are used.

[0059] The term media “component” or “ingredient” refers to any compound, whether of chemical or biological origin, that can be used in the cultivation of a cell, to maintain or promote the growth and proliferation of cells. The terms “component,” “nutrient”, “ingredient”, “species”, can be used interchangeably and are all meant to refer to such compounds. Typical ingredients that are used in cell culture media include amino acids, salts, metals ions, trace elements, polyamines, sugars, carbohydrates, lipids, nucleic acids, hormones, vitamins, fatty acids, buffer salts, proteins and the like. Other ingredients that promote or maintain cultivation of cells *ex vivo* can be selected by those of skill in the art, in accordance with the particular need.

[0060] Spraying: In certain embodiments, the “component” for layering may be sprayed on to the base particle, or the base granule. In certain embodiments, a singular “component” may be sprayed on to the base particle, or the base granule. In other embodiments, multiple “components” are sprayed. When multiple “components” are sprayed, they may be grouped together, for example, according to their reactivity, their solubility, their properties (for *e.g.*, amino acid versus sugar), and sprayed together as a mixture. Alternately, the components may be sprayed one after another sequentially.

[0061] The term “solvent” refers to any liquid, such as water, any hydrant, any buffer, or an organic liquid like ethanol, etc. that can dissolve one or more “components” that needs to be layered. Layering may occur through the “spraying” of the liquid with the dissolved “component” or “mixture of components”. The solvent may dissolve one or more “like” components; for *e.g.*, ethanol may dissolve lipids, fatty acids, cholesterol, etc. or the solvent may dissolve one or more “dissimilar” components like “reactive components” and “anti-oxidants” together, probably because, the anti-oxidants or other such molecules/ components help stabilize or slow-down the degrading steps of the reactive species or groups. The solvent may be sprayed sequentially or all at once. When sprayed sequentially, each solvent sprayed may have the same composition, or may have different compositions. In certain instances, a plurality of solvents can be sprayed on to the same base particle or granule to form a multilayered base particle or granule. In certain instances, the multilayered base particle or granule spatially separate active or reactive

species (or ingredients) from sensitive species. In one embodiment, the rate of the solvent introduction may be between about 1 gm/min up to about 30 gm/ min. In another embodiment, the rate of the solvent introduction may be about 5 gm/min.

[0062] The term “sprayer” refers to the equipment that sprays the liquid carrying one or more components onto to the base particle or base granule. Sprayer may be selected from the group consisting of: a top sprayer, a bottom sprayer and a tangential sprayer. One sprayer may be used for making a granulated particle (say, agglomerated particle), whereas a second sprayer, in one embodiment, a bottom sprayer may be used to layer the solvents and the components as desired and described above.

[0063] “Reactive species” refers to those components that are easily react with other components in the medium or feed, thereby producing undesirable products such as adducts, cross-linked products, precipitates etc. Reactive species may self-react or may be activated to react due to exposure to higher temperatures, to irradiation, to the presence of other chemicals or reactive species, etc. exemplary reactive species include but are not limited to, metal ions, sugars that form adducts, trace metal components, reactive amino acids, etc.

[0064] “Sensitive species” refers to those components that are easily destroyed due to their unwanted reaction, with more reactive species or groups from the medium or feed. Sensitive (or labile) species may self-react or may be activated to react with other components, especially reactive species, due to their exposure to higher temperatures, to irradiation, to the presence of other chemicals or reactive species, etc. Exemplary sensitive species include but are not limited to, vitamins, certain amino acids, polyamines such as ethanolamine, etc., biological components like growth factors etc. which are destroyed over time, or at higher temperature, or upon exposure to irradiation, or due to a combination of one or more of these factors.

[0065] The phrases "cell culture medium," "culture medium," and "medium formulation" (plural "media" in each case) refer to a nutritive solution that supports the cultivation and/or growth of cells; these phrases may be used interchangeably.

[0066] The term "combining" refers to the mixing or admixing of ingredients in a cell culture medium formulation. Combining can occur in liquid or powder form or with one or more powders and one or more liquids. In another example, two or more powdered components may be admixed and then agglomerated to produce a complex mixture such as media, media supplements, media subgroups or buffers.

The term “particle size” refers to the size (which may be a distribution) of the layered particles determined through a ‘sieve’ measurement. In an embodiment, the layered particle or base granule size maybe about 0.05mm to 7 mm. In a preferred embodiment, the layered particle or base granule size may be about 0.05 mm to about 0.5mm, about 0.05 mm to about 1mm, about 0.05 mm to about 2mm, about 0.05 mm to about 3mm, about 0.05 mm to about 4mm, about 0.05 mm to about 5mm, about 0.05 mm to about 6mm, about 0.05 mm to about 0.1mm, about 0.05 mm to about 0.2mm, about 0.05 mm to about 0.3mm, about 0.05 mm to about 0.4mm, about 0.1mm to about 1mm, about 0.1mm to about 2mm, about 0.1mm to about 3mm, about 0.1mm to about 4mm, about 0.1mm to about 5mm, about 0.1mm to about 6mm, about 0.5mm to about 1mm, about 0.5mm to about 2mm, about 0.5mm to about 3mm, about 0.5mm to about 4mm, about 0.5mm to about 5mm, about 0.5mm to about 6mm, about 0.5mm to about 7mm, about 1mm to about 2mm, about 1 mm to about 3mm, about 1 mm to about 4mm, about 1 mm to about 5mm, about 1 mm to about 6mm, about 1 mm to about 7mm. In yet another embodiment, the size of the layered particle or granule may be larger than about 0.5mm, a size larger than about 0.4 mm, larger than about 0.3 mm, larger than about 0.2 mm, larger than about 0.6 mm, larger than about 0.7 mm, larger than about 0.8 mm, larger than about 0.9mm, larger than about 1mm.

[0067] EXAMPLES

[0068] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

[0069] Example 1: Exemplary Process for making a Layered Cell Culture Media Granule – Prototypes A and B (using the Bottom Sprayer)

[0070] Granule formulations were designed and produced by layering methods by using a combination of a top sprayer for granulation and a bottom sprayer (for e.g., Wurster) for coating. In one example, bottom spray coating was performed with a GPCG 1.1 with a 6” Wurster Insert, 2 Liter Granulator/Dryer/Coater. For the bottom spray layering, the layer composition may vary for each granulation. For example, for prototypes A and B - (see Figures 1a, 1b; 2a, 2b; 3a, 3b). Granulated Base

Medium for Prototypes A & B used SKU PL003021, Lot 1024MER1601. Base medium was produced by top-spray granulation.

[0071] Prototype A was layered as follows: Solution #1 (vitamin B-12), SKU PL003023, Lot 1101MER1601.

[0072] Apply Spray #1 (use ~95 ml per batch of 200X conc.) Prototype B was layered as follows: With Solution #2 (Salt solution NaCl,) SKU PL003024, Lot 1101MER1602. With Solution #3 (Thiamine HCl solution) SKU PL003029, Lot 1109MER1601. Apply Spray #2 (use ~38 ml per batch of 500X conc.) followed by Spray #3 (use ~38 ml per batch of 500X conc.). End with final application of Spray #2 (use ~38 ml per batch of 500X conc.). SEM images of Prototypes A and B are shown in Figures 2a and 2b. SEM of dried layered product shows Prototype A (bottom spray) with smoother surface compared to granulated base powder (top spray). SEM of Prototype B rough coated surface compared to granulated base powder (top spray) possibly because the outermost layer is a salt layer (NaCl).

[0073] Example 2: Comparison of cell viability and growth in an assay of reconstituted layered feed media

[0074] Comparison of cell viability and growth in an assay of reconstituted layered feed media (test= Prototype A tested) against positive control regular feed media (see Figures 3a and 3b). For this assay, DG44-IgG cell line was cultured in CD- CHO (medium) # 12490 with Efficient Feed B (supplement) #A2530 (positive control); while the test was reconstituted layered feed media (Prototype A); and negative control = media fed with glucose.

[0075] All cells were sub-passaged as follows: 3 subpassages for 3 days; then cells from each subpassage was split to 3×10^5 viable cells/ml. At 4th subpassage, after 3 days, daily cell counts were taken. All test and control feed media were reconstituted with liquid, then sterile filtered. As seen from Figures 3a and 3b, Prototype A showed high % viability comparable to cell culture supplemented with the unlayered, Positive Control Feed Medium. For cell growth, Prototype A showed viable cell counts of $\sim 6.6 \times 10^6$ cells /ml (growth), that is, only slightly lower numbers than the cell culture supplemented with the Positive Control Feed ($\sim 7.5 \times 10^6$). For comparison, un-supplemented cell culture assay may be labeled as Glucose Feed (Negative Control).

[0076] Example 3: Exemplary Process for the Production of Layered Media/ Feed Granules for Cell Culture

Granule formulations were designed and produced by layering methods, using a combination of a top sprayer for granulation and a bottom sprayer (Wurster) for coating. See Figures 4, 5a and 5b.

A base powder contains amino-acids, d-glucose, salts buffers and select vitamins (SKU 12681).

The powder was blended, for e.g., using a Blender (4qt), granulated using a solvent (for e.g., water) using a top-spray process (see Table 1) and with equipment including but not limited to, for e.g., Niro MP-1, Peristaltic Pump, Quadro Comil U5; then milled, for e.g., using a Fitzmill L1A. Here, the base powder was granulated before layering, but granulation of the base powder may not be a necessary step.

Granulation may use top spray, bottom spray or tangential spray. Layering may be usually done using bottom spray layering and the Layer composition may vary for each granulation. See Table 1 below for top spray granulating parameters, and see Figures 4 – 11.

[0077] Table 1: Exemplary Top Spray granulating parameters

Formulation	Batch size (g)	Initial Granulation Parameters	7 min Granulation Parameters	20 min Granulation Parameters	30 min Granulation Parameters
1	1312	Bed temp: 44°C Gas flow: 20 CMH Outlet T _g : 5°C Bed LGD: 0.7wt%	Bed temp: 30°C Gas flow: 75 CMH Outlet T _g : 13.5°C Bed LGD: 2.2wt%	Bed temp: 34.5°C Gas flow: 60 CMH Outlet T _g : 14.7°C Bed LGD: 2.2wt%	Bed temp: 33°C Gas flow: 60 CMH Outlet T _g : 10°C Bed LGD: 1.7wt%
2	1437	Bed temp: 44°C Gas flow: 20 CMH Outlet T _g : 3°C Bed LGD: 0.7wt%	Bed temp: 31°C Gas flow: 75CMH Outlet T _g : 13.5°C Bed LGD: 2.5wt%	Bed temp: 34°C Gas flow: 60 CMH Outlet T _g : 11°C Bed LGD: 2.3wt%	Bed temp: 35°C Gas flow: 60 CMH Outlet T _g : 6°C Bed LGD: 1.9wt%

[0078] Granulated Base powders were subjected to particle size and SEM analysis (see Figures 6a and b; 7a and b; and 8a and b). Exemplary process parameters that may be used for making a granule are as follows; see Table 2:

Table 2: Process Parameters	Value	Unit
Fluidization air Flow rate	45	CFM
Inlet Temperature (process)	50	°C
Inlet dew point	<5	°C
Liquid spray rate	5 +/- 0.5	g/min
Atomization air pressure	1.1	bar
Bed Temperature	35 +/- 2	°C

Exhaust dew point	<10	°C
Product Parameter	Value	Unit
Product Temperature Target	< 40	°C
% final moisture	<2.5	%

[0079] In Table 2 (above), bottom spray coating was performed with a Niro MP-1 with a 6" modified bowl, a Schlick 970 nozzle and a 1.2 mm liquid tip (range 0.5-4.0 mm). The Nozzle was fixed at 4 cm above the base with a column air gap of 20 mm (range). There were 7 coatings for formulation 1 and 8 coatings for formulation 2. All coating runs were at least 20 minutes to ensure uniform coating. Between each coating, 5 mL of water was washed through the lines. At the end of the run, there was a 10 minute drying step with the atomizer off and the inlet temperature set to 40°C.

[0080] There were 7 coatings for formulation 1 and 8 coatings for formulation 2. A schematic diagram of each layer sprayed for Formulations 1 & 2 are shown in Figures 5a and 5b, and the description is also given below in Table 3.

[0081] Table 3: Description of Formulation 1 & 2: Contents of the base granules and coatings that were sprayed.

[0082] Descriptions are relative to Thermo Fisher catalog (catalog blend) CD OptiCHO AGT SKU# A11222-05.

	Formulation 1		Formulation 2	
	Description	Total wt%	Description	Total wt%
Base	- Remove cys, cystine (cys₂), met - Remove aliphatic amino acids^a	82%	- Remove cys, met - Add post-granulation NaCl	94%
Spray 1	- Vitamin spray with glutathione, cys, met 19% cys, 34% met (solids weight) 11% w/v solids in water	0.7%	- Vitamin spray with glutathione, cys, met 26% cys, 39% met (solids weight) 11% w/v solids in water	0.7%
Spray 2	- Neutral spray with dextran sulfate, cys, met 3.1% cys, 5.7% met (solids weight) 8.8% w/v solids in water	0.6%	- Alcohol Solution 0.11% w/v solids in 60% EtOH/water	0.01%
Spray 3	- Alcohol spray with cys, met 12% cys, 22% met (solids weight) 0.16% w/v solids in 50% EtOH/water	0.01%	- Neutral spray with dextran sulfate, cys, met 8.8% w/v solids in water	0.5%
Spray 4	- Aliphatic amino acids 4.9% w/v solids in water	3.5%	- Amines^b with cys and met 20% cys, 36% met (solids weight) 11% w/v solids in water	0.7%
Spray 5	- Iron chelate spray 0.31% w/v solids in water	0.02%	- Iron chelate spray 0.31% w/v solids in water	0.02%
Spray 6	- Trace element spray A 0.15% w/v solids in water	0.01%	- Trace element spray A 0.15% w/v solids in water	0.01%
Spray 7	- Trace element spray B 5e-3% w/v solids in water	0.0002%	- Trace element spray B 5e-3% w/v solids in water	0.0002%
Spray 8	- Aliphatic amino acids with cys and met 3.7% cys, 6.7% met (solids weight) 5.5% w/v solids in water	3.9%		--
Blend	Catalog Blend	9.5%	Pluronic F68 only	3.9%

[0083] For Formulation 1: Concept design #1: to achieve sensitive group protection using bottom spray layering (coating) method (Multi-layered, Multi-Ingredients) and consists of the following layers:

[0084] Base granulation ingredients (e.g., D-glucose, salts, amino acids, buffers and some vitamins) coated with a first layer of antioxidants ("Core"). Then coated with a second layer of nutrients that have anti-oxidant properties. Followed by a third layer that contains sensitive nutrients (i.e., concentration decreases as a result of gamma irradiation) mixed with anti-oxidant nutrients. Then a fourth layer may be applied as a barrier to separate sensitive ingredients from the remaining 3 layers which include: a salt layer, additional separation barrier layer, an outer antioxidant layer ("Shell").

[0085] Formulation 1 included 8 coats with a total coating thickness of about 10 μm , and D50 = 180 μm . Sieve analysis before and after bottom spray coating was performed (see Figures 6a and 7a). The coated granules have a smaller average size than the starting uncoated granules due to granule attrition during the

process. Sieve Analysis used for example, the Retsch sieve shaker, but any shaker can be used. Details: 8" sieves, amplitude 6, pulsed, 6 minutes duration.

[0086] An exemplary layered AGT Prototype or "Onionskin" layered AGT was produced using bottom spray method. The layered AGT prototype was made where reactive groups were segregated/ layered. The method was scalable process up to 1-2 kg. Layer formation was identified and confirmed by analytical methods. An exemplary prototype product could consist of the following three layers: Bulk granulation components, Solution A= Vitamins, Solution B (or Suspension)* = anti-oxidant amino acid layer (for example, Cysteine & Methionine), Solution C = Trace Elements (or other oxygen reactive components). *Note- Cysteine can be formulated as a solution in one granulation. Cysteine has the potential to form cystine (dimerization) in solution. One approach to avoid the formation of cystine may be to formulate cysteine as micro-suspension in a second granulation.

[0087] For Formulation 2: Concept design #2: to achieve reactive group segregation using bottom spray layering (coating) method (Multi-layered, Multi-Ingredients) and consists of the following layers:

[0088] Base granulation ingredients (e.g., d-glucose, salts, amino acids, buffers and some vitamins). Solution A contains sensitive nutrients (i.e., concentration decreases as a result of gamma irradiation). Solution B contains nutrients that have anti-oxidant properties. Solution C contains nutrients that may be reactive toward base granulated components.

[0089] Formulation 2 included 7 coats with a total coating thickness of about 5 μm and D50 = 180 μm . "Onionskin" layered (thin layers). Sieve analysis before and after bottom spray coating was performed (see Figures 6b and 7b).

[0090] An exemplary layered media, Formulation 2 was prepared as described: Bulk granulation components- list of media chemicals for granulation step; 1st inner layer; (Vitamins w/Antioxidants) = for example, Vitamins + cysteine- HCl- H₂O + methionine= 2nd layer; (Polyamines w/Antioxidants)* = for example, cysteine & methionine + polyamines + ethanolamine= 3rd layer; Salts #1 = (Iron Chelate Solution), for example, EDTA + Ferrous Sulfate 7H₂O= 4th layer; Salts #2 (Trace Element Solution A (0116031)) = 5th layer ; Salts #3 (Trace Element Solution B (0116026))= 6th layer.

[0091] For Formulation 3: An exemplary layered media, Formulation 3 (F3) was prepared as described herein: "Core-Shell" layered AGT produced using bottom spray method ("Core-Shell" layering). Reduction to practice of micro-suspension layering method(s) (i.e. scalable process up to 1-2 kg) Formulation 3 (F3) is described herein: Bulk granulation components, 1st inner layer, Coating #2 (Vitamins w/Antioxidants) = Vitamins + cysteine- HCl- H₂O + methionine=2nd layer; (Antioxidants

microsuspension)* = (cysteine & methionine micronized/suspended in Pluronic/water carrier solution or PEG/water carrier solution) = 3rd layer; Salts #1 = (Iron Chelate Solution)= EDTA + Ferrous Sulfate, 7H₂O = 4th layer; Salts #2 (Trace Element Solution A (0116031)) = 5th layer ; Salts #3 (Trace Element Solution B (0116026)) = 6th layer. Or layers 4, 5 and 6 may be combined.

*Note: Cysteine has the potential to form cystine (dimerization) in solution. One approach to avoid the formation of cystine may be to formulate cysteine as micro-suspension. Test the feasibility of using pluronic or PEG as solvents for micro-suspensions since these polymers are compatible with water soluble and water insoluble compounds.

[0092] Formulation Processes for Bottom-Spray Solutions: “Onionskin” layered AGT produced using bottom spray method. Steps for preparing Formulation 2 (F2) or Formulation 3 (F3) is described herein. Bulk granulation components (inner core). *Note- Polyamines w/Antioxidants can be formulated as a solution, see below. Step 1. A solution of polyamines (pH range= 6.4-6.6) has been pre-formulated, sterile filtered (0.2um). Step 2. Add Antioxidants in the polyamine solution prepared in step 1, stir the solution (magnetic stir plate) until dissolved (a clear solution forms). Step 3. Measure & record the pH of the clear solution (pH range 2.0- 3.0). Step 4. Adjust the solution pH to 6.5 – 7.5 using 5N NaOH. The solution should remain clear and can be used to produce bottom-spray layered granulation.

[0093] Physical Properties of Formulations 1 & 2

Table 4: Formulation 1 Physical Properties	
Coat thickness	≈10μm
Tap density	0.89
Bulk density	0.82
Carr index	7.9

Table 5: Formulation 2 Physical Properties	
Coat thickness	≈5μm
Tap density	0.84
Bulk density	0.75
Carr index	10.7

[0094] For comparison, the base granulated particle size (Figures 9a and b) and milled base granulated particle size (Figures 10a and b) were also performed.

[0095] Example 4: Analytical testing of Formulation 1 & 2 before and after gamma radiation

[0096] The dry, layered cell culture media (formulations 1 and 2) prepared by methods described above were tested further for gamma irradiation stability. The goal of this experiment was to determine if a radiation-tolerant media could be prepared by changing the process conditions only, here, layering media/feed components (i.e., without changes to the cell culture medium formulation). The layered media was treated with gamma irradiation in the dose range of about 20kGy to about 70 kGy as shown in the Table below. The gamma-irradiation tolerance of the resultant layered granulated media was analyzed by measuring the concentration of sensitive chemical markers (for e.g., vitamins like thiamine, vitamin B-12, etc.) before and after gamma radiation. For each formulation (F1 & F2) and gamma radiation condition, two 1-L media batches were prepared using MilliQ water. Each sample was also tested (by HPLC) for tryptophan, niacinamide, folic acid, thiamine, and vitamin B12. Dose column lists average dosage of gamma radiation that the formulation was exposed to for this study. The results are presented below in Table 6 and in Figure 11. In addition, physical characterization of the resultant granules was done (Tables 4 and 5). It was found that the multicomponent cell culture media prepared using bottom spray layering techniques gives excellent uniformity of content. It was also noted that controlled placement of each layer around a base granulated powder provided a method to physically separate reactive and sensitive chemicals within the same formulation. Grouped layers further improved chemical stability during exposure to conditions that cause thermal reactivity or degradation, photochemical reactivity or degradation, radiation induced reactivity or degradation.

[0097] Table 6: Radiation Analysis Table (dose in kGy)

Sample	Dose	% Remaining				
		L-Tryptophan	Niacinamide	Folic Acid	Thiamine HCl	B12
Formulation 1-0	0	100%	100%	100%	100%	100%
Formulation 1-2	25	100%	97%	95%	94%	78%
Formulation 1-1	35	100%	99%	96%	96%	73%
Formulation 1-3	65	99%	101%	96%	95%	64%
Formulation 2-0	0	100%	100%	100%	100%	100%
Formulation 2-1	25	102%	97%	94%	95%	73%
Formulation 2-2	35	101%	98%	95%	94%	69%
Formulation 2-3	65	99%	98%	94%	91%	56%
Catalog-0	0	100%	100%	100%	100%	100%
Catalog-1	25	100%	100%	99%	96%	72%
Catalog-2	35	101%	99%	100%	96%	67%
Catalog-3	65	100%	99%	99%	93%	51%

[0098] Summary of Table 6 and other Assays for Formulations 1 & 2: Thiamine degraded up to 9% in a dose-dependent fashion and vitamin B12 degraded as much as 49% in a dose-dependent fashion. The degradation of thiamine and vitamin B12 are shown in Figure 11. Vitamin B12 degradation at 60 – 70 kGy was reduced by 18% and 26% relative to the catalog control for formulations 1 and 2, respectively (Protection of gamma radiation sensitive nutrients in Layered granulations). Gamma Radiation Treatment-The catalog CD OptiCHO AGT control, formulation 1, and formulation 2 were shipped for example to Steris for gamma radiation treatment. All samples were stored at 5°C and were shipped and irradiated at dry ice temperature (-78°C). Each formulation was divided into four batches and kept either (a) at 5°C, or (b) irradiated with a total dose of (b) 20 – 30 kGy, (c) 30 – 40 kGy, or (d) 60 – 70 kGy.

[0099] Tryptophan and niacinamide assay levels were within 3% of the non-irradiated media for all radiation levels tested. Folic acid content was within 6% of the non- irradiated media for all radiation doses. Gamma Radiation Treatment-The catalog CD OptiCHO AGT control, formulation 1, and formulation 2 were shipped for example, to Steris, for gamma radiation treatment. All samples were stored at 5°C and was shipped and irradiated in dry ice temperature (-78°C). Each formulation was divided into four batches and either kept (a) at 5°C, or irradiated with a total dose of (b) 20 – 30 kGy, (c) 30 – 40 kGy, or (d) 60 – 70 kGy.

[00100]The processes described above are applicable for cultivation of any cell type: mammalian, bacterial, insect, fungal, etc., that derive their nutrient support from the reconstituted dry-format, layered, cell culture media described throughout this specification. As described in some embodiments above, also encompassed within the invention's scope is the application of a layer composed of ingredients

formulated as a microsuspension, or as a coating for cell culture granulated media. The large number of permutations in which cell culture media ingredients can be grouped, separated or otherwise organized within layers around any powdered cell culture media/ feed, or granulated cell culture media/ feed makes this methodology useful for a wide variety of applications, such as, to increase thermal stability, radiation tolerance, modified dissolution profiles, etc., as will be readily appreciated by one of skill in the art.