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High soy protein nuggets and applications in food products

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(54) Title: HIGH SOY PROTEIN NUGGETS AND APPLICATIONS IN FOOD PRODUCTS

(57) Abstract: The present invention relates to food materials containing a high concentration of vegetable protein and processes for their manufacture. More particularly, the present invention relates to vegetable protein extrudates containing high concentrations of protein and low concentrations of carbohydrates, processes for manufacturing such protein extrudates, and the use of such protein extrudates as functional food ingredients.

HIGH SOY PROTEIN NUGGETS AND APPLICATIONS IN FOOD PRODUCTS

FIELD OF THE INVENTION

[0001] The present invention relates to food materials containing a high concentration of vegetable protein and processes for their manufacture. More particularly, the present invention relates to vegetable protein extrudates containing high concentrations of protein and low concentrations of carbohydrates, processes for manufacturing such protein extrudates, and the use of such protein extrudates as functional food ingredients.

BACKGROUND OF THE INVENTION

[0002] Texturized vegetable protein products are known in the art and are typically prepared by heating a mixture of protein material along with water under mechanical pressure in a cooker extruder and extruding the mixture through a die. Upon extrusion, the extrudate generally expands to form a fibrous cellular structure as it enters a medium of reduced pressure (usually atmospheric). Expansion of the extrudate results from inclusion of soluble carbohydrates which reduce the gel strength of the mixture. The extrudates are then used to form other products such as vegetable meat analogs. Extrusion methods for forming textured protein meat analogs are well known and disclosed, for example, in U.S. Patent No. 4,099,455.

[0003] Extrusion cooking devices have long been used in the manufacture of a wide variety of edible and other products such as human and animal feeds. Generally speaking, these types of extruders include an elongated barrel together with one or more internal, helically flighted, axially rotatable extrusion screws therein. The outlet of the extruder barrel is equipped with an apertured extrusion die. In use, a material to be processed is passed into and through the extruder barrel and is subjected to

increasing levels of temperature, pressure and shear. As the material emerges from the extruder die, it is fully cooked and shaped and may typically be subdivided using a rotating knife assembly. Conventional extruders of this type are described, for example, in U.S. Patent Nos. 4,763,569, 4,118,164 and 3,117,006, which are incorporated herein by reference.

[0004] Attempts to develop processes for producing suitable meat substitutes from vegetable protein sources include extrusion cooking defatted soy flour or other vegetable proteins in order to texturize and orient the vegetable protein and produce meat extenders in the form of texturized protein products for use with hamburger or similar products. Exemplary processes of this type are taught in U.S. Patent Nos. 3,047,395; 3,142,571; 3,488,770 and 3,870,805. Although these extrusion processes have met with a certain degree of acceptance in the art, the meat substitute products heretofore produced have possessed several characteristics which have seriously limited their use, particularly as full substitutes for meat. One of the most persistent objections to those prior products stems from the expanded, cellular, spongy nature thereof. In particular, most of these meat extenders are produced under high pressure and temperature conditions in the extrusion cooker which results in a twisted, randomly oriented meat extender. After rehydration, these extenders are characterized by a chewy structure of twisted layers lacking the appearance, mouth feel or range of utility of meat. This has for the most part limited the use of these products to the role of meat extenders in ground hamburger type meats and the like. Moreover, if too much of the prior vegetable protein product is employed in such hamburger-type meats, the extended meat becomes unacceptably spongy and exhibits a random, unappealing appearance and mouth feel.

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Alternatively, the texturized protein product may be cut into smaller extrudates such as "nuggets" or powders for use as food ingredients or as functional food products.

Regardless of its form, texturized protein products must have an acceptable density, texture, and mouth feel for use as a food ingredient. Thus, conventional texturized protein products typically have a protein content of from about 40% to about 60% by weight on a moisture-free basis. Increasing the protein content of the texturized product has not been feasible because a significant fraction of carbohydrate has been deemed necessary to provide the protein extrudate with an acceptable texture and density. But in certain instances high carbohydrate functional food ingredients are undesirable to consumers wishing to reduce carbohydrate intake. Thus, a need exists for a high protein, low carbohydrate texturized protein product having an acceptable density, texture and mouth feel for use as a functional food ingredient.

SUMMARY OF THE INVENTION

Among objects of certain embodiments of the present invention, therefore, may be noted the provision of a novel protein extrudate having a high concentration of vegetable protein and a low concentration of carbohydrates; the provision of such an extrudate having a lower density than conventional protein extrudates containing high levels of protein; and the provision of such an extrudate for use as an ingredient or a source of protein in food products.

Briefly, therefore, in one embodiment, the present invention is directed to a protein extrudate comprising at least about 80% by weight vegetable protein on a moisture-free basis and having a density of from about 0.20 g/cm^3 to about 0.27 g/cm^3.

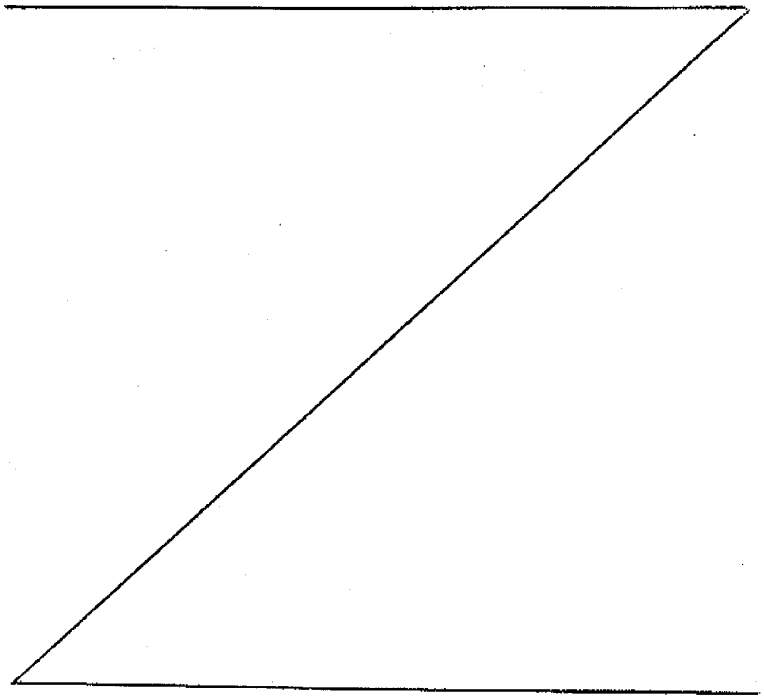
In another embodiment, the present invention is

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directed to a protein extrudate comprising unhydrolyzed vegetable protein and at least about 2 parts by weight hydrolyzed protein per part by weight unhydrolyzed protein.

In another embodiment, the present invention is directed to a functional food ingredient comprising from about 40% to about 95% by weight meat material and up to about 4% by weight of a soy protein extrudate on a total weight basis, the soy protein extrudate comprising at least about 80% by weight soy protein on a moisture-free basis, less than about 5% weight carbohydrate on a moisture-free basis, a degree of hydrolysis of less than about 15%, and having a density of from about 0.20 g/cm^3 to about 0.27 g/cm^3.



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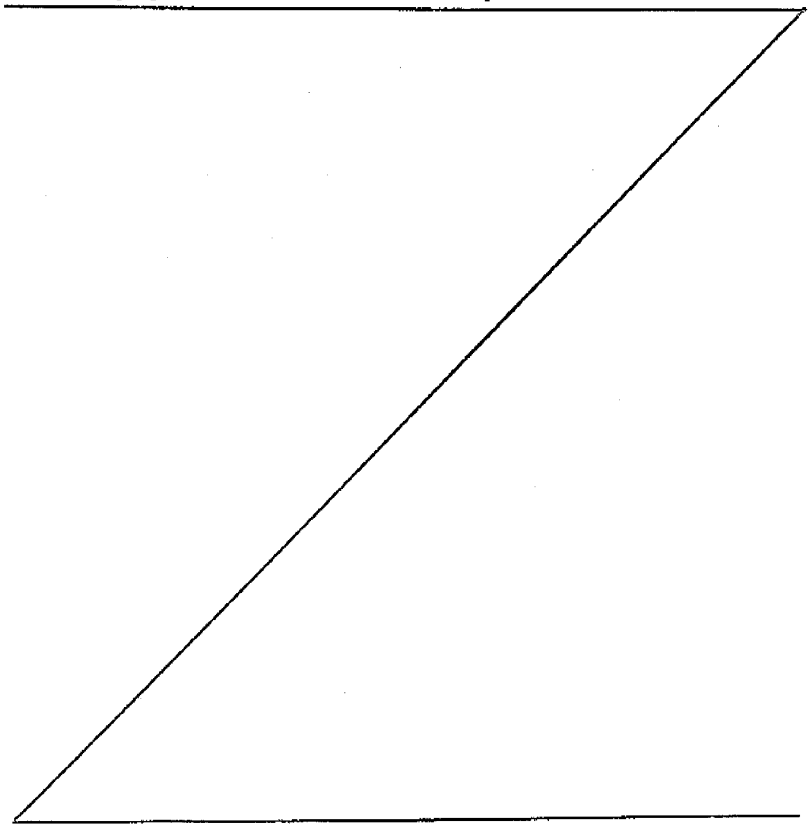
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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic flow sheet of a process useful in preparing the protein extrudates of the present invention.

Fig. 2 is a photomicrograph of high soy protein textured products prepared in accordance with the present invention.



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[0018] Fig. 3 is a photomicrograph of high soy protein textured products prepared in accordance with the present invention.

[0019] Fig. 4 is a photomicrograph of high soy protein textured products prepared in accordance with the present invention.

[0020] Fig. 5 is a photomicrograph of high soy protein textured products prepared in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] In accordance with the present invention, it has been discovered that textured vegetable protein products containing high concentrations of protein and low concentrations of carbohydrates can be manufactured to have a desired density and an acceptable texture using extrusion technology. Such protein extrudates can be formed as "nuggets" or pellets for use as an ingredient or source of protein in health and nutrition bars, snack bars and ready to eat cereal. Alternatively, the protein extrudates may be further processed for use as a binder, a stabilizer or a source of protein in beverages, health and nutrition bars, dairy, and baked and emulsified/ground meat food systems. In certain embodiments, the protein extrudates may be ground into fine particles (i.e., powder) to allow for incorporation into soy beverages. Such ground particles typically have a particle size of from approximately 1 to about 5 Φm to allow suspension in a liquid.

[0022] A process of the present invention for preparing protein extrudates generally comprises forming a pre-conditioned feed mixture by contacting the feed mixture with moisture, introducing the pre-conditioned feed mixture into an extruder barrel, heating the pre-conditioned feed mixture under mechanical pressure to form a molten extrusion mass, and extruding the

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molten extrusion mass through a die to produce a protein extrudate.

The protein-containing feed mixture typically comprises at least one source of protein and has an overall protein concentration of at least about 80% protein by weight on a moisture-free basis. Proteins contained in the feed mixture may be obtained from one or more suitable sources including, for example, dairy protein materials and vegetable protein materials. Dairy protein materials include, for example, casein and sweet dairy whey. Vegetable protein materials may be obtained from cereal grains such as wheat, corn, and barley, and vegetables such as soybeans and peas. Preferably, the feed mixture contains vegetable proteins and, more preferably, the protein-containing feed mixture comprises a soy protein material as a source of protein.

Suitable soy protein materials include soy flakes, soy flour, soy grits, soy meal, soy protein concentrates, soy protein isolates, and mixtures thereof. The primary difference between these soy protein materials is the degree of refinement relative to whole soybeans. Soy flakes are generally produced by dehulling, defatting, and grinding the soybean and typically contain less than about 65 wt.% soy protein on a moisture-free basis. Soy flakes also contain soluble carbohydrates, insoluble carbohydrates such as soy fiber, and fat inherent in soy. Soy flakes may be defatted, for example, by extraction with hexane. Soy flours, soy grits, and soy meals are produced from soy flakes by comminuting the flakes in grinding and milling equipment such as a hammer mill or an air jet mill to a desired particle size. The comminuted materials are typically heat treated with dry heat or steamed with moist heat to "toast" the ground flakes and inactivate anti-nutritional elements present in soy such as Bowman-Birk and Kunitz trypsin inhibitors. Heat treating the ground flakes in the presence of significant amounts of water is

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avoided to prevent denaturation of the soy protein in the material and to avoid costs involved in the addition and removal of water from the soy material. The resulting ground, heat treated material is a soy flour, soy grit, or a soy meal, depending on the average particle size of the material. Soy flour generally has a particle size of less than about 150 μm. Soy grits generally have a particle size of about 150 to about 1000 μm. Soy meal generally has a particle size of greater than about 1000 μm.

[0025] Soy protein concentrates typically contain about 65 wt.% to about 85 wt.% soy protein, with the major non-protein component being fiber. Soy protein concentrates are typically formed from defatted soy flakes by washing the flakes with either an aqueous alcohol solution or an acidic aqueous solution to remove the soluble carbohydrates from the protein and fiber. On a commercial scale, considerable costs are incurred with the handling and disposing of the resulting waste stream.

[0026] Soy protein isolates, more highly refined soy protein materials, are processed to contain at least 90% soy protein and little or no soluble carbohydrates or fiber. Soy protein isolates are typically formed by extracting soy protein and water soluble carbohydrates from defatted soy flakes or soy flour with an alkaline aqueous extractant. The aqueous extract, along with the soluble protein and soluble carbohydrates, is separated from materials that are insoluble in the extract, mainly fiber. The extract is typically then treated with an acid to adjust the pH of the extract to the isoelectric point of the protein to precipitate the protein from the extract. The precipitated protein is separated from the extract, which retains the soluble carbohydrates, and is dried after being adjusted to a neutral pH or is dried without any pH adjustment. On a commercial scale, these steps contribute significant cost to the product.

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In preparation of the high protein extrudates, a feed mixture comprising at least about 80 wt.% protein, on a moisture-free basis (i.e., dry basis), is prepared. More preferably, the feed mixture comprises at least about 90% by weight vegetable protein on a moisture-free basis.

The overall protein content of the feed mixture may be achieved by a combination (i.e., blend) of suitable sources of protein described above.

In certain embodiments, it is preferred for soy protein isolates to constitute one or more of the sources of protein contained in the feed mixture. This is generally due to the higher degree of refinement of soy protein isolates as compared to the other soy protein materials described above and, in particular, due to soy protein isolates containing the highest protein content and lowest carbohydrate content of the soy protein materials. For example, a preferred feed mixture formulation may comprise a blend of two or more soy protein isolates. Other suitable formulations may comprise a soy protein concentrate in combination with a soy protein isolate. Typically, a protein-containing feed mixture comprising one or more soy protein isolates contains from about 80% to about 100% by weight soy protein isolate on a moisture-free basis and, accordingly, from about 80% to about 95% by weight protein.

Generally, the bulk density of the source of soy protein or blend of sources is from about 0.20 g/cm^3 to about 0.27 g/cm^3 and, more typically, from about 0.24 g/cm^3 to about 0.27 g/cm^3.

In certain embodiments in which the feed mixture comprises a plurality of soy protein materials, it is desired that at least one of the soy protein materials exhibits low viscosity and low gelling properties. The viscosity and/or

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gelling properties of an isolated soy protein may be modified by a wide variety of methods known in the art. For example, the viscosity and/or gelling properties of a soy protein isolate may be decreased by partial hydrolysis which partially denatures the protein materials. Typically, soy protein materials treated in this manner are described in terms of degree of hydrolysis which can be determined based on molecular weight distributions, sizes of proteins and chain lengths, or breaking down of beta-conglycinin or glycinin storage proteins. As used herein, the term "percent degree of hydrolysis" of a sample is defined as the percentage of cleaved peptide bonds out of the total number of peptide bonds in the sample. The proportion of cleaved peptide bonds in a sample can be measured by calculating the amount of trinitrobenzene sulfonic acid (TNBS) that reacts with primary amines in the sample under controlled conditions.

[0032] Trinitrobenzene sulfonic acid (TNBS) reacts under controlled conditions with the primary amines of proteins to produce a chromophore which absorbs light at 420 nm. The intensity of color produced from the TNBS-amine reaction is proportional to the total number of amino terminal groups and therefore is an indicator of the degree of hydrolysis of a sample. In conducting the TNBS assay, 0.2 ml of 0.3 M TNBS solution is reacted with 2 ml of a protein sample prepared by slurrying 0.1 grams of protein material in 100 mL of 0.0245 N NaOH. The reaction is carried out in the presence of a 9.5 pH sodium borate buffer. The reaction is allowed to proceed for 15 minutes after which time the reaction is terminated and the absorbance of the reaction solution and the protein sample are measured. The absorbance values provide the TNBS value which represents the moles of free amino acids produced per 100 kg of protein which is calculated according to the following formula: TNBS value = $(As_{420} - Ab_{420})x(8.073)x(1/W)x\ F\ x\ 100/P$. As_{420} is the TNBS absorbance of the sample. Ab_{420} is the TNBS absorbance of

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the reaction solution. W is the weight of sample. F is the inverse of dilution factor of the measured sample to the sample produced by the reaction (i.e., diluting the reaction sample by a factor of 10 before measuring its absorbance provides a dilution factor of 0.1). 8.073 is the extinction coefficient and dilution factor/unit conversion for the procedure. P is the protein content of the sample determined using the Kjeldahl method described below. Such measurement procedures are described, for example, by Adler-Nissen in J. Agric. Food Chem., Vol. 27(6), p. 1256 (1979).

[0033] Percent degree of hydrolysis is determined from the TNBS value using the following equation: % degree of hydrolysis = $((TNBS_{value} - 24)/885)x100$. 24 is the correction for lysyl amino group of a non-hydrolyzed sample and 885 is the moles of amino acid per 100 kg of protein.

[0034] The Nitrogen-Ammonia-Protein Modified Kjeldahl Method of A.O.C.S. Methods Bc4-91 (1997), Aa 5-91 (1997), and Ba 4d-90(1997) used in the determination of the protein content may be performed as follows with a soy material sample. 0.0250-1.750 grams of the soy material are weighed into a standard Kjeldahl flask. A commercially available catalyst mixture of 16.7 grams potassium sulfate, 0.6 grams titanium dioxide, 0.01 grams of copper sulfate, and 0.3 grams of pumice is added to the flask, then 30 milliliters of concentrated sulfuric acid is added to the flask. Boiling stones are added to the mixture, and the sample is digested by heating the sample in a boiling water bath for approximately 45 minutes. The flask should be rotated at least 3 times during the digestion. 300 milliliters of water is added to the sample, and the sample is cooled to room temperature. Standardized 0.5N hydrochloric acid and distilled water are added to a distillate receiving flask sufficient to cover the end of a distillation outlet tube at the bottom of the receiving flask. Sodium hydroxide solution is added to the digestion flask in an

amount sufficient to make the digestion solution strongly alkaline. The digestion flask is then immediately connected to the distillation outlet tube, the contents of the digestion flask are thoroughly mixed by shaking, and heat is applied to the digestion flask at about a 7.5-min boil rate until at least 150 milliliters of distillate is collected. The contents of the receiving flask are then titrated with 0.25N sodium hydroxide solution using 3 or 4 drops of methyl red indicator solution--0.1% in ethyl alcohol. A blank determination of all the reagents is conducted simultaneously with the sample and similar in all respects, and correction is made for blank determined on the reagents. The moisture content of the ground sample is determined according to the procedure described below (A.O.C.S Official Method Ba 2a-38). The nitrogen content of the sample is determined according to the formula: Nitrogen (%)=1400.67x[[(Normality of standard acid)x(Volume of standard acid used for sample (ml))]-[(Volume of standard base needed to titrate 1 ml of standard acid minus volume of standard base needed to titrate reagent blank carried through method and distilled into 1 ml standard acid (ml))x(Normality of standard base)]-[(Volume of standard base used for the sample (ml))x(Normality of standard base)]]/(Milligrams of sample). The protein content is 6.25 times the nitrogen content of the sample.

[0035] The term "moisture content" as used herein refers to the amount of moisture in a material. The moisture content of a soy material can be determined by A.O.C.S. (American Oil Chemists Society) Method Ba 2a-38 (1997), which is incorporated herein by reference in its entirety. According to the method, the moisture content of a soy material may be measured by passing a 1000 gram sample of the soy material through a 6x6 riffle divider, available from Seedboro Equipment Co., Chicago, Ill., and reducing the sample size to 100 grams. The 100 gram sample is then immediately placed in an airtight container and weighed. 5

grams of the sample are weighed onto a tared moisture dish (minimum 30 gauge, approximately 50x20 millimeters, with a tight-fitting slip cover--available from Sargent-Welch Co.). The dish containing the sample is placed in a forced draft oven and dried at 130+/- 3EC for 2 hours. The dish is then removed from the oven, covered immediately, and cooled in a dessicator to room temperature. The dish is then weighed. Moisture content is calculated according to the formula: Moisture content (%)=100x[(loss in mass (grams)/mass of sample (grams)].

[0036] Hydrolyzed protein materials used in accordance with the process of the present invention typically exhibit TNBS values of less than about 160, more typically less than about 115 and, still more typically, from about 30 to about 70.

[0037] Hydrolyzed soy protein sources sufficient for use as a low viscosity/low gelling material in the process of the present invention typically have a degree of hydrolysis of less than about 15%, more typically less than about 10% and, still more typically, from about 1% to about 5%. In the case of soy protein isolates, the hydrolyzed soy protein material typically comprises a partially hydrolyzed isolate having a degree of hydrolysis of from about 1% to about 5%.

[0038] Suitable methods for hydrolysis of soy protein sources include acid hydrolysis and caustic hydrolysis. Soy protein sources (e.g., a soy protein isolate) may also be hydrolyzed by treatment of the material with an enzyme such as a protease obtained from a plant or microbial source; for example, contacting the isolate with a protease at a pH of from about 7 to about 8. Suitable proteolytic enzymes include bromelin and papain. It is currently believed that proteolytic hydrolysis attacks certain peptide bonds, thereby reducing the molecular weights of certain proteins present in the proteins in the feed mixture.

[0039] The viscosity and/or gelling properties of dairy whey may also be modified by partial hydrolysis. Hydrolysis may be carried out by, for example, treating the dairy whey with a proteolytic enzyme. Suitable proteolytic enzymes include, for example, bromelin, papain, and rennin.

[0040] Gel strength, expressed in terms of the extent of gelation (G) may be determined by preparing a slurry (commonly 200 grams of a slurry having a 1:5 weight ratio of soy protein source to water) to be placed in an inverted frustoconical container which is placed on its side to determine the amount of the slurry that flows from the container. The container has a capacity of approximately 150 ml (5 ounces), height of 7 cm, top inner diameter of 6 cm, and a bottom inner diameter of 4 cm. The slurry sample of the soy protein source may be formed by cutting or chopping the soy protein source with water in a suitable food cutter including, for example, a Hobart Food Cutter manufactured by Hobart Corporation (Troy, OH). The extent of gelation, G, indicates the amount of slurry remaining in the container over a set period of time. Low viscosity/low gelling sources of soy protein suitable for use in accordance with the present invention typically exhibit an extent of gelation, on a basis of 200 grams of sample introduced to the container and taken five minutes after the container is placed on its side, of from about 1 to about 80 grams (i.e., from about 1 to about 80 grams, 0.5% to about 40%, of the slurry remains in the container five minutes after the container is placed on its side). High viscosity/medium to high gelling sources of soy protein suitable for use in accordance with the present invention typically exhibit an extent of gelation, on the same basis described above, of from about 45 to about 140 grams (i.e., from about 45 to about 140 grams, 22% to about 70%, of the slurry remains in the container five minutes after the container is placed on its side). A blend of sources comprising a low viscosity/low gelling

source and a high viscosity/high gelling source typically have a gelation rate, on the same basis, of from about 20 to about 120 grams.

[0041] In accordance with the present invention, a low viscosity/low gelling source is preferably combined with a high viscosity/high gelling source to form the blend. The presence of the high viscosity/high gelling source reduces the risk of excessive expansion of the blend upon extrusion, provides a honeycomb structure to the extrudate, and generally contributes stability to the blend. The low viscosity/low gelling and high viscosity/high gelling sources can be combined in varying proportions depending on the desired characteristics of the extrudate.

[0042] In a preferred embodiment, the protein-containing feed mixture typically comprises a blend of soy protein isolates comprising at least about 2 parts by weight of a hydrolyzed (i.e., generally low viscosity/low gelling) protein isolate per part by weight of an unhydrolyzed (i.e., generally high viscosity/high gelling) protein isolate, more typically at least about 3 parts by weight of a hydrolyzed protein isolate per part by weight of an unhydrolyzed protein isolate and, still more typically, at least about 4 parts by weight of a hydrolyzed protein isolate per part by weight of an unhydrolyzed protein isolate. Preferably, the blend of soy protein isolates comprises from about 2 parts by weight to about 8 parts by weight of a hydrolyzed protein isolate per part by weight of an unhydrolyzed protein isolate. More preferably, the blend of soy protein isolates comprises from about 4 parts by weight to about 6 parts by weight of a hydrolyzed protein isolate per part by weight of an unhydrolyzed protein isolate.

[0043] Blends comprising a plurality of soy protein isolates, one of which is a low viscosity/low gelling source produced by partial hydrolysis of a soy protein isolate typically

comprise from about 60% to about 100% by weight of a hydrolyzed protein isolate on a moisture-free basis and from about 0% to about 33% by weight of an unhydrolyzed protein isolate on a moisture-free basis. More typically, such blends comprise from about 60% to about 90% by weight of a hydrolyzed protein isolate on a moisture-free basis and from about 0% to about 20% by weight of an unhydrolyzed isolate on a moisture-free basis. More typically, such blends comprise from about 60% to about 90% by weight of a hydrolyzed protein isolate on a moisture-free basis and from about 5% to about 20% by weight of an unhydrolyzed isolate on a moisture-free basis. Still more typically, such blends comprise from about 65% to about 85% by weight of a hydrolyzed protein isolate on a moisture-free basis and from about 10% to about 20% by weight of an unhydrolyzed isolate on a moisture-free basis. Even more typically, such blends comprise from about 65% to about 75% by weight of a hydrolyzed protein isolate on a moisture-free basis and from about 15% to about 20% by weight of an unhydrolyzed isolate on a moisture-free basis. With respect to certain protein sources (e.g., casein) higher ratios of unhydrolyzed to hydrolyzed protein are acceptable, up to and including 100% casein.

[0044] Suitable isolated soy protein sources exhibiting a low viscosity and/or low gelling (i.e., partially hydrolyzed) for use as a low viscosity/low gelling soy protein material include SUPRO 670 and SUPRO 710, available from The Solae Company (St. Louis, MO), and PROFAM 931 and PROFAM 873 available from Archer Daniels Midland (Decatur, IL). For both SUPRO 670 and SUPRO 710, the degree of hydrolysis can range from 0.5%-5.0%. The molecular weight distribution of each of these isolates can be determined by size exclusion chromatography.

[0045] Suitable sources of high viscosity and/or medium/high gelling isolated soy protein (i.e., unhydrolyzed) for use as the second soy protein isolate include SUPRO 620, SUPRO

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500E, SUPRO 630, and SUPRO EX33 available from The Solae Company (St. Louis, MO); PROFAM 981 available from Archer Daniels Midland (Decatur, IL); and PROLISSE soy protein isolate available from Cargill Soy Protein Solutions, Inc. (Minneapolis, MN).

Table 1 provides molecular weight distributions for certain of the commercial SUPRO® products mentioned above.

Table 1. Estimated Molecular Weight Distribution of SUPRO® products determined at an absorbance of 280 nm using HPLC-SEC (High Performance Liquid Chromatography - Size Exclusion Chromatography) gel filtration in 6M guanidine HCl.

Product	>50,000	20,000-50,000	5000-20,000	2000-5000
SUPRO® 620	21%	44%	30%	5%
SUPRO® 670	7%	17%	55%	21%
SUPRO® 710	2%	12%	55%	31%

The protein-containing feed mixture may also contain one or more soluble carbohydrate sources in an amount of from about 0.001% to about 20% by weight soluble carbohydrates on a moisture-free basis. Typically, the protein-containing feed mixture comprises from about 0% to about 5% by weight soluble carbohydrates on a moisture-free basis. Suitable sources of soluble carbohydrates include, for example, cereals, tubers and roots such as rice (e.g., rice flour), wheat, corn, barley, potatoes (e.g., native potato starch), and tapioca (e.g., native tapioca starch).

In addition to soluble carbohydrates, the feed mixture may also contain insoluble carbohydrate such as soy fiber which does not contribute to nutritive carbohydrate load and which, generally, is present as an aid in processing of the mixture because the fiber serves to facilitate flowability and expansion of the feed mixture. When soy fiber is present in the mixture to serve either as filler to increase the volume of the

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mixture or as a processing aid, the amount of fiber present can vary widely. Generally, however, the feed mixture comprises from about 0.001% to about 5% by weight fiber and, more generally, from about 1% to about 3% by weight fiber. Soy fiber absorbs moisture as the extrusion mass flows through the extrusion barrel to the die. A modest concentration of soy fiber is believed to be effective in obstructing cross-linking of protein molecules, thus preventing excessive gel strength from developing in the cooked extrusion mass exiting the die. Unlike the protein, which also absorbs moisture, soy fiber readily releases moisture upon release of pressure at the die exit temperature. Flashing of the moisture released contributes to expansion, i.e., "puffing," of the extrudate, thus conducing to the formation of the low density extrudate of the invention.

[0049] Referring now to Fig. 1, one embodiment of the process of the present invention is shown. The process comprises introducing the particular ingredients of the protein-containing feed mixture formulation into a mixing tank 101 (i.e., an ingredient blender) to combine the ingredients and form a protein feed pre-mix. The pre-mix is then transferred to a hopper 103 where the pre-mix is held for feeding via screw feeder 105 to a pre-conditioner 107 to form a conditioned feed mixture. The conditioned feed mixture is then fed to an extrusion apparatus (i.e., extruder) 109 in which the feed mixture is heated under mechanical pressure generated by the screws of the extruder to form a molten extrusion mass. The molten extrusion mass exits the extruder through an extrusion die.

[0050] In pre-conditioner 107, the particulate solid ingredient mix is 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 feed mixture and improves its flow characteristics.

The preconditioner 107 contains one or more paddles to promote uniform mixing of the feed and transfer of the feed 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 feed mixture in the preconditioner or extruder barrel. Generally, the speed of the paddles is from about 500 to about 1300 revolutions per minute (rpm).

[0051] Typically, the protein-containing feed mixture is pre-conditioned prior to introduction into the extrusion apparatus 109 by contacting a pre-mix with moisture (i.e., steam and/or water) at a temperature of at least about 45°C (110°F). More typically, the feed mixture is conditioned prior to heating by contacting a pre-mix with moisture at a temperature of from about 45°C (110°F) to about 85°C (185°F). Still more typically, the feed mixture is conditioned prior to heating by contacting a pre-mix with moisture at a temperature of from about 45°C (110°F) to about 70°C (160°F). It has been observed that higher temperatures in the preconditioner may encourage starches to gelatinize, which in turn may cause lumps to form which may impede flow of the feed mixture from the preconditioner to the extruder barrel.

[0052] Typically, the pre-mix is conditioned for a period of about 30 to about 60 seconds, depending on the speed and the size of the conditioner. More typically, the pre-mix is conditioned for a period of from about 40 to about 50 seconds, most typically about 45 seconds. The pre-mix is contacted with steam and/or water and heated in the pre-conditioner 107 at generally constant steam flow to achieve the desired temperatures. The water and/or steam conditions (i.e., hydrates) the feed mixture, 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. In certain embodiments, the feed mixture pre-mix is contacted with both water and steam to produce a conditioned feed mixture. For example, experience to date suggests that it may be preferable to add both water and steam to increase the density of the dry mix as steam contains moisture to hydrate the dry mix and also provides heat which promotes hydration of the dry mix by the water.

[0053] The conditioned pre-mix may contain from about 5% to about 25% by weight water. Preferably, the conditioned pre-mix contains from about 5% to about 15% by weight water. The conditioned pre-mix typically has a bulk density of from about 0.25 g/cm^3 to about 0.6 g/cm^3. Generally, as the bulk density of the pre-conditioned feed mixture increases within this range, the feed 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.

[0054] The conditioned pre-mix is generally introduced to the extrusion apparatus 109 at a rate of no more than about 10 kilograms (kg)/min (no more than about 20 lbs/min). Typically, the conditioned pre-mix is introduced to the barrel at a rate of from about 2 to about 10 kg/min (from about 5 to about 20 lbs/min), more typically from about 5 to about 10 kg/min (from about 10 to about 20 lbs/min) and, still more typically, from about 6 to about 8 kg/min (from about 12 to about 18 lbs/min). Generally, it has been observed that the density of the extrudate decreases as the feed rate of pre-mix to the extruder increases. The residence time of the extrusion mass in the extruder barrel is typically less than about 60 seconds, more typically less than about 30 seconds and, still more typically, from about 15 to about 30 seconds.

[0055] Typically, extrusion mass passes through the barrel at a rate of from about 7.5 kg/min to about 40 kg/min (from about 17 lbs/min to about 85 lbs/min). More typically, extrusion mass passes through the barrel at a rate of from about 7.5 kg/min to about 30 kg/min (from about 17 lbs/min 65 lbs/min). Still more typically, extrusion mass passes through the barrel at a rate of from about 7.5 kg/min to about 22 kg/min (from about 17 lbs/min to about 50 lbs/min). Even more typically, extrusion mass passes through the barrel at a rate of 7.5 kg/min to about 15 kg/min (from about 17 lbs/min to about 35 lbs/min).

[0056] Various extrusion apparatus suitable for forming a molten extrusion mass from a feed material comprising vegetable protein are well known in the art. One suitable extrusion apparatus is a double-barrel, twin screw extruder as described, for example, in U.S. Patent No. 4,600,311. Examples of commercially available double-barrel, twin screw extrusion apparatus include a CLEXTRAL Model BC-72 extruder manufactured by Clextral, Inc. (Tampa, FL) having an L/D ratio of 13.5:1 and four heating zones; a WENGER Model TX-57 extruder manufactured by Wenger (Sabetha, KS) having an L/D ratio of 14:1 and four heating zones; and a WENGER Model TX-52 extruder manufactured by Wenger (Sabetha, KS) having an L/D ratio of 14:1 and four heating zones. Other suitable extruders include CLEXTRAL Models BC-82 and BC-92 and WENGER Models TX-138, TX-144, TX-162, and TX-168.

[0057] The ratio of the length and diameter of the extruder (L/D ratio) generally determines the length of extruder necessary to process the mixture and affects the residence time of the mixture therein. Generally the L/D ratio is greater than about 10:1, greater than about 15:1, greater than about 20:1, or even greater than about 25:1.

[0058] 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.

[0059] The speed of the screw or screws of the extruder may vary depending on the particular apparatus. However, the screw speed is typically from about 250 to about 350 revolutions per minute (rpm), more typically from about 250 to about 335 rpm and, still more typically, from about 270 to about 305 rpm. Generally, as the screw speed increases, the density of the extrudates decreases.

[0060] The extrusion apparatus 109 generally comprises a plurality of heating zones through which feed mixture is conveyed under mechanical pressure prior to exiting the extrusion apparatus 109 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 (between about 15°F and about 125°F), more generally by between about 10°C and about 50°C (from about 15°F to about 90°F) and, more generally, from about 10°C to about 30°C (from about 15°F to about 55°F).

[0061] Typically, the temperature in the last heating zone is from about 90°C to about 150°C (from about 195°F to about 300°F), more typically from about 100°C to about 150°C (from about 212°F to about 300°F) and, still more typically, from about 100°C to about 130°C (from about 210°F to about 270°F).

[0062] Typically, the temperature in the next to last heating zone is from about 80°C to about 120°C (from about 175°C to about 250°C) and, more typically, from about 90°C to about 110°C (from about 195°F to about 230°F).

[0063] Typically, the temperature in the heating zone immediately before the next to last heating zone is from about 70°C to about 100°C (from about 160°F to about 210°F) and, more

typically, from about 80°C to about 90°C (from about 175°F to about 195°F).

[0064] Typically, the temperature in the heating zone separated from the last heating zone by two heating zones is from about 60°C to about 90°C (from about 140°F to about 195°F) and, more typically, from about 70°C to about 80°C (from about 160°F to about 175°F).

[0065] Typically, the extrusion apparatus comprises at least about three heating zones and, more typically, at least about four heating zones. In a preferred embodiment, the conditioned pre-mix is transferred through four heating zones within the extrusion apparatus, with the feed mixture heated to a temperature of from about 100°C to about 150°C (from about 212°F to about 302°F) such that the molten extrusion mass enters the extrusion die at a temperature of from about 100°C to about 150°C (from about 212°F to about 302°F).

[0066] In such an embodiment, the first heating zone is preferably operated at a temperature of from about 60°C to about 90°C (from about 140°F to about 195°F), the second heating zone is operated at a temperature of from about 70°C to about 100°C (from about 160°F to about 212°F), the third heating zone is operated at a temperature of from about 80°C to about 120°C (from about 175°F to about 250°F) and the fourth heating zone is operated at a temperature of from about 90°C to about 150°C (from about 195°F to about 302°F).

[0067] The temperature within the heating zones may be controlled using suitable temperature control systems including, for example, Mokon temperature control systems manufactured by Clextral (Tampa, FL). Steam may also be introduced to one or

more heating zones via one or more valves in communication with the zones to control the temperature.

[0068] Apparatus used to control the temperature of the heating zones may be automatically controlled. One such control system includes suitable valves (e.g., solenoid valves) in communication with a programmable logic controller (PLC).

[0069] The pressure within the extruder barrel is not narrowly critical. Typically the extrusion mass is subjected to a pressure of at least about 400 psig (about 28 bar) and generally the pressure within the last two heating zones is from about 1000 psig to about 3000 psig (from about 70 bar to about 210 bar). 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.

[0070] The heating zones within the barrel may be characterized in terms of the action upon the mixture therein. For example, zones in which the primary purpose is to convey the mixture longitudinally along the barrel are generally referred to as "conveying zones" and zones in which the primary purpose is mixing are generally referred to as "mixing zones." Zones in which the primary purpose is to compress the mixture are generally referred to as "compression zones" and zones in which the primary purpose is to provide shearing of the proteins are referred to as "shearing zones." It should be understood that more than one action may occur within a zone; for example, there may be "shearing/compression" zones or "mixing/shearing" zones. The action upon the mixture within the various zones is generally determined by various conditions within the zone including, for example, the temperature of the zone and the screw profile within the zone.

[0071] The extruder is characterized by its screw profile which is determined, at least in part, by the length to pitch

ratio of the various portions of the screw. Length (L) indicates the length of the screw while pitch (P) indicates the distance required for 1 full rotation of a thread of the screw. In the case of a modular screw containing a plurality of screw portions having varying characteristics, L can indicate the length of such a portion and P the distance required for 1 full rotation of a thread of the screw. The intensity of mixing, compression, and/or shearing generally increases as the pitch decreases and, accordingly, L:P increases. L:P ratios for the twin-screws within the various heating zones of one embodiment of the present invention are provided below in Table 2.

Table 2

Zone	L:P	Flow
Conveying	200/100	Double flow
Conveying	200/100	Double flow
Conveying	150/100	Double flow
Compression	200/66	Double flow
Compression	200/66	Double flow
Shearing	100/50	Double flow
Shearing	100/40	Single flow
Shearing	100/30 (reverse)	Single flow

[0072] Water is injected into the extruder barrel to hydrate the feed 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 30% 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 are introduced to the barrel and, more typically less than about 0.5 kg of water per kg of protein and, still more typically, less than about 0.25 kg of water per kg of protein are introduced to the barrel. Generally, from about 0.1 kg to about 1 kg of water per kg of protein are introduced to the barrel.

[0073] Referring again to Fig. 1, the molten extrusion mass in extrusion apparatus 109 is extruded through a die (not shown) to produce an extrudate, which is then dried in dryer 111.

[0074] Extrusion conditions are generally such that the product emerging from the extruder barrel typically has a moisture content of from about 20% to about 45% by weight wet basis and, more typically, from about 30% to about 40% by weight wet basis. The moisture content is derived from water present in the mixture introduced to the extruder, moisture added during preconditioning and/or any water injected into the extruder barrel during processing.

[0075] Upon release of pressure, the molten extrusion mass exits the extruder barrel through the die, superheated water present in the mass flashes off as steam, causing simultaneous expansion (i.e., puffing) of the material. The level of expansion of the extrudate upon exiting of mixture from the extruder in terms of the ratio of the cross-sectional area of extrudate to the cross-sectional area of die openings is generally less than about 15:1, more generally less than about 10:1 and, still more generally, less than about 5:1. Typically, the ratio of the cross-sectional area of extrudate to the cross-sectional area of die openings is from about 2:1 to about 11:1 and, more typically, from about 2:1 to about 10:1.

[0076] The extrudate is cut after exiting the die. Suitable apparatus for cutting the extrudate include flexible

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knives manufactured by Wenger (Sabetha, KS) and Clextral (Tampa, FL).

The dryer 111 used to dry the extrudates 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 135°C to about 185°C (from about 280°F to about 370°F). Typically, the temperature of the air within one or more of the zones is from about 140°C to about 180°C (from about 290°F to about 360°F), more typically from about 155°C to 170°C (from about 310°F to 340°F) and, still more typically, from about 160°C to about 165°C (from about 320°F to about 330°F). Typically, the extrudate is present in the dryer for a time sufficient to provide an extrudate having a desired moisture content. This desired moisture content may vary widely depending on the intended application of the extrudate and, typically, is from about 2.5% to about 5.0% by weight. Generally, the extrudate is dried for at least about 5 minutes and, more generally, for at least about 10 minutes. Suitable dryers include those manufactured by Wolverine Proctor & Schwartz (Merrimac, MA), National Drying Machinery Co. (Philadelphia, PA), Wenger (Sabetha, KS), Clextral (Tampa, FL), and Buehler (Lake Bluff, IL).

The extrudates may further be comminuted to reduce the average particle size of the extrudate. Suitable grinding apparatus include hammer mills such as Mikro Hammer Mills manufactured by Hosokawa Micron Ltd. (England).

Preferably, the novel protein extrudates of the present invention comprise at least about 80% by weight protein on a moisture-free basis, at least about 90% by weight protein on a moisture-free basis. In one preferred embodiment, the protein extrudate

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comprises from about 80% to about 95% by weight protein on a moisture-free basis.

The protein extrudates comprise vegetable protein and may also include other components including fiber (e.g., soy fiber and cereal fiber), carbohydrates (e.g., complex carbohydrates such as starches), and water. Preferably, a majority of the protein in the food product comprises soy proteins and, preferably, the source of a majority of the protein in the extrudate is one or more soy protein isolates.

In one embodiment, the protein extrudate is in the form of a low density snack product including a majority solids component and a water component. Typically, such products include between about 25% and about 95% protein on a majority solids component and water component basis.

In another embodiment, the protein extrudate is in the form a low density, low moisture content proteinaceous food product comprising a principal solid component which includes protein in a concentration of between about 25% and about 95% by weight of the water present in the product and the dry basis weight of the principal solid component. In one variation of this embodiment, the principal solid component is in form of a proteinaceous solid matrix and, in another, a proteinaceous solid extrudate.

Generally, the protein extrudates of the present invention generally have a density of from about 0.20 g/cm^3 to about 0.27 g/cm^3, or from about 0.24 g/cm^3 to about 0.27 g/cm^3.

Low density snack food products prepared in accordance with the present invention generally have a density of

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within the above ranges. Generally, such extrudates exhibit a crisp, non-fibrous eating texture.

In a preferred embodiment, the protein extrudates of the present invention comprise hydrolyzed soy protein and unhydrolyzed soy protein as described above. Typically, the protein extrudate comprises at least about 1 part by weight hydrolyzed soy protein per part by weight unhydrolyzed soy protein and, more preferably at least 2 parts by weight hydrolyzed soy protein per part by weight unhydrolyzed soy protein.

More typically, the protein extrudate comprises from about 2 to about 8 parts by weight hydrolyzed soy protein per part by weight unhydrolyzed soy protein, from about 2 to about 4 parts by weight hydrolyzed soy protein per part by weight unhydrolyzed soy protein, or from about 4 to about 6 parts by weight hydrolyzed soy protein per part by weight unhydrolyzed soy protein.

In certain embodiments, the food product includes hydrolyzed soy protein and at least partially hydrolyzed soy protein isolates and unhydrolyzed soy protein (e.g., a soy protein isolate, a soy protein concentrate, or soy flour) and the partially hydrolyzed protein is present in the product in a weight ratio of between 80:20 to 55:45 to the unhydrolyzed soy protein.

Preferably, the extrudate contains less than about 5%

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by weight and, even more preferably, from about 2% to about 5% by weight carbohydrates.

[0089] Carbohydrate (i.e., starch) present in the feed mixture typically forms microparticles of starch gels under the conditions of the extruder barrel caused by denaturing of starches. Thus, the starch present is partially gelatinized. The degree of starch gelatinization of the starch portions of the extrudate may be determined by a starch iodine test or by polarized microscopy. Typically, the starch present in the extrudate exhibits a degree of gelatinization of from about 70% to about 90%. While the starch is not present in an amount sufficient to provide a gelatinous character to the extrudate, its degree of gelatinization can be used as a measure of the degree of "cooking" of the extrusion mass within the barrel as generally increased temperatures are necessary for gelatinization of starches.

[0090] Typically, the extrudates contains from about 0.001% to about 5% by weight fiber on a moisture free basis and, more typically, from about 1% to about 3% by weight fiber on a moisture free basis. Fiber in the extrusion mass aids in expansion of the extrusion mass as it exits the extrusion die. It is presently believed that fiber in the extrusion mass disrupts formation of bonds between proteins which generally form a matrix which tends to trap water present in the mixture and prevent expansion. This disruption of bond formation and the natural tendency of the fiber to release water facilitates flashing of water from the extrusion mass as steam and expansion of the extrusion mass.

[0091] In addition to protein, the majority solids component or principal solid component of food products of the present invention may comprise other solid components (i.e., fillers) such as carbohydrates or fibers. The product may include filler in a ratio of filler to protein in the range of

from about 5:95 to about 75:25. In certain embodiments, a majority of the filler is starch. Suitable starches include rice flour, potato, tapioca, and mixtures thereof.

[0092] Generally, water is present in the dried extrudate at a concentration of from about 2% to about 5.5% by weight. The amount of water may vary depending on other characteristics of the extrudate (e.g., carbohydrate content and density).

[0093] Low density food products of the present invention including a majority solids component or a principal solid component typically contain water at a concentration of between about 1% and about 7% by weight of protein, filler, and water and, more typically, between about 3% and about 5% by weight of protein, filler, and water.

[0094] The protein extrudates of the present invention may further be characterized as having a hardness of at least about 1000 grams. Typically, the protein extrudates have a hardness of from about 1000 to about 50,000 grams and, more typically, from about 30,000 to about 45,000 grams. The hardness of the extrudates is generally determined by placing an extrudate sample in a container and crushing the sample with a probe. The force required to break the sample is recorded; the force that is required to crush the sample based on its size or weight is proportional to the hardness of the product. The hardness of the extrudates may be determined using a TA.TXT2 Texture Analyzer having a 25 kg load cell, manufactured by Stable Micro Systems Ltd. (England). Extrudates having a chewy texture are preferred in certain embodiments. Generally, such extrudates have a hardness of less than about 40,000 grams.

[0095] The protein extrudates may exhibit a wide range of particle sizes and may generally be characterized as an oval or round nugget or pellet. The following weight percents for characterizing the particle sizes of the extrudates of the

present invention are provided on an "as is" (i.e., moisture-containing) basis.

[0096] In certain embodiments, the particle size of the extrudate is such that from about 5% to about 10% by weight of the particles are retained on a 6 Mesh Standard U.S. sieve, from about 80% to about 90% by weight of the particles are retained on an 8 Mesh Standard U.S. sieve, from about 5% to about 10% by weight are retained on a 10 Mesh Standard U.S. sieve, and from about 1% to about 3% by weight of the particles pass through a 10 Mesh Standard U.S. Sieve.

[0097] Such extrudates typically have a length of from about 3 to about 7 mm and, more typically, about 5 mm. The width of such extrudates is typically from about 0.5 to about 3.5 mm and, more typically, about 2 mm.

[0098] Extrudates having such particle sizes are shown in the photomicrographs in Figs. 2 and 3.

[0099] Extrudate nuggets having these characteristics may be shredded to produce a textured soy protein product such that from about 5% to about 10% by weight of the particles are retained on a 1/8 inch Standard U.S. sieve, from about 10% to about 20% by weight (typically about 15% by weight) of the particles are retained on a 6 Mesh Standard U.S. Sieve, from about 60% to about 80% by weight (typically 70% by weight) of the particles are retained on a 20 Mesh Standard U.S. Sieve, and from about 3% to about 5% by weight of the particles pass through a 20 Mesh Standard U.S. Sieve. Such shredded extrudates are shown in Fig. 4.

[00100] In other embodiments, the particle size of the extrudate is such that from 5% to about 10% by weight are retained on a 4 Mesh Standard U.S. sieve, from about 60% to about 80% by weight are retained on a 6 Mesh Standard U.S. sieve, from about 20% to about 40% by weight are retained on an 8 Mesh

Standard U.S. sieve, and from about 1% to about 3% by weight of the particles pass through a 8 Mesh Standard U.S. Sieve.

[00101] Such extrudates typically have a length of from about 6 to about 10 mm and, more typically, about 8 mm. The width of such extrudates is typically from about 2.5 to about 5.5 mm and, more typically, about 4 mm.

[00102] Extrudates having such particle sizes are shown in the photomicrographs in Figs. 2, 3, and 5.

[00103] Extrudate nuggets having these characteristics may be shredded to produce a textured soy protein product having a particle size such that from about 10% to about 20% by weight are retained on a 1/4 inch Standard U.S. sieve, from about 50% to about 80% by weight (typically about 65% by weight) are retained on a 7 Mesh Standard U.S. sieve, from about 20% to about 50% by weight (typically about 35% by weight) are retained on a 16 Mesh Standard U.S. Sieve, and from about 3% to about 5% by weight pass through a 16 Mesh Standard U.S. sieve. Such shredded extrudates are shown in Fig. 4.

[00104] In still other embodiments, the particle size of the extrudate is such that from 5% to about 10% by weight of the particles are retained on a 1/2 inch Standard U.S. sieve, from about 80% to about 90% by weight of the particles are retained on a 1/4 inch Standard U.S. sieve, and from about 1% to about 3% by weight pass through a 1/4 inch Standard U.S. Sieve.

[00105] Such extrudates typically have a length of from about 7 to about 13 mm and, more typically, about 10 mm. The width of such extrudates is typically from about 4 to about 10 mm and, more typically, about 7.5 mm. Extrudates having such particle sizes are shown in Fig. 2.

[00106] The extrudate nuggets described above may be ground to produce a powdered soy protein product. Such powder typically exhibits a particle size such that from about 2% to about 5% by weight of the powder is retained on a 200 Mesh Standard U.S.

Sieve, from about 10% to about 25% by weight of the powder is retained on a 325 Mesh Standard U.S. Sieve, and from about 70% to about 100% by weight (typically about 75% by weight) of the powder passes through a 325 Mesh Standard U.S. Sieve. Ground extrudates are shown in Fig. 4.

[00107] The products can also have a wide range of pellet durability index (PDI) values usually on the order of from about 65-99, more preferably from about 80-97.

[00108] The extrudates of the present invention are suitable for incorporation into a variety of food products including, for example, food bars and ready to eat cereals. Such extrudates may generally be oval or round and may be also be shredded.

[00109] In certain embodiments, the protein extrudate is ground or comminuted as described above to produce a powdered extrudate. Typically, such powder has an average particle size of less than about 10μm. More typically, the average particle size of the comminuted extrudate is less than about 5μm and, still more typically, from about 1 to about 3μm. Such powdered extrudates are suitable for incorporation into a variety of food products including, for example, beverages, dairy products (e.g., soy milk and yogurt), baked products, meat products, soups, and gravies. The protein extrudates can be incorporated in such applications in the form of nuggets or pellets, shredded nuggets or pellets, or powders as described above.

[00110] Experience to date suggests that a particle size of less than about 5 μm is particularly desirable in the case of extrudates incorporated into beverages to prevent a "gritty" taste in the product.

[00111] A particularly preferred application in which the soy protein product of the present invention is used is in emulsified meats. The soy protein product may be used in emulsified meats to provide structure to the emulsified meat, which gives the emulsified meat a firm bite and a meaty texture.

The soy protein product also decreases cooking loss of moisture from the emulsified meat by readily absorbing water, and prevents "fatting out" of the fat in the meat so the cooked meat is juicier.

[00112] The meat material used to form a meat emulsion in combination with the soy protein product of the present invention is preferably a meat useful for forming sausages, frankfurters, or other meat products which are formed by filling a casing with a meat material, or can be a meat which is useful in ground meat applications such as hamburgers, meat loaf and minced meat products. Particularly preferred meat material used in combination with the soy protein product includes mechanically deboned meat from chicken, beef, and pork; pork trimmings; beef trimmings; and pork backfat.

[00113] A meat emulsion containing a meat material and the ground soy protein product contains quantities of each which are selected to provide the meat emulsion with desirable meat-like characteristics, especially a firm texture and a firm bite.

[00114] Typically, the ground soy protein product is present in the meat emulsion in an amount of from about 0% to about 4% by weight, more typically from about 0% to about 3% by weight and, still more typically, from about 1% to about 3% by weight.

[00115] Typically, the meat material is present in the meat emulsion in an amount of from about 40% to about 95% by weight, more typically from about 50% to about 90% by weight and, still more typically, from about 60% to about 85% by weight.

[00116] The meat emulsion also contains water, which is typically present in an amount of from about 0% to about 25% by weight, more typically from about 0% to about 20% by weight, even more typically from about 0% to about 15% by weight and, still more typically, from about 0% to about 10% by weight.

[00117] The meat emulsion may also contain other ingredients that provide preservative, flavoring, or coloration qualities to

the meat emulsion. For example, the meat emulsion may contain salt, typically from about 1% to about 4% by weight; spices, typically from about 0.1% to about 3% by weight; and preservatives such as nitrates, typically from about 0.001% to about 0.5% by weight.

[00118] The soy protein product of the present invention may also be used in beverage applications including, for example, acidic beverages. Typically, the ground soy protein product is present in the beverage in an amount of from about 0.5% to about 3.5% by weight. The beverages in which the soy protein product is incorporated typically contain from about 70% to about 90% by weight water. The beverages typically also contain sugars (e.g., fructose and sucrose) in an amount of up to about 20% by weight.

[00119] Preferred food product formulations are described below in various formulation examples.

[00120] In the case of product for the healthy diet consumer, the dried formed product has total protein (e.g., hydrolyzed and unhydrolyzed) in the range of between about 25% and 55%, by weight of dried formed product. The ratio of at least partially hydrolyzed soy isolates to unhydrolyzed or gelling protein is in the range of between about 80:20 to about 55:45 preferably in the range of between about 60:20 to about 60:45 and most preferably about 60:40. Filler, preferably a carbohydrate such as starch (a complex carbohydrate), is present in the range of between about 50% and 75% by weight of dried formed product. The total moisture content is present as described above coating can be applied to the dried formed product as described above. Also, the above-mentioned optional ingredients can also be added, for example, nutrients, flavorants, anti-microbial agents, etc. The total fat content of the finished product, i.e., the dried formed product with flavoring and additives added thereto is less than about 5% and

preferably in the range of between about 0.2% and about 5% by weight of finished product.

[00121] In the case of product for the balanced diet consumer, protein is present in the range of between about 55% and 70% by weight of dried formed product. The ratio of at least partially hydrolyzed soy isolates to the unhydrolyzed or gelling protein is in the range of between about 80:20 to about 55:45 and preferably about 70:30. Filler, preferably starch, is present in the range of between about 30% and 50% by weight of dried formed product. Typically, balanced diet consumers prefer a higher fat content since they view fat as an important element of a balanced diet. In this event, total fat in the finished product is in the range of between about 0.2% and about 20%, and preferably in the range of between about 15% and about 20% by weight of finished product. Most of the fat is preferably added with the coating since it is desirable to not mix the fat prior to extrusion in with the components of the product that are extruded. The other ingredients as mentioned for the healthy diet consumer can also be added to this product category in approximately the same amounts.

[00122] For the high protein diet consumer product, it is preferred to add little if any filler in order to increase the protein content and reduce the carbohydrate content which to some consumers is detrimental to a high protein diet. For such a product line, the protein is present in the range of between about 70% and 95% by weight of dried formed product. The ratio of at least partially hydrolyzed soy isolates to unhydrolyzed or gelling protein is in the range of between about 80:20 and about 55:45 and preferably about 70:30. Filler, is kept low and is present in the range of between about 0% and about 30%, preferably in the range of between about 5% and about 20% by weight of dried formed product. Fat, can be present in this type of product and would preferably be added with the coating. Fat

is present in the range of between about 0.2% and about 30% and preferably in the range of between about 7% and about 20% by weight of finished product. Other optional ingredients as discussed above can be added to this type of product in approximately the same amounts.

EXAMPLES

[00123] The following examples are simply intended to further illustrate and explain the present invention. The invention, therefore, should not be limited to any of the details in these examples.

[00124] Example 1

[00125] This example illustrates the preparation of soy protein nuggets comprising 70%, 75%, 80%, 85%, and 88% soy protein using various feed mixture formulations.

[00126] The feed mixtures are described below in Table 3.

Table 3

	Product				
Feed composition	70% protein	75% protein	80% protein	85% protein	88% protein
SUPRO 670	63.6%	68.2%	71.7%	77.3%	100%
SUPRO 620	15.9%	17.0%	17.8%	19.3%	0%
Tapioca starch	18.2%	12.5%	9.0%	3.4%	0%
Fibrim	2%	2%	1.2%	0%	0%
NaCl	0.3%	0.3%	0.3%	0%	0%

[00127] As shown in Table 3, the weight ratio of hydrolyzed to unhydrolyzed isolates is approximately 4:1 in the feed mixtures for preparing the 70%, 75%, 80%, and 85% protein nuggets. The 88% protein nuggets are prepared from a feed mixture which did not contain an unhydrolyzed isolate.

[00128] The ingredients of each feed mixture are mixed in an ingredient blender for 5 to 10 minutes to ensure uniform distribution. The dry feed mixture is pneumatically conveyed to a volumetric feeder (i.e., hopper) and fed to a pre-conditioning

tank at a rate of 6.3 to 7.7 kg/min (14-17 lb/min) in which the dry mix is pre-conditioned with steam and water. Water is introduced to the pre-conditioner at a rate of 0.2 to 0.7 kg/min (0.5-1.5 lb/min) and steam is injected into a conditioning tank at a rate of 0.16 to 0.22 kg/min (0.4-0.5 lb/min or 25-30 lb/hr). The mixture in the pre-conditioner is continuously stirred with a paddle rotating at 1300-1500 rpm and the flow of steam is carefully monitored to maintain the temperature of the protein mixture within the pre-conditioner between about 60° and about 70.5°C (140°F-159°F).

[00129] The dry mix is then introduced to the inlet of the extruder barrel inlet by a conveyor. Conditioned feed mix is introduced into the extruder at a rate of 6 to 9 kg/min (13.3 to 20 lb/min) using an extruder screw speed of from 275 to 320 rpm.

[00130] The extruder used is a double-barrel, twin-screw extruder, CLEXTRAL Model BC-72 manufactured by Clextral, Inc. (Tampa, FL) having an L/D ratio of 15:1 and four heating zones. The screw profile for the extruder is described in Table 4.

Table 4

Length	Pitch
200	100
200	100
150	100
200	66
200	66
100	50
100	40
100	30*

* Reverse

[00131] Water is introduced into the extruder barrel at a rate of 1.8 to 2.7 kg/min (4-6 lb/min) without steam injection. The barrel temperatures are controlled with a Mokon temperature

control system manufactured by Clextral (Tampa, FL). The extruder contains 4 heating zones through which the feed mixture passes, the temperature profile of the BC-72 extruder is shown in Table 5 below.

Table 5

Pre-conditioner	Extrusion Zone 1	Extrusion Zone 2	Extrusion Zone 3	Extrusion Zone 4 (Die end)
60-71°C (140-160EF)	28-29.5°C (82-85.1EF)	93-96°C (200-205EF)	132-135°C (270-275EF)	140-146°C (284-295EF)

[00132] The conditioned feed mix is cooked in the extruder barrel with mechanical energy generated from the extruder screw rpm/shear and electrical energy at high temperatures to reach the glass transition temperature. At high temperatures, shear, and pressure the feed mix melts and interacts with water and other ingredients to form a plastic like material which is then extruded through backup plate having a #1-inch (25-mm) diameter before passing through an extrusion die.

[00133] The extrudates are cut using a 6 bladed knife rotating at 2000-3000 rpm to obtain the product size, density and granulation. The die knife area is ventilated by sparging compressed air (within the cutter guard) to aid face plate cooling/product cutting.

[00134] The soy protein nuggets are dried with a Proctor single band conveyor dryer at a temperature of from about 145E to about 165EC (295E to about 325°F) for a residence time of 5-7 minutes. The dried soy nuggets are sieved using #3 and #8 Sweco sieves to remove the fines.

[00135] The hardness of the extrudates is determined using a texture analyzer, Model # TA.TXT2 with a 25 kg load cell manufactured by Stable Micro Systems Ltd. (England). The density

and hardness of the various soy protein extrudates are summarized below in Table 6.

Table 6

Protein content (%)	Density (g/cm^3)	Texture (g)
70	0.235	21680.1
75	0.247	23918.7
80	0.256	25230.2
85	0.234	22526.4

[00136] The effect of varying certain process conditions for various runs used to prepare 80% soy protein nuggets are summarized below in Table 7.

Table 7

Effect of Extruder Screw Speed, Water Feed Rate, and Mixture Feed Rate on Power Required and Density and Texture of 80% Soy Protein Nuggets

Run	Extruder RPM (%)	Barrel Water Feed Rate (%)	Mixture Feed Rate (%)	Power required (AMPS)	Density (g/cc)	Texture (g)
1	90	80	85	80	0.122	5535.4
2	80	90	85	104	0.2436	25850.6
3	90	90	85	104	0.2216	16706.6
4	90	90	85	104	0.2278	18138.3
5	80	80	75	80	0.2518	23821.3
6	90	90	75	80	0.2163	14992.1
7	85	85	80	104	0.237	19387.5
8	80	90	75	80	0.2458	21717.7
9	90	80	75	85	0.2091	13092.1
10	80	80	85	90	0.2518	24777.1
11	85	85	80	104	0.2328	19065.7
12	90	80	75	80	0.2161	12855.7
13	90	80	85	90	0.1331	6234.8
14	80	80	85	80	0.2444	23395.8
15	90	90	75	80	0.2161	12322.4
16	80	90	75	90	0.2728	29065.4
17	80	90	85	85	0.2583	26035.7
18	80	80	75	90	0.2466	24827

The equivalents of extruder rpm (%), mixture feed rate (%) and extruder barrel water rate (%) are presented below:

Extruder rpm:
80% = 267 rpm
85% = 284 rpm
90% = 301 rpm

Extruder feed rate:
75% = 15 lb/min
80% = 16 lb/min
85% = 17 lb/min

Extruder barrel water rate:
80% = 4.8 lb/min
85% = 5.1 lb/min
90% = 5.4 lb/min

[00137] Preferred formulations are provided in the following formulation examples. All percents (%) are by weight.

[00138] Nutritional Bar (sheet and cut type)

Ingredients	%
Marshmallow mixture -sugar -polydextrose -corn syrup -margarine -water -corn syrup	39.0
High soy protein nuggets	31.5
Dried Apples	13.5
Dried cranberries	13.0
Soybean oil	2.0
Cranberry juice concentrate	1.0
Total	100

[00139] Nutritional Bar (extruded)

Ingredients	%
Ground, Comminuted high soy protein nuggets	34.2
Corn syrup	26.0
High Fructose corn syrup	21.3
Rice Syrup solids, 26 DE	7.85
Glycerin	3.95
Vitamin and mineral premix	0.70
Natural and artificial	0.67

flavors (Chocolate & Vanilla)	
Salt	0.11
Total	100.00

[00140] Acidic pH beverage

Ingredients	%
Water	84.59
Sucrose	4.29
Ground, Comminuted high soy protein nuggets	1.65
Fructose	2.91
Carrot concentrate, 42 Brix	4.02
Citric acid	0.10
Pectin	0.45
Vitamin Premix	1.09
Phosphoric acid (75%)	0.7
Natural and Artificial Flavor	0.2
Total	100.00

[00141] Emulsified meat system

Ingredient	%
Beef Trim (10% Fat)	33.4
Pork Trim (27% Fat)	2.8
Pork Trim (57% Fat)	25.1
Ground, Comminuted high soy protein nuggets	2.0
Spices	0.53
Sodium phosphate	0.4
Sodium nitrite	0.01
Sodium Erythorbate	0.02
Dextrose	1.0
Corn Syrup Solids	2.0
Oleoresin Blend	0.01
Garlic Powder	0.01
Onion Powder	0.02
Total	100.0

[00142] Ground meat, beef patties

Ingredient	%
Beef Trim (10% Fat)	59.00
Beef Trim (15% Fat)	10.00
Beef Trim (50% Fat)	25.00
Water	5.0
Ground, Comminuted high soy protein nuggets	1.0

Total	100.00

[00143] High protein cookie

Ingredients	%
Butter	11.00
Butter flavored shortening	8.00
Brown Sugar	7.50
Polydextrose	11.00
Invert sugar syrup	3.50
Whole eggs	10.50
Soy Lecithin	0.02
Vanilla	0.25
Cake flour	5.30
Sodium bicarbonate	0.50
High soy protein nuggets	5.30
Ground, Comminuted high soy protein nuggets	10.50
Salt	0.25
Oats	15.43
Total	100.00

[00144] Hot Dog

Ingredients	%
Turkey (Mechanically deboned)	60.00
Beef trimmings	15.00
Water	15.00
Salt	2.00
Curing salt (6.25% $NaNO_2$)	0.15
Sodium ascorbate	0.05
Phosphate	0.30
Corn syrup solids	1.20
Ground textured Soy protein product	1.20
Modified potato starch	1.20
Tomato paste	2.00
Chili powder	0.50
Paprika powder	0.50
Cumin powder	0.25
Dehydrated onions	0.25
Smoke flavor	0.10
Total	100.00

[00145] Smoked Italian Sausage

Ingredients	%
Pork trimmings	49.20

Chicken (Mechanically deboned)	15.00
Pork fat trimmings	10.00
Water	20.00
Salt	1.70
Curing salt (6.25% $NaNO_2$)	0.20
Phosphate	0.30
Sodium ascorbate	0.05
Ground textured soy protein product	1.60
Non fat dry milk	0.80
Smoke flavor	0.25
Paprika powder	0.25
Fennel	0.25
Red pepper	0.15
White pepper	0.15
Anise	0.10
Total	100.00

[00146] Smoked Sausage

Ingredients	%
Pork picnics	48.00
Beef meat	20.00
Turkey (Mechanically deboned)	10.00
Water	15.00
Salt	1.80
Curing salt	0.20
Sodium ascorbate	0.05
Corn syrup solids	1.50
Ground textured soy protein product	1.50
Non fat dry milk	1.50
White pepper	0.25
Marjoram	0.10
Nutmeg	0.10
Total	100.00

[00147] Beef Smoked Sausage

Ingredients	%
Beef meat	20.00
Beef navels	52.00
Water	20.00
Salt	2.10
Curing salt (6.25% $NaNO_2$)	0.15
Sodium ascorbate	0.05
Corn syrup	2.20
Ground textured Soy protein	

product	2.20
Non fat dry milk powder	0.60
Onion powder	0.20
Seasoning	0.50
Total	100.00

[00148] Variety Meat Smoked Sausage

Ingredients	%
Beef tripe (flaked/ground)	16.00
Beef head meat (flaked/ground)	10.00
Beef meat (pre-cured)	10.00
Beef heart emulsion	10.00
Beef tongue	16.00
Pork meat (pre-cured)	10.00
Chicken (Mechanically deboned)	10.00
Water	10.00
Salt	2.30
Curing salt (6.25% $NaNO_2$)	0.15
Sodium ascorbate[4]	0.05
Corn syrup	2.30
Ground textured Soy protein product	2.30
Seasoning	0.90
Total	100.00

* * * * * *

[00149] The present invention is not limited to the above embodiments and can be variously modified. The above description of preferred embodiments is intended only to acquaint others skilled in the art with the invention, its principles and its practical application so that others skilled in the art may adapt and apply the invention in its numerous forms, as may be best suited to the requirements of a particular use.

[0001] With reference to the use of the word(s) "comprise" or "comprises" or "comprising" in this entire specification (including the claims below), it is noted that unless the context requires otherwise, those words are used on the basis and clear understanding that they are to be interpreted inclusively, rather than exclusively, and that it is intended each of those words to be so interpreted in construing this entire specification.

Further, any prior art reference or statement provided in the specification is not to be taken as an admission that such art constitutes, or is to be understood as constituting, part of the common general knowledge in Australia.

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The claims defining the invention are as follows:

1. A protein extrudate comprising at least about 80% by weight vegetable protein on a moisture-free basis, less than about 5% weight carbohydrate on a moisture-free basis, a degree of hydrolysis of less than about 15%, and having a density of from about 0.20 g/cm^3 to about 0.27 g/cm^3.

2. A protein extrudate as set forth in claim 1 comprising at least about 80% by weight soy protein on a moisture-free basis.

3. A protein extrudate as set forth in claim 1 or 2 wherein said extrudate comprises less than about 5% by weight carbohydrate on a moisture-free basis.

4. A protein extrudate as set forth in claim 2 comprising from about 2 to about 8 parts by weight hydrolyzed soy protein per part by weight unhydrolyzed soy protein.

5. A protein extrudate as set forth in claim 4 wherein said hydrolyzed soy protein exhibits a TNBS value of from about 30 to about 70.

6. A protein extrudate as set forth in any one of claims 1 to 5 wherein said extrudate has a hardness of from about 1000 grams to about 50,000 grams, as measured by a texture analyzer having a 25 kg load cell.

7. A protein extrudate as set forth in any one of claims 1 to 6, substantially as hereindescribed with reference to any one of the Examples.

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8. A functional food ingredient comprising from about 40% to about 95% by weight meat material and up to about 4% by weight of a soy protein extrudate on a total weight basis, the soy protein extrudate comprising at least about 80% by weight soy protein on a moisture-free basis, less than about 5% weight carbohydrate on a moisture-free basis, a degree of hydrolysis of less than about 15%, and having a density of from about 0.20 g/cm^3 to about 0.27 g/cm^3.

9. A functional food ingredient as set forth in claim 8, substantially as hereindescribed with reference to any one of the Examples.

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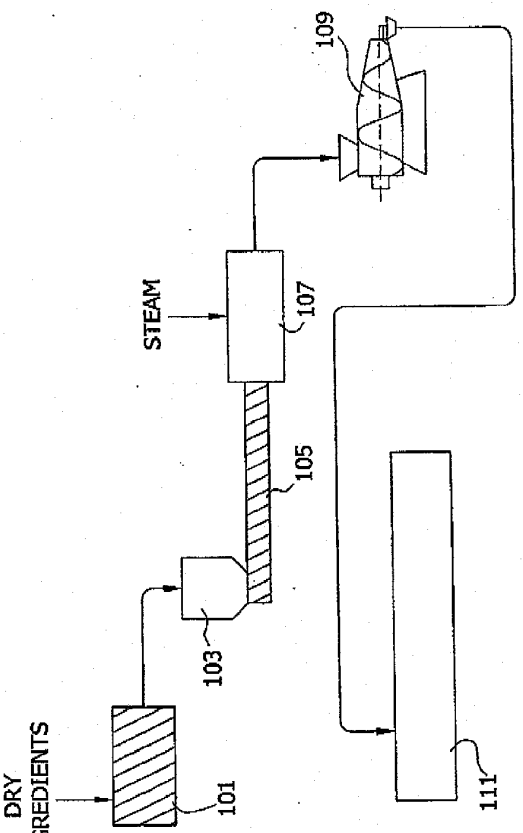


FIG. 1

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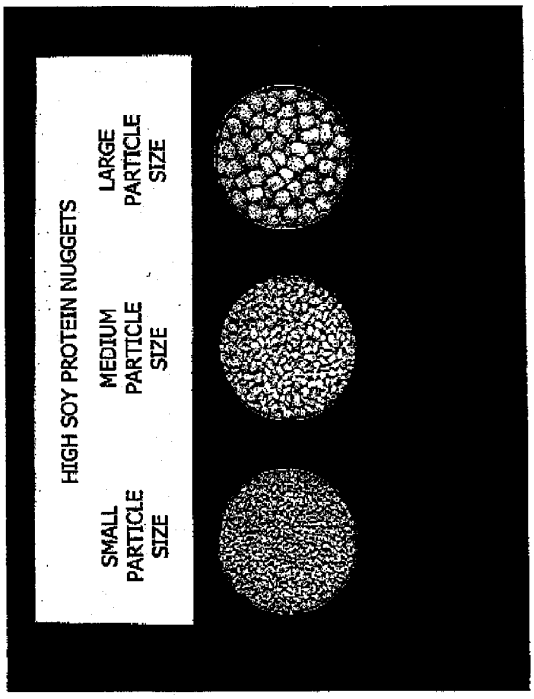


FIG. 2

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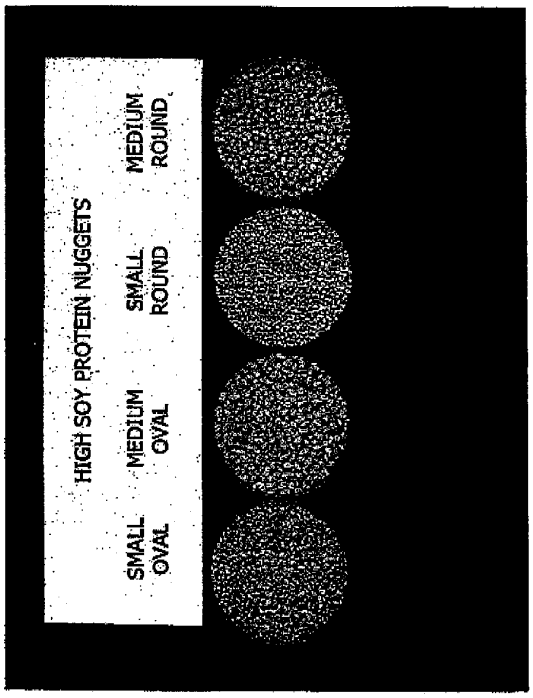


FIG. 3

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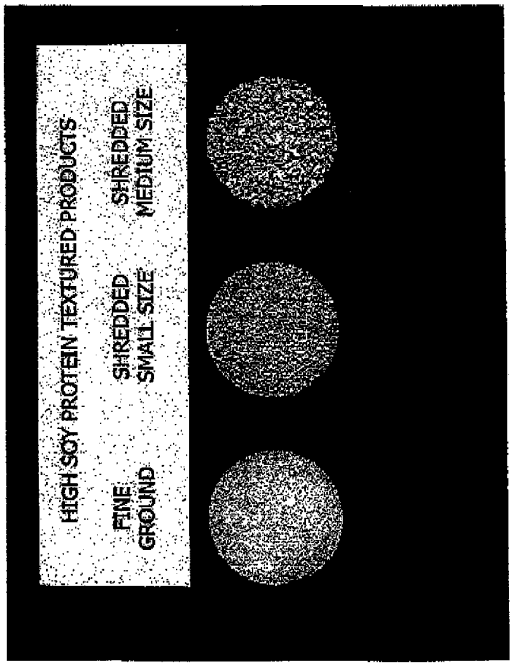
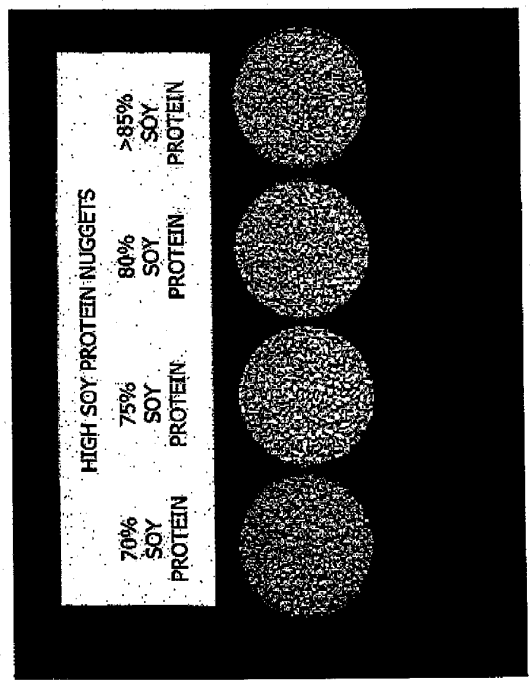


FIG. 4

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FIG. 5



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