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(54) Title: MEAT COMPOSITIONS COMPRISING COLORED STRUCTURED PROTEIN PRODUCTS

(57) Abstract: The invention provides animal meat compositions and simulated animal meat compositions. In particular, the meat compositions comprise colored structured protein products along with other ingredients.

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MEAT COMPOSITIONS COMPRISING COLORED STRUCTURED PROTEIN PRODUCTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Application Serial No. 60/910,339 filed on April 5, 2007, U.S. Provisional Application Serial No. 60/991,470 filed on November 30, 2007, and US Non-Provisional Serial Application No. 12/062,366 filed on April 3, 2008, which are hereby incorporated by reference in their entirety.

FIELD OF THE INVENTION

[0002] The present invention provides meat compositions and meat analog compositions comprising colored structured protein products and optionally may include animal meat. The invention also provides processes for producing the colored structured protein products.

BACKGROUND OF THE INVENTION

[0003] Food scientists have devoted much time developing methods for preparing acceptable meat-like food products, such as beef, pork, poultry, fish, and shellfish analogs, from a wide variety of proteins from different sources. Extrusion of high protein mixtures has been widely utilized to form meat analogs. While some high protein extrudates have much more meat-like characteristics than other high protein extrudates, many have the disadvantage of being light beige or straw colored. Oftentimes, the meat analog can be mixed with animal meat and the mixture can be colored to resemble to color of the final meat product. In applications where the final meat product is a cured or smoked meat product, however, the meat analog generally resists coloration.

[0004] Thus, there is an unmet need for a colored meat analog that simulates the fibrous structure of animal meat and mimics the color of an all meat product. For example, it is desirable to have a colored meat analog that would resemble the color of cured meat products.

SUMMARY OF THE INVENTION

[0005] One aspect of the present invention provides animal meat compositions comprising animal meat and colored structured protein products having protein fibers that are substantially aligned. The colored structured protein product is formed by extruding a protein-containing material and at least one colorant through a die assembly, whereby the colored extrudate has protein fibers that are substantially aligned.

[0006] Another aspect of the invention provides simulated animal meat compositions comprising colored structured protein products. The colored structured protein product is formed by extruding a protein-containing material and at least one colorant through a die assembly, whereby the colored extrudate has protein fibers that are substantially aligned.

[0007] Other aspects and features of the invention are described in more detail below.

REFERENCE TO COLOR FIGURES

[0008] The application contains at least one photograph executed in color. Copies of this patent application publication with color photographs will be provided by the Office upon request and payment of the necessary fee.

FIGURE LEGENDS

[0009] **Figure 1** depicts an image of a micrograph showing a structured protein product of the invention having protein fibers that are substantially aligned.

[0010] **Figure 2** depicts an image of a micrograph showing a protein product not produced by the process of the present invention. The protein fibers comprising the protein product, as described herein, are crosshatched.

[0011] **Figure 3** depicts a perspective view of one embodiment of the peripheral die assembly that may be used in the extrusion process of the protein containing materials.

[0012] **Figure 4** depicts an exploded view of the peripheral die assembly showing the die insert, die sleeve, and die cone.

[0013] **Figure 5** depicts a cross-sectional view taken showing a flow channel defined between the die sleeve, die insert, and die cone arrangement.

[0014] **Figure 5A** depicts an enlarged cross-sectional view of Figure 5 showing the interface between the flow channel and the outlet of the die sleeve.

[0015] **Figure 6** depicts a cross-sectional view of an embodiment of the peripheral die assembly without the die cone.

[0016] **Figure 7** depicts a perspective view of the die insert.

[0017] **Figure 8** depicts a top view of the die insert.

[0018] **Figure 9** depicts a photographic image of slices of a cured turkey ham product of Example 8 in which part of the turkey thigh meat is replaced with pink/red-colored structured protein product (SPP). No color retention aid is present in this patty.

[0019] **Figure 10** depicts a photographic image of slices of a cured turkey ham product of Example 9 in which part of the turkey thigh meat is replaced with pink/red-colored structured protein product (SPP). Maltodextrin is present as a color retention aid in this patty.

[0020] **Figure 11** depicts a photographic image of slices of a cured turkey ham product of Example 10 in which part of the turkey thigh meat is replaced with pink/red-colored structured protein product (SPP). Calcium alginate is present as a color retention aid in this patty.

DETAILED DESCRIPTION OF THE INVENTION

[0021] The present invention provides animal meat compositions comprising colored structured protein products having protein fibers that are substantially aligned. The colored structured protein products are formed by extruding a protein-containing material and at least one colorant through a die assembly, such that the colored extrudate has substantially aligned protein fibers. The colored structured protein products may have a variety of colors. As an example, the colored structured protein products may have a reddish color that mimics the color of cured or smoked meats. Alternatively, the colored structured protein products may have a whitish color that mimics the color of cooked white meat from poultry or white-fleshed fish. The compositions of the invention include an animal meat composition comprising animal meat and colored structured protein products, as well as a simulated animal meat composition comprising colored structured protein products.

(I) Animal Meat Compositions and Simulated Animal Meat Compositions

[0022] One aspect of the invention provides animal meat compositions comprising colored structured protein products and animal meat. Another aspect of the invention provides simulated animal meat compositions comprising colored structured protein products. The composition and properties of the colored structured protein products are detailed below in section (I)A. Because the colored structured protein products have protein fibers that are substantially aligned in a manner similar to animal meat, the meat compositions of the invention generally have the texture and eating quality characteristics of compositions comprised of one hundred percent animal meat.

[0023] The animal meat compositions and the simulated animal meat compositions of the invention may comprise conventionally grown ingredients, or the meat compositions may comprise organically grown ingredients. Furthermore, the animal meat compositions may comprise kosher Halal certified ingredients. Additionally, the simulated animal meat compositions may comprise entirely plant-derived ingredients, and therefore, be vegan. Or the simulated animal meat composition may comprise plant, dairy, and/or egg derived ingredients, and therefore, be lacto-, ovo-, or lacto-ovo-vegetarian.

A. Colored Structured Protein Products

[0024] The colored structured protein products have protein fibers that are substantially aligned, as described below. A colored structured protein product is made by extruding a protein-containing material and at least one colorant through a die assembly under conditions of elevated temperature and pressure, such that the colored extrudate has substantially aligned protein fibers. A variety of protein-containing materials and a variety of colorants, as described below, may be used to produce the colored structured protein products. The protein-containing materials may be derived from plant or animal sources. Additionally, combinations of protein-containing materials from various sources may be used in combination to produce structured protein products having substantially aligned protein fibers.

(a) protein-containing materials

[0025] As mentioned above, the protein-containing material may be derived from a variety of sources and then further utilized in a thermal plastic extrusion process to produce structured protein products suitable for use in the meat and simulated meat compositions (meat analog compositions). Irrespective of its source or ingredient classification, the ingredients utilized in the extrusion process are typically capable of forming structured protein products having protein fibers that are substantially aligned. Suitable examples of such ingredients are detailed more fully below.

[0026] The amount of protein present in the ingredient(s) can and will vary depending upon the application. For example, the amount of protein present in the ingredient(s) utilized may range from about 40% to about 100% by weight. In another embodiment, the amount of protein present in the ingredient(s) utilized may range from about 50% to about 100% by weight. In an additional embodiment, the amount of protein present in the ingredient(s) utilized may range from about 60% to about 100% by weight. In a further embodiment, the amount of protein present in the ingredient(s) utilized may range from about 70% to about 100% by weight. In still another embodiment, the amount of protein present in the ingredient(s) utilized may range from about 80% to about 100% by weight. In a further embodiment, the amount of protein present in the ingredient(s) utilized may range from about 90% to about 100% by weight.

[0027] A variety of ingredients that contain protein may be utilized in a thermal plastic extrusion process to produce structured protein products suitable for use in the ground meat simulated meat compositions. While ingredients comprising proteins derived from plants are typically used, it is also envisioned that proteins derived from other sources, such as animal sources, may be utilized without departing from the scope of the invention. For example, a dairy protein selected from the group consisting of casein, caseinates, whey protein, and mixtures thereof may be utilized. In an exemplary embodiment, the dairy protein is whey protein. By way of further example, an egg protein selected from the group consisting of ovalbumin, ovoglobulin, ovomucin, ovomucoid, ovotransferrin, ovovitella, ovovitellin, albumin globulin, vitellin, and combinations thereof may be utilized. Further, meat proteins or protein ingredients consisting of collagen, blood, organ meat, mechanically separated meat, partially defatted tissue, blood serum proteins, and combinations thereof may be included as one or more of the ingredients of the structured protein products.

[0028] It is envisioned that other ingredient types in addition to proteins may be utilized. Non-limiting examples of such ingredients include sugars, starches, oligosaccharides, soy fiber, other dietary fibers, and combinations thereof.

[0029] While in some embodiments gluten may be used as a protein, it is also envisioned that the protein-containing starting materials may be gluten-free. Further, it is envisioned that the protein-containing starting materials may be wheat-free. Because gluten is typically used in filament formation during the extrusion process, if a gluten-free starting material is used, an edible cross-linking agent may be utilized to facilitate filament formation. Non-limiting examples of suitable cross-linking agents include Konjac glucomannan (KGM) flour, 1,3 BetaGlucan, Curdlan from Kirin Food-Tech (Japan), transglutaminase, calcium salts, magnesium salts, and combinations thereof. One skilled in the art can readily determine the amount of cross-linking material needed, if any, in gluten-free embodiments.

[0030] Irrespective of its source or ingredient classification, the ingredients utilized in the extrusion process are typically capable of forming extrudates having protein fibers that are substantially aligned. Suitable examples of such ingredients are detailed more fully below.

(i) plant protein-containing materials

[0031] In an exemplary embodiment, at least one ingredient derived from a plant will be utilized to form the structured protein product. Generally speaking, the ingredient will comprise a protein. The protein containing material derived from a plant may be a plant extract, a plant meal, a plant-derived flour, a plant protein isolate, a plant protein concentrate, or a combination thereof.

[0032] The ingredient(s) utilized in extrusion may be derived from a variety of suitable plants. The plants may be grown conventionally or organically. By way of non-limiting examples, suitable plants include amaranth, arrowroot, barley, buckwheat, cassava, canola, channa (garbanzo), corn, kamut, lentil, lupin, millet, oat, pea, peanut, potato, quinoa, rice, rye, sorghum, sunflower, tapioca, triticale, wheat, or a mixture thereof. Exemplary plants include soy, wheat, canola, corn, lupin, oat, pea, potato, and rice.

[0033] In one embodiment, the ingredients may be isolated from wheat and soybeans. In another exemplary embodiment, the ingredients may be isolated from soybeans. In a further embodiment, the ingredients may be isolated from wheat. Suitable wheat derived protein-containing ingredients include wheat gluten, wheat flour, and mixtures thereof. Examples of commercially available wheat gluten that may be utilized in the invention include Manildra Gem of the West Vital Wheat Gluten and Manildra Gem of the West Organic Vital Wheat Gluten each of which is available from Manildra Milling. Suitable soy derived protein-containing ingredients ("soy protein material") include soy protein isolate, soy protein concentrate, soy flour, and mixtures thereof, each of which is detailed below.

[0034] In an exemplary embodiment, as detailed above, soy protein isolate, soy protein concentrate, soy flour, and mixtures thereof may be utilized in the extrusion process. The soy protein materials may be derived from whole soybeans in accordance with methods generally known in the art. The whole soybeans may be standard soybeans (i.e., non genetically modified soybeans), organic soybeans, commoditized soybeans, genetically modified soybeans, and combinations thereof.

[0035] In one embodiment, the soy protein material may be a soy protein isolate (ISP). In general, a soy protein isolate has a protein content of at least about 90% soy protein on a moisture-free basis. Generally speaking, when soy protein isolate is used, an isolate is preferably selected that is not a highly hydrolyzed soy protein isolate. In certain embodiments, highly hydrolyzed soy protein isolates, however, may be used in combination with other soy protein isolates provided that the highly hydrolyzed soy protein isolate content of the combined soy protein isolates is generally less than about 40% of the combined soy protein isolates, by weight. Additionally, the soy protein isolate utilized preferably has an emulsion strength and gel strength sufficient to enable the protein in the isolate to form fibers that are substantially aligned upon extrusion. Examples of soy protein isolates that are useful in the present invention are commercially available, for example, from Solae, LLC (St. Louis, MO.), and include SUPRO® 500E, SUPRO® EX 33, SUPRO® 620, SUPRO® EX45, SUPRO® 595, and combinations thereof. In an exemplary embodiment, a form of SUPRO® 620 is utilized as detailed in Example 3.

[0036] Alternatively, soy protein concentrate may be blended with the soy protein isolate to substitute for a portion of the soy protein isolate as a source of soy protein material. Typically, if a soy protein concentrate is substituted for a portion of the soy protein isolate, the soy protein concentrate is substituted for up to about 55% of the soy protein isolate by weight. The soy protein concentrate can be substituted for up to about 50% of the soy protein isolate by weight. It is also possible in an embodiment to substitute 40% by weight of the soy protein concentrate for the soy protein isolate. In another embodiment, the amount of soy protein concentrate substituted is up to about 30% of the soy protein isolate by weight. Examples of suitable soy protein concentrates useful in the invention include ALPHA™ DSP-C, PROCON™ 2000, ALPHA™ 12, ALPHA™ 5800, and combinations thereof, which are commercially available from Solae, LLC (St. Louis, MO.).

[0037] If soy flour is substituted for a portion of the soy protein isolate, the soy flour is substituted for up to about 35% of the soy protein isolate by weight. The soy flour should be a high protein dispersibility index (PDI) soy flour. When soy flour is used, the starting material is preferably defatted soybean flour or flakes. Full fat soybeans contain approximately 40% protein by weight and approximately 20% oil by weight. These whole full fat soybeans may be defatted through conventional processes when a defatted soy flour or flakes form the starting protein material. For example, the bean may be cleaned, dehulled, cracked, passed through a series of flaking rolls and then subjected to solvent extraction by use of hexane or other appropriate solvents to extract the oil and produce "spent flakes". The defatted flakes may be ground to produce a soy flour. Although the process is yet to be employed with full fat soy flour, it is believed that full fat soy flour may also serve as a protein source. However, where full fat soy flour is processed, it is most likely necessary to use a separation step, such as three-stage centrifugation to remove oil. In yet another embodiment, the soy protein material may be soy flour, which has a protein content of about 49% to about 65% on a moisture-free basis. Alternatively, soy flour may be blended with soy protein isolate or soy protein concentrate.

[0038] Any fiber known in the art can be used as the fiber source in the application. Soy cotyledon fiber may optionally be utilized as a fiber source. Typically, suitable soy cotyledon fiber will generally effectively bind water when the mixture of soy protein and soy cotyledon fiber is extruded. In this context, "effectively bind water" generally means that the soy cotyledon fiber has a water holding capacity of at least 5.0 to about 8.0 grams of water per gram of soy cotyledon fiber, and preferably the soy cotyledon fiber has a water holding capacity of at least about 6.0 to about 8.0 grams of water per gram of soy cotyledon fiber. When present in the soy protein material, soy cotyledon fiber may generally be present in the soy protein material in an amount ranging from about 1% to about 20% by weight on a moisture free basis, preferably from about 1.5% to about 20% by weight on a moisture free basis, and most preferably, at from about 2% to about 5% by weight on a moisture free basis. Suitable soy cotyledon fiber is commercially available. For example, FIBRIM® 1260 and FIBRIM® 2000 are soy cotyledon fiber materials that are commercially available from Solae, LLC (St. Louis, MO.).

(ii) animal protein-containing materials

[0039] A variety of animal meats are suitable as a protein source. Animals from which the meat is obtained may be raised conventionally or organically. By way of example, meat and meat ingredients defined specifically for the various structured vegetable protein patents include intact or ground beef, pork, lamb, mutton, horsemeat, goat meat, meat, fat and skin of poultry (domestic fowl such as chicken, duck, goose or turkey) and more specifically flesh tissues from any fowl (any bird species), fish flesh derived from both fresh and salt water, animal flesh of shellfish and crustacean origin, animal flesh trim and animal tissues derived from processing such as frozen residue from sawing frozen fish, chicken, beef, pork etc., chicken skin, pork skin, fish skin, animal fats such as beef fat, pork fat, lamb fat, chicken fat, turkey fat, rendered animal fat such as lard and tallow, flavor enhanced animal fats, fractionated or further processed animal fat tissue, finely textured beef, finely textured pork, finely textured lamb, finely textured chicken, low temperature rendered animal tissues such as low temperature rendered beef and low temperature rendered pork, mechanically separated meat or mechanically deboned meat (MDM) (meat flesh removed from bone by various mechanical means) such as mechanically separated beef, mechanically separated pork, mechanically separated fish including surimi, mechanically separated chicken, mechanically separated turkey, any cooked animal flesh, organ meats derived from any animal species, and combinations thereof. Meat flesh should be extended to include muscle protein fractions derived from salt fractionation of the animal tissues, protein ingredients derived from isoelectric fractionation and precipitation of animal muscle or meat and hot boned meat as well as mechanically prepared collagen tissue, gelatin, dried meat broth and combinations thereof. Additionally, meat, fat, connective tissue and organ meats of game animals such as buffalo, deer, elk, moose, reindeer, caribou, antelope, rabbit, bear, squirrel, beaver, muskrat, opossum, raccoon, armadillo and porcupine as well as well as reptilian creatures such as snakes, turtles, lizards, and combinations thereof should be considered meat.

[0040] In a further embodiment, the animal meat may be from fish or seafood. Non-limiting examples of suitable fish include bass, carp, catfish, cobia, cod, grouper, flounder, haddock, hoki, perch, pollock, salmon, snapper, sole, trout, tuna, whitefish, whiting, tilapia, and combinations thereof. Non-limiting examples of seafood include scallops, shrimp, lobster, clams, crabs, mussels, oysters, and combinations thereof.

[0041] It is also envisioned that a variety of meat qualities may be utilized in the invention. The meat may comprise muscle tissue, organ tissue, connective tissue, skin, and combinations thereof. The meat may be any meat suitable for human consumption. The meat may be non-rendered, non-dried, raw meat, raw meat products, raw meat by-products, and mixtures thereof. For example, whole meat muscle that is either ground or in chunk or steak form may be utilized. In another embodiment, the meat may be mechanically deboned or separated raw meats using high-pressure machinery that separates bone from animal tissue, by first crushing bone and adhering animal tissue and then forcing the animal tissue, and not the bone, through a sieve or similar screening device. The process forms an unstructured, paste-like blend of soft animal tissue with a batter-like consistency and is commonly referred to as mechanically deboned meat or MDM. Alternatively, the meat may be a meat by-product. In the context of the present invention, the term "meat by-products" is intended to refer to those non-rendered parts of the carcass of slaughtered animals including but not restricted to mammals, poultry and the like and further processed meat and meat products. Examples of meat by-products are organs and tissues such as lungs, spleens, kidneys, brain, liver, blood, bone, partially defatted low-temperature fatty tissues, stomachs, intestines free of their contents, dried collagen, gelatin, dried meat broth, and the like.

[0042] The protein source may also be an animal derived protein other than animal meat tissues. For example, the protein-containing material may be derived from a dairy product. Suitable dairy protein products include non-fat dried milk powder, milk protein isolate, milk protein concentrate, casein protein isolate, casein protein concentrate, caseinates, whey protein isolate, whey protein concentrate, and combinations thereof. The milk protein-containing material may be derived from cows, goats, sheep, donkeys, camels, camelids, yaks, or water buffalos. In an exemplary embodiment, the dairy protein is whey protein.

[0043] By way of further example, a protein-containing material may also be from an egg product. Suitable egg protein products include powdered egg, dried egg solids, dried egg white protein, liquid egg white protein, egg white protein powder, isolated ovalbumin protein, and combinations thereof. Examples of suitable isolated egg proteins include ovalbumin, ovoglobulin, ovomucin, ovomucoid, ovotransferrin, ovovitella, ovovitellin, albumin globulin, vitellin, and combinations thereof. Egg protein products may be derived from the eggs of chicken, duck, goose, quail, or other birds.

(iii) combinations of protein-containing materials

[0044] Non-limiting combinations of protein-containing materials isolated from a variety of sources are detailed in Table A. In one embodiment, the protein-containing material is derived from soybeans. In a preferred embodiment, the protein-containing material comprises a mixture of materials derived from soybeans and wheat. In another preferred embodiment, the protein-containing material comprises a mixture of materials derived from soybeans and canola. In still another preferred embodiment, the protein-containing material comprises a mixture of materials derived from soybeans, wheat, and dairy, wherein the dairy protein is whey.

Table A. Combinations of Protein-Containing Materials.

First protein ingredient	Second protein ingredient
soybean	wheat
soybean	canola
soybean	corn
soybean	lupin
soybean	oat
soybean	pea
soybean	rice
soybean	sorghum
soybean	amaranth
soybean	arrowroot
soybean	barley
soybean	buckwheat
soybean	cassava
soybean	channa (garbanzo)
soybean	millet
soybean	peanut
soybean	potato
soybean	rye
soybean	sunflower
soybean	tapioca

soybean	triticale
soybean	dairy
soybean	whey
soybean	egg
soybean	wheat and canola
soybean	wheat and corn
soybean	wheat and lupin
soybean	wheat and oat
soybean	wheat and pea
soybean	wheat and rice
soybean	wheat and sorghum
soybean	wheat and amaranth
soybean	wheat and arrowroot
soybean	wheat and barley
soybean	wheat and buckwheat
soybean	wheat and cassava
soybean	wheat and channa (garbanzo)
soybean	wheat and millet
soybean	wheat and peanut
soybean	wheat and rye
soybean	wheat and potato
soybean	wheat and sunflower
soybean	wheat and tapioca
soybean	wheat and triticale
soybean	wheat and dairy
soybean	wheat and whey
soybean	wheat and egg
soybean	canola and corn
soybean	canola and lupin
soybean	canola and oat

soybean	canola and pea
soybean	canola and rice
soybean	canola and sorghum
soybean	canola and amaranth
soybean	canola and arrowroot
soybean	canola and barley
soybean	canola and buckwheat
soybean	canola and cassava
soybean	canola and channa (garbanzo)
soybean	canola and millet
soybean	canola and peanut
soybean	canola and rye
soybean	canola and potato
soybean	canola and sunflower
soybean	canola and tapioca
soybean	canola and triticale
soybean	canola and dairy
soybean	canola and whey
soybean	canola and egg
soybean	corn and lupin
soybean	corn and oat
soybean	corn and pea
soybean	corn and rice
soybean	corn and sorghum
soybean	corn and amaranth
soybean	corn and arrowroot
soybean	corn and barley
soybean	corn and buckwheat
soybean	corn and cassava
soybean	corn and channa (garbanzo)

soybean	corn and millet
soybean	corn and peanut
soybean	corn and rye
soybean	corn and potato
soybean	corn and sunflower
soybean	corn and tapioca
soybean	corn and triticale
soybean	corn and dairy
soybean	corn and whey
soybean	corn and egg

(b) colorants

[0045] The colored structured protein product also comprises at least one colorant. As described more fully in section (I)A(d) below, the colorant(s) may be mixed with the protein-containing material and other ingredients prior to being fed into the extruder. Alternatively, the colorant(s) may be combined with the protein-containing material and other ingredients after being fed into the extruder. In the presence of the heat or the heat and pressure utilized during the extrusion process, some combinations of colorants and protein-containing materials result in unexpected colors. As an example, when carmine (soluble dye or lake) is contacted with the protein-containing material during the extrusion process, the color changes from red to violet/purple. This is likely the result of an ingredient dependent pH shift occurring when all ingredients are combined.

[0046] The colorant(s) may be a natural colorant, a combination of natural colorants, an artificial colorant, a combination of artificial colorants, or a combination of natural and artificial colorants. Suitable examples of natural colorants approved for use in food include annatto (reddish-orange), anthocyanins (red to blue, depending upon pH), beet juice, beta-carotene (orange), beta-APO 8 carotenal (orange), black currant, burnt sugar; canthaxanthin (pink-red), caramel, carmine/carminic acid (bright red), cochineal extract (red), curcumin (yellow-orange); lac (scarlet red), lutein (red-orange); lycopene (orange-red), mixed carotenoids (orange), monascus (red-purple, from fermented red rice), lac color, paprika, red cabbage juice, riboflavin (yellow), saffron, titanium dioxide (white), turmeric (yellow-orange), and combinations thereof.

Suitable examples of artificial colorants approved for food use in the United States include FD&C Red No. 3 (Erythrosine), FD&C Red No. 40 (Allura Red), FD&C Yellow No. 5 (Tartrazine), FD&C Yellow No. 6 (Sunset Yellow FCF), FD&C Blue No. 1 (Brilliant Blue), FD&C Blue No. 2 (Indigotine), and combinations thereof. Artificial colorants that may be used in other countries include CI Food Red 3 (Carmoisine), CI Food Red 7 (Ponceau 4R), CI Food Red 9 (Amaranth), CI Food Yellow 13 (Quinoline Yellow), CI Food Blue 5 (Patent Blue V), and combinations thereof. Food colorants may be dyes, which are powders, granules, or liquids that are soluble in water. Alternatively, natural and artificial food colorants may be lake colors, which are combinations of dyes and insoluble materials. Lake colors are not oil soluble, but are oil dispersible; tinting by dispersion.

[0047] Suitable colorant(s) may be combined with the protein-containing materials in a variety of forms. Non-limiting examples include solid, semi-solid, powdered, liquid, gel, and combinations thereof. The type and concentration of colorant(s) utilized may vary depending on the protein-containing materials used and the desired color of the colored structured protein product. Typically, the concentration of colorant(s) may range from about 0.001% to about 5.0% by weight. In one embodiment, the concentration of colorant(s) may range from about 0.01% to about 4.0% by weight. In another embodiment, the concentration of colorant(s) may range from about 0.05% to about 3.0% by weight. In still another embodiment, the concentration of colorant(s) may range from about 0.1% to about 3.0% by weight. In a further embodiment, the concentration of colorant(s) may range from about 0.5% to about 2.0% by weight. In another embodiment, the concentration of colorant(s) may range from about 0.75% to about 1.0% by weight.

[0048] The protein-containing materials may further comprise an pH regulator to maintain the pH in the optimal range for the colorant(s) utilized. The pH regulator may be an acidulent. Examples of acidulents that may be added to food include citric acid, acetic acid (vinegar), tartaric acid, malic acid, fumaric acid, lactic acid, phosphoric acid, sorbic acid, benzoic acid, and combinations thereof. The concentration of the pH regulator utilized may vary depending on the protein-containing materials and the colorant used. Typically, the concentration of acidity regulator may range from about 0.001% to about 5.0% by weight. In one embodiment, the concentration of pH regulator may range from about 0.01% to about 4.0% by weight. In another embodiment, the concentration of pH regulator may range from about

0.05% to about 3.0% by weight. In still another embodiment, the concentration of pH regulator may range from about 0.1% to about 3.0% by weight. In a further embodiment, the concentration of pH regulator may range from about 0.5% to about 2.0% by weight. In another embodiment, the concentration of pH regulator may range from about 0.75% to about 1.0% by weight. In an alternative embodiment, the pH regulator may be a pH-raising agent, such as but not limited to disodium diphosphate.

(c) additional ingredients

(i) carbohydrates

[0049] It is envisioned that other ingredient additives in addition to proteins may be utilized in the structured protein products. Non-limiting examples of such ingredients include sugars, starches, oligosaccharides, and dietary fibers. As an example, starches may be derived from wheat, corn, tapioca, potato, rice, and the like. A suitable fiber source may be soy cotyledon fiber. Typically, suitable soy cotyledon fiber will generally effectively bind water when the mixture of soy protein and soy cotyledon fiber is co-extruded. In this context, "effectively bind water" generally means that the soy cotyledon fiber has a water holding capacity of at least 5.0 to about 8.0 grams of water per gram of soy cotyledon fiber, and preferably the soy cotyledon fiber has a water holding capacity of at least about 6.0 to about 8.0 grams of water per gram of soy cotyledon fiber. Soy cotyledon fiber may generally be present in the soy protein-containing material in an amount ranging from about 1% to about 20% by weight on a moisture free basis, preferably from about 1.5% to about 20% by weight on a moisture free basis, and most preferably, at from about 2% to about 5% by weight on a moisture free basis. Suitable soy cotyledon fiber is commercially available. For example, FIBRIM® 1260 and FIBRIM® 2000 are soy cotyledon fiber materials that are commercially available from Solae, LLC (St. Louis, MO.).

[0050] In each of the embodiments delineated in Table A, the combination of protein-containing materials may be combined with one or more ingredients selected from the group consisting of a starch, flour, gluten, dietary fiber, and mixtures thereof. In one embodiment, the protein-containing material comprises protein, starch, gluten, and fiber. In an exemplary embodiment, the protein-containing material comprises from about 45% to about 65% soy protein on a dry matter basis; from about 20% to about 30% wheat gluten on a dry matter basis; from about 10% to about 15% wheat starch on a dry matter basis; and from about 1% to about

5% fiber on a dry matter basis. In each of the foregoing embodiments, the protein-containing material may comprise dicalcium phosphate, L-cysteine, and combinations of both dicalcium phosphate and L-cysteine.

(ii) pH-adjusting agent

[0051] In some embodiments, it may be desirable to lower the pH of the protein-containing material to an acidic pH (i.e., below approximately 7.0). Thus, the protein-containing material may be contacted with a pH-lowering agent, and the mixture is then extruded according to the process detailed below. In one embodiment, the pH of the protein-containing material to be extruded may range from about 6.0 to about 7.0. In another embodiment, the pH may range from about 5.0 to about 6.0. In an alternate embodiment, the pH may range from about 4.0 to about 5.0. In yet another embodiment, the pH of the material may be less than about 4.0.

[0052] Several pH-lowering agents are suitable for use in the invention. The pH-lowering agent may be organic. Alternatively, the pH-lowering agent may be inorganic. In exemplary embodiments, the pH-lowering agent is a food grade edible acid. Non-limiting acids suitable for use in the invention include acetic, lactic, hydrochloric, phosphoric, citric, tartaric, malic, glucono, deltalactone, gluconic, and combinations thereof. In an exemplary embodiment, the pH-lowering agent is lactic acid.

[0053] As will be appreciated by a skilled artisan, the amount of pH-lowering agent contacted with the protein-containing material can and will vary depending upon several parameters, including, the agent selected and the desired pH. In one embodiment, the amount of pH-lowering agent may range from about 0.1% to about 15% on a dry matter basis. In another embodiment, the amount of pH-lowering agent may range from about 0.5% to about 10% on a dry matter basis. In an alternate embodiment, the amount of pH-lowering agent may range from about 1% to about 5% on a dry matter basis. In still another embodiment, the amount of pH-lowering agent may range from about 2% to about 3% on a dry matter basis.

[0054] In some embodiments, it may be desirable to raise the pH of the protein-containing material. Thus, the protein-containing material may be contacted with a pH-raising agent, and the mixture is then extruded according to the process detailed below.

(iii) antioxidants

[0055] One or more antioxidants may be added to any of the combinations of protein-containing materials mentioned above without departing from the scope of the invention. Antioxidants may be included to increase the shelf-life or nutritionally enhance the structured protein products. Non-limiting examples of suitable antioxidants include BHA, BHT, TBHQ, vitamins A, C and E and derivatives, and various plant extracts, such as those containing carotenoids, tocopherols or flavonoids having antioxidant properties, and combinations thereof. The antioxidants may have a combined presence at levels of from about 0.01% to about 10%, preferably, from about 0.05% to about 5%, and more preferably from about 0.1% to about 2%, by weight of the protein-containing materials that will be extruded.

(iv) minerals and amino acids

[0056] The protein-containing material may also optionally comprise supplemental minerals. Suitable minerals may include one or more minerals or mineral sources. Non-limiting examples of minerals include, without limitation, chloride, sodium, calcium, iron, chromium, copper, iodine, zinc, magnesium, manganese, molybdenum, phosphorus, potassium, selenium, and combinations thereof. Suitable forms of any of the foregoing minerals include soluble mineral salts, slightly soluble mineral salts, insoluble mineral salts, chelated minerals, mineral complexes, non-reactive minerals such as carbonate minerals, reduced minerals, and combinations thereof.

[0057] Free amino acids may also be included in the protein-containing material. Suitable amino acids include the essential amino acids, i.e., arginine, cysteine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, tyrosine, valine, and combinations thereof. Suitable forms of the amino acids include salts and chelates.

(v) color retention aid

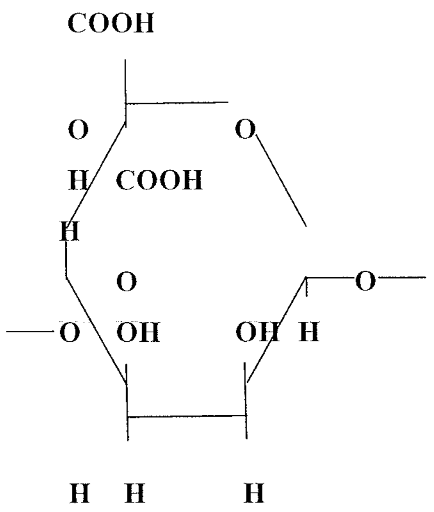
[0058] The color in the colored structured protein product tends to migrate during the duration required to prepare the material by tumbling and blending. In order to control color migration, a color retention aid is employed to suppress or control color migration from the dyed structured vegetable protein piece. The color retention aid employed is selected form the group consisting of maltodextrin and a hydrated alginate that gels when exposed to divalent cation, most preferably calcium ion.

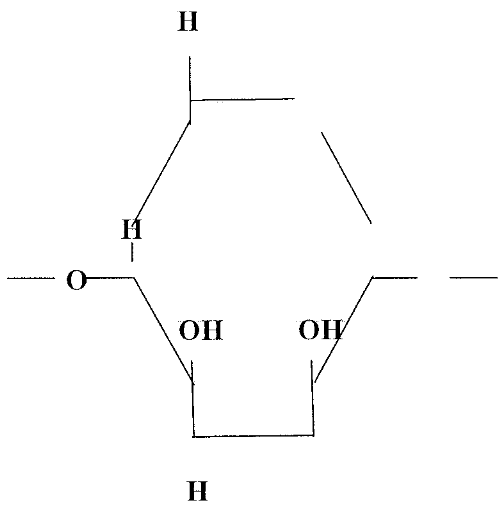
[0059] The color retention aid may be mixed with the colorant(s), protein-containing material and other ingredients prior to being fed into the extruder. Alternatively, the color retention aid may be mixed with the colorant(s), the protein-containing material and other ingredients after being fed into the extruder.

[0060] Generally the concentration of the color retention aid in the protein containing material is from about 0.025% to about 40.0% by weight. Preferably the concentration of the color retention aid in the protein containing material is from about 0.035% to about 35.0% by weight. Most preferably the concentration of the color retention aid in the protein containing material may range from about 0.04% to about 33.0% by weight.

[0061] Maltodextrin is classified as a relatively unsweet polysaccharide. While containing only slight sweet qualities, maltodextrin is considered to contain fewer calories than sugar. Usually made from rice, corn, or potato starch, maltodextrin is produced by cooking down the starch. During the cooking process, which is often referred to as a hydrolysis of starch, natural enzymes and acids help to break down the starch even further. The end result is a simple white powder that contains roughly four calories per gram, and extremely small amounts of fiber, fat, carbohydrates and protein. In employing maltodextrin as a color retention aid, a 50% aqueous solution of maltodextrin is prepared and the pH is adjusted to between about 4 and about 6.5 with a suitable pH lowering agent as discussed above. The maltodextrin acts to increase percentage solids in the hydrated material; its function is independent of pH. Maltodextrins function in the capacity to retard dye migration functions in neutral and alkaline environments. The prepared maltodextrin solution and colorant are then added to the protein-containing material either before or after extrusion. The colorant may be added either before or after the addition of the maltodextrin color retention aid. The weight ratio of dyed/colored structured plant protein ingredient to maltodextrin is generally from about 1 to 1.

[0062] As is commonly known in the art, and as used herein, the alginate compounds herein are polysaccharides which are formed from units of beta-1,4-D-mannuronic acid and alpha-1,4-L-guluronic acid. Such units have the following structures:





β-1,4-D-mannuronate (mannuronate) **α-1,4-L-guloronate (guloronate)**

[0063] The units of the alginate compound may be arranged in any manner, i.e., in random or block arrangement.

[0064] Alginates are naturally derived co-polymers of mannuronic and guluronic acids and are hydrocolloids extracted from seaweeds. The alginates may be partly neutralized to sodium, potassium, calcium salts. Any metal alginate compound may be utilized in the compositions of the present invention. For example, the alginate compound may be a naturally occurring alginate compound (naturally occurring alginates may, for example, be derived from seaweed). As used herein, the term "naturally occurring" with respect to the alginate compound means that the alginate compound utilized is found in nature or is prepared synthetically, but chemically equivalent to an alginate compound found in nature. Preferably, the alginate compound utilized herein is a naturally occurring alginate. Sodium alginate is commercially available from a variety of sources including, for example, as SALTIALGINE GS 300, from SKW Bio-Systems, Boulogne, France. A preferred metal alginate is formed by crossbridging hydrated sodium alginate with a divalent cation such as calcium ion. Calcium alginate is freshly prepared by reacting calcium chloride or calcium lactate with an alginic acid prior to combining with a colorant or prepared in situ with the colorant by forming a solution of colorant and alginate and slowly adding either calcium chloride or calcium lactate to form the calcium alginate in the presence of the colorant. Typically the equivalent weight ratio of alginic acid to a source of calcium ions from either calcium chloride or calcium lactate is from about 1-3 to 1.

The weight ratio of metal alginate to dry vegetable protein ingredient is generally from about 0.005-0.042 to 1. As with the maltodextrin color retention aid, the prepared metal alginate solution and colorant are then added to the protein-containing material either before or after extrusion.

[0065] Preferably, the alginate compound is low in mannuronic acid units relative to guluronic acid units. Specifically, the ratio (by number of units, not by weight of units) of mannuronic acid units to guluronic acid units is preferably less than about 1, more preferably from about 0.1 to about 0.9, and most preferably from about 0.1 to about 0.5.

(d) making the colored structured protein products

[0066] The colored structured protein products of the invention are made by extruding protein-containing material through a die assembly under conditions of elevated temperature and pressure. Typically, the protein-containing material may be combined with at least one colorant before it is put in the extruder. Optionally, the protein-containing material is combined with at least one colorant after exiting the extruder. After extrusion, the resulting colored structured protein product comprises protein fibers that are substantially aligned.

(i) moisture content

[0067] As will be appreciated by the skilled artisan, the moisture content of the protein-containing materials can and will vary depending upon the extrusion process. Generally speaking, the moisture content may range from about 1% to about 80% by weight. In low moisture extrusion applications, the moisture content of the protein-containing materials may range from about 1% to about 35% by weight. Alternatively, in high moisture extrusion applications, the moisture content of the protein-containing materials may range from about 35% to about 80% by weight. In an exemplary embodiment, the extrusion application utilized to form the extrudates is low moisture. An exemplary example of a low moisture extrusion process to produce colored structured protein products having protein fibers that are substantially aligned is detailed below and in Example 3.

(ii) extrusion of the protein-containing material

[0068] The colored structured protein products of the invention are made by extruding protein-containing material through a die assembly under conditions of elevated temperature and pressure. Generally, at least one colorant may be combined with the protein-containing material either prior to or during the extrusion process. Suitable colorants are detailed in section (I)A(b) above. As described more fully below, the colorant(s) may be combined with the protein-containing material prior to its introduction into the extruder. In one embodiment, the colorant(s) may be combined with the protein-containing material and other ingredients forming a colored pre-mix. In another embodiment, the colorant(s) may be combined with the protein-containing material and other ingredients, including a conditioner, forming a conditioned colored pre-mix. In still another embodiment, the colorant(s) may be combined with the protein-containing material after it has entered the extruder. In an alternative to this embodiment, the colorant(s) may be injected into the extruder barrel during the extrusion process. Regardless of the point at which the protein-containing material and the colorant(s) are combined, the concentration of colorant(s) generally range from about 0.001% to about 5.0% by weight. The type and concentration of colorant(s) utilized may vary depending on the protein-containing materials used, the desired color of the colored structured protein product, and the point of the process the colorant(s) is introduced. Typically, the concentration of colorant(s) may range from about 0.001% to about 5.0% by weight. In one embodiment, the concentration of colorant(s) may range from about 0.01% to about 4.0% by weight. In another embodiment, the concentration of colorant(s) may range from about 0.05% to about 3.0% by weight. In still another embodiment, the concentration of colorant(s) may range from about 0.1% to about 3.0% by weight. In a further embodiment, the concentration of colorant(s) may range from about 0.5% to about 2.0% by weight. In another embodiment, the concentration of colorant(s) may range from about 0.75% to about 1.0% by weight.

[0069] A suitable extrusion process for the preparation of a colored structured protein product comprises introducing the protein-containing material and other ingredients into a mixing tank (i.e., an ingredient blender) to combine the ingredients and form a blended protein material pre-mix. In one embodiment, the blended protein material pre-mix may be combined with at least one colorant. The blended protein material pre-mix may then be transferred to a hopper from which the blended ingredients may be introduced along with moisture into the extruder. In another embodiment, the blended protein material pre-mix may be combined with a conditioner to form a conditioned protein material mixture. In an alternative embodiment, at least one colorant may be combined with the conditioner forming a colored conditioned protein material mixture. The conditioned material may then be fed into an extruder in which the protein material mixture is heated under mechanical pressure generated by the screws of the extruder to form a colored molten extrusion mass. In an exemplary embodiment, at least one colorant may be injected into the extruder barrel via one or more injection jets. The colored extrudate exits the extruder through an extrusion die and comprises protein fibers that are substantially aligned.

(iii) extrusion process conditions

[0070] Among the suitable extrusion apparatuses useful in the practice of the present invention is a double barrel, twin-screw extruder as described, for example, in U.S. Patent No. 4,600,311. Further examples of suitable commercially available extrusion apparatuses include a CLEXTRAL® Model BC-72 extruder manufactured by Clextral, Inc. (Tampa, Florida); a WENGER Model TX-57 extruder, a WENGER Model TX-168 extruder, and a WENGER Model TX-52 extruder all manufactured by Wenger Manufacturing, Inc. (Sabetha, Kansas). Other conventional extruders suitable for use in this invention are described, for example, in U.S. Patent Nos. 4,763,569, 4,118,164, and 3,117,006, which are hereby incorporated by reference in their entirety.

[0071] A single-screw extruder could also be used in the present invention. Examples of suitable, commercially available single-screw extrusion apparatuses include the WENGER Model X-175, the WENGER Model X-165, and the WENGER Model X-85, all of which are available from Wenger Manufacturing, Inc.

[0072] The screws of a twin-screw extruder can rotate within the barrel in the same or opposite directions. Rotation of the screws in the same direction is referred to as single flow whereas rotation of the screws in opposite directions is referred to as double flow or counter rotating. The speed of the screw or screws of the extruder may vary depending on the particular apparatus; however, it is typically from about 250 to about 450 revolutions per minute (rpm). Generally, as the screw speed increases, the density of the extrudate will decrease. The extrusion apparatus contains screws assembled from shafts and worm segments, as well as mixing lobe and ring-type shearlock elements as recommended by the extrusion apparatus manufacturer for extruding plant protein material.

[0073] The extrusion apparatus generally comprises a plurality of heating zones through which the protein mixture is conveyed under mechanical pressure prior to exiting the extrusion apparatus through an extrusion die. The temperature in each successive heating zone generally exceeds the temperature of the previous heating zone by between about 10°C and about 70°C. In one embodiment, the conditioned pre-mix is transferred through four heating zones within the extrusion apparatus, with the protein mixture heated to a temperature of from about 100°C to about 150°C such that the molten extrusion mass enters the extrusion die at a temperature of from about 100°C to about 150°C. One skilled in the art could adjust the temperature either heating or cooling to achieve the desired properties. Typically, temperature changes are due to work input and can happen suddenly.

[0074] The pressure within the extruder barrel is typically between about 50 psig to about 500 psig preferably between about 75 psig to about 200 psig. Generally, the pressure within the last two heating zones is from about 100 psig to about 3000 psig preferably between about 150 psig to about 500 psig. The barrel pressure is dependent on numerous factors including, for example, the extruder screw speed, feed rate of the mixture to the barrel, feed rate of water to the barrel, and the viscosity of the molten mass within the barrel.

[0075] Water is injected into the extruder barrel to hydrate the plant protein material mixture and promote texturization of the proteins. As an aid in forming the molten extrusion mass, the water may act as a plasticizing agent. Water may be introduced to the extruder barrel via one or more injection jets in communication with a heating zone. Typically, the mixture in the barrel contains from about 15% to about 35% by weight water. The rate of introduction of water to any of the heating zones is generally controlled to promote production of an extrudate having desired characteristics. It has been observed that as the rate of introduction of water to the barrel decreases, the density of the extrudate decreases. Typically, less than about 1 kg of water per kg of protein is introduced to the barrel. Preferably, from about 0.1 kg to about 1 kg of water per kg of protein are introduced to the barrel.

(iv) optional preconditioning

[0076] In a pre-conditioner, the protein-containing material, reducing sugar and other ingredients (protein-containing mixture) are preheated, contacted with moisture, and held under controlled temperature and pressure conditions to allow the moisture to penetrate and soften the individual particles. The preconditioning step increases the bulk density of the particulate fibrous material mixture and improves its flow characteristics. The preconditioner contains one or more paddles to promote uniform mixing of the protein and transfer of the protein mixture through the preconditioner. The configuration and rotational speed of the paddles vary widely, depending on the capacity of the preconditioner, the extruder throughput and/or the desired residence time of the mixture in the preconditioner or extruder barrel. Generally, the speed of the paddles is from about 100 to about 1300 revolutions per minute (rpm). Agitation must be high enough to obtain even hydration and good mixing.

[0077] The protein-containing mixture may be pre-conditioned prior to introduction into the extrusion apparatus by contacting the pre-mix with moisture (i.e., steam and/or water). In one embodiment, the pre-mix may be combined with moisture and at least one colorant. Preferably the protein-containing mixture is heated to a temperature of from about 25°C to about 80°C, more preferably from about 30°C to about 40°C in the preconditioner.

[0078] Typically, the protein-containing pre-mix is conditioned for a period of about 0.5 minutes to about 10.0 minutes, depending on the speed and the size of the pre-conditioner. In an exemplary embodiment, the protein-containing pre-mix is conditioned for a period of about 3.0 minutes to about 5.0 minutes. In another embodiment, the period for conditioning is about 30 seconds to about 60 seconds. The pre-mix is contacted with steam and/or water and heated in the pre-conditioner at generally constant steam flow to achieve the desired temperatures. The water and/or steam conditions (i.e., hydrates) the pre-mix, increases its density, and facilitates the flowability of the dried mix without interference prior to introduction to the extruder barrel where the proteins are texturized. If low moisture pre-mix is desired, the conditioned pre-mix may contain from about 1% to about 35% (by weight) water. If high moisture pre-mix is desired, the conditioned pre-mix may contain from about 35% to about 80% (by weight) water.

[0079] The conditioned pre-mix typically has a bulk density of from about 0.25 g/cm^3 to about 0.60 g/cm^3. Generally, as the bulk density of the pre-conditioned protein mixture increases within this range, the protein mixture is easier to process. This is presently believed to be due to such mixtures occupying all or a majority of the space between the screws of the extruder, thereby facilitating conveying the extrusion mass through the barrel.

(v) extrusion process

[0080] The dry pre-mix or the conditioned pre-mix is then fed into an extruder to heat, shear, and ultimately plasticize the mixture. The extruder may be selected from any commercially available extruder and may be a single screw extruder or preferably a twin-screw extruder that mechanically shears the mixture with the screw elements.

[0081] The rate at which the pre-mix is generally introduced to the extrusion apparatus will vary depending upon the particular apparatus. Generally, the pre-mix is introduced at a rate of no more than about 75 kilograms per minute. Generally, it has been observed that the density of the extrudate decreases as the feed rate of pre-mix to the extruder increases. Whatever extruder is used, it should be run in excess of about 50% motor load. The rate at which the pre-mix is generally introduced to the extrusion apparatus will vary depending upon the particular apparatus. Typically, the conditioned pre-mix is introduced to the extrusion apparatus at a rate of between about 16 kilograms per minute to about 60 kilograms per minute. In another embodiment, the conditioned pre-mix is introduced to the extrusion apparatus at a rate between 20 kilograms per minute to about 40 kilograms per minute. The conditioned pre-mix is introduced to the extrusion apparatus at a rate of between about 26 kilograms per minute to about 32 kilograms per minute. Generally, it has been observed that the density of the extrudate decreases as the feed rate of pre-mix to the extruder increases.

[0082] The pre-mix is subjected to shear and pressure by the extruder to plasticize the mixture. The screw elements of the extruder shear the mixture as well as create pressure in the extruder by forcing the mixture forwards though the extruder and through the die assembly. The screw motor speed determines the amount of shear and pressure applied to the mixture by the screw(s). Preferably, the screw motor speed is set to a speed of from about 200 rpm to about 500 rpm, and more preferably from about 300 rpm to about 450 rpm, which moves the mixture through the extruder at a rate of at least about 20 kilograms per minute, and more preferably at least about 40 kilograms per minute. Preferably the extruder generates an extruder barrel exit pressure of from about 500 to about 3000 psig, and more preferably an extruder barrel exit pressure of from about 600 to about 1000 psig is generated.

[0083] The extruder heats the mixture as it passes through the extruder further denaturing the protein in the mixture. Passing through the extruder the denatured protein is restructured or reconfigured to produce a structured protein material with protein fibers substantially aligned. The extruder includes a means for heating the mixture to temperatures of from about 100°C to about 180°C. Preferably the means for heating the mixture in the extruder comprises extruder barrel jackets into which heating or cooling media such as steam or water may be introduced to control the temperature of the mixture passing through the extruder. The extruder also includes steam injection ports for directly injecting steam into the mixture within the extruder. The extruder may also include colorant injection ports for directly injecting colorant into the mixture within the extruder. The extruder preferably includes multiple heating zones that can be controlled to independent temperatures, where the temperatures of the heating zones are preferably set to increase the temperature of the mixture as it proceeds through the extruder. In one embodiment, the extruder may be set in a four temperature zone arrangement, where the first zone (adjacent the extruder inlet port) is set to a temperature of from about 80°C to about 100°C, the second zone is set to a temperature of from about 100°C to 135°C, the third zone is set to a temperature of from 135°C to about 150°C, and the fourth zone (adjacent the extruder exit port) is set to a temperature of from 150°C to 180°C. The extruder may be set in other temperature zone arrangements, as desired. In another embodiment, the extruder may be set in a five temperature zone arrangement, where the first zone is set to a temperature of about 25°C, the second zone is set to a temperature of about 50°C, the third zone is set to a temperature of about 95°C, the fourth zone is set to a temperature of about 130°C, and the fifth zone is set to a temperature of about 150°C. In still another embodiment, the extruder may be set in a six temperature zone arrangement, where the first zone is set to a temperature of about 90°C, the second zone is set to a temperature of about 100°C, the third zone is set to a temperature of about 105°C, the fourth zone is set to a temperature of about 100°C, the fifth zone is set to a temperature of about 120°C, and the sixth zone is set to a temperature of about 130°C.

[0084] [0070] The mixture forms a melted colored plasticized mass in the extruder. A die assembly is attached to the extruder in an arrangement that permits the colored plasticized mixture to flow from the extruder exit port into the die assembly and produces substantial alignment of the protein fibers within the colored plasticized mixture as it flows through the die assembly. The die assembly may include either a faceplate die or a peripheral die.

[0085] The mixture forms a melted plasticized mass in the extruder. A die assembly is attached to the extruder in an arrangement that permits the plasticized mixture to flow from the extruder exit port into the die assembly and produces substantial alignment of the protein fibers within the plasticized mixture as it flows through the die assembly. The die assembly may include either a faceplate die or a peripheral die.

[0086] The width and height dimensions of the die aperture(s) are selected and set prior to extrusion of the mixture to provide the fibrous material extrudate with the desired dimensions. The width of the die aperture(s) may be set so that the extrudate resembles from a cubic chunk of meat to a steak filet, where widening the width of the die aperture(s) decreases the cubic chunk-like nature of the extrudate and increases the filet-like nature of the extrudate. Preferably the width of the die aperture(s) is/are set to a width of from about 5 millimeters to about 40 millimeters.

[0087] The height dimension of the die aperture(s) may be set to provide the desired thickness of the extrudate. The height of the aperture(s) may be set to provide a very thin extrudate or a thick extrudate. Preferably, the height of the die aperture(s) may be set to from about 1 millimeter to about 30 millimeters, and more preferably from about 8 millimeters to about 16 millimeters.

[0088] It is also contemplated that the die aperture(s) may be round. The diameter of the die aperture(s) may be set to provide the desired thickness of the extrudate. The diameter of the aperture(s) may be set to provide a very thin extrudate or a thick extrudate. Preferably, the diameter of the die aperture(s) may be set to from about 1 millimeter to about 30 millimeters, and more preferably from about 8 millimeters to about 16 millimeters.

[0089] Referring to the drawings (FIGS 3-8), one embodiment of the peripheral die assembly is illustrated and generally indicated as 10 in FIG. 3. The peripheral die assembly 10 may be used in an extrusion process for extruding an extrusion, such as a plant protein-water mixture, in a manner that causes substantial parallel alignment of the protein fibers of the extrusion as shall be discussed in greater detail below. In the alternative, the extrusion may be made from a meat and/or plant protein-water mixture.

[0090] As shown in FIGS. 3 and 4 the peripheral die assembly 10 may include a die sleeve 12 having a cylindrical-shaped two-part sleeve die body 17. The sleeve die body 17 may include a rear portion 18 coupled to an end plate 20 that collectively define an internal area 31 in communication with opposing openings 72, 74. The die sleeve 12 may be adapted to receive a die insert 14 and a die cone 16 for providing the necessary structural elements to facilitate substantially parallel flow of the extrusion through the peripheral die assembly 10 during the extrusion process.

[0091] In one embodiment, the end plate 20 of the die sleeve 12 may be secured to a die cone 16 adapted to interface with the die insert 14 when the end plate 20 is secured to the rear portion 18 of the die sleeve 12 during assembly of the peripheral die assembly 10. As further shown, the rear portion 18 of die sleeve 12 defines a plurality of circular-shaped outlets 24 along the sleeve body 17 which are adapted to provide a conduit for the egress of extrusion from the peripheral die assembly 10 during the extrusion process. In the alternative, the plurality of outlets 24 may have different configurations, such as square, rectangular, scalloped or irregular. As further shown, the rear portion 18 of the die sleeve 12 may include a circular flange 37 that surrounds opening 72 and defines a pair of opposing slots 82A and 82B that are used to properly align the die sleeve 12 when engaging the die sleeve 12 to the extruding apparatus (not shown).

[0092] Referring to FIGS. 3-8, one embodiment of the die insert 14 may include a cylindrical-shaped die insert body 19 having a front face 27 in communication with an opposing rear face 29 through a throat 34 defined between the rear and front faces 27, 29. The front face 27 of the die insert 14 may define a slanted bottom portion 64 in communication with a plurality of raised flow diverters 38 that are spaced circumferentially around the front face 27 of the die insert body 19 and which surrounds an inner space 44 that communicates with throat 34. In one embodiment, the flow diverters 38 may have a pie-shaped configuration, although other embodiments may have other configurations adapted to divert and funnel the flow of the extrusion through the outlets 24 of the peripheral die assembly 10. In addition, the front face 27 of the die insert 14 defines a plurality of openings 70 adapted to communicate with a respective outlet 24 with the openings 70 being circumferentially spaced around the peripheral edge of the die insert 14.

[0093] Referring to FIGS. 3, 4, and 7 the throat 34 defined between the rear and front faces 27, 29 of the die insert 14 communicates with an opening 36 (FIG. 5) which is in communication with a well 52 (FIGS. 5 and 6) defined along the rear face 29 of die insert body 19. In one embodiment, the well 52 has a generally bowl-shaped configuration surrounded by a flange 90 (FIG 5). The well 52 may be adapted to permit the extrusion to enter the throat 34 and flow into the inner space 44 (FIG. 7) through opening 36 (FIGS. 5 and 6) having substantially parallel flow as the extrusion enters the die insert 14 from an extrusion apparatus (not shown). In other embodiments, the well 52 may be sized and shaped to different configurations suitable for permitting substantially parallel flow of the extrusion through the throat 34 as the extrusion enters the front face 29 of the die insert 14.

[0094] As shown specifically in FIGS. 7 and 8, each flow diverter 38 has a raised configuration defining a curved back portion 68 having a beveled peripheral edge 46 in communication with opposing side walls 50 that meet at an apex 66. In addition, each flow diverter 38 defines a pie-shaped surface 48 adapted to interface with die cone 16 (FIG 4). As further shown, the opposing side walls 50 of adjacent flow diverters 38 and the bottom portion 64 of the die insert 14 collectively define a tapered flow pathway 42 that forms a portion of a flow channel 40 (FIG 5) when the peripheral die assembly 10 is fully assembled. The flow pathway 42 may be in communication with an entrance 84 at one end and a respective outlet 24 (FIGS 3, 4, and 5) at a terminal end of the flow pathway 42.

[0095] As further shown, each flow pathway 42 has a three-sided tapered configuration collectively defined between the opposing side walls 50 of adjacent flow diverters 38 and the slanted configuration of bottom portion 64 of the die insert 14. In one embodiment, this three-sided tapered configuration gradually tapers inwardly on all three sides of the flow pathway 42 from the entrance 84 to the outlet 24.

[0096] In an embodiment, the front face 27 of the die insert 14 may include eight flow diverters 38 that define a respective flow pathway 42 between adjacent flow diverters 38 for a total of eight flow pathways 42. However, other embodiments may define at least two or more flow diverters 38 circumferentially spaced around the peripheral edge of the 76 (FIG 4) of the die insert 14 in order to provide at least two or more flow pathways 42 along the front face 27 of the die insert 14.

[0097] During the extrusion process, as shown in figures 5, 6, 7, and 8, the peripheral die assembly 10 may be operatively engaged with an extruding apparatus (not shown) that produces an extrusion that contacts the well 52 defined by the rear face 29 of the die insert 14 and flows into the throat 34 and enters the inner space opening 36 as indicated by flow path A. The extrusion may enter the inner space 44 defined by the die insert 14 and enter the entrance 84 of each tapered flow channel 42. As noted above, the extrusion then flows through each flow channel 42 and exits from a respective outlet 24 in a manner that causes the substantial alignment of the plant protein fibers in the extrusion produced by the peripheral die assembly 10.

[0098] Examples of peripheral die assemblies suitable for use in this invention to produce the structured protein fibers that are substantially aligned are described in U.S. Pat. App. No. 60/882,662, and U.S. Pat. App. No. 11/964,538, which are hereby incorporated by reference in their entirety.

[0099] The extrudate may be cut after exiting the die assembly. Suitable apparatuses for cutting the extrudate include flexible knives manufactured by Wenger Manufacturing, Inc. (Sabetha, KS) and Clextral, Inc. (Tampa, FL). Typically, the speed of the cutting apparatus is from about 1000 rpm to about 2500 rpm. In an exemplary embodiment, the speed of the cutting apparatus is about 1600 rpm. A delayed cut can also be done to the extrudate. One such example of a delayed cut device is a guillotine device.

[00100] A dryer, if one is used, generally comprises a plurality of drying zones in which the air temperature may vary. Generally, the temperature of the air within one or more of the zones will be from about 100°C to about 185°C. Typically, the extrudate is present in the dryer for a time sufficient to provide an extrudate having the desired moisture content. Generally, the extrudate is dried for at least about 5 minutes and more generally, for at least about 10 minutes. Alternatively, the extrudate may be dried at lower temperatures, such as about 70°C, for longer periods of time. Suitable dryers include those manufactured by CPM Wolverine Proctor (Lexington, NC), National Drying Machinery Co. (Trevose, PA), Wenger (Sabetha, KS), Clextral (Tampa, FL), and Buehler (Lake Bluff, IL).

[00101] Another option is to use microwave assisted drying. In this embodiment, a combination of convective and microwave heating is used to dry the product to the desired moisture. Microwave assisted drying is accomplished by simultaneously using forced-air convective heating and drying to the surface of the product while at the same time exposing the product to microwave heating that forces the moisture that remains in the product to the surface whereby the convective heating and drying continues to dry the product. The convective dryer parameters are the same as discussed previously. The addition is the microwave-heating element, with the power of the microwave being adjusted dependent on the product to be dried as well as the desired final product moisture. As an example the product can be conveyed through an oven that contains a tunnel that is equipped with wave-guides to feed the microwave energy to the product and chokes designed to prevent the microwaves from leaving the oven. As the product is conveyed through the tunnel the convective and microwave heating simultaneously

work to lower the moisture content of the product whereby drying. Typically, the air temperature is 50°C to about 80°C, and the microwave power is varied dependent on the product, the time the product is in the oven, and the final moisture content desired.

[00102] The desired moisture content may vary widely depending on the intended application of the extrudate. Generally speaking, the extruded material has a moisture content of less than 10% moisture as a further example the material may have a moisture content typically from about 5% to about 13% by weight, if dried. Although not required in order to separate the fibers, hydrating in water until the water is absorbed is one way to separate the fibers. If the protein material is not dried or not fully dried and is to be used immediately, its moisture content can be higher, generally from about 16% to about 30% by weight. If a protein material with high moisture content is produced, the protein material may require immediate use or refrigeration to ensure product freshness, and minimize spoilage.

[00103] The dried extrudate may further be comminuted, either before or after drying, to reduce the average particle size of the extrudate. Typically, the reduced dried extrudate has an average particle size of from about 0.1 mm to about 40.0 mm. In one embodiment, the reduced dried extrudate has an average particle size of from about 5.0 mm to about 30.0 mm. In another embodiment, the reduced dried extrudate has an average particle size of from about 0.5 mm to about 20.0 mm. In a further embodiment, the reduced dried extrudate has an average particle size of from about 0.5 mm to about 15.0 mm. In an additional embodiment, the reduced dried extrudate has an average particle size of from about 0.75 mm to about 10.0 mm. In yet another embodiment, the reduced dried extrudate has an average particle size of from about 1.0 mm to about 5.0 mm (Shenzhen City, Taiwan). Suitable apparatus for reducing particle size include hammer mills, such as Mikro Hammer Mills manufactured by Hosokawa Micron Ltd., Fitz Mill manufactured by She Hui Machinery Co., Ltd., and Comitrols, such as those manufactured by Urschel Laboratories, Inc. (Valparaiso, IN).

(e) characteristics of the colored structured protein products

[00104] The colored structured protein products produced in section (I)A(d) above, typically comprise protein fibers that are substantially aligned. In the context of this invention "substantially aligned" generally refers to the arrangement of protein fibers such that a significantly high percentage of the protein fibers forming the structured protein product are

contiguous to each other at less than approximately a 45° angle when viewed in a horizontal plane. Typically, an average of at least 55% of the protein fibers comprising the structured protein product are substantially aligned. In another embodiment, an average of at least 60% of the protein fibers comprising the structured protein product are substantially aligned. In a further embodiment, an average of at least 70% of the protein fibers comprising the structured protein product are substantially aligned. In an additional embodiment, an average of at least 80% of the protein fibers comprising the structured protein product are substantially aligned. In yet another embodiment, an average of at least 90% of the protein fibers comprising the structured protein product are substantially aligned.

[00105] Methods for determining the degree of protein fiber alignment are known in the art and include visual determinations based upon micrographic images. By way of example, Figures 1 and 2 depict micrographic images that illustrate the difference between a structured protein product having substantially aligned protein fibers compared to a protein product having protein fibers that are significantly crosshatched. Figure 1 depicts a structured protein product prepared according to (I)A(d) having protein fibers that are substantially aligned. Contrastingly, Figure 2 depicts a protein product containing protein fibers that are significantly crosshatched and not substantially aligned. Because the protein fibers are substantially aligned, as shown in Figure 1, the structured protein products utilized in the invention generally have the texture and consistency of animal meat. In contrast, traditional extrudates having protein fibers that are randomly oriented or crosshatched generally have a texture that is soft or spongy.

[00106] In addition to having protein fibers that are substantially aligned, the colored structured protein products of the invention also typically have shear strength substantially similar to whole meat muscle. In this context of the invention, the term "shear strength" provides one means to quantify the formation of a sufficient fibrous network to impart whole-muscle like texture and appearance to the colored structured protein product. Shear strength is the maximum force in grams needed to puncture through a given sample. A method for measuring shear strength is described in Example 1. Generally speaking, the colored structured protein products of the invention will have average shear strength of at least 1400 grams. In an additional embodiment, the colored structured protein products will have average shear strength of from about 1500 to about 1800 grams. In yet another embodiment, the colored structured protein products will have average shear strength of from about 1800 to about 2000 grams. In a

further embodiment, the colored structured protein products will have average shear strength of from about 2000 to about 2600 grams. In an additional embodiment, the colored structured protein products will have average shear strength of at least 2200 grams. In a further embodiment, the colored structured protein products will have average shear strength of at least 2300 grams. In yet another embodiment, the colored structured protein products will have average shear strength of at least 2400 grams. In still another embodiment, the colored structured protein products will have average shear strength of at least 2500 grams. In a further embodiment, the colored structured protein products will have average shear strength of at least 2600 grams.

[00107] A means to quantify the size of the protein fibers formed in the colored structured protein products may be done by a shred characterization test. Shred characterization is a test that generally determines the percentage of large pieces formed in the colored structured protein product. In an indirect manner, percentage of shred characterization provides an additional means to quantify the degree of protein fiber alignment in a colored structured protein product. Generally speaking, as the percentage of large pieces increases, the degree of protein fibers that are aligned within a colored structured protein product also typically increases. Conversely, as the percentage of large pieces decreases, the degree of protein fibers that are aligned within a colored structured protein product also typically decreases. A method for determining shred characterization is detailed in Example 2. The colored structured protein products of the invention typically have an average shred characterization of at least 10% by weight of large pieces. In a further embodiment, the colored structured protein products have an average shred characterization of from about 10% to about 15% by weight of large pieces. In another embodiment, the colored structured protein products have an average shred characterization of from about 15% to about 20% by weight of large pieces. In yet another embodiment, the colored structured protein products have an average shred characterization of from about 20% to about 25% by weight of large pieces. In another embodiment, the average shred characterization is at least 20% by weight, at least 21% by weight, at least 22% by weight, at least 23% by weight, at least 24% by weight, at least 25% by weight, or at least 26% by weight large pieces.

[00108] Suitable colored structured protein products of the invention generally have protein fibers that are substantially aligned, have average shear strength of at least 1400 grams, and have an average shred characterization of at least 10% by weight large pieces. More

typically, the colored structured protein products will have protein fibers that are at least 55% aligned, have average shear strength of at least 1800 grams, and have an average shred characterization of at least 15% by weight large pieces. In exemplary embodiment, the colored structured protein products will have protein fibers that are at least 55% aligned, have average shear strength of at least 2000 grams, and have an average shred characterization of at least 17% by weight large pieces. In another exemplary embodiment, the colored structured protein products will have protein fibers that are at least 55% aligned, have average shear strength of at least 2200 grams, and have an average shred characterization of at least 20% by weight large pieces.

B. Animal Meat

[00109] The animal meat composition, in addition to the colored structure protein product, may also comprise animal meat. As detailed above in section (I)A(a)(ii), suitable animal meats include beef, veal, pork, lamb, goat, poultry, fowl, wild game, fish, seafood, and combinations thereof.

[00110] The term "meat" is understood to apply not only to the flesh of cattle, swine, sheep, goats, other mammals, poultry, and seafood, but also comprises meat by-products. By way of example, meat includes striated muscle, which is skeletal muscle, or smooth muscle that is found, for example, in the tongue, diaphragm, heart, or esophagus, with or without accompanying overlying fat and portions of the skin, sinew, nerve and blood vessels that normally accompany the meat flesh. Examples of meat by-products are organs and tissues such as lungs, spleens, kidneys, brain, liver, blood, bone, partially defatted low-temperature fatty tissues, skin, stomachs, intestines free of their contents, connective tissue, and the like. Poultry by-products include non-rendered, clean parts of carcasses, such as heads, feet, and viscera, free from fecal content and foreign matter. The term "meat by-products" is intended to refer to those non-rendered parts of the carcass of slaughtered animals including but not restricted to mammals, poultry and the like and including such constituents as are embraced by the term "meat by-products" in the Definitions of Feed Ingredients published by the Association of American Feed Control Officials, Incorporated. The terms "meat," and "meat by-products," are understood to apply to all of those mammal, poultry and marine products defined by association.

[00111] It is envisioned that a variety of meat forms may be utilized in the invention depending upon the product's intended use. In one embodiment, whole muscle meat pieces that are essentially intact may be used. In another embodiment, the meat may be in chunk or steak form. In an alternate embodiment, the meat may be coarsely ground. In another embodiment, the meat may be finely ground or comminuted. In yet another embodiment, mechanically deboned meat (MDM) may be utilized. In the context of the present invention, MDM is any mechanically deboned meat including a meat paste that is recovered from a variety of animal bones, such as, beef, pork and chicken bones, using commercially available equipment. MDM is generally an untexturized comminuted product that is devoid of the natural fibrous texture found in intact muscles. It is well known in the art to produce mechanically deboned or separated raw meats using high-pressure machinery that separates bone from animal tissue, by first crushing bone and adhering animal tissue and then forcing the animal tissue, and not the bone, through a sieve or similar screening device.

[00112] Non-limiting examples of animal meats that may be used in the present invention include pork shoulder, pork skirt, beef shoulder, beef flank, poultry thigh, poultry breast meat, fish fillets and trim, seafood meat, beef liver, beef cheeks, beef head, beef heart, pigs heart, pork heads, pork bellies, beef mechanically deboned meat, pork mechanically deboned meat, chicken mechanically deboned meat, and combinations thereof.

[00113] It is also envisioned that combinations of meat products may be used. For example, whole meat muscle and MDM may be used. Alternatively, coarsely ground meat muscle and coarsely ground meat by-products may be used. One skilled in the art will also appreciate that the amount of fat in the different animal meats varies widely. In some embodiments, therefore, an additional fat source may also be included. Suitable fat sources are presented below in section (II)C(c).

[00114] It is also envisioned that other meat products may also be used. Including any of the meat sources described in I(A)(a)(ii) above.

C. Other ingredients

[00115] The animal meat compositions and the simulated animal meat compositions of the invention may comprise a variety of other ingredients to enhance the flavor, the nutritional profile, and the appearance of the final product.

(a) curing agent

[00116] In some embodiments, the meat composition may further comprise a curing agent. In general, a curing agent consists only of a form of nitrites or nitrates. It is generally recognized the curing agent is reduced to nitric oxide, which combines with myoglobin to form metric oxide myoglobin. Nitric oxide myoglobin, when heated to fix the pigment, becomes nitroso hemochrome.

[00117] Suitable curing agents include sodium nitrite, sodium nitrate, potassium nitrate, potassium nitrate, and the like. The concentration of the curing agent may range from about 0.001% to about 0.02% by weight. In a preferred embodiment, the curing agent comprises about 0.015% by weight of sodium or potassium nitrite.

(b) flavoring agent

[00118] The animal meat compositions or the simulated animal meat compositions may also comprise a variety of flavorings, spices, or other ingredients to enhance the flavor of the final food product. As will be appreciated by a skilled artisan, the selection of ingredients added to the meat compositions can and will depend upon the food product to be manufactured. For example, the meat compositions may further comprise a flavoring agent such as an animal meat flavor, an animal meat oil, spice extracts, spice oils, natural smoke solutions, natural smoke extracts, yeast extract, mushroom extract, shiitake extract, and combinations thereof. Additional flavoring agents may include onion extract, onion powder, garlic extract, garlic powder, and combinations thereof. Herbs or spices may be added as flavoring agents. Suitable herbs and spices include allspice, basil, bay leaves, black pepper, caraway seeds, cayenne, celery leaves, celery seeds, chervil, chili pepper, chives, cilantro, cinnamon, cloves, coriander, cumin, dill, fennel, ginger, marjoram, mustard, nutmeg, paprika, parsley, oregano, rosemary, saffron, sage, savory, shallots, smoked pimento, tarragon, thyme, white pepper, and combinations thereof. The meat composition may further comprise a flavor enhancer. Examples of flavor enhancers that may be used include salt (sodium chloride, potassium chloride), glutamic acid salts (e.g., monosodium glutamate), glycine salts, guanylic acid salts, inosinic acid salts, 5'-ribonucleotide salts, hydrolyzed proteins, hydrolyzed vegetable proteins, and combinations thereof. The

concentration of the flavoring agents and/or flavoring enhancers may range from about 0.01% to about 10% by weight, and more preferably from about 0.1% to about 3% by weight.

[00119] Phosphates may be added (up to 0.5% phosphate) to increase the water holding capacity of the final product. Suitable phosphates include he sodium tripolyphosphate, sodium hexametaphosphate, sodium acid pyrophosphate, sodium pyrophosphate, monosodium phosphate, disodium phosphate, and combinations thereof.

(c) fat source

[00120] In some embodiments, an animal meat composition or a simulated animal meat composition may also further comprise a fat source to impart flavor and improve texture. In general, the total fat concentration of a meat composition will range from about 1% to about 40% by weight. Thus, the amount of a fat source added to the composition can and will vary depending upon the ingredients utilized. The fat source may be an animal derived fat, or the fat source may be a plant derived oil. Non-limiting examples of suitable animal derived fats includes tallow, lard, chicken fat, butter, fish oil, and mixtures thereof. Non-limiting examples of suitable plant derived oils include canola oil, coconut oil, corn oil, cottonseed oil, flax seed oil, grape seed oil, olive oil, peanut oil, palm oil, soybean oil, rice oil, sunflower seed oil, and mixtures thereof. The plant derived oil may nonhydrogenated, partially hydrogenated, or fully hydrogenated. Typically, a simulated animal meat composition will comprise a plant derived fat substance when it is formulated as a vegetarian composition.

(d) antioxidant

[00121] An antioxidant may also be included in the animal meat compositions or the simulated animal meat compositions. The antioxidant may prevent the oxidation of the polyunsaturated fatty acids in the meat products, and the antioxidant may also prevent oxidative color changes in the colored structured protein product and the animal meat products. The antioxidant may be natural or synthetic. Suitable antioxidants include, but are not limited to, ascorbic acid and its salts, ascorbyl palmitate, ascorbyl stearate, anoxomer, N-acetylcysteine, benzyl isothiocyanate, m-aminobenzoic acid, o-aminobenzoic acid, p-aminobenzoic acid (PABA), butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), caffeic acid, canthaxantin, alpha-carotene, beta-carotene, beta-caraotene, beta-apo-carotenoic acid, carnosol,

carvacrol, catechins, cetyl gallate, chlorogenic acid, citric acid and its salts, clove extract, coffee bean extract, p-coumaric acid, 3,4-dihydroxybenzoic acid, N,N'-diphenyl-p-phenylenediamine (DPPD), dilauryl thiodipropionate, distearyl thiodipropionate, 2,6-di-tert-butylphenol, dodecyl gallate, edetic acid, ellagic acid, erythorbic acid, sodium erythorbate, esculetin, esculin, 6-ethoxy-1,2-dihydro-2,2,4-trimethylquinoline, ethyl gallate, ethyl maltol, ethylenediaminetetraacetic acid (EDTA), eucalyptus extract, eugenol, ferulic acid, flavonoids (e.g., catechin, epicatechin, epicatechin gallate, epigallocatechin (EGC), epigallocatechin gallate (EGCG), polyphenol epigallocatechin-3-gallate), flavones (e.g., apigenin, chrysin, luteolin), flavonols (e.g., datiscetin, myricetin, daemfero), flavanones, fraxetin, fumaric acid, gallic acid, gentian extract, gluconic acid, glycine, gum guaiacum, hesperetin, alpha-hydroxybenzyl phosphinic acid, hydroxycinammic acid, hydroxyglutaric acid, hydroquinone, N-hydroxysuccinic acid, hydroxytryrosol, hydroxyurea, rice bran extract, lactic acid and its salts, lecithin, lecithin citrate; R-alpha-lipoic acid, lutein, lycopene, malic acid, maltol, 5-methoxy tryptamine, methyl gallate, monoglyceride citrate; monoisopropyl citrate; morin, beta-naphthoflavone, nordihydroguaiaretic acid (NDGA), octyl gallate, oxalic acid, palmityl citrate, phenothiazine, phosphatidylcholine, phosphoric acid, phosphates, phytic acid, phytylubichromel, pimento extract, propyl gallate, polyphosphates, quercetin, trans-resveratrol, rosemary extract, rosmarinic acid, sage extract, sesamol, silymarin, sinapic acid, succinic acid, stearyl citrate, syringic acid, tartaric acid, thymol, tocopherols (i.e., alpha-, beta-, gamma- and delta-tocopherol), tocotrienols (i.e., alpha-, beta-, gamma- and delta-tocotrienols), tyrosol, vanilic acid, 2,6-di-tert-butyl-4-hydroxymethylphenol (i.e., Ionox 100), 2,4-(tris-3',5'-bi-tert-butyl-4'-hydroxybenzyl)-mesitylene (i.e., Ionox 330), 2,4,5-trihydroxybutyrophenone, ubiquinone, tertiary butyl hydroquinone (TBHQ), thiodipropionic acid, trihydroxy butyrophenone, tryptamine, tyramine, uric acid, vitamin K and derivates, vitamin Q10, wheat germ oil, zeaxanthin, and combinations thereof.

[00122] The concentration of the antioxidant in the meat compositions may range from about 0.0001% to about 20% by weight. In another embodiment, the concentration of an antioxidant in an animal meat composition may range from about 0.001% to about 5% by weight. In yet another embodiment, the concentration of an antioxidant in an animal meat composition may range from about 0.01% to about 1% by weight.

(e) binding agent

[00123] The animal meat compositions or the simulated animal meat compositions may also further comprise a binding or gelling agent to improve the texture and/or the appearance of the product. Suitable binding agents include isolated proteins, such as soy protein; starches, such as corn starch, wheat starch, potato starch, and the like; alginic acid and its salts; agar; carrageenan and its salts; processed Eucheuma seaweed; gums, such as carob bean, guar, tragacanth, and xanthan; pectins; sodium carboxymethylcellulose, methylcellulose (high viscosity forms), egg white, dried egg white, egg albumin, blood proteins, bovine serum albumin, and combinations thereof.

(f) pH-lowering agent

[00124] In some embodiments, an animal meat composition or a simulated animal meat composition may further comprise a pH-lowering agent to increase the chewiness of the final product. In exemplary embodiments, the pH-lowering agent is a food grade edible acid. Non-limiting examples of acids suitable for use in the invention include acetic, lactic, gluconic, hydrochloric, phosphoric, citric, tartaric, malic, and combinations thereof.

(g) vitamins and minerals

[00125] Vitamins and minerals may also be included in the animal meat compositions or the simulated animal meat compositions. The vitamins may be fat-soluble or water soluble vitamins. Suitable vitamins include vitamin C, vitamin A, vitamin E, vitamin B12, vitamin K, riboflavin, niacin, vitamin D, vitamin B6, folic acid, pyridoxine, thiamine, pantothenic acid, biotin, and combinations thereof. The form of the vitamin may include salts of the vitamin, derivatives of the vitamin, compounds having the same or similar activity of a vitamin, and metabolites of a vitamin.

[00126] Suitable minerals may include one or more minerals or mineral sources. Non-limiting examples of minerals include, without limitation, chloride, sodium, calcium, iron, chromium, copper, iodine, zinc, magnesium, manganese, molybdenum, phosphorus, potassium, selenium, and combinations thereof. Suitable forms of any of the foregoing minerals include soluble mineral salts, slightly soluble mineral salts, insoluble mineral salts, chelated minerals,

mineral complexes, non-reactive minerals such as carbonate minerals, and reduced minerals, and combinations thereof.

(h) polyunsaturated fatty acid

[00127] The animal meat compositions or the simulated animal meat compositions may also further include a polyunsaturated fatty acid (PUFA), which is a fatty acid having at least two carbon-carbon double bonds generally in the cis-configuration. The PUFA may be a long chain fatty acid having at least 18 carbons atoms. In an exemplary embodiment, the PUFA may be an omega-3 fatty acid in which the first double bond occurs in the third carbon-carbon bond from the methyl end of the carbon chain (i.e., opposite the carboxyl acid group). Examples of omega-3 fatty acids include alpha-linolenic acid (18:3, ALA), stearidonic acid (18:4), eicosatetraenoic acid (20:4), eicosapentaenoic acid (20:5; EPA), docosatetraenoic acid (22:4), n-3 docosapentaenoic acid (22:5; n-3DPA), and docosahexaenoic acid (22:6; DHA). The PUFA may also be an omega-6 fatty acid, in which the first double bond occurs in the sixth carbon-carbon bond from the methyl end. Examples of omega-6 fatty acids include linoleic acid (18:2), gamma-linolenic acid (18:3), eicosadienoic acid (20:2), dihomo-gamma-linolenic acid (20:3), arachidonic acid (20:4), docosadienoic acid (22:2), adrenic acid (22:4), n-6 docosapentaenoic acid (22:5), and combinations thereof. The fatty acid may also be an omega-9 fatty acid, such as oleic acid (18:1), eicosenoic acid (20:1), mead acid (20:3), erucic acid (22:1), nervonic acid (24:1), and combinations thereof.

(II) Preparing Animal Meat Compositions and Simulated Animal Meat Compositions

[00128] The process for producing the meat compositions generally comprises hydrating the colored structured protein product, reducing its particle size if necessary, optionally mixing it with animal meat, adding flavoring and other ingredients to the mixture, and further processing the mixture into a food product.

A. Hydrating the Colored Structured Protein Product

[00129] The colored structured protein product may be mixed with water to rehydrate it. The amount of water added to the structured protein product can and will vary. The ratio of

water to structured protein product may range from about 1.5:1 to about 4:1. In one embodiment, the ratio of water to structured protein product may be about 2.5:1. In another embodiment, the ratio of water to structured protein product may be about 3:1.

[00130] The concentration of colored structured protein product in the meat compositions can and will vary depending upon the product being made. In embodiments comprising a high percentage of animal meat, the percentage of colored structured protein product will be low. Whereas, in embodiments without added animal meat, the percentage of colored structured protein product will be high. Thus, the concentration of the colored structured protein product in the various meat compositions may be about 1%, 2%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or 99% by weight.

[00131] The particle size of the colored structured protein product may be further reduced by grinding, shredding, slicing, cutting, or chopping the hydrated product. The particle size can and will vary depending upon the meat composition being made. Typically, the reduced hydrated product has an average particle size of from about 0.1 mm to about 40.0 mm. In one embodiment, the reduced hydrated product has an average particle size of from about 5.0 mm to about 30.0 mm. In another embodiment, the reduced hydrated product has an average particle size of from about 0.5 mm to about 20.0 mm. In a further embodiment, the reduced hydrated product has an average particle size of from about 0.5 mm to about 15.0 mm. In an additional embodiment, the reduced hydrated product has an average particle size of from about 0.75 mm to about 10.0 mm. In yet another embodiment, the reduced hydrated product has an average particle size of from about 1.0 mm to about 5.0 mm. Suitable apparatus for reducing particle size include hammer mills, such as Mikro Hammer Mills manufactured by Hosokawa Micron Ltd., (Cheshire, UK), Fitz Mill manufactured by She Hui Machinery Co., Ltd., (Shenzhen City, Taiwan), and Comitrols, such as those manufactured by Urschel Laboratories, Inc. (Valparaiso, IN).

B. Optional Blending with Animal Meat

[00132] The hydrated colored structured protein product may optionally be blended with animal meat, which was detailed above in section (I)B. In general, the hydrated colored structured protein product will be blended with animal meat that has a similar particle size. In some embodiments, the concentration of animal meat may be about 50%, 55%, 60%, 65%, 70%,

75%, or 80% by weight, and the concentration of the colored structured protein product may be about 20%, 15%, 10%, 5%, 4%, 3%, 2%, or 1% by weight. In other embodiments, the concentration of animal meat may be about 2%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, or 45% by weight, and the concentration of the colored structured protein product may be about 45%, 40%, 35%, 30%, 25%, 20%, 15%, 10%, or 5% by weight. In one embodiment, the concentration of animal meat may range from about 60% to about 80% by weight, and the concentration of the colored structured protein product may range from about 1% to about 20% by weight. In another embodiment, the concentration of animal meat may range from about 40% to about 60% by weight, and the concentration of the colored structured protein product may range from about 1% to about 40% by weight. In still another embodiment, the concentration of animal meat may range from about 20% to about 40% by weight, and the concentration of the colored structured protein product may range from about 1% to about 60% by weight.

[00133] The animal meat utilized in the animal meat composition may be raw. Raw meat is preferably provided in at least a substantially frozen form so as to avoid microbial spoilage prior to processing. In one embodiment, the temperature of the animal meat is below about -40°C. In another embodiment, the temperature of the meat is below about -20°C. In yet another embodiment, the temperature of the meat is from about -10°C to about 6°C. In a further embodiment, the temperature of the meat is from about -2°C to about 2°C. While refrigerated or chilled meat may be used, it is generally impractical to store large quantities of unfrozen meat for extended periods of time at a plant site. The frozen products provide a longer lay time than do the refrigerated or chilled products. The frozen meat may be stored at a temperature of about -18°C. to about 0°C. Frozen meat is generally supplied in 20 kilogram blocks. Upon use, the blocks are permitted to thaw up to about 10°C, that is, to defrost, but in a tempered environment. Thus, the outer layer of the blocks, for example up to a depth of about ¼ inch, may be defrosted or thawed but still at a temperature of about 0°C, while the remaining inner portion of the blocks, while still frozen, are continuing to thaw and thus keeping the outer portion at below about 10°C.

[00134] In lieu of frozen animal meat, the animal meat may be freshly prepared for the preparation of the animal meat compositions, as long as the freshly prepared animal meat is stored at a temperature that does not exceed about 4°C.

[00135] The moisture content of the raw frozen or unfrozen meat is generally at least about 50% by weight, and most often from about 60% by weight to about 75% by weight, based

upon the weight of the raw meat. In embodiments of the invention, the fat content of the raw frozen or unfrozen meat may be at least 1% by weight, generally from about 15% by weight to about 30% by weight. In other embodiments of the invention, meat products having a fat content of less than about 10% by weight and defatted meat products may be used.

[00136] In some embodiments, the animal meat may be pre-cooked to partially dehydrate the flesh and prevent the release of those fluids during further processing applications (e.g., such as retort cooking), to remove natural oils that may have strong flavors, to coagulate the animal protein and loosen the meat from the skeleton, or to develop desirable and textural flavor properties. The pre-cooking process may be carried out in steam, water, oil, hot air, smoke, or a combination thereof. The animal meat is generally heated until the internal temperature is between 60°C and 85°C.

C. Blending with Other Ingredients

[00137] The hydrated colored structured protein product or the mixture of hydrated colored structured protein product and animal meat may be blended with water and a variety of flavorings, spices, antioxidants, or other ingredients, as detailed above in section (I)C. As will be appreciated by a skilled artisan, the selection of ingredients added to the animal meat composition can and will depend upon the food product to be manufactured.

[00138] The order in which the ingredients are mixed and blended can and will vary depending upon the product being made. In one embodiment, the animal meat may be blended with flavorings and other ingredients, with the hydrated colored structured protein product added last. In another embodiment, the animal meat and the hydrated colored structured protein may be blended together and then additional ingredients may be added simultaneously or sequentially. In still another embodiment, the animal meat may be wet cured in a brine solution before being combined with the hydrated colored structured protein product. In other embodiments, the hydrated colored structured protein product may be blended with flavorings and other ingredients simultaneously or sequentially (with no added animal meat).

[00139] Irrespective of the order in which the ingredients are combined, the mixture may be blended by stirring, agitating, or mixing the ingredients for a period of time sufficient to form a homogenous mixture. Conventional means for stirring, agitating, blending, or mixing the mixture may be used to effect the blending of the mixture. Ice chips may replace part of the

water of the formulation, such that the mixture remains at about 10°C or less during the blending step(s). Alternatively, carbon dioxide snow may be incorporated during the blending to keep the mixture at about 10°C or less.

D. Processing into Meat Products

[00140] The meat mixture or simulated meat mixture typically will then be processed into a variety of food products having a variety of shapes. As an example, the product may be a wet cured or dry cured meat product, such as pork ham, poultry ham, pork bacon, poultry bacon, corned beef, corned pork, pastrami, salami, pepperoni, and the like. The product may be a smoked meat product, such as smoked salmon, kippered herring, bacon, sausages, frankfurters, bologna, and the like. Alternatively, the product may be a red colored product, such as pepperoni or chorizo, whose color is derived from red peppers, pimentos, or paprika. The product may be a white colored product, such as cutlets, patties, sticks, or nuggets made from poultry white meat, white-fleshed fish, veal, or pork. Lastly, the product may be a brown colored product, such as slices, patties, chunks, or chips of beef, lamb, or poultry dark meat.

[00141] In some embodiments, the meat mixture or the simulated meat mixture may be pumped into casings to form links, rings, loaves, rolls, and so forth. The mixture may be wet cured before being inserted into a casing. The casing may be a permeable casing, such as a cellulose casing, a fibrous casing, a collagen casing, or a natural membrane. Alternatively, or the casing may be an impermeable plastic casing. In another embodiment, the meat mixture may be formed into blocks, loaves, rolls, cutlets, patties, links, or other shapes before being processed further. The formed meat product may be coated with a batter and/or it may be coated with a breading. Alternatively, the formed meat product may then be sliced, cubed, chunked, or shredded. In yet another embodiment, the meat mixture or the formed meat mixture may be introduced into a sealable package, pouch, or can for further processing.

[00142] After the mixture is formed into the desired shape or introduced into the desired package, the food product may be further processed. The processing may include cooking, partial cooking, freezing, or any method known in the art for producing a shelf stable product. In one embodiment, the formed food product may be cooked on-site. Any method known in the art for cooking the final meat product may be used. Non-limiting examples of cooking methods include hot water cooking, steam cooking, par-boiling, par-frying, frying, retort cooking, hot

smoke cooking under controlled humidity, and oven methods, including microwave, traditional, and convection. Typically, a meat product is cooked to an internal temperature of at least 70°C. Prior to cooking, some meat products may be wet cured or dried cured by storing them at a temperature of about 4°C for a period of time. Furthermore, some meat products may be subjected to a period of smoking before or during cooking.

[00143] In one embodiment, the meat product may be cooked in hot water cooker, preferably at about 80°C, to an internal temperature of about 70°C to about 80°C. In another embodiment, the meat product may be steam cooked, to an internal temperature of about 70°C to about 80°C. In an alternative embodiment, the meat product may be par-fried in 190°C oil and then cooked to an internal temperature of about 74°C in a humidity controlled oven. In another embodiment, the meat product, either cooked or uncooked, may be packed and sealed in cans in a conventional manner and employing conventional sealing procedures in preparation for sterilization by retorting. In still another embodiment, the final meat product may be partially cooked for finishing at a later time, or frozen either in an uncooked state, partially cooked state, or cooked state. While simulated meat product comprising colored structured protein product may not have to be cooked to the same internal temperature as products containing animal meat, they generally are heated to a temperature sufficient to congeal the optional binding agent(s), remove excess moisture, or stabilize the product. The foregoing products may be sealed in plastic, placed in a tray with overwrap, vacuum packed, frozen, or retorted.

DEFINITIONS

[00144] The terms "animal meat" or "meat" as used herein refers to the muscles, organs, and by-products thereof derived from an animal, wherein the animal may be a land animal or an aquatic animal.

[00145] The term "comminuted meat" as used herein refers to a meat paste that is recovered from an animal carcass. The meat, on the bone, or meat and bone are forced through a deboning device such that meat is separated from the bone and reduced in size. Meat that is off the bone would not be further treated with a deboning device. The meat is separated from the meat/bone mixture by forcing through a cylinder with small diameter holes. The meat acts as a liquid and is forced through the holes while the remaining bone material remains behind. The fat content of the comminuted meat may be adjusted upward by the addition of animal fat.

[00146] The term "extrudate" as used herein refers to the product of extrusion. In this context, the structured protein products comprising protein fibers that are substantially aligned may be extrudates in some embodiments.

[00147] The term "fiber" as used herein refers to a structured protein product having a size of approximately 4 centimeters in length and about 0.2 centimeters in width after the shred characterization test detailed in Example 2 is performed.

[00148] The term "gluten" as used herein refers to a protein fraction in cereal grain flour, such as wheat, that possesses a high content of protein as well as unique structural and adhesive properties.

[00149] The term "large piece" as used herein is the manner in which a structured protein product's shred percentage is characterized. The determination of shred characterization is detailed in Example 2.

[00150] The term "meat emulsion" or "emulsified meat" as used herein refers to a flowable meat product, such as a meat slurry, where the meat is more malleable than unprocessed meats.

[00151] The term "simulated" as used herein refers to an animal meat composition that contains no animal meat.

[00152] The term "protein fiber" as used herein refers the individual continuous filaments or discrete elongated pieces of varying lengths that together define the structure of the protein products of the invention. Additionally, because the protein products of the invention have protein fibers that are substantially aligned, the arrangement of the protein fibers impart the texture of whole meat muscle to the protein products.

[00153] The term "soy cotyledon fiber" as used herein refers to the polysaccharide portion of soy cotyledons containing at least about 70% dietary fiber. Soy cotyledon fiber typically contains some minor amounts of soy protein, but may also be 100% fiber. Soy cotyledon fiber, as used herein, does not refer to, or include, soy hull fiber. Generally, soy cotyledon fiber is formed from soybeans by removing the hull and germ of the soybean, flaking or grinding the cotyledon and removing oil from the flaked or ground cotyledon, and separating the soy cotyledon fiber from the soy protein material and carbohydrates of the cotyledon.

[00154] The term "soy flour" as used herein, refers to full fat soy flour, enzyme-active soy flour, defatted soy flour, and mixtures thereof. Defatted soy flour refers to a comminuted form

of defatted soybean material, preferably containing less than about 1% oil, formed of particles having a size such that the particles can pass through a No. 100 mesh (U.S. Standard) screen. The soy cake, chips, flakes, meal, or mixture of the material are comminuted into soy flour using conventional soy grinding processes. Soy flour has a soy protein content of about 49% to about 65% on a moisture free basis. Preferably the flour is very finely ground, most preferably so that less than about 1% of the four is retained on a 300 mesh (U.S. Standard) screen. Full fat soy flour refers to ground whole soybeans containing all of the original oil, usually 18% to 20%. The flour may be enzyme-active or it may be heat-processed or toasted to minimize enzyme activity. Enzyme-active soy flour refers to a full fat soy flour that has been minimally heat-treat in order not to neutralize its natural enzyme.

[00155] The term "soy protein concentrate" as used herein is a soy material having a protein content of from about 65% to less than about 90% soy protein on a moisture-free basis. Soy protein concentrate also contains soy cotyledon fiber, typically from about 3.5% up to about 20% soy cotyledon fiber by weight on a moisture-free basis. A soy protein concentrate is formed from soybeans by removing the hull and germ of the soybean, flaking or grinding the cotyledon and removing oil from the flaked or ground cotyledon, and separating the soy protein and soy cotyledon fiber from the soluble carbohydrates of the cotyledon.

[00156] The term "soy protein isolate" as used herein is a soy material having a protein content of at least about 90% soy protein on a moisture free basis. A soy protein isolate is formed from soybeans by removing the hull and germ of the soybean from the cotyledon, flaking or grinding the cotyledon and removing oil from the flaked or ground cotyledon, separating the soy protein and soluble carbohydrates of the cotyledon from the cotyledon fiber, and subsequently separating the soy protein from the soluble carbohydrates.

[00157] The term "starch" as used herein refers to starches derived from any native source. Typically sources for starch are cereals, tubers, roots, and fruits.

[00158] The term "strand" as used herein refers to a structured protein product having a size of approximately 2.5 to about 4 centimeters in length and greater than approximately 0.2 centimeter in width after the shred characterization test detailed in Example 2 is performed.

[00159] The term "wheat flour" as used herein refers to flour obtained from the milling of wheat. Generally speaking, the particle size of wheat flour is from about 14 to about 120 μm.

[00160] The invention having been generally described above, may be better understood by reference to the examples described below. The following examples represent specific but non-limiting embodiments of the present invention.

EXAMPLES

[00161] The following examples illustrate properties of the structure protein product and various meat compositions of the invention.

Example 1. Determination of Shear Strength of the Structured Protein Product.

[00162] Shear strength of a sample is measured in grams and may be determined by the following procedure. Weigh a sample of the structured protein product and place it in a heat sealable pouch and hydrate the sample with approximately three times the sample weight of room temperature tap water. Evacuate the pouch to a pressure of about 0.01 Bar and seal the pouch. Permit the sample to hydrate for about 12 to about 24 hours. Remove the hydrated sample and place it on the texture analyzer base plate oriented so that a knife from the texture analyzer will cut through the diameter of the sample. Further, the sample should be oriented under the texture analyzer knife such that the knife cuts perpendicular to the long axis of the textured piece. A suitable knife used to cut the extrudate is a model TA-45, incisor blade manufactured by Texture Technologies (USA). A suitable texture analyzer to perform this test is a model TA, TXT2 manufactured by Stable Micro Systems Ltd. (England) equipped with a 25, 50, or 100 kilogram load cell. Within the context of this test, shear strength is the maximum force in grams needed to shear through the sample.

Example 2. Determination of Shred Characterization of the Structured Protein Product.

[00163] A procedure for determining shred characterization may be performed as follows. Weigh about 150 grams of a structured protein product using whole pieces only. Place the sample into a heat-sealable plastic bag and add about 450 grams of water at 25° C. Vacuum seal the bag at about 150 mm Hg and allow the contents to hydrate for about 60 minutes. Place the hydrated sample in the bowl of a Kitchen Aid mixer model KM14G0 (Saint Joseph, MI) equipped with a single blade paddle and mix the contents at 130 rpm for two minutes. Scrape the paddle and the sides of the bowl, returning the scrapings to the bottom of the bowl. Repeat

the mixing and scraping two times. Remove ~200g of the mixture from the bowl. Separate the ~200g of mixture into one of three groups. Group 1 is the portion of the sample having fibers at least 4 centimeters in length and at least 0.2 centimeters wide. Group 2 is the portion of the sample having strands between 2.5 cm and 4.0 cm long, and which are ≥ 0.2 cm wide. Group 3 is the portion that does not fit within the parameters of Group 1 or Group 2. Weigh each group, and record the weight. Add the weights of Group 1 and Group 2 together, and divide by the starting weight (e.g. ~200g). This determines the percentage of large pieces in the sample. If the resulting value is below 15%, or above 20%, the test is complete. If the value is between 15% and 20%, then weigh out another ~200g from the bowl, separate the mixture into the three groups, and perform the calculations again.

Example 3. Production of Colored Structured Protein Products.

[00164] The following extrusion process may be used to prepare the colored structured protein products of the invention, similar to as those utilized in Examples 1 and 2. As an example, a red colored structured protein product is made by combining the ingredients listed in Table 1 in a paddle blender.

Table 1. Formulation

Ingredient	Amount (%)
SUPRO® 620 (soy isolate)	59.16
Manildra wheat gluten	26.00
Wheat starch	12.00
FIBRIM® 2000	2.00
Dicalcium phosphate	0.50
L-cysteine	0.10
Carmine (#3405 Sensient Colors, Inc.)	0.24
Total	100.00

[00165] The contents are mixed to form a dry blended soy protein mixture. The dry blend is then transferred to a hopper from which the dry blend is introduced into a preconditioner along

with water to form a conditioned soy protein pre-mixture. The conditioned soy protein pre-mixture is then fed to a twin-screw extrusion apparatus at a rate of not more than 75 kg/minute. The extrusion apparatus comprises five temperature control zones, with the protein mixture being controlled to a temperature of from about 25°C in the first zone, about 50°C in the second zone, about 95°C in the third zone, about 130°C in the fourth zone, and about 150°C in the fifth zone. The extrusion mass is subjected to a pressure of at least about 400 psig in the first zone up to about 1500 psig in the fifth zone. Water is injected into the extruder barrel, via one or more injection jets in communication with a heating zone. The molten extruder mass exits the extruder barrel through a die assembly consisting of a die and a backplate. As the mass flows through the die assembly the protein fibers contained within are substantially aligned with one another forming a fibrous extrudate. As the fibrous extrudate exits the die assembly, it is cut with flexible knives and the cut mass is then dried to a moisture content of about 10% by weight.

Example 4. Chicken Patties Comprising White-Colored Structured Protein Product.

[00166] Uncolored structured protein product (SPP) has a straw or grayish color that differs from the color of cooked ground or emulsified chicken breast meat. SPP that was colored white through the incorporation of titanium dioxide during the extrusion process, however, has a whitish/tan color that resembles the color of cooked chicken breast meat. Chicken patties comprising ground chicken white meat and white-colored SPP may be prepared according to the formulation presented in Table 2.

Table 2 Chicken Patty Formulation

Ingredient	Test Product with SPP (%)
Chicken white meat	63.00
Water	20.00
Chicken skin (from white meat trim)	9.25
SPP (colored white)	6.00
Salt	0.60
Natural or artificial poultry flavoring	0.50
Sodium tripolyphosphate	0.35
MSG	0.14

Onion powder	0.06
Garlic powder	0.05
Ground white pepper	0.03
Ground celery seed	0.02
Total	100.00

[00167] The SPP is generally hydrated in three parts of water to each part of dry SPP (w/w). The hydrated SPP may be ground through an 1/8-1/4 (3-6 mm) inch grinder plate or it may be Comitrol-cut to reduce the particle size. Boneless chicken breast meat and chicken skin may be ground through a 1/8 inch (3 mm) grinder plate. The chicken meat and skin should be maintained as cold as possible during the grinding, blending, and packaging. The ground chicken meat mixture may be blended with the ground or chopped hydrated SPP for about 1-2 minutes. The remaining ingredients, except for the salt, are added to the meat mixture, which then may be blended for about 1-2 minutes. Carbon dioxide snow may be incorporated during the blending to maintain the mixture at a temperature of about –2 to about 0°C. The salt is added, and the mixture may be blended for about 30 seconds. Firmer patties may be obtained by blending the meat mixture in the presence of the salt for a longer period of time. The meat mixture may be formed into the desired shape and size using commercial forming equipment. Immediately after forming, the patties may be battered and breaded (<30% on a final breaded weight basis). The patties may then be par-fried in 188-193°C frying oil for 30 seconds. The patties may then be cooked to an internal temperature of 74°C using a humidity controlled oven. The cooked patties may then be frozen via IQF and packaged.

Example 5. Fish Patties Comprising White-Colored Structured Protein Product.

[00168] Fish patties comprising ground fish meat and white-colored SPP may be prepared according to the formulation presented in Table 3. The fish meat may be from tilapia, halibut, cod, or any other white-fleshed fish. The fish patty may be prepared using a protocol similar to that described in Example 1. The patties may be battered and breaded with about 27.4% (final dry weight basis) and cooked as described in Example 1.

Table 3 Fish Patty Formulation

Ingredient	Test Product with SPP (%)
White fish trim	57.27
SPP (colored white)	10.00
Water	30.00
Salt	1.00
Dried onion	1.00
Dried dill	0.50
Herbalox antioxidant (type HT-W, Kalsec)	0.08
Ground white pepper	0.15
Total	100.00

Example 6. Genoa-Type Salami Comprising Red-Colored Structured Protein Product.

[00169] A dry-cured Genoa-type salami product may be prepared in which part of the ground pork meat is replaced with SPP that was colored red with carmine during the extrusion process. Formulations with or without the colored SPP are listed in Table 4.

Table 4 Salami Formulations.

Ingredient	Control Product (%)	Test Product with SPP (%)
Pork trim (25% fat)	96.115	81.698
Salt	2.901	2.901
Sodium nitrate	0.074	0.074
Ground black pepper	0.250	0.250
Whole black pepper	0.130	0.130
Garlic powder	0.030	0.030
Dextrose	0.500	0.500
Hydrated SSP (colored red)	-	14.417

Starter culture	+	+
Total	100.001	100.001

[00170] The pork meat may be ground through a 1/4 or 1/2 inch grinder plate and kept cold. The hydrated SPP may be ground through a 1/4 or 1/2 inch grinder plate or it may be Comitrol-cut to reduce the particle size. The ground pork and ground colored SPP may be mixed with the curing and seasoning ingredients and blended until homogeneous. The mixture is stuffed into casings and then fermented and dry cured under a controlled cool temperature and humidity. The control product may be prepared in the same manner, but without the SPP.

Example 7. Canned Corned Beef Comprising Red-Colored Structured Protein Product.

[00171] Among the retorted, canned meat products that may be prepared using red-colored SPP is a canned corned beef product. A formulation in which part of the beef is replaced with red-colored SPP is presented in Table 5.

Table 5 Corned Beef Formulations.

Ingredient	Control Product (%)	Test Product with SPP (%)
Beef (15% fat)	25.00	15.0
Beef fat (80% fat)	1.00	1.00
Beef cheek (15% fat)	15.00	15.00
Beef connective tissue-type 1	5.00	5.00
Beef head (20% fat)	3.00	3.00
Beef connective tissue-type 2	25.00	22.90
Beef shank	1.00	1.00
Beef stomach	3.00	3.00
Water	11.03	11.03
Wheat starch	7.00	7.00
Salt	2.70	2.70
Sodium nitrite	0.01	0.02

Sucrose	1.10	1.10
MSG	0.15	0.15
FXP M0188	-	2.00
Sodium tripolyphosphate	-	0.10
SPP (colored red)	-	2.50
Water for hydrating SPP	-	7.50
Total	100.00	100.00

[00172] The beef meats may be ground through a 1/2 inch grinder plate, and the connective tissue and stomach ingredients may be ground through a 1/8 inch grinder plate. The ground meats may be blended with the ground/shredded hydrated SPP. The salt, sucrose, MSG, nitrite, part of the water may be added and blended for about 3 min. The FXP M0188 may be added and blended for 30 sec, then the rest of the water may be added and the mixture blended for about 3 min. Lastly, the starch may be added and the mixture blended for about 3 min. The mixture may be inserted into cans at about 15-20°C, and heated at 112.8°C for 120 min. The control product may be prepared in the same manner, but without the SPP.

Example 8. Cured Turkey Ham Product Comprising Red-Colored Structured Protein Product.

[00173] A cured turkey ham product is prepared in which part of the turkey thigh meat is replaced with pink/red-colored SPP colored. A formulation is presented in Table 6 in which 22% of the turkey thigh meat is replaced with colored SPP.

Table 6 Turkey Thigh Ham Formulations.

Ingredient	Control Product (%)	Test Product with SPP (%)
Turkey thigh meat	31.000	24.000
Carmine (3.5% carminic acid)	0.035	0.027
Water	48.291	48.291
Salt	1.425	1.425

Prague powder (curing agent)	0.400	0.400
Blend of proteins, starches and acid phosphates(SUPRO Systems M112)	7.410	7.410
Sodium tripolyphosphate	0.410	0.410
Sodium erythorbate	0.045	0.045
Sucrose	0.900	0.900
Spices	0.800	0.800
MSG	0.080	0.080
Liquid smoke	0.100	0.100
Potato starch	6.454	6.454
Corn starch	2.050	2.050
Kappa Carrageenan mixture	0.600	0.600
SPP (colored pink/red)		1.752
Water for hydrating SPP		5.256
Total	100.000	100.000

[00174] The turkey thigh meat is ground through a 3/8 inch grinder plate, and the hydrated colored SPP is passed through a 1/2 inch grinder plate. A brine solution is prepared by mixing together the rest of the ingredients; 30% ice is used in the brine solution. The brine solution and the ground turkey meat are combined and massaged for 2.5 hours at 19 rpm. The hydrated SPP is added to the mixture during the last 10 min of the massaging process. The mixture is pumped into a casing and cooked to an internal temperature of 76°C. The product, as a chunk or log, is then sliced for color comparison with the colors of the products detailed in Examples 9 and 10.

Example 9. Cured Turkey Ham Product Comprising Red-Colored Structured Protein Product and a Maltodextrin Color Retention Aid.

[00175] The procedure of Example 8 (Test Product with SPP) is repeated wherein this example further comprises 2.33 % of maltodextrin. The product, as a chunk or log, is then sliced for color comparison with the color of the control product of Example 8.

Example 10. Cured Turkey Ham Product Comprising Red-Colored Structured Protein Product and a Calcium Alginate Color Retention Aid.

[00176] The procedure of Example 8 (Test Product with SPP) is repeated wherein this example further comprises 0.07 % of calcium alginate. The product, as a chunk or log, is then sliced for color comparison with the color of the control product of Example 8.

[00177] Figure 9 depicts a photographic image of a cured turkey ham product slice of Example 8 in which part of the turkey thigh meat is replaced with pink/red-colored structured protein product (SPP). No color retention aid is present in this patty. The Example 8 Test Product with SPP is a control for comparison to the colors of Examples 9 and 10 in Figures 10 and 11, respectively.

[00178] Figure 10 depicts a photographic image of a cured turkey ham product slice of Example 9 in which part of the turkey thigh meat is replaced with pink/red-colored structured protein product (SPP). Maltodextrin is present as a color retention aid in this patty. As shown in Figure 10, the Example 9 color does not show the color fade of Example 8 in Figure 9.

[00179] Figure 11 depicts a photographic image of a cured turkey ham product slice of Example 10 in which part of the turkey thigh meat is replaced with pink/red-colored structured protein product (SPP). Calcium alginate is present as a color retention aid in this patty. As shown in Figure 11, the Example 10 color does not show the color fade of Example 8 in Figure 9.

[00180] While the invention has been explained in relation to exemplary embodiments, it is to be understood that various modifications thereof will become apparent to those skilled in the art upon reading the description. Therefore, it is to be understood that the invention disclosed herein is intended to cover such modifications as fall within the scope of the appended claims.

CLAIMS

What is claimed is:

1. A animal meat composition, the composition comprising:
   a. an amount of animal meat; and
   b. a colored structured protein product, the colored structured protein product having protein fibers that are substantially aligned.
2. The animal meat composition of claim 1, wherein the colored structured protein product comprises protein fibers substantially aligned in the manner depicted in the micrographic image of Figure 1.
3. The animal meat composition of claim 2, wherein the colored structured protein product has an average shear strength of at least 1400 grams and an average shred characterization of at least 10%.
4. The animal meat composition of claim 3, wherein the colored structured protein product comprises protein-containing material selected from the group consisting of soy, wheat, canola, corn, lupin, oat, pea, rice, sorghum, dairy, whey, egg, and mixtures thereof.
5. The animal meat composition of claim 1, wherein the colored structured protein product has from about 40% to about 90% protein on a dry mater basis.
6. The animal meat composition of claim 7, wherein the colored structured protein product comprises protein, starch, gluten, fiber, and mixtures thereof.
7. The animal meat composition of claim 8, wherein the colored structured protein product comprises:
   a. from about 35% to about 65% soy protein on a dry matter basis;
   b. from about 20% to about 30% wheat gluten on a dry matter basis;
   c. from about 10% to about 15% wheat starch on a dry matter basis; and
   d. from about 1% to about 5% fiber on a dry matter basis.
8. The animal meat composition of claim 1, wherein the colorant is selected from the group consisting of carmine, FD&C Red No. 40, annatto, caramel, titanium dioxide and mixtures thereof, wherein the concentration of the colorant ranges from about 0.001% to about 5.0% by weight.

9. The animal meat composition of claim 1, further comprising a color retention aide selected form the group consisting of maltodextrin, a metal alginate, and combinations thereof.

10. The animal meat composition of claim 1, further comprising an pH regulator that is an acidulent selected from the group consisting of citric acid, acetic acid, tartaric acid, malic acid, fumaric acid, lactic acid, phosphoric acid, sorbic acid, benzoic acid, and combinations thereof, wherein the amount of the pH regulator combined with the colored structured protein product is from 0.1% to about 5% by weight on a dry matter basis.

11. The animal meat composition of claim 1, wherein the animal meat is selected from the group consisting of beef, veal, pork, lamb, poultry, fowl, wild game, seafood, and combinations thereof.

12. The animal meat composition of claim 11, wherein the composition comprises from about 1% to about 40% by weight of the colored structured protein product, and from about 20% to about 80% by weight of animal meat.

13. The animal meat composition of claim 1, wherein the composition is a cured meat product, the structured protein product is selected from the group consisting of:

a. a colored red product, the structured protein product is colored red and the meat is selected from the group consisting of beef, pork, fowl, fish, and combinations thereof;

b. a white meat product, the structured protein product is colored white and the meat is a white meat selected from the group consisting of chicken, turkey, fish, pork, veal, and combinations thereof;

c. a dark meat product, the structured protein product is colored brown and the meat is a dark meat selected from the group consisting of beef, veal, pork, lamb, fowl, wild game, and combinations thereof; and,

d. combinations thereof.

14. The animal meat composition of claim 13, further comprising water and an agent selected from the group consisting of sugar, flavoring agent, antioxidant, binding agent, curing agent, and combinations thereof.

15. The animal meat composition of claim 14, wherein the product is coated with a batter and a breading.

16. The animal meat composition of claim 1, further comprising at least one animal material with the mixture, wherein the animal protein material is selected from the group consisting of casein, caseinates, whey protein, milk protein concentrate, milk protein isolate, ovalbumin, ovaglobulin, ovomucin, ovomucoid, ovotransferrin, ovovitella, ovovitellin, albumin globulin, vitellin, and mixtures thereof.

17. A simulated animal meat composition, the composition comprising a colored structured protein product, wherein the colored structured protein product is formed by extruding a plant protein-containing material and at least one colorant through a die assembly, the colored extrudate having protein fibers that are substantially aligned.

18. The simulated animal meat composition of claim 17, wherein the colored structured protein product comprises protein fibers substantially aligned in the manner depicted in the micrographic image of Figure 1.

19. The simulated animal meat composition of claim 17, wherein the colored structured protein product has an average shear strength of at least 1400 grams and an average shred characterization of at least 10%.

20. The simulated animal meat composition of claim 17, further comprising a fat source, wherein the fat source is selected from the group consisting of a dairy based fat, a plant based fat, and animal based fat, and combinations thereof.

21. The simulated animal meat composition of claim 17, wherein the fat source is a plant based fat selected from the group consisting of canola oil, cottonseed oil, grape seed oil, olive oil, peanut oil, palm oil, soybean oil, rice oil, sunflower seed oil, and mixtures thereof.

22. The simulated animal meat composition of claim 17, wherein the fat source is an animal based fat selected from the group consisting of butter, lard, tallow, poultry fat, fish oil, and mixtures thereof.

23. The simulated animal meat composition of claim 17, further comprising an agent selected from the group consisting of flavoring agent, fat source, antioxidant,

binding agent, pH-regulating agent, vitamin, mineral, polyunsaturated fatty acid, and combinations thereof.

FIG. 1

FIG. 2

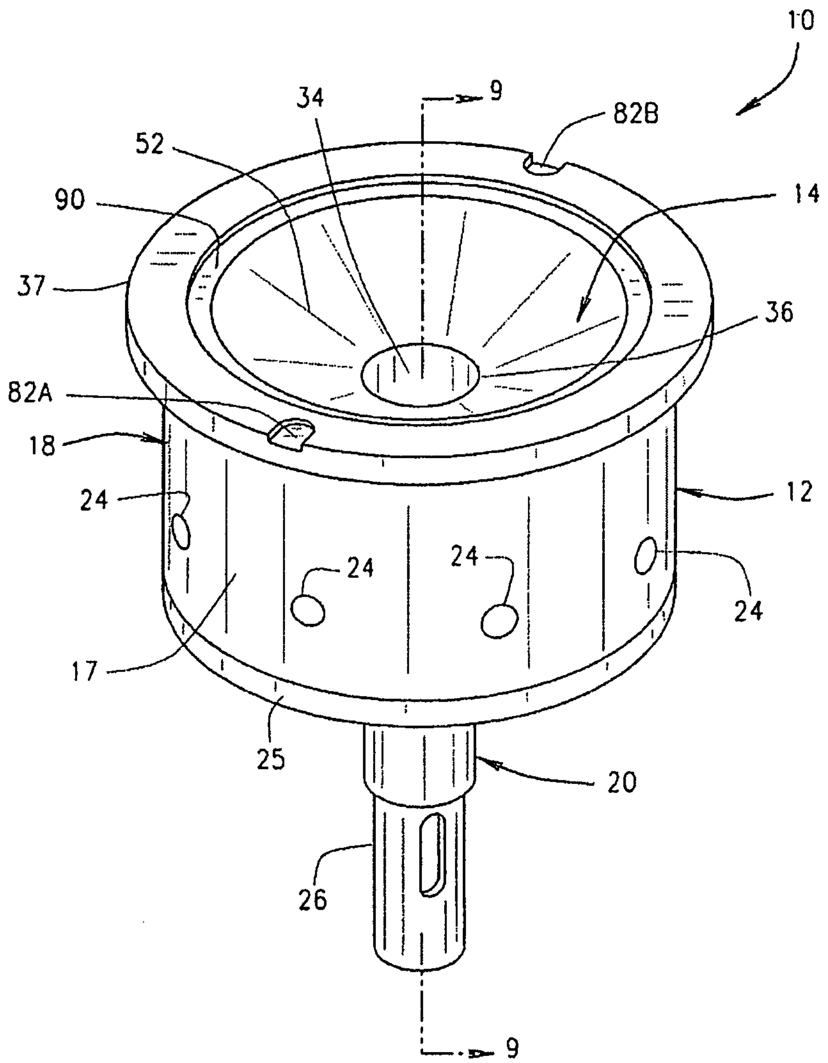
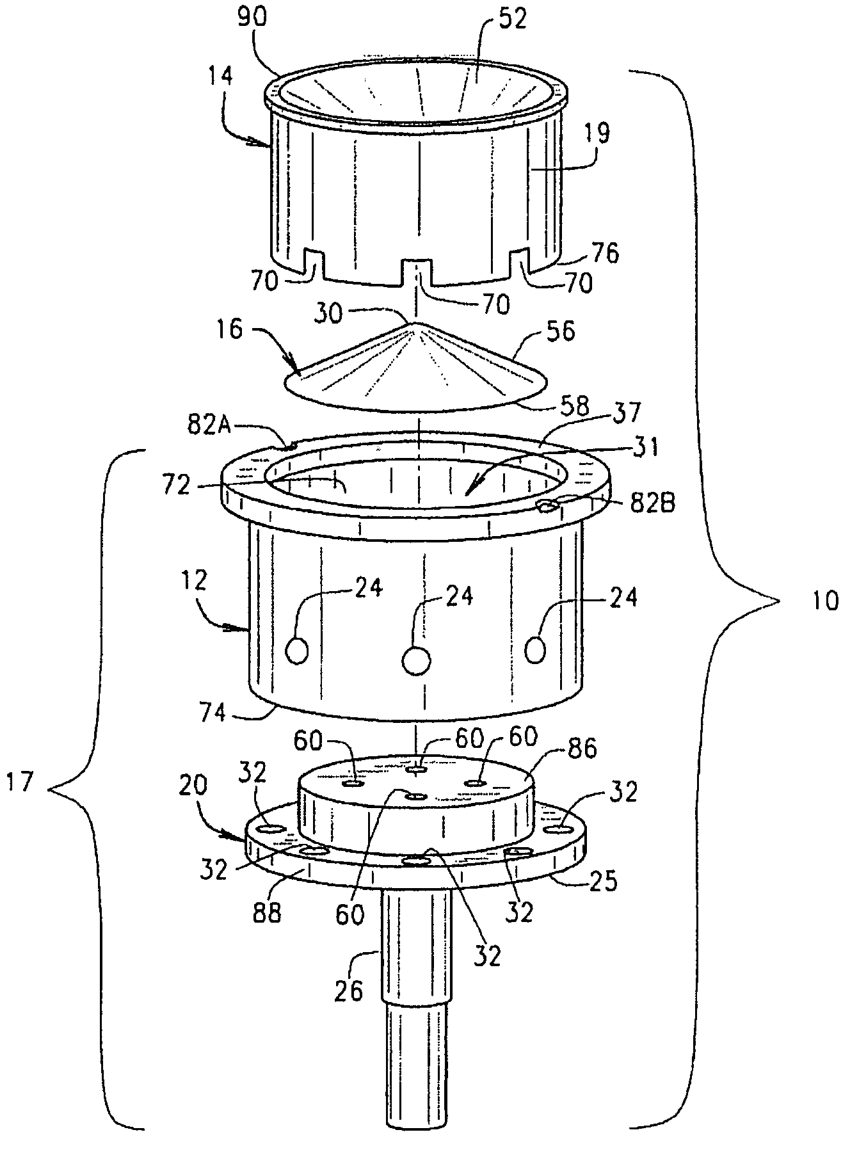


FIG. 3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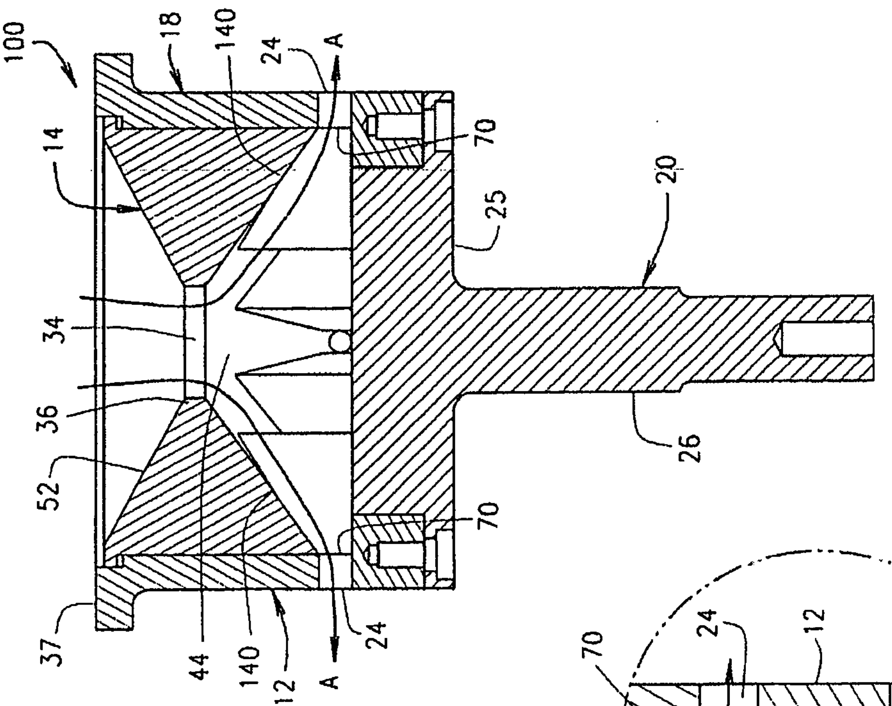

FIG. 6

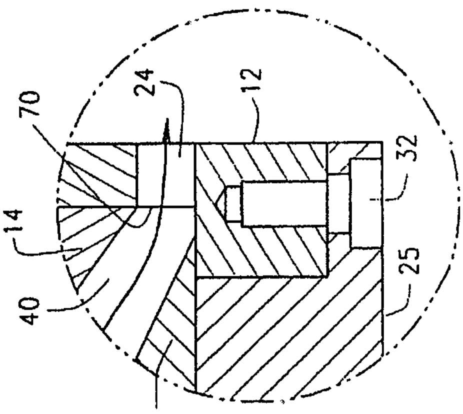

FIG. 5A

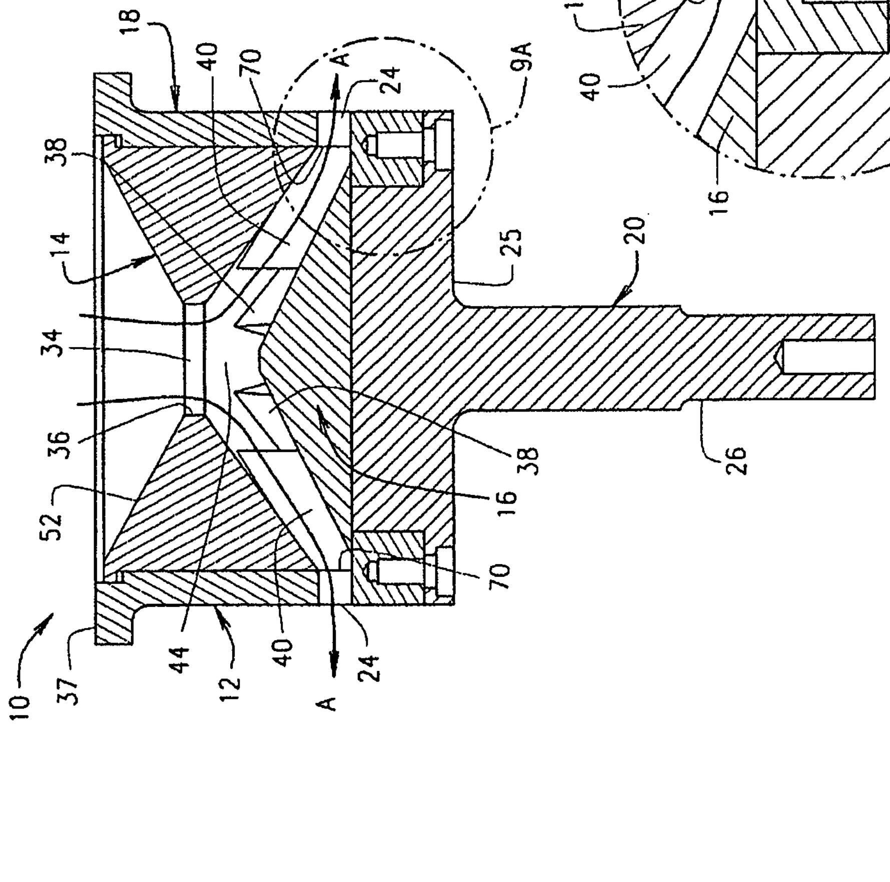

FIG. 5

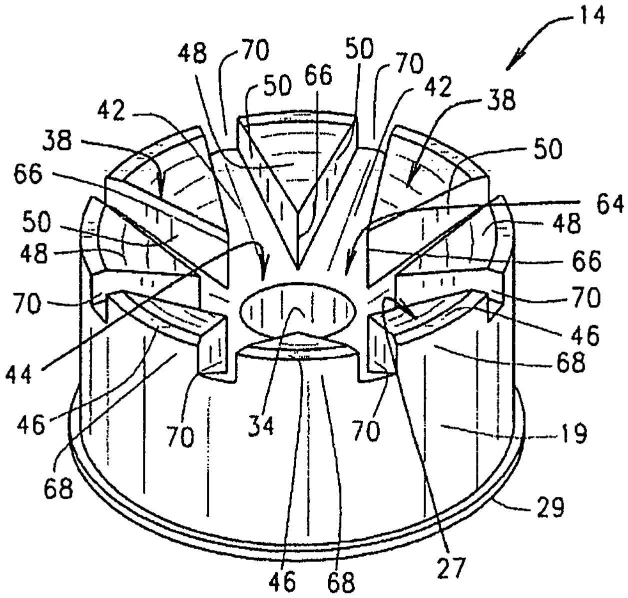
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FIG. 7

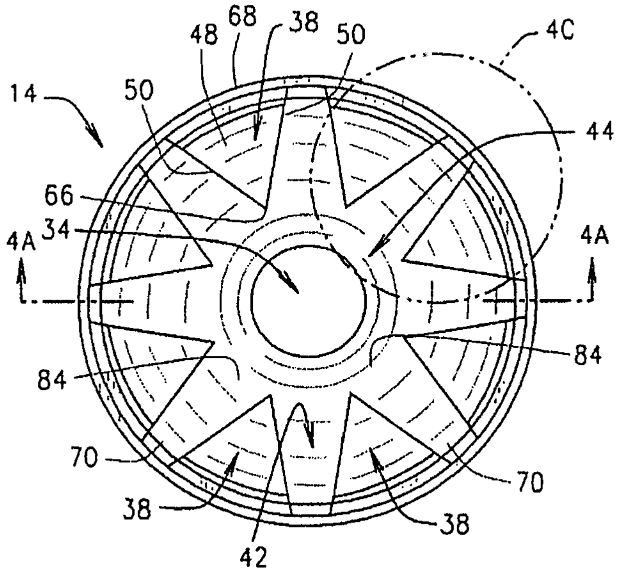
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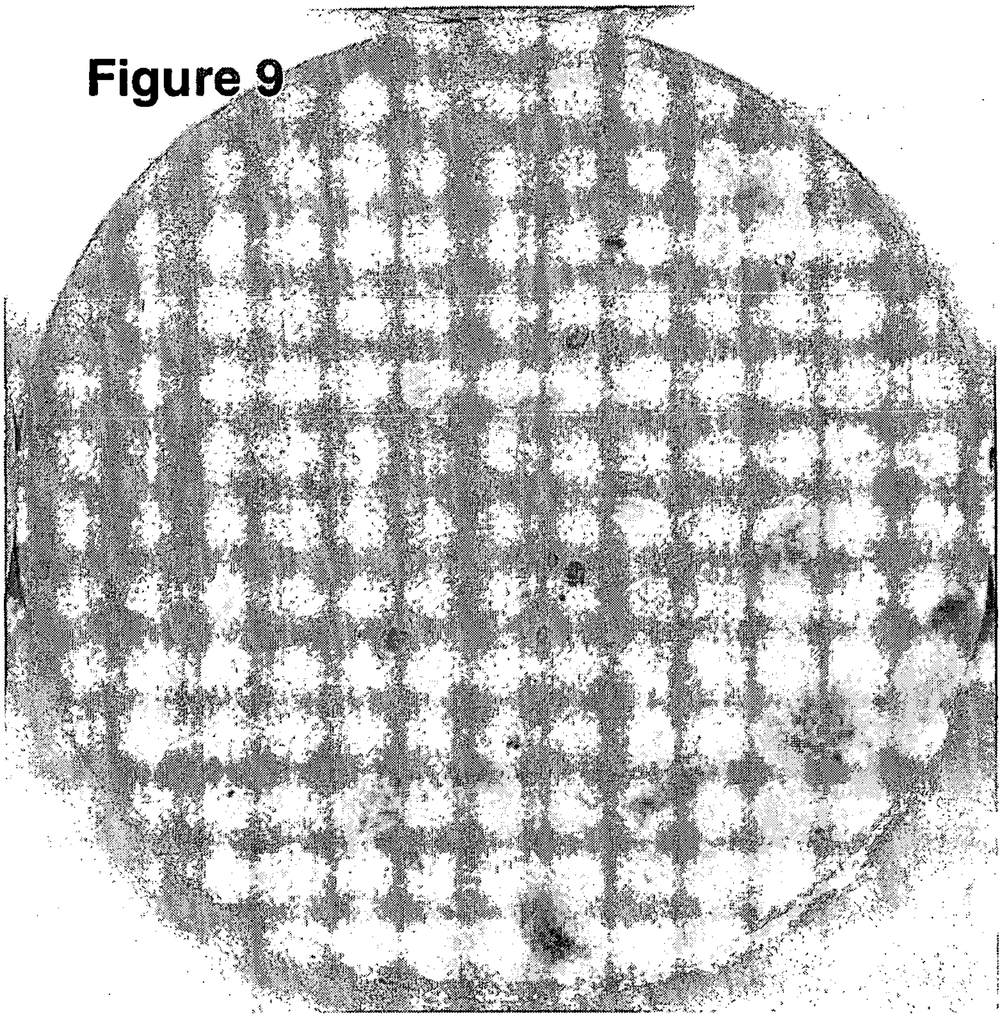
FIG. 8

Figure 9



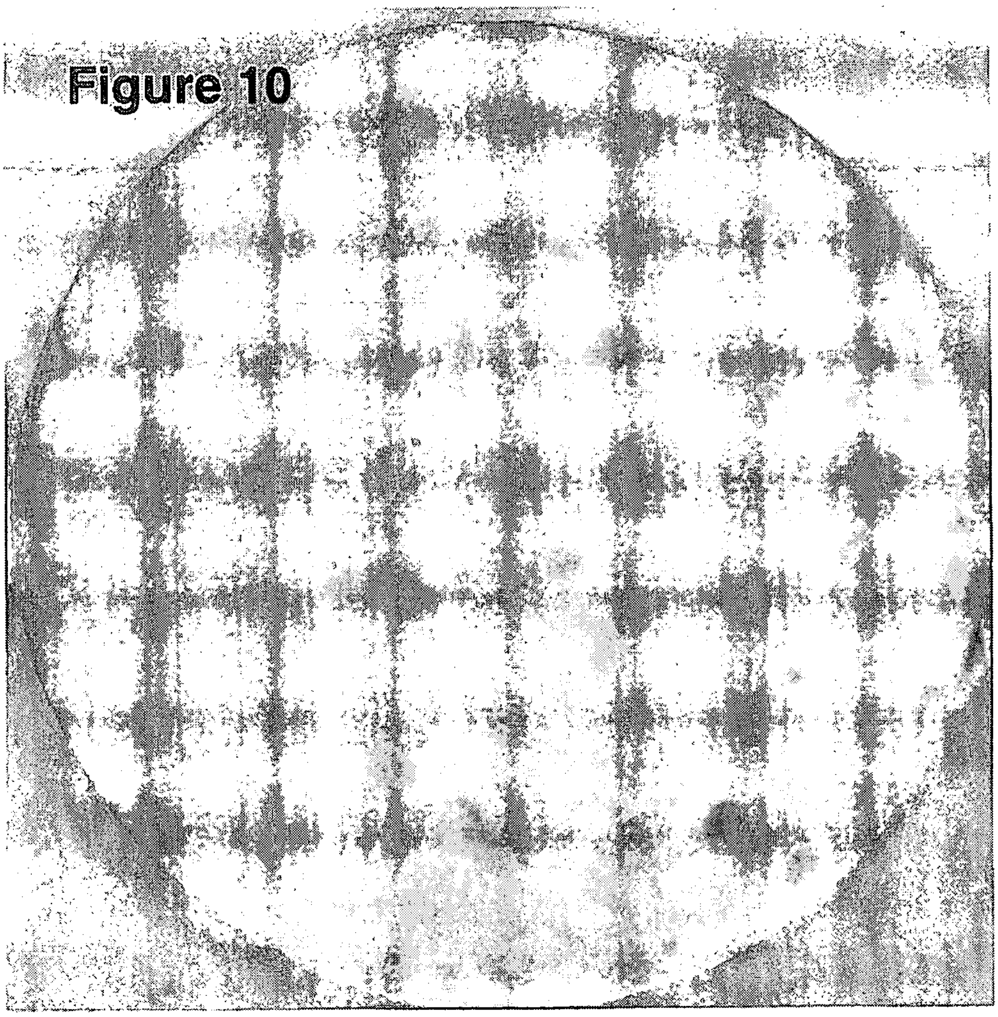
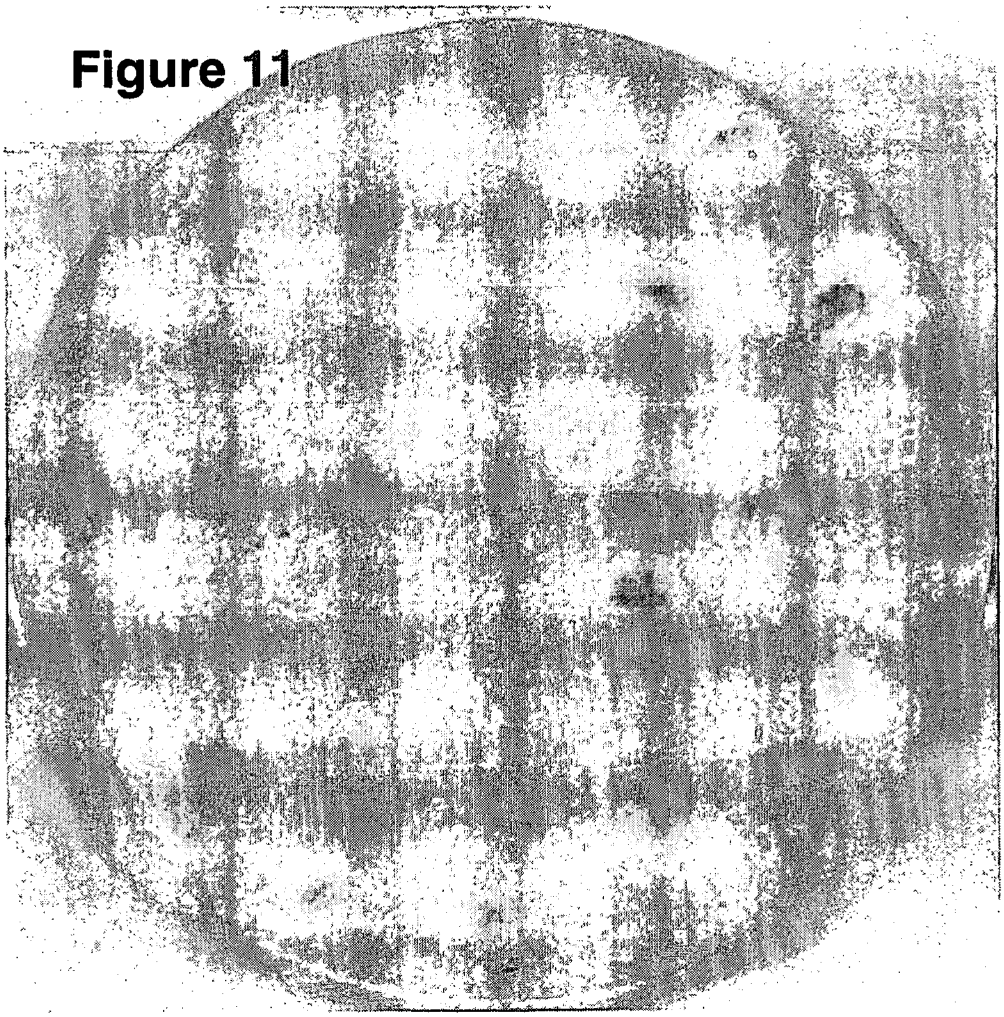


Figure 10

Figure 11



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/059466

A. CLASSIFICATION OF SUBJECT MATTER
INV. A23L1/314 A23L1/317

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A23L A23J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, FSTA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/035005 A1 (MCMINDES MATTHEW K [US] ET AL) 16 February 2006 (2006-02-16) the whole document	1-23
X,P	WO 2007/137125 A (SOLAE LLC [US]; MCMINDES MATTHEW K [US]; GODINEZ EDUARDO [US]; MUELLER) 29 November 2007 (2007-11-29) the whole document	1-23
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Y	JP 08 066157 A (FUJI OIL CO LTD) 12 March 1996 (1996-03-12) the whole document	1-23

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10 July 2008	21/07/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Vernier, Frédéric

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/059466

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No
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