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(54) SOYBEAN BEVERAGE BASE AND PROCESS

(71) We, UNIVERSITY OF ILLINOIS FOUNDATION, a Corporation organised and existing under the laws of the State of Illinois, United States of America, of 224, Illini Union Urbana, County of Champaign, State of Illinois, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a process for preparing a bland stable, aqueous dispersion of whole soybeans and to processes for the preparation thereof.

Soybeans have long been used as a well balanced source of nutrients for both animals and humans. In particular, soybeans are an excellent high protein low carbohydrate source. Despite these nutritional credits, the use of soybeans, especially as a beverage base, has been quite limited principally because of the undesirable bean-like or "painty" flavor and odor heretofore associated with such beverages. Prior attempts to overcome this problem have been largely unsuccessful. The undesirable flavor and odor are principally caused by an enzyme system, lipoxidase, which catalyzes the oxidation of the polyunsaturated oils and fats in the soybeans. The reaction takes place quickly whenever: (1) the bean cell structure is damaged, as when the bean cotyledons are bruised, cracked or ground, so that the enzyme and oil are permitted to contact each other, and (2) a minimum amount of water is present. As little as one part in one billion of the reaction product can be detected organoleptically and, for this reason, it is difficult and expensive to remove sufficient reaction product to impart a bland taste to the resulting beverage.

Soybean beverages, principally employed as a substitute for milk, have been prepared for hundreds of years, especially in the Orient, conventionally, by soaking soybeans in water for several hours, followed in order by grinding with water to thereby extract the pro-

tein into the aqueous phase, filtering the resulting slurry to recover the protein-rich extract and cooking the recovered filtrate. Although this process is simple and the resulting beverage is high in protein, the product has the distinct bean-like off-flavor and odor which has now become associated with soybean beverages.

It was subsequently found that various heating techniques such as boiling, steaming or infrared treatment of the beans could reduce the off-flavor of the soybean beverages. It soon was recognized, however, that although heating is necessary to reduce the undesirable bean-like flavor, it has the concomitant effect of insolubilizing or denaturing the protein, thereby substantially decreasing the protein concentration of the filtrate. Consequently, a compromise was effected wherein the heating operation was restricted, thereby retaining some of the bean-like off-flavor, in an effort to retain high protein concentration. This compromise has limited the acceptability of the resulting soybean beverages and has confined its salability to such areas as animal feeds and non-allergenic milk substitutes for babies.

High protein, low carbohydrate substitutes for milk and other dairy products have come into high demand. This has resulted in extensive research and development efforts to develop a soybean beverage which can be sold as a stable suspension which will not separate on standing, thereby giving rise to the formation of "sludge" in the beverage container. Moreover, there has been great impetus to significantly improve the palatability of the beverage with respect to taste, odor and mouth feel, i.e., a grainy or sandy feeling in the mouth and throat upon swallowing the beverage.

Recently, attempts have been made to prepare soybean beverages from whole soybeans without including an extraction step. In this manner, most of the nutritional components of the soybean are retained in the beverage, the product yield is higher and the labor costs

are reduced. These attempts have been largely unsuccessful, resulting instead, in relatively unstable suspensions and poor flavor and mouth feel. Many attempts have been made to reduce the particle size of the solids in a soybean beverage in order to improve mouthfeel and stability since it was believed that poor mouthfeel and lack of stability of the dispersion were related to the presence of large particles remaining in the beverage. In some instances, the suspension has been centrifuged to separate and remove the larger, heavier particles. In other processes, size reduction had been effected through use of hammer mills, roller mills, disc mills, disintegrators, and the like. Such size reduction apparatus has been used alone, in combination and in further combination with homogenizing and/or emulsifying apparatus. Nevertheless, permanently stable suspensions have still not been obtained. In many instances, suspending agents or suspension stabilizers are still required. Moreover, none of these techniques have provided a whole soybean product which combines the features of: (1) being essentially free of the beanlike or "painty", off-flavor normally associated with soybean beverages; (2) maintaining a permanently stable suspension; and (3) exhibiting good mouth feel.

Accordingly, the present invention provides a process for preparing a bland, stable aqueous dispersion of whole soybeans which minimizes the deficiencies of the prior art.

Thus according to the present invention there is provided a process for preparing a bland, stable aqueous dispersion of whole soybeans comprising:

- i) tenderizing intact soybean cotyledons until the soybeans exhibit a tenderometer value of between 16 and 300 pounds/100 gms. of soybeans on a whole soybean basis, which step includes heating the intact soybean cotyledons sufficiently to inactivate the lipoxidase enzyme;
- ii) forming a slurry of the soybeans and water, the said slurry preferably having a soybean concentration of less than about 20 percent by weight; and
- iii) homogenizing the slurry until a major amount of the oil in the soybean is complexed with the protein therein.

At the present time, the reasons for the clear superiority of the soybean beverages of the present invention as compared to the prior art are not completely understood; however, while not wishing to be bound by any proposed theory or mechanism, it is currently believed that the combination of tenderization of the intact soybean cotyledons and homogenization of the slurry resulting therefrom results in the formation of hydrophilic lipid-protein complexes which enable the present soybean dispersion to remain stable, with no appreciable separation, for over two months. Soybean protein is normally quite hydrophobic. This leads to protein aggregation causing precipitation of the resultant relatively heavy particles. Colloidal stability of a soybean beverage can be defined as the continued maintenance of a homogeneous liquid system, i.e., the absence of the separation, either settling or floating, of the solids within the liquid. The system is not, in fact, a true colloidal system because the particle size of the solids exceeds the range normally considered as being the colloidal size range. Thus, contrary to the prior art concern for the obtainment of small particle size as a prerequisite for good stability and mouthfeel, it is now believed that hydration of the protein renders it more hydrophilic thereby enabling prolonged suspension thereof. Tenderization of the intact soybean cotyledon in accordance with the present invention is believed to effect hydration of the molecular constituents of the soybean, e.g., the proteins, carbohydrates or combinations thereof. Thus, upon tenderization, the soybean protein becomes more amenable to subsequent phospholipid-protein complex formation during homogenization. The resulting complex is believed to comprise a protein particle enveloping a core of soybean oil with hydrophilic moieties of phospholipid molecules emanating from the protein particle, the said hydrophilic phospholipid moieties tending to create a water sheath about the protein in the aqueous dispersion, thereby imparting a hydrophilic character to the resulting complex. Moreover, because of the soybean oil core, the resulting complex exhibits less density than normal protein particles, thereby assisting in avoiding settling and maintaining the stability of the suspension.

All known varieties of soybeans can be employed in practicing the present invention. Typical varieties include Hark, Wayne, Amsoy, Corsoy or Clark.

Normally, soybeans are removed from their pods and stored "dry" at moisture contents of from about 10 to 12% and at normal ambient temperatures. Storage under conditions for a year or more will not result in deterioration of the beans.

Preferably, for the purposes of this invention, dry soybeans are air-cleaned by conventional means, inspected and off-colored and defective beans as well as foreign matter such as stones removed.

The initial step in the process of the present invention is tenderization of the intact bean cotyledons. It is considered important that tenderization be effected with intact soybean cotyledons. The term "intact soybean cotyledon" as used herein is intended to encompass whole soybeans whether with or without hulls. It is considered critical, however, that the cotyledons be retained intact, i.e., retain their structural integrity, during at least a portion of the tenderization process wherein the lipoxidase is inactivated.

Tenderization can be effected in accordance

with the present invention by exposing the intact cotyledons, i.e., the whole soybean whether with the hulls intact or during or after dehulling, to a combination of moisture and heat, either simultaneously or sequentially, until a tenderometer value in the range of from 16 to 300 pounds per 100 grams soybeans on a whole bean basis is obtained. Exposure to heat at some point in the tenderization process is necessary to prevent the bean-like or painty flavor in the resulting beverage.

The desired degree of tenderization as measured by tenderometer value can be obtained in several different ways. For example, the soybeans can be thoroughly soaked in tap water, softened water, or most preferably in a slightly alkaline, aqueous solution (7.5—8.5 pH) for several hours or until the beans are saturated with the solution. A practical ratio of solution to beans is about one gallon to 3 or 4 pounds of beans. While the aqueous solution can be made alkaline in any conventional manner such as by adding a base thereto such as NaOH, KOH, Na_3PO_4 or Na_2CO_3 , it is considered preferable to add NaHCO_3 at 0.5% concentration, thereby obtaining a solution pH of above 7.8. The soaking is preferably carried out at room temperature for a period of 4 to 10 hours; although, the soaking period can be shortened by soaking at elevated temperatures of from above room temperature (77° F.) to about 212° F.

Although not considered necessary, the use of an alkaline solution as the soak medium is considered preferable since it has been found to impart a degree of flexibility to the process of the present invention. It has been found that when an alkaline soak medium and most preferably, a sodium bicarbonate (NaHCO_3) solution is employed, it has the effect of enhancing the tenderization process thereby reducing the time and/or temperature requirements for effecting tenderization.

If the beans are soaked as described above, then the solution can be drained off from the soaked beans, and a fresh neutral to slightly alkaline solution, preferably 0.5% NaHCO_3 , added to cover the beans (about 1 gallon to 3 pounds of beans). The soybeans either soaked or unsoaked as aforesaid, can then be blanched at or near the boiling temperature of the solution for a period of time sufficient to inactivate the lipoxidase in the bean. Typically, this requires a minimum of about 5 minutes and generally 20—40 minutes depending upon such variables as bean variety and storage conditions. The blanching also kills the anti-trypsin factor present in soybeans, thereby improving the nutritional value of the product as well as giving it a completely bland taste as a result of inactivating the lipoxidase present. In the present process, blanching can also be effected by direct treat-

ment with steam or other heat source in which instances, the duration of treatment will vary with the ability of such treatments to effect the desired degree of tenderization. As indicated, blanching alone, without prior soaking, can be employed to effect tenderization of the beans. If soaking is employed, however, a subsequent heat treatment is necessary to inactivate the lipoxidase and trypsin inhibitor.

Other means for exposing the beans to the combined effects of moisture and heat can similarly be employed. For example, pressure cooking can be employed with or without prior soaking of the beans.

Regardless of the method of tenderization employed, the proper degree of tenderization can be easily determined through use of a L.E.E.-Kramer Shear Press equipped with an electronic recording attachment (Laboratory of Electronic Engineering, Washington, D.C.). 100 grams (wet weight) of tenderized beans are placed in the standard test cell (cell #C274) for each determination. The piston stroke is adjusted to take 14.5 seconds employing a 300 lb. test ring. Results are expressed as maximum shear force in lbs. per 100 grams of wet weight of soybeans. Employing this procedure, it has been found that in order to obtain the superior soybean beverage of the present invention, tenderization of the soybeans must first be effected to a tenderometer value in the range of from 16 to 300 pounds per 100 grams (wet weight) soybeans. The lower limit is specified as 16 pounds 100 grams only because this is the minimum reliable value that can be read on the L.E.E.-Kramer Shear Press with the test cell employed. Tenderization to this value gives a satisfactory product. Some additional tenderization beyond this point may also give a satisfactory product. However, it has found that the tenderization step can be overdone; although over-tenderization does not affect stability, it does have a detrimental effect on mouth feel. Overtenderization can occur, for example, if blanching is conducted for an excessive period of time such as about 70 minutes or if several tenderization procedures are combined such as water soaking and pressure cooking. If the beans are insufficiently tenderized, i.e. having a tenderometer value of more than 300 pounds per 100 grams, the resulting beverage will be unsatisfactory in either colloidal stability or mouth feel or in both. While combinations of procedures can be employed in the present invention, the degree of tenderization should be periodically determined to ascertain the proper duration of treatment.

Heating, as part of the tenderization process, must be conducted on the intact cotyledons in order to inactivate the lipoxidase and prevent the bean-like or painty flavor in the final product. Thus, for example, if the beans

are simultaneously ground (thereby destroying the structural integrity of the cotyledons) and heated, the resulting beverage exhibits poor flavor. The some poor result is obtained if the beans are first ground and then heated. Heating just sufficiently to inactivate the lipoxidase will result in a beverage with unacceptable stability and mouth feel. The heating of whole soybeans must be continued at least until the maximum acceptable tenderometer reading of 300 pounds is attained. However, this tenderization after lipoxidase inactivation need not be done on the intact cotyledons; the soybeans may be dehulled and the cotyledons may be subdivided to varying degrees for further tenderization. Such subdivided soybeans at the same degree of tenderness will give a lower tenderometer reading by virtue of the mechanics of the test cell. Thus, a new specification giving equivalent tenderness must be developed for each degree of subdivision.

After tenderization, it is preferred to drain off the blanching solution and wash the whole beans with water. At this point, it is convenient to dehull the beans if a less creamy product with lower fiber content is desired. The hulls can be removed earlier while the beans are still dry, but a satisfactory product is obtained if the hulls are not removed at all. It has been found that by dehulling, the resultant product does have a lower fiber content and viscosity. Thus, one factor in determining whether or not to dehull is the desired final viscosity and fiber content.

An aqueous slurry of the tenderized beans is made by wet milling or grinding. The moisture content is adjusted at this stage. A slurry concentration of from about 10 to 15% by weight of soybean solids is preferred. Suitably, milling can be effected with any conventional mill such as, for example, a hammer mill (Fitzmill—Registered Trade Mark), roller mill, disc mill or Rietz disintegrator which will readily break up the beans to form a slurry. One or more wet milling steps can be utilized. Other conventional milling procedures and apparatus can be employed and give comparable results. Milling is not considered critical to the present invention. The purpose of milling is to reduce the particle size of the beans so as not to clog or damage the valves of the subsequently employed homogenizer. Thus, depending upon the capacity or capability of the homogenizer employed, milling may be dispensed with altogether. However, for most efficient operation, it is considered preferable to reduce the particle size of the beans to less than about 0.25 inch and most preferably, the particles are milled to a size at least as fine as a Fitzmill No. 1 screen to give an easy-to-handle slurry. During the milling operation, water is added to the soybeans to form a slurry having a solids concentration of less

than about 20% and preferably, about 10 to 15%. The slurry concentration is not considered critical and is dependent upon the viscosity which can be conveniently handled by the homogenizer. Generally, a concentration of less than about 20% is employed, most preferably however, the slurry concentration is less than about 12%. As the slurry concentration decreases, the temperature and pressure requirements within the homogenizer become commensurately less severe to effect the same degree of homogenization.

The resulting slurry is therefore subjected to homogenization under pressure. It has been found in accordance with the present invention that the minimum degree of homogenization required to obtain the superior soybean beverage products of the present invention is inversely related to the degree of tenderization of the soybeans, i.e., as the soybeans become more tenderized, the homogenization conditions, e.g., pressure, temperature, and the number of passes or stages through the homogenizer can be reduced or become less severe. In general, homogenization of the soybean slurry can be effected at pressures ranging from 1000 to 10,000 psi with the slurry temperature ranging from 32° F. to the boiling point of the slurry at the pressure maintained within the homogenizer. Conditions of temperature and pressure within the homogenizer must be maintained so that the slurry is maintained essentially in the liquid state at all times; otherwise, processing difficulties will be encountered within the homogenizer. It has been observed that slurry temperature and homogenizing pressure vary inversely, i.e. to effect a given degree of homogenization at low slurry temperatures, higher pressures should be employed and conversely, lower pressures within the range set forth should be employed at higher slurry temperatures. As indicated hereinabove, the severity of the homogenization conditions can be further lessened if the slurry concentration is decreased. Also, the degree of homogenization will depend upon the number of passes through the homogenizer or passage through a number of stages in a given homogenizer.

As described hereinabove, the soybeans are tenderized to a degree such that they exhibit a tenderometer value ranging from 16 to 300 pounds per 100 grams soybeans and preferably, exhibit a tenderometer value of from 16 to less than 185. It has now been found that depending upon the degree of tenderization of the soybeans, commensurately more or less stringent homogenization conditions will be required to obtain a superior product. Thus, for example, if soybeans are tenderized in accordance with the present invention to a tenderometer value of 165 pounds per 100 grams of soybeans, a superior soybean beverage is obtained by homogenization of a 12% slurry of such beans at a slurry

temperature of 180° F. upon passing the slurry through the homogenizer twice at 3500 psi. In comparison, beans tenderized to a tenderometer value of only 250 require, for obtainment of a superior product, more stringent homogenization at a slurry temperature of about 210° F. by passing twice through the homogenizer at a pressure of about 5000 psi. Homogenization of this latter slurry under the conditions employed for the former-described slurry, will result in a beverage of only borderline acceptability. Thus, it has been found that beans tenderized to a tenderometer value ranging from 16 to less than 185 can be homogenized under relatively mild conditions to provide a superior beverage. Generally, assuming a slurry concentration of 10%—15%, homogenization can be effected in at least one and preferably two passes (or stages) through the homogenizer at pressures ranging from 1000 to less than about 6000 psi with slurry temperatures ranging from 32° F. to the boiling point of the slurry at the system pressure. Preferably, such slurries are homogenized at about 180° F. by passing the slurry twice through the homogenizer at about 3500 psi. When, however, the beans are tenderized to a tenderometer value ranging from 185 to 300, it has been found that successful homogenization can be effected by passing the slurry, at temperatures ranging from 180° F. to the boiling point of the slurry under the system pressure, through the homogenizer at least once and preferably twice, at pressures ranging from greater than from 6000 to 10,000 psi. If the pressure is sufficiently high during the first pass, i.e., about 8,000 to 10,000 psi, the pressure in the second pass can be lower, e.g. about 3500 to 6,000 psi., if desired. Of course, as indicated above, required homogenizer conditions will become more severe, i.e. higher pressures and/or temperatures, as the slurry concentration is increased up to about 20%.

If alkaline solutions are employed at any point in the process, it is considered preferably although not necessary that the final product be neutralized by addition of an acid such as hydrochloric acid prior to the last homogenization.

A wide variety of additives can be added to the beverage of the present invention most conveniently just before the last homogenization. Thus, for example, flavorings, sugar or salt can be added, as desired. The beverages of the present invention, as distinguished from the prior art, do not require stabilizers or emulsifiers to maintain stability of the dispersion upon storage. Moreover, the beverage of the present invention remains stable and does not separate regardless of its ultimate dilution or viscosity and regardless of whether it is prepared with or without inclusion of the soybean hulls. In addition, the product of the present invention can utilize the whole

bean including the hulls. In contradistinction to many prior art processes, there is no need in the present invention to remove any of the bean constituents in order to obtain a stable product.

If the slurry has been heated sufficiently before homogenization, there is generally no need to pasteurize the soybean beverage separately. If, however, lower homogenization temperatures are employed, the resulting beverage must be pasteurized to at least partially sterilize the beverage. The pasteurized beverage can then be bottled, spray-dried or freeze-dried. The pasteurized beverages will remain stable until residual microbial action generates sufficient acid to gel and thus spoil the product. Alternatively, the beverage can be sterilized and canned, or condensed, sterilized and canned. The sterile, canned product has remained stable for over two years.

The homogenized whole bean slurry, the basic product of the present invention, is rich-tasting although relatively low in fat content which, advantageously, is liquid (unsaturated) soybean oil and contains no cholesterol. There is no objectionable mouth or throat feel; and of course, since the lipoxidase has been inactivated, there is no discernible beanlike or painty flavor. The beverage base is a non-settling, non-creaming dispersion which is less susceptible to microbiological deterioration than whole cow's milk. Refrigeration at 45° F. or lower will prevent spoilage at room temperature or the product can be preserved by canning or dehydration.

The stable, bland soybean dispersion obtained in accordance with the present invention can be employed as a palatable, nutritious beverage base for a wide variety of products such as soy milk, flavored soy milk, frozen soy milk desserts, soy milk shakes, flavored spreads or dips, yogurt, diet margarine, soybean butter, custard or oriental tofu.

In the preparation of shakes from the beverage base of the present invention, it is considered preferable to lower the viscosity of the dispersion thereby enhancing its whipping characteristics. In order to lower the viscosity of the final product, it has been found that the addition of from 100 to 400 parts per million of SO_2 , Na_2SO_3 , or NaHSO_3 to the slurry prior to homogenization greatly lowers the viscosity of the final product by preventing the occurrence of cross-linking. It is considered preferable to add the SO_2 , Na_2SO_3 , or NaHSO_3 while maintaining the slurry under alkaline conditions. Surprisingly, the beverage base of the present invention maintains its stability regardless of variations in viscosity and exhibits satisfactory stability even at quite low viscosities. In contradistinction, many prior art processes employ suspending aids and stabilizers which effect an increase in viscosity in order to attain acceptable stability.

In addition, it has been found that the soybean dispersion of the present invention can be used as a coffee whitener or "cream" that does not "feather" or coagulate and separate when mixed into hot coffee. This has been accomplished by adding a food grade phosphate compound to the soybean beverage base. Both sodium hexameta phosphate and tripoly sodium phosphate were tried and are satisfactory. Additionally, either the potassium salts or a dry powder containing phosphate will serve as a satisfactory additive for the coffee whitener. The concentration of phosphate needed depends upon the strength or concentration of the coffee. It has been found that a phosphate additive in a proportion of about 0.5% is sufficient even for strong coffee. Moreover, it has been found that the addition of a food grade phosphate to the beverage base imparts freeze-thaw stability thereto thereby enabling the preparation of a coffee whitener than can be frozen and that will not separate or coagulate upon thawing. Still further, by inclusion of a small amount of fat, i.e., generally about 8 to 12% by weight in the coffee whitener, a coffee whitener with excellent whiteing power is obtained.

It has also been found that the acid whey from cottage cheese, which normally exhibits an undesirable odor and flavor and which is usually disposed of as a waste by-product, provides an excellent source of milk sugar and protein for the beverage base of the present invention. Surprisingly, the inclusion of the cottage cheese whey imparts excellent flavor to the resulting product.

The following examples further define, describe and compare methods for preparing the soybean beverage base of the present invention and of utilizing said base to prepare a wide variety of useful food products. Parts and percentages are by weight unless otherwise indicated.

EXAMPLE 1.

Wayne variety bin-run soybeans were passed through a Key cleaner which used size separation and air aspiration to remove foreign material. The cleaned beans were soaked in a solution of 0.5% sodium bicarbonate in tap water at room temperature for about 10 hours; the ratio was one gallon solution for each 4 lb. beans. This solution was drained and discarded. The soaked beans were transferred to a steam jacketed kettle containing fresh, boiling 0.5% sodium bicarbonate solution in a ratio of 2 gallons to 10 lb. soaked beans and boiling continued for 30 minutes. The blanching solution was drained and discarded. The blanched beans exhibited a tenderometer value of below 180. The blanched beans were passed through a Bauer burr mill with the plate to plate distance adjusted to break the beans into 2 or 3

pieces. This loosened the hulls so they could be floated off by flushing with room temperature tap water. Sufficient tap water was added to the dehulled soybean pieces to make 12% total solids. The suspension was then passed through a hammer mill (Fitzmill) using a No. 4 screen (0.25 inch openings). The resulting slurry was again passed through the same hammer mill but this time using the No. 1 screen (0.028 inch openings). The second slurry was placed in a steam jacketed kettle and heated to 200° F. The hot slurry was passed through a single piston, single stage, Manton-Gaulin lab homogenizer using 3500 psi. pressure. The finished product, a soybean beverage base, was poured into a covered can which was placed in a room kept at 34° F. for cooling and storage.

EXAMPLE 2.

A soy beverage base was prepared as in Example 1 except that the blanched beans were not dehulled. The whole blanched beans exhibited a tenderometer value below 180.

EXAMPLE 3.

Twelve pounds of base at 12% total solids prepared as in Example 1 were mixed with 4 pounds of water and neutralized to pH 7.1 with 6 N HCl solution. 1.45 grams of vanillin, 14.5 grams of salt and 363 grams of sugar were added to the diluted base which was then heated to 180° F. in a steam jacketed kettle. This was removed from the kettle and a small amount, 0.5 ml, diacetyl flavor was added just before it was passed through the same homogenizer again at 3500 psi. The beverage was bottled in capped prescription bottles which were placed in the 34° F. room for cooling and storage. The bottles were labeled "100% Soy Beverage". After one day the product was cool so it could be evaluated. It was completely lacking in bean-like or painty flavor and the taste and mouth feel were judged highly desirable; some people said it reminded them of a milk shake. The total plate count was under 20 bacteria per gram. After one month storage at 34° F., there was no noticeable settling or separation, the flavor was still acceptable and the total plate count was 350 per gram. After about 2 months storage the total plate count had exceeded one million, but no significant pathogenic bacteria were found.

EXAMPLE 4.

Twelve pounds of base prepared exactly as in Example 2 were treated exactly as in Example 3. The resulting beverage containing the hulls was considered equal in quality to that described in Example 3 except it was creamier in texture.

EXAMPLE 5.

Eight pounds of the base prepared in Example 1 were mixed with 8 pounds of fresh cottage cheese whey containing about 7% total solids and the mixture was adjusted to pH 7.1 with 20% NaOH solution. This liquid was then treated in exactly the same manner as was the diluted and neutralized base in Example 3, except that the salt content was reduced to half, 7.25 grams. The bottles were labeled "Soy-Whey Beverage". This product had a thinner mouth feel than the 100% Soy Beverage of Example 3 and thus was more desirable to some people. The flavor was highly desirable. After one month at 34° F. the product had not settled and the taste was still acceptable. After four months at 34° F., the product was still acceptable and the total plate count was only 30 per gram.

EXAMPLE 6.

Eight pounds of soy beverage base from Example 1 were mixed with 8 lbs. fresh cottage cheese whey and the pH adjusted to 7.1 with 20% NaOH. 109 grams sugar and 109 grams 42 D.E. corn syrup were added and the mixture was heated to 180° F. in a steam jacketed kettle. Two ml. of imitation milk flavor were added to the hot liquid just before homogenizing at 3500 psi. The product was bottled, labeled "Milk Substitute" and placed in 34° F. storage. The taste was less sweet than the Soy-Whey Beverage of Example 5 and the flavor was highly desirable. After one month at 34° F. the product had not settled and the taste was still acceptable.

EXAMPLE 7.

This product was prepared exactly as in Example 3 except that one additional ingredient was added—73 grams of a low-fat cocoa. The initial flavor of this chocolate soy beverage was highly desirable and after one month at 34° F. it was still acceptable. Although it showed some settling of cocoa solids within a few days, they could be resuspended with shaking.

EXAMPLE 8.

Soy base was prepared as in Example 1 except that less water was added; sufficient water was added to the dehulled soybean pieces to make 14.7% instead of 12% total solids. Fresh cottage cheese whey was concentrated from 7% to 14% total solids in a vacuum pan. Four lbs. base, 1.33 pounds whey, 11.74 grams stabilizer (National Pectin Co., No. 333), 293 grams sugar, 139 grams corn syrup, 2.9 grams salt, 0.59 grams of vanillin and 66 grams of coconut oil were mixed and the pH was adjusted to 7.1 with 20% NaOH solution. The solution was heated to 180° F. and homogenized twice at

3500 psi. After cooling to about 70° F., a Taylor shake freezer was used to further cool to 27—28° F. and whip in air. This product imitated a soft serve ice cream and was judged to be highly desirable in flavor, texture and body.

EXAMPLE 9.

A soy beverage base was prepared exactly as in Example 2. Four lbs. of this base, 3.1 grams sodium benzoate, 2 ml. diacetyl flavor, 60 grams salt and 4.35 grams carboxymethylcellulose were mixed together. 1209 grams soybean oil were treated with 80 grams mono- and diglycerides, 4.5 grams lecithin, and 0.8 ml. beta-carotene. The treated oil was heated to melt all ingredients and thoroughly mixed. The two liquids were mixed with a beater, the pH was adjusted to 5.5 with 6 N HCl, and the mixture was solidified in a home-type ice cream freezer. The finished product was an imitation diet margarine. It was evaluated as a cracker spread by many people and uniformly judged excellent in both flavor and texture.

EXAMPLE 10.

A 14.7% total solids soy beverage base was prepared as in Example 8. 3700 grams of this base, 4500 grams fresh cottage cheese whey, 1950 grams water, 1020 grams sugar, 240 grams stabilizer (Sure-Shake, National Pectin Prod. Co.), 4.8 grams vanilla extract (R. W. Snyder Co.), 1.92 grams salt, 300 grams coconut oil, 193 grams protein isolate (D 100 WA, Gunther Prod. Co.), 1.2 grams sodium sulfite, and 1.2 grams dibasic potassium phosphate were mixed and the pH adjusted to 7.1 with 20% sodium hydroxide solution. This was heated to 180° F. in a steam jacketed kettle and homogenized at 3500 psi. After cooling to 70° F. the liquid was passed through a Taylor shake freezer to further cool to 27—28° F. and whip in air. The product drawn from the freezer was added to a sweet vanilla flavored syrup in a ratio of 9 oz. to 1 oz. and whipped with a Hamilton-Beach fountain mixer. The product was an imitation vanilla milk shake. The first overrun was 29% and the second overrun was 38%. The product was judged to have good texture and a flavor.

EXAMPLE 11.

Employing the procedure described in Example 1, 0.5% hexametaphosphate was added to the hot slurry before homogenization. The homogenized beverage base exhibited excellent freeze-thaw stability.

EXAMPLE 12.

Twelve pounds of base at 12% total solids prepared as in Example 1 was diluted to 9% total solids. Coconut fat (1.2 lbs.) was added to the base. The resulting mixture was

neutralized by addition of HCl, heated to 180° F., homogenized at 3500 psi and then bottled. The resulting product served as a highly desirable coffee whitener with excellent whitening power. The coffee whitener did not feather, coagulate or separate when mixed into hot coffee.

EXAMPLE 13.

The procedure described in Example 12 was repeated except that 0.5% hexameta-phosphate was additionally added to the base along with the coconut fat. The resulting coffee whitener exhibited excellent freeze-thaw stability.

EXAMPLE 14.

One pound beverage base at 9% solids prepared as in Example 4 was heated to 180° F. and $\frac{1}{4}$ % CaSO_4 was added as a water slurry. The resulting mixture formed a curd upon cooling within one hour. When this curd was cut and pressed as in cheese making, water is expressed from the curd thereby increasing the soy protein concentration. The resulting concentrated product is known in the Orient as tofu.

EXAMPLE 15.

One pound beverage base at 9% solids prepared as in Example 4 and at room temperature or below was mixed with a 0.25% of glucono delta lactone in a water slurry. The resulting mixture is heated in a water bath between 180° F. to 212° F. until coagulation occurs. The resulting product is a highly palatable soybean curd. Water was expressed from the curd to form tofu as described in Example 14.

The following examples illustrate the need for the combination of the requisite tenderization and homogenization effected by the process of the present invention. Unless, or to the extent, otherwise specified, the standard procedure used in the following examples was as follows:

Six pounds of Wayne variety of soybeans were soaked overnight in 0.5% NaHCO_3 solution and then blanched in fresh 0.5% NaHCO_3 solution for 30 minutes. The drained beans were milled with cold water to obtain a 12% bean slurry. The slurry was then heated to 180° F. and homogenized at 3500 psi. Thereafter the base was neutralized and again heated to 180° F. and given a second homogenization at 3500 psi.

Example 16.

Three samples were treated in the following manner:

A. Raw beans, without prior soaking, were blanched for 30 minutes in tap water at 212° F. Thereafter, the standard procedure was followed.

B. Raw beans, without prior soaking, were blanched for 30 minutes in a 0.5% NaHCO_3 solution at 212° F. Thereafter, the standard procedure was followed.

C. Sample B was repeated except that the standard procedure was modified by homogenizing the slurry twice at a temperature of 210° C. and a pressure of about 4500 psi.

The tenderometer values, homogenization conditions and evaluation of the resulting beverages are summarized in Table 1 below:

TABLE 1

Sample	Tenderometer Value (#/100 gm beans)	Homogenization Conditions			Beverage Evaluation
		Temp (°F)	Pressure (psi)	No. of Passes	
A	310	180	3500	2	poor mouthfeel, separated on standing
B	185	180	3500	2	borderline mouthfeel and stability
C	185	210	4500	2	excellent mouthfeel and stability

EXAMPLE 17.

Soybeans were soaked overnight in water and then, without prior cooking, simultaneously ground in 10 times its weight of boiling water. The resulting slurry was then treated in accordance with the standard procedure described above. The resulting beverage exhibited unacceptable mouthfeel in four hours and separation in three days. The product exhibited an unacceptable bean-like or painty flavor. This example illustrates that simultaneous grinding and heating is ineffective in inactivating the lipoxidase enzyme and

preventing the bean-like or painty flavor in the final product. Additionally, this example demonstrates the need to effect tenderization and inactivation of the lipoxidase enzyme by treatment of the soybean cotyledons.

EXAMPLE 18.

In this example, soybeans were soaked overnight in 0.5% NaHCO_3 solution and blanched for various periods of time in 0.5% NaHCO_3 solution at 212° F. Thereafter the standard procedure was employed except to the extent noted in Table 2 below which summarizes the results obtained.

TABLE 2

Sample	Duration of Blanch (min.)	Tenderometer Value (#/100 gms)	Homogenization Conditions		
			Temp (°F)	Pressure (psi)	No. of Passes
A	5	250	180	3500	2
B	5	250	210	8000 (1st pass) 3500 (2nd pass)	2
C	20	165	180	3500	2

Sample A exhibited borderline colloidal stability and mouthfeel.

Sample B exhibited excellent colloidal stability and highly acceptable mouthfeel.

Sample C exhibited excellent colloidal stability and highly acceptable mouthfeel.

EXAMPLE 19.

This example illustrates the effects of both over-tenderization and under-tenderization on the resulting soybean beverage.

There is an apparent limit on tenderization beyond which the beans become over-tenderized and a satisfactory beverage cannot be produced. It is difficult to precisely define the minimum acceptable tenderometer value since the lowest tenderometer value which can be recorded on a L.E.E.-Kramer shear press is about 16 pounds/100 grams soybeans. It has been found that beans tenderized to a tenderometer value of 16 pounds provide an entirely satisfactory beverage when further treated in accordance with the present invention. It has also been found that soybeans can be tenderized by prolonged blanching or pressure cooking to a tenderometer value which should obviously be below 16 but can-

not be given a precise numerical value except <16. These latter beans which are believed to be over-tenderized have consistently been found to result in an unsatisfactory beverage. In addition to the fact that processes which effect over-tenderization are generally not economically attractive, it has also been found that the resulting beans are often discolored and the resulting beverage is characterized by poor stability, mouthfeel and especially, poor flavor. It is believed that over-tenderization in some way adversely affects the protein structure thereby giving rise to these undesirable characteristics in the resulting product.

The following samples were prepared and illustrate the above.

A. Unsoaked soybeans were blanched for 30 minutes in boiling tap water resulting in a tenderometer value of 310 pounds per 100 grams. The tenderized beans were then treated in accordance with the standard procedure described above. The resulting beverage separated upon standing and had unacceptable mouthfeel.

B. Soybeans were water soaked overnight and then pressure cooked at 250° F. for 60

30

35

40

45

50

55

minutes to give a tenderometer value of <16 pounds per 100 grams. The tenderized beans were then treated in accordance with the standard procedure described above. The resulting beverages exhibited good colloidal stability (did not separate on standing) and acceptable mouthfeel.

EXAMPLE 20.

This example evidences the formation of an aqueous phospholipid-protein complex dispersion through the process of the present invention.

Hexane extraction is the industrial method for extracting oil from soybeans; of the original about 20% soybean oil, all but about 1% is extractable with hexane.

Enzyme inactivation and subsequent drum drying (heating) of whole soybeans does not result in complexing as is obtained in the present invention: drum dried flakes made from enzyme inactive Hark soybeans showed 17.3% fat by Soxhlet extraction with hexane.

A milk shake prepared from the beverage base of the present invention showed zero fat by the same extraction analytical procedure. To a homogenized 12% base obtained in accordance with Example 1 was added water, sugar flavor, stabilizer (gum) and coconut oil to equal 3% of the finished product. The mix was then heated and homogenized a second time. A sample was freeze dried and the resulting powder was placed in a Soxhlet extraction apparatus with the same solvent as above. No fat was recovered from the solvent showing that the protein complexed not only the native soybean oil but with the added coconut oil as well.

It is known that hexane, a non-polar solvent, dissolves only non-polar compounds, i.e., when fat is complexed with protein it becomes polar. One method of determining complexed fat is to digest the mixture with concentrated sulfuric acid. This solubilizes the protein and frees the fat which then rises as a layer of fat on water where it is measured.

This so-called "Babcock" test developed for the dairy industry was applied to the soy beverage of the present invention containing, in this sample, 3.1% protein. Taking the usual ratio of 2 parts protein to 1 part fat in soybeans, the expected fat concentration was 1.65%. The test showed 1.70% fat, indicating complete recovery within experimental error.

Since the beverage must be digested with sulfuric acid to "free" the fat which is not soluble in hexane, this is positive evidence of complex formation.

Although this example illustrates that all of the soybean oil is complexed with the soybean protein, it is currently believed that an acceptable product can be obtained with a major amount i.e. greater than 50% of

the soybean oil complexed while a minor amount of the soybean oil, preferably less than about 10—15% remains uncomplexed.

Although specific materials and conditions were set forth in the above exemplary processes for making the soybean beverage base of the present invention and using said base to form other food products, these are merely intended as illustrations of the present invention. Various other tenderization techniques, lipoxidase inactivation techniques, milling methods, homogenization techniques, additives, derivative food products and operating conditions such as those described hereinabove may be substituted in the examples with similar results.

Other modifications of the present invention will occur to those skilled in the art upon a reading of the present disclosure. These are intended to be included within the scope of this invention. Thus, for example, the process of the present invention can be conducted by soaking soybeans overnight, then heating the beans for a period sufficient to inactivate the lipoxidase but insufficient to fully tenderize the beans into the desired tenderometer range. The lipoxidase-inactivated, partially tenderized beans can then undergo partial size reduction to increase the effective bean surface area thereby increasing the rate of further tenderization. Thereafter, further tenderization can be effected into the desired range followed by further milling and homogenization to obtain a desirable beverage. In such instances, the tenderometer values obtained with the beans which have undergone partial size reduction will generally be lower than the tenderometer values obtained on similarly treated whole beans since the smaller particles will pass through the tenderometer faster. The tenderometer values will, however, be equivalent on a whole bean basis.

As used herein, the phrase "tenderometer value on an equivalent whole bean basis" is intended to denote a tenderometer value of a whole bean including the hull. In the present invention, it is important that tenderization be affected on intact soybean cotyledons. The process is operative whether the beans have been dehulled or not. When employing dehulled cotyledons or pieces of dehulled cotyledons, it is necessary to use a different cell in the L.E.E.-Kramer Shear Press, one with smaller openings such that the cotyledons will not fall through. In order to obtain a tenderometer value which would be equivalent to a similarly tenderized bean before dehulling, it is necessary to determine (with the smaller cell) tenderness of the tenderized bean both before and after dehulling. By taking bean samples at several degrees of tenderness, a calibration curve can be plotted which would provide the necessary conversion factor from tenderometer values of

cotyledons or pieces to whole (with hulls) beans.

WHAT WE CLAIM IS:—

1. A stable, bland aqueous dispersion of phospholipid-soybean protein complex in which a major amount of the phospholipids in the dispersion is unextractable by hexane extraction.

2. An aqueous dispersion as claimed in claim 1 wherein substantially all of the phospholipids in the dispersion are unextractable by hexane extraction.

3. An aqueous dispersion as claimed in claim 1 substantially as hereinbefore described.

4. An aqueous dispersion as claimed in claim 1 substantially as hereinbefore described in any one of the Examples.

5. A process for preparing an aqueous dispersion as claimed in claim 1 comprising:

i) tenderizing intact soybean cotyledons until the soybeans exhibit a degree of tenderization as measured by equivalent tenderometer values, on a whole bean basis, of between 16 and 300 pounds per 100 grams soybeans (wet basis), which step also includes heating of the intact soybean cotyledons sufficiently to inactivate the lipoxidase enzyme therein;

ii) forming an aqueous slurry of the soybean solids; and

iii) homogenizing the slurry until a major amount of the oil in the soybeans is complexed with the protein therein.

6. A process as claimed in claim 5 wherein the slurry is homogenized until substantially all of the oil is complexed.

7. A process for preparing an aqueous dispersion as claimed in claim 1 comprising:

i) tenderizing intact soybean cotyledons until the soybeans exhibit a tenderometer value of between 16 and 300 pounds/100 gms of soybeans, which step includes simultaneous or sequential heating of the intact soybean cotyledons sufficiently to inactivate the lipoxidase enzyme;

ii) forming a slurry of the soybeans and water, the said slurry having a soybean concentration of less than 20 percent by weight;

iii) homogenizing the slurry in at least one pass through a homogenization zone at a pressure between 1,000 and 10,000 psi. at a temperature between 32° F. and the boiling point of the slurry at the pressure within the homogenizing zone; and,

iv) recovering a bland, stable aqueous dispersion of whole soybeans.

8. A process as claimed in any one of claims 5 to 7 wherein the soybeans are dehulled before, during or after tenderization.

9. A process as claimed in any one of claims 5 to 7 wherein tenderization is effected on whole hull-containing soybeans.

10. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by exposing intact soybean cotyledons either

simultaneously or sequentially to a combination of moisture and heat until an equivalent tenderometer value in the range of from 16 to 300 pounds per 100 grams soybeans on a whole bean basis is obtained.

11. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by (a) soaking the soybeans in water until the beans are saturated therewith and then (b) blanching the soybeans for a period of time sufficient to inactivate the lipoxidase enzyme.

12. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by blanching previously unsoaked soybeans.

13. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by pressure cooking the soybeans.

14. A process as claimed in any one of claims 5 to 13 wherein homogenization is effected such that the minimum degree of homogenization is inversely related to the degree of tenderization effected.

15. A process for preparing an aqueous dispersion as claimed in claim 1 comprising:

i) tenderizing intact soybeans cotyledons by (a) soaking the soybeans in an aqueous NaHCO₃ solution and then (b) blanching the soaked soybeans in an aqueous NaHCO₃ solution, the combined effect of the said soaking and blanching being such that the soybeans exhibit a tenderometer value of from 16 to less than 185 pounds per 100 grams soybeans and that the lipoxidase enzyme therein is inactivated;

ii) wet milling the beans to obtain an aqueous slurry of the soybeans having a solids content of about 12% by weight; and

iii) passing the slurry twice through a homogenization zone at a temperature of about 180° F. and a pressure of about 3500 psi.

16. A process as claimed in claim 15 wherein the pH of the aqueous NaHCO₃ solution is between 7.5 and 8.5.

17. A process as claimed in claim 5 substantially as hereinbefore described in any one of the Examples.

18. A process as claimed in claim 5 substantially as described herein.

19. A modification of a process as claimed in claim 5 or claim 6 in which step (i) comprises heating of the intact soybean cotyledons sufficiently to inactivate the lipoxidase enzyme therein, reducing the size of the soybeans in order to increase their surface area, and thereafter tenderizing the treated soybeans until they exhibit the degree of tenderization recited in claim 5.

20. A soybean dispersion that has been prepared by a process as claimed in any one of claims 5 to 19.

21. A beverage, milk substitute, ice cream, margarine or tofu when made from a soybean dispersion as claimed in claim 20.

cotyledons or pieces to whole (with hulls) beans.

WHAT WE CLAIM IS:—

1. A stable, bland aqueous dispersion of phospholipid-soybean protein complex in which a major amount of the phospholipids in the dispersion is unextractable by hexane extraction.
2. An aqueous dispersion as claimed in claim 1 wherein substantially all of the phospholipids in the dispersion are unextractable by hexane extraction.
3. An aqueous dispersion as claimed in claim 1 substantially as hereinbefore described.
4. An aqueous dispersion as claimed in claim 1 substantially as hereinbefore described in any one of the Examples.
5. A process for preparing an aqueous dispersion as claimed in claim 1 comprising:
 - i) tenderizing intact soybean cotyledons until the soybeans exhibit a degree of tenderization as measured by equivalent tenderometer values, on a whole bean basis, of between 16 and 300 pounds per 100 grams soybeans (wet basis), which step also includes heating of the intact soybean cotyledons sufficiently to inactivate the lipoxidase enzyme therein;
 - ii) forming an aqueous slurry of the soybean solids; and
 - iii) homogenizing the slurry until a major amount of the oil in the soybeans is complexed with the protein therein.
6. A process as claimed in claim 5 wherein the slurry is homogenized until substantially all of the oil is complexed.
7. A process for preparing an aqueous dispersion as claimed in claim 1 comprising:
 - i) tenderizing intact soybean cotyledons until the soybeans exhibit a tenderometer value of between 16 and 300 pounds/100 gms of soybeans, which step includes simultaneous or sequential heating of the intact soybean cotyledons sufficiently to inactivate the lipoxidase enzyme;
 - ii) forming a slurry of the soybeans and water, the said slurry having a soybean concentration of less than 20 percent by weight;
 - iii) homogenizing the slurry in at least one pass through a homogenization zone at a pressure between 1,000 and 10,000 psi. at a temperature between 32° F. and the boiling point of the slurry at the pressure within the homogenizing zone; and,
 - iv) recovering a bland, stable aqueous dispersion of whole soybeans.
8. A process as claimed in any one of claims 5 to 7 wherein the soybeans are dehulled before, during or after tenderization.
9. A process as claimed in any one of claims 5 to 7 wherein tenderization is effected on whole hull-containing soybeans.
10. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by exposing intact soybean cotyledons either simultaneously or sequentially to a combination of moisture and heat until an equivalent tenderometer value in the range of from 16 to 300 pounds per 100 grams soybeans on a whole bean basis is obtained.
11. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by (a) soaking the soybeans in water until the beans are saturated therewith and then (b) blanching the soybeans for a period of time sufficient to inactivate the lipoxidase enzyme.
12. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by blanching previously unsoaked soybeans.
13. A process as claimed in any one of claims 5 to 9 wherein tenderization is effected by pressure cooking the soybeans.
14. A process as claimed in any one of claims 5 to 13 wherein homogenization is effected such that the minimum degree of homogenization is inversely related to the degree of tenderization effected.
15. A process for preparing an aqueous dispersion as claimed in claim 1 comprising:
 - i) tenderizing intact soybeans cotyledons by (a) soaking the soybeans in an aqueous NaHCO₃ solution and then (b) blanching the soaked soybeans in an aqueous NaHCO₃ solution, the combined effect of the said soaking and blanching being such that the soybeans exhibit a tenderometer value of from 16 to less than 185 pounds per 100 grams soybeans and that the lipoxidase enzyme therein is inactivated;
 - ii) wet milling the beans to obtain an aqueous slurry of the soybeans having a solids content of about 12% by weight; and
 - iii) passing the slurry twice through a homogenization zone at a temperature of about 180° F. and a pressure of about 3500 psi.
16. A process as claimed in claim 15 wherein the pH of the aqueous NaHCO₃ solution is between 7.5 and 8.5.
17. A process as claimed in claim 5 substantially as hereinbefore described in any one of the Examples.
18. A process as claimed in claim 5 substantially as described herein.
19. A modification of a process as claimed in claim 5 or claim 6 in which step (i) comprises heating of the intact soybean cotyledons sufficiently to inactivate the lipoxidase enzyme therein, reducing the size of the soybeans in order to increase their surface area, and thereafter tenderizing the treated soybeans until they exhibit the degree of tenderization recited in claim 5.
20. A soybean dispersion that has been prepared by a process as claimed in any one of claims 5 to 19.
21. A beverage, milk substitute, ice cream, margarine or tofu when made from a soybean dispersion as claimed in claim 20.



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