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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A23L 1/308, 1/05	A1	(11) International Publication Number: WO 96/32852
		(43) International Publication Date: 24 October 1996 (24.10.96)

(21) International Application Number: PCT/US96/05213

(22) International Filing Date: 16 April 1996 (16.04.96)

(30) Priority Data:
08/426,244 21 April 1995 (21.04.95) US

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(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: FIBER-DERIVED COLLOIDAL DISPERSIONS AND USE IN FOODS

(57) Abstract

Fiber-derived homogeneous colloidal dispersions or gels and powders produced therefrom are described. The dispersions or gels are prepared by enzyme hydrolysis and subsequent mechanical disintegration. Food formulations comprising the stable, homogeneous colloidal dispersions, gels and powders are also described.

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FIBER-DERIVED COLLOIDAL DISPERSIONS AND USE IN FOODS

Background

Dietary fiber can be defined as including all the insoluble and soluble components of food that are not broken down by the digestive tract enzymes to produce low molecular weight compounds that can be readily absorbed into the blood stream. Plant cell wall materials such as cellulose, hemicellulose, lignin and pectins are the primary source of dietary fiber in human and many animal diets. The maintenance of adequate levels of fiber is important for the proper health and function of the body. Diets high in fiber have been found to be useful in obesity control and weight reduction programs because of their high ratio of bulk to calories. For these reasons, the food and feed industries have turned to dietary fillers and bulking agents for supplying the fiber requirements demanded by the market.

Dietary fillers and bulking agents can be categorized by solubility. The soluble group includes primarily the gums, pectins and mucilages. These material can have a substantial effect on the functional properties of other food components, and therefore have limited application in many food formulations. The insoluble fillers which have played a major role in this field include alpha-cellulose and microcrystalline cellulose. Alpha-cellulose is produced by grinding ordinary, kraft paper pulp obtained by the sulfiting of hardwood. Consumer acceptance of this product has been limited to some extent by its objectionable texture and mouth feel. The cellulose chains of kraft pulp comprise both crystalline and amorphous regions. When treated with acid hydrolysis as described by Battista et al. in U.S. Patent No. 3,023,104, the amorphous

regions are hydrolyzed, leaving particles of crystallite aggregates, otherwise known as microcrystalline cellulose. Thompson et al. (U.S. Patent No. 4,307,121) discloses a method for converting relatively nonligneous cellulose material such as soybean hulls to a short fiber cellulose suitable for human consumption. The process involves heating these materials in a slurry with a strong oxidizing reagent such as chlorine gas, followed by an alkaline cook, to yield a purified cellulose product.

It has been the general view of those knowledgeable about the manufacture and applications of cellulose powder that in order to achieve an end product containing an appropriate level of cellulose microcrystals, the acid hydrolysis process described above, or minor modification thereof, should be used. Although other methods of cellulose degradation have been studied, e.g., enzymatic hydrolysis, such methods have not been considered appropriate for commercial cellulose powder production because the product does not have the desired crystallinity. Prior studies of cellulosic material have utilized enzyme hydrolysis to enzymatically convert cellulose into a soluble sugar solution and provide a practical process for cellulose utilization. Generally the aim of such studies has been to completely hydrolyze the cellulosic starting material and not to change its properties.

Summary of the Invention

This invention pertains to the discovery that certain insoluble fibers can be converted into stable, homogeneous colloidal dispersions or gels. The gels can be dried to produce a powder with an average particle size of less than about 15μ when viewed under a light microscope. The resulting powder has a water absorption of from about 200 to about 400% and an oil absorption of from about 100 to

about 200%. Rehydration of the powder with shear results in the formation of a colloidal dispersion or gel with characteristics similar to its never dried counterpart. Additionally, the colloidal dispersion can be co-dried with other hydrocolloids or polymers to alter the properties of the dispersion.

The stable, homogeneous colloidal dispersions or gels are produced by treating an insoluble fiber material with a hydrolase enzyme, such as an endo-cellulase, and subsequent mechanical disintegration. The enzymatic treatment makes the fiber more susceptible to degradation when subjected to mechanical disintegration, such as by two-stage high pressure homogenization. The two step process yields a stable, homogeneous colloidal dispersion or gel which can be dried and subsequently rehydrated.

This invention also relates to the preparation of food products containing the stable, homogeneous colloidal dispersions, gels or powders, and to food formulations which comprise the colloidal dispersions, gels or powders produced by the methods detailed herein. Never dried or rehydrated colloidal dispersions or gels can be incorporated into foods and beverages to manage water activity, to increase bulk and to decrease caloric value. For some food formulations, a powder resulting from the drying of the colloidal dispersion or gel can be used directly in foods without prior rehydration. The colloidal dispersions or gels and powders of the present invention are suitable for use in food formulations which would benefit from a reduced particle size and low water and oil absorption. Some examples of suitable food formulations include, but are not limited to, chocolate, frostings, spreads, yogurt, cream fillings and peanut butter, juices, extruded foods, meats, and dairy products such as natural and processed cheese.

Detailed Description of the Invention

The present invention pertains to a stable, homogeneous colloidal dispersion or gel which can be dried to produce a powder. The powder has a reduced particle size (an average of less than about 15 μ compared to 300-400 μ of the starting material) and reduced water or oil absorption compared to the starting material. The powder can be rehydrated in the presence of shear to give a product with characteristics similar to the never dried colloidal dispersion or gel. Additionally, the stable, homogeneous colloidal dispersion or gel can be co-dried with other hydrocolloids or polymers to alter the properties of the dispersion.

The never dried or rehydrated stable, homogeneous colloidal dispersions or gels and powders therefrom can be incorporated into food formulations to increase bulk, decrease caloric value and yield superior organoleptic properties, taste and mouth feel. Terms used herein have their art-recognized meaning unless otherwise indicated.

Stable, homogeneous colloidal dispersions or gels are produced by treating an insoluble fiber material with a hydrolase enzyme, such as an endo-cellulase, and subsequent mechanical disintegration. The enzymatic treatment makes the fibers more susceptible to degradation when subjected to mechanical disintegration, such as by two-stage high pressure homogenization. The two step process yields a stable, homogeneous colloidal dispersion or gel which can be dried and subsequently rehydrated.

Various grades and forms of insoluble fiber can be used as the starting material in the process of the present invention. Such materials include natural fiber sources as well as products derived from microbial sources such as fermentation. The insoluble fiber can contain cellulose and hemicellulose, and can also contain a small percentage of lignin, preferably less than about 10 percent. For

example, the fiber can be derived from partially or fully delignified oat hulls, such as OPTA™ Oat Fiber 770 (U.S. Patent No. 5,023,103). The insoluble fiber can also be derived from various seed plant materials including cotton seed fiber, oat hulls, pea hulls, corn hulls, peanut hulls and stems, wood, straw, wheat fiber, sugar beet fiber, rice fiber and other similar materials. Preferably, the fiber is derived from a non-woody source. The raw starting material can be pretreated in order to remove hemicellulose and lignin and increase the enzymatic reactivity of the material. Such pretreatment methods include but are not limited to steam explosion, swelling with alkaline agents, acid treatment, ammonia treatment, delignification and grinding. The fiber can be dried or can be used in wet form such as undried pulp, pulp slurry or other hydrated form.

According to the method of the present invention, the insoluble fiber material is first treated with a hydrolase enzyme under conditions which effect hydrolysis. A preferred enzyme is an endo-enzyme, particularly an endo-cellulase. Enzymes from various sources are suitable for use in the present invention to effect hydrolysis of the cellulose material in the fiber. Suitable sources include commercial cellulase preparations and enzymes derived from cultured native microorganisms or recombinant microbial sources. These include commercial preparations of cellulase which are combinations of several enzymes that have both endo-cellulase and exo-cellulase activity, as well as cellulases which have been enriched with particular components having endo-cellulase activity or modified to reduce or remove the exo-cellulase activity. Endo-cellulase activity selectively hydrolyzes the amorphous regions of the cellulose, while exo-cellulose activity acts to remove the crystalline portions and, thus, is less desirable. A rich source of cellulase is the organism

Trichoderma longibrachiatum (formerly known as T. reesi), and several commercial preparations are available that have enriched endo-cellulase activity. For example, MULTIFECT® Cellulase GC (Genencor International, Inc., Rochester, NY) or ECONASE® CE (Enzyme Development Corp., New York, NY) can be used to hydrolyze the cellulose in the insoluble fiber. Additionally, the cellulase enzyme may be produced by actinomyces, bacteria, fungi or yeast. Enzymes from different sources will normally differ in their ability to hydrolyze different forms of cellulose.

The cellulase enzyme can also be combined with other enzymes which have a particularly desired activity. For example, the cellulase enzyme can be combined with a xylanase enzyme, which hydrolyzes hemicellulose, and/or with a peroxidase or laccase enzyme, which oxidize lignin, and/or with a ligninase enzyme, which hydrolyzes lignin.

The preferred concentration of enzyme is from about 100 ppm to about 5000 ppm of enzyme where the insoluble fiber is present at a concentration of from about 0.25 g/l to about 200 g/l, and preferably from about 0.25 g/l to about 120 g/l, depending upon the starting material and the degree of hydrolysis to be effected.

The enzymatic hydrolysis step should be carried out in the presence of a suitable buffering system. A preferred buffering agent is citrate-phosphate or citric acid at from about pH 4.5. Other suitable buffers with appropriate pH characteristics can also be selected based upon the particular enzyme used. Commercial buffer systems utilizing a pH probe can also be used to maintain the pH at a stable level in the desired range. The enzymatic hydrolysis step can be expedited by changing the buffer every 2 to 3 hours in order to reduce the end product inhibition of the reaction resulting from the short chain polymers produced by the reaction. Alternatively, any method which removes the short chain polymers or low

molecular weight compounds in the solution can be utilized to increase the efficiency of the enzymatic hydrolysis reaction.

The enzymatic hydrolysis step should also be carried out at a temperature ranging from about 35°C to about 75°C, with from about 40°C to about 60°C being the preferred range. Higher or lower temperatures may be utilized as long as the activity of the enzyme is not adversely affected.

The reaction time for enzymatic hydrolysis of the cellulose in the fiber will vary depending on the identity of the starting material, enzyme and other reaction conditions; however, in general an appropriate degree of hydrolysis can be achieved in from about 5 to about 72 hours. As used herein, the degree of hydrolysis is considered appropriate when 11 to 15% (w/w) of the starting material assays as glucose using an enzyme-linked membrane on a YSI Model 2700 Select Biochemical Analyzer. An appropriate degree of hydrolysis can also be determined by monitoring the effects of attrition or mechanical disintegration on the reaction product. If the level of hydrolysis is appropriate, subsequent high shear of the enzymatically-treated fiber results in disruption of the long strands of fiber into amorphous thread-like material projecting from the fiber when viewed under a phase contrast light microscope at 100x magnification. Additionally, any degree of enzymatic hydrolysis which, when followed by high shear, results in a stable, homogeneous colloidal dispersion or gel is appropriate.

The enzymatic hydrolysis step is followed by mechanical disintegration to disrupt the fiber. The concentration of enzyme-treated fiber prior to mechanical disintegration should be at least 2% by weight, with at least 5% by weight being preferred. Mechanical shear or disintegration can be carried out in several ways. For

instance, the material can be subjected to attrition in a mill, or to high speed cutting action, or to high pressure on the order of at least 2000 psi. For instance, a two-stage Gaulin homogenizer or POLYTON® Homogenizer can be used. The shear is carried out in the presence of a liquid medium, although when very high pressure alone is used the liquid medium may not be necessary. Water is the preferred medium, but other, preferably edible, liquids are suitable, including but not limited to sugar solutions, polyols (e.g., glycerol), milk, and alcohols (e.g., ethanol). A preferred method of shear is the use of a two-stage Gaulin homogenizer in the presence of an aqueous medium.

Using an appropriate method, shear is carried out to such an extent to form a stable, homogeneous colloidal dispersion or gel in the aqueous medium in which the enzymatically-treated fiber is sheared. The phrase "stable, homogeneous colloidal dispersion" is intended to mean a dispersion from which the product will not settle out but will remain suspended indefinitely under storage conditions, even for weeks or months. The stable, homogeneous colloidal dispersions or gels are further characterized by their ability to form extremely adherent films when deposited on a glass panel or sheet or other suitable surfaces. At lower solids concentration the product exists as a dispersion, while at higher solids concentrations it is a gel.

The sheared product having 35% solids or greater, although not a gel, will easily form a gel upon manual stirring with water. The stable, homogeneous, colloidal dispersions and gels described herein are free of layers or sedimentation; instead, the stable dispersions and gels are uniform and homogeneous throughout, having a uniform color and a smooth mouth feel. The preferred dispersions and gels are those that are stable for at least a week, and the most preferred are stable for a month or longer.

Dispersions and gels that are stable for at least an hour to a day are also useful for some purposes, as they can be used immediately.

Generally, the concentration of the fiber particles stably suspended in the homogeneous colloidal dispersion is at least 3% by weight, and more preferably, 4% to 5% by weight. However, stable dispersions having solids content of up to about 6% to 8% by weight can be made. In some food formulations, lower use levels can also have benefits. The concentration of fiber particles in the gel will be limited or determined by the handling conditions for the gel. The gels are usually thixotropic in nature when they contain 5% to 10% solids.

Either before or after mechanical disintegration of the enzymatically-treated fiber, the gels or suspensions can optionally be dried to any practical moisture content in which state they are redispersible in water, with the aid of a suitable attrition step, to reform a colloidal dispersion or gel. The resulting dispersion or gel can again be dried if desired, and again redispersed. When the attrition step is performed in an aqueous medium, drying is preferably carried out after the disintegration step. Drying can be carried out under vacuum, or in air at room temperature or higher. Another useful drying method is displacing the water in the enzymatically-treated fiber by means of a low boiling point water miscible organic compound, such as a low molecular weight aliphatic alcohol (e.g., ethanol or methanol). Some drying procedures are more advantageous than others because the dried product re-disperses more easily. For example, freeze drying, spray drying, drum drying and drying by solvent displacement produce a powder which is more easily re-dispersed in water, compared with a similar powder produced by oven drying or air drying.

As described above, the method for making stable, homogeneous colloidal dispersions or gels and powders is completely carried out prior to the incorporation of the fiber into the food formulations. However, the final mechanical disintegration step can be performed *in situ* during the preparation of a wide range of foods and beverages. According to this embodiment, the ingredients of the food product are added to the slurry containing the enzymatically-treated fiber material. The mixture is then subjected to mechanical disintegration, attrition or high shear. The attrition process disrupts the enzymatically-treated fiber and produces a food product containing a stable, homogeneous colloidal dispersion or gel. Producing foods containing the colloidal dispersions or gels of the present invention in a single stage operation provides a cost advantage from a manufacturing standpoint. In addition, there may be some product advantages which result from the single stage operation. The properties of the products from the single stage operation are indistinguishable from the properties of the corresponding product, prepared from the same ingredients, in which the colloidal dispersion or gel is separately prepared. This process is useful for producing fillings, soups, gravies, toppings, beverages and other food products.

The organoleptic properties of the stable, homogeneous colloidal dispersion or gel can be altered by the addition of hydrophilic polymers such as cellulose esters or ethers (e.g., carboxymethyl cellulose, methyl cellulose), gums and starches. A small amount of such a hydrocolloid can vary the mouth feel and texture of the resulting fiber-derived product. The amount of the hydrocolloid can range from about 0.1% to about 30% by weight, with about 5% being preferred. Suitable gums and polymers include but are not limited to guar gum, gum arabic and locust bean gum and hydrocolloids such as carrageenan, agar and alginate. The

polymers can be added to the enzymatically-treated fiber before or after the mechanical disintegration step. The step at which the polymer or polymers should be added will be dictated by the properties of the hydrocolloid. Addition of the hydrocolloid to the liquid suspension of the fiber material prior to mechanical disintegration can prevent de-watering of the fiber under high pressure and allow the slurry to be homogenized at higher slurry concentrations. However, certain hydrocolloids or polymers, such as guar gum or xanthan gum, may result in an undesirably high viscosity of the mixture if added prior to shearing, and, thus, should be added to the product after mechanical disintegration.

The colloidal dispersions or gels and powders of the present invention are suitable for use in food formulations which would benefit from a reduced particle size and low water and oil absorption. For example, the products of this invention are suitable as bulking agents in low fat/low sugar foods which rely on low water activity for microbial preservation. The small size of the fiber particles also make them suitable for use in beverages because they are readily suspended in solution and are virtually undetectable in the mouth. Furthermore, the colloidal dispersions, gels and powders of this invention facilitate the manufacture of food products that are fiber-fortified. The colloidal dispersions, gels and powders can be used in ready-to-drink beverages, yogurt, cream fillings, peanut butter, among other food formulations.

The colloidal dispersions, gels and powders are also suitable for use in bakery products including but not limited to breads, cakes, cookies, biscuits, pies, doughnuts; snack items, such as pretzels; pastries and other specialties; prepared mixes for making any of the above-mentioned products; and in cereals and pasta products. Baked goods contain predominantly starch. It is

possible to replace the flour and reduce the caloric content of the baked products without effecting the organoleptic properties of the product by using the colloidal dispersions or gels and powders. Cakes and cookies prepared with the products of this invention retain moisture and help to prevent the staling of the baked goods.

The fiber-derived product of this invention can be incorporated into foods containing predominantly carbohydrates such as sugars and starches; for example, the product can be incorporated into puddings, custards and toppings and dry mixes for preparing the same. In the case of dry mixes, the fiber-derived product helps to retain the aqueous or oily ingredients, thereby preventing leaching of the liquid or absorption of the liquid onto the walls of the package containing the mix.

The products of this invention can be used in foods such as dressings and spreads which are prepared with fats and oils. Besides reducing the caloric content of the product, the fiber-derived product assists in preventing syneresis while providing a desirable thickening effect. In reduced fat/reduced sugar low water activity systems such as peanut butter and cream fillings, the low oil and water holding capacity provides a desired thickening effect without a deleterious increase in firmness typical of most food polymers.

In meat products such as sausages, sausage products and meat loaf, the texture, juiciness and other organoleptic characteristics are improved by the use of products of this invention. In the preparation of sausage products and meat loaf, the addition of the product helps to simplify the processing steps by making the meat emulsion and meat mixers easier to handle.

Another food application for the products of this invention is in dairy food products, such as natural and

processed cheese and in foods using milk and cream. No-fat natural cheese can be produced by dispersing the product into milk before the culturing and renneting steps. The fiber-derived product may function as a fat mimetic by partitioning into the curd and increasing the yield as well as softening the texture.

The fiber-derived products are also suitable for confections including candy, chewing gum, bakers confections and similar products. In candy, the colloidal dispersions, gels or powders can be used to deliver colors by absorption of edible dyes. In chewing gum, the fiber-derived product can be used as a carrier for the flavors.

Other foods in which the fiber-derived product may be incorporated include gravies, sauces, jellies, beverages and similar foods. The thickening effect of the product is particularly advantageous for products such as gravies and sauces.

The invention will be further illustrated by the following non-limiting examples:

EXAMPLES

EXAMPLE 1

Pilot Scale Production of a Stable, Homogeneous Colloidal Dispersion or Gel

A total of 30 liters of buffer (100 mM citrate-phosphate, pH 4.5), was placed in a jacketed ribbon blender DRB-5 (American Process Systems, Gurnee, IL) with 60°C water recirculating through the jacket. The cellulase enzyme (200 ml, MULTIFECT® Cellulase GC, Genencor International, Inc., Rochester, NY) was added to the buffer and mixed. Then 3 kilograms of OPTA™ oat fiber 770 (Opta Food Ingredients, Inc., Bedford, MA) was added. The mixture was agitated by the blender mixing blades and the temperature maintained at 60°C throughout the enzymatic

reaction. The reaction was followed by periodically removing 10 ml aliquots and (i) assaying for glucose and (ii) shearing the sample. The fiber/buffer suspension was centrifuged at approximately 1400 g for 5 minutes. The supernatant was assayed for glucose using a YSI model 2700 Select Biochemical Analyzer (Yellow Springs instrument Co., Inc., Yellow Springs, OH). The reaction was complete when 11-15% (w/w) assayed as glucose. The remainder of the fiber was resuspended in water and homogenized with a POLYTON® Homogenizer (Brinkmann Instruments Inc., Westbury, NY) at 24,000 rpm for 5 minutes. The fiber was examined under a light microscope (Olympus BH-2 with Optimus image analyzer) with phase contrast at 100x magnification. As the reaction progressed, the long strands of fiber were disrupted into amorphous thread-like material projecting from the fiber. After 46 hours, when the long fiber strands could no longer be seen, the reaction was complete.

The fiber suspension was heated to 70°C to irreversibly inactivate the enzyme. The fiber was centrifuged and washed with excess water. The washed fiber was resuspended in water at approximately 5-6% solids by weight and then homogenized using a two-stage Gaulin Homogenizer 15MR-8TBA (APV Gaulin Inc., Wilmington, MA) at 5000 to 6000 psi, 2 passes. The overall yield of the fiber was approximately 70%. The homogeneous colloidal disperion or gel was then spray dried (APV Crepaco, Tonawanda, NY) using an inlet temperature of 340-350°F (170-176°C) to give a fine powder.

EXAMPLE 2

Characterization of a Stable, Homogeneous Colloidal Dispersion or Gel

A. Compositional Analysis

Cellulose, hemicellulose and lignin determinations were conducted at Hazelton, Wisconsin. The methods used have been developed for the characterization of forages and feeds. They involve the determination of neutral detergent fiber (NDF; USDA Forage and Fiber Analysis, Agriculture Handbook #379 (1970); American Association of Cereal Chemists, 8th Edition (1983) Method 32.20, (modified)), acid detergent fiber (ADF; Forage and Fiber Analysis, Agriculture Handbook #379.8, United States Department of Agriculture (1970) (modified)) and acid detergent lignin (ADL; USDA Forage Fiber Analysis, Agriculture Handbook #379 (1970) (modified)) by different boiling detergent treatments followed by gravimetric analysis. From the values obtained, the cellulose and hemicellulose content of the spray dried fiber are calculated as follows (see Table 1):

NDF - ADF = Hemicellulose (%)

ADF - ADL = Cellulose (%)

ADL = Lignin (%)

Table 1

Compositional Analysis

Sample	Cellulose (%)	Hemicellulose (%)	Lignin (%)
OPTA™ Oat Fiber 770	76.0	12.3	0.1
Enzyme-Modified Sheared OPTA™ Oat Fiber 770 (Spray Dried Powder, Example 1)	78.9	5.4	0.1

B. Water Absorption

The water absorption (percent by weight) was determined by a modification of American Association of Cereal Chemists Method 88-04 (see Table 2). Instead of using 5 grams of the test fiber and centrifuging at 2000 g, 3.0 grams of the fiber was centrifuged at 1450 g and spray dried as described in Example 1.

C. Oil Absorption

The determination of the oil absorption (percent by weight) of the fiber was identical to that described in method B except that store bought Wesson vegetable oil was used instead of water (see Table 2).

Table 2

Water and Oil Absorption of a Spray Dried Powder Prepared from a Stable, Homogeneous Colloidal Dispersion or Gel

Sample	Water Absorption (%)	Oil Absorption (%)
OPTA™ Oat Fiber 770	625 ± 6.0	496 ± 8.2
Enzyme-Modified Sheared OPTA™ Oat Fiber 770 (Spray dried powder, Example 1)	372 ± 2.4	104 ± 3.8

D. Light Microscope

The fiber was suspended in water and an aliquot examined under the light microscope using phase contrast and 100x magnification. The OPTA™ Oat Fiber 770 had long thin strands with an average length of 300 - 400 μ. The spray dried powder had an average particle size of 10 μ with an occasional particle of 50 to 60 μ.

E. Suspendability

The suspendability of the fiber was determined by placing 2 grams of spray dried powder (as prepared in Example 1), or a homogeneous colloidal dispersion prepared by rehydrating the spray dried powder, in a 100 ml graduated cylinder. After the addition of water up to the 100 ml mark, the cylinder was placed in a Branson bath sonicator and sonicated until a steady packed volume was obtained. The cylinder was then removed and the volume of the packed fiber was recorded (see Table 3). The number of inversions by hand required to completely free the packed fiber and create a free-flowing suspension was also noted.

Table 3

Suspendability of the Fiber

Sample	Volume After Sonication (ml)	Number of Inversions
OPTA™ Oat Fiber 770	19	32
Enzyme-Modified Sheared OPTA™ Oat Fiber 770 (Spray Dried Powder, Example 1)	20	over 100
Sheared Enzyme-Modified Sheared OPTA™ Oat Fiber 770 (Homogeneous Colloidal Dispersion, Rehydrated)	75	To free 85%: 20 To free 100%: 85

EXAMPLE 3

Bench Scale Production of a Stable, Homogeneous Colloidal Dispersion or Gel Using MULTIFECT® Cellulase GC

200 grams of OPTA™ Oat fiber 770 or 780 (Opta Food Ingredients, Inc., Bedford, MA) was added to buffer (5mM

citrate-phosphate, pH 4.5) containing 13.4 ml MULTIFECT® Cellulase GC. The mixture was then incubated in a shaking water bath at 60°C. After 2-3 hours, the fiber suspension was filtered and the fiber resuspended in fresh buffer, and the incubation continued at 60°C. The reaction was monitored as described in Example 1. After a total of 6-8 hours with 2 buffer changes, the enzymatic reaction was complete. The fiber suspension was heated to 70°C to irreversibly inactivate the enzyme. The fiber was centrifuged and washed with excess water. The washed fiber was resuspended in water at approximately 5-6% solids by weight and then homogenized using a two-stage Gaulin Homogenizer (APV Gaulin Inc., Wilmington, MA) at 2000 to 3000 psi, 2 passes. The overall yield of the fiber was approximately 70%. The homogeneous colloidal dispersion or gel was then spray dried (APV Crepaco, Tonawanda, NY) using an inlet temperature of 340-350°F (170-175°C) to give a fine powder.

EXAMPLE 4

Bench Scale Production of a Stable, Homogeneous Colloidal Dispersion or Gel Using ECONASE® CE

Two hundred grams of OPTA™ Oat Fiber 770 or 780 (Opta Food Ingredients, Inc., Bedford, MA) was added to buffer (5mM citrate-phosphate, pH 5.0) containing 13.4 ml ECONASE® CE (Enzyme Development Corp., New York, NY). The mixture was then incubated in a shaking water bath at 50°C. The rest of the experiment was identical to that described in Example 3.

EXAMPLE 5

Bench Scale Production of a Stable, Homogeneous Colloidal Dispersion or Gel Using MULTIFECT® Cellulase GC

This experiment was identical to that described in Example 3 except that the fiber was not sheared after the

enzymatic reaction was completed. The enzyme-modified fiber was air-dried to give very hard rock-like pellets. The hard rock-like material was ground to a fine powder using a Hammermill followed by a milling using a Retsch Ultra Centrifugal Mill ZM-1 (Brinkmann Instruments, Inc.) equipped with a 0.12 mesh screen. Alternatively the filter cake was reslurried into ethanol and rinsed to remove any water. The fiber was air-dried and then ground in a Retsch Ultra Centrifugal Mill to give a fine powder.

EXAMPLE 6

Bench Scale Production of a Stable, Homogeneous Colloidal Dispersion or Gel Using Wet Fiber as the Starting Material

This experiment was identical to that described in Example 3 except that wet fiber was used as the starting material. The product was the same as that produced in Example 3.

EXAMPLE 7

Preparation of Co-Dried Hydrocolloids and Stable, Homogeneous Colloidal Dispersion or Gel

A. Guar Gum

Guar gum (Germantown, Broomall, PA) was prehydrated in water and added to the sheared colloidal dispersion prepared as described in Example 1. The concentration of the guar gum was 5% that of the fiber (w/w). The resulting mixture was then spray dried as described in Example 1.

B. Carboxymethyl Cellulose

Carboxymethyl cellulose (FMC Corp., Philadelphia, PA) was prehydrated in water and then added to the sheared colloidal dispersion prepared as described in Example 1. The concentration of the carboxymethyl cellulose was 10% that of the fiber (w/w). The resulting mixture was then spray dried as described in Example 1.

EXAMPLE 8

Preparation of Sheared Fiber Without Enzymatic Treatment

OPTA™ Oat Fiber 770 or 780 (Opta Food Ingredients, Inc., Bedford, MA) at 6% by weight solids in water was sheared using a Gaulin Homogenizer (APV Gaulin Inc., Wilmington, MA) at 5000 to 6000 psi. A sample of the fiber was sheared further using a Microfluidizer (Microfluidics International Corp., Newton, MA). The resulting fiber was lyophilized to dryness and then ground in a Retsch Ultra Centrifugal Mill ZM1 (Brinkmann Instruments, Inc., Westbury, NY). Table 4 shows that the water absorption of the fiber increased slightly with the number of passes through the Gaulin homogenizer. After homogenization, the product was more colloidal in nature and had the same or increased water absorption as compared with the product of enzyme hydrolysis followed by high shear treatment (Example 1).

Table 4

Water Absorption as a Function of Shear

Gaulin Treatment	Water Absorption
0 passes	593
2 passes	568
5 passes	600
10 passes	620
15 passes	620
20 passes	634
5 passes Gaulin, 3 passes Microfluidizer	730

EXAMPLE 9

Peanut Butter

The spray dried powder prepared as described in Example 1 was incorporated into a peanut butter spread; percents listed are percent by weight.

Formulation:

Ingredients	SAMPLES				
	A	B	C	D	E
	(%)	(%)	(%)	(%)	(%)
SKIPPY™ Peanut Butter	70	70	92.19	92.19	100
MALTRIN® M-520 (Grain Processing Corporation)	30	20	0	0	0
Spray dried powder (Example 1)	0	10	7.81	0	0
OPTA™ Oat Fiber 770 (Opta Food Ingredients, Inc.)	0	0	0	7.81	0

The peanut butter was heated to 170°F (76°C) by placing in a conventional oven. The warmed peanut butter and the rest of the ingredients were placed in a bowl of a mini food processor (SUNBEAM OSKAR®). The ingredients were blended until uniformly dispersed using maximum shear (2-3 minutes). The mixture was cooled to 95-100°F (35-37.8°C) before filling containers.

The samples were paneled by 3 expert tasters. The samples A and C were most similar to the peanut butter control (Sample E).

EXAMPLE 10

Chocolate Drink

The spray dried powder prepared as described in Example 1 was incorporated into a ready-to-serve chocolate drink; percents listed are percent by weight.

Formulation:

Ingredients	SAMPLES		
	A (%)	B (%)	C (%)
Whole milk	91.975	90.935	90.935
Granulated sugar	7.0	7.0	7.0
Carrageenan (Seakem CM 611, FMC Corp)	0.025	0.025	0.025
Cocoa powder (De Zaen D-11-ASOL)	1.0	1.0	1.0
OPTA™ Oat Fiber 770 (Opta Food Ingredients, Inc.)	0	0	1.04
Spray dried powder (Example 1)	0	1.04	0

The cold milk and all the dry ingredients were blended in a kitchen blender at a high speed for 5 minutes. The mixture was then pasteurized at 195°F (90°C) for 60 seconds followed immediately by homogenization in a two-stage Gaulin Homogenizer 15MR-8TBA (APV Gaulin Inc., Wilmington, MA) at 2500/500 psi. The drinks were then transferred to capped containers and quickly cooled to 40°F (5°C) Samples were held at 40°F (5°C) for at least 24 hours before analysis.

The samples were subsequently paneled by 3 expert panelists. The sample containing the spray dried powder (Sample B) was very similar in smoothness and overall textural preference to the control (Sample A). Sample C was less smooth relative to Sample A and B and also showed some settling of the fiber.

EXAMPLE 11

No-Fat Yogurt

The spray dried powders prepared as described in Examples 1 and Example 7A were used to prepare no-fat yogurts; percents listed are percent by weight.

Formulation:

Ingredients	SAMPLES		
	A (%)	B (%)	C (%)
Water	86.25	86.25	86.25
Non-fat milk	10.50	10.50	10.50
Granulated sugar	3.25	3.25	3.25
Spray dried powder (Example 1)	0	1.1	0
Spray dried powder with guar (Example 7A)	0	0	1.4

The water was heated to 200°F (93°C) and transferred to a standard kitchen blender. The other dry ingredients were added as a blend and sheared on high speed for 2 minutes. The mixture was then pasteurized by holding at 185°F (88°C) for 30 minutes and then homogenized in a two-stage Gaulin Homogenizer 15MR-8TBA (APV Gaulin Inc., Wilmington, MA) at 2500/500 psi. After homogenization, the mixture was cooled to 104°F (42°C) and inoculated with the yogurt starter culture 653 (Marshall Products, Wisconsin), incubated at 104°F (42°C) for 6 hours and then stored at 50°F (10°C).

Sample B, containing the spray dried powder, had the least amount of decantable serum and syneresis. It was superior in stir down and fat-like sensory qualities relative to the other two samples.

Equivalents

Those skilled in the art will recognize, or be able to ascertain, using no more than routine experimentation, many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

CLAIMS

The invention claimed is:

1. A stable, homogenous colloidal dispersion or gel, derived from an insoluble fiber material that has been enzymatically hydrolyzed and then subjected to mechanical disintegration, having low water absorption or low oil absorption.

2. The colloidal dispersion or gel of Claim 1 wherein the insoluble fiber material is derived from partially or totally delignified wood, oat hulls, pea hulls, corn hulls, peanut hulls and stems, cotton seed fiber, straw, wheat fiber, sugar beet fiber or rice fiber.

3. The colloidal dispersion of Claim 1 further comprising hydrophilic polymers, hydrocolloids, gums, starches, or combination thereof.

4. A powder produced by drying a stable, homogenous colloidal dispersion or gel, derived from an insoluble fiber material that has been enzymatically hydrolyzed and then subjected to mechanical disintegration, having an average particle size of less than about 15 μ and having low water absorption or low oil absorption.

5. The powder of Claim 4 having a water absorption of from about 200 to about 400% and an oil absorption of from about 100 to about 200%.

6. The powder of Claim 4 wherein the insoluble fiber material is derived from partially or totally delignified wood, oat hulls, pea hulls, corn hulls,

peanut hulls and stems, cotton seed fiber, straw, wheat fiber, sugar beet fiber or rice fiber.

7. The powder of Claim 4 further comprising hydrophilic polymers, hydrocolloids, gums, starches, or combination thereof.

8. A food formulation comprising a stable, homogenous colloidal dispersion, gel or powder produced therefrom, derived from an insoluble fiber material that has been enzymatically hydrolyzed and then subjected to mechanical disintegration, having an average particle size of less than about 15 μ and having low water absorption or low oil absorption.

9. The food formulation of Claim 8 wherein the insoluble fiber material is derived from partially or totally delignified wood, oat hulls, pea hulls, corn hulls, peanut hulls and stems, cotton seed fiber, straw, wheat fiber, sugar beet fiber or rice fiber.

10. The food formulation of claim 8 wherein the food is a low water activity food.

11. The food formulation of Claim 8 wherein the food is a meat product.

12. The food formulation of Claim 8 wherein the food is a dairy product.

13. The food formulation of Claim 8 wherein the food is a baked good.

14. The food formulation of Claim 8 wherein the food is a dressing or spread.

15. The food formulation of Claim 8 wherein the food is a confection.

16. The food formulation of Claim 8 wherein the food is a beverage.

17. The food formulation of Claim 8 which is a peanut butter, yogurt, chocolate, frosting or cream filling, gravies, sauce, jelly, candy, chewing gum.

18. A stable, homogeneous colloidal dispersion or gel having low water absorption or low oil absorption produced by a process, said process comprising the steps of:

a) subjecting an insoluble fiber material to a hydrolase enzyme, to hydrolyze cellulose present in the fiber; and

b) subjecting the product of step a) to mechanical disintegration, thereby producing the stable, homogeneous colloidal dispersion.

19. The colloidal dispersion of Claim 18 wherein the insoluble fiber material is derived from partially or totally delignified wood, oat hulls, pea hulls, corn hulls, peanut hulls and stems, cotton seed fiber, wheat fiber, sugar beet fiber or rice fiber.

20. The colloidal dispersion of Claim 18 wherein the hydrolase enzyme is an endo-cellulase.

21. A method of making a food formulation comprising a stable, homogenous colloidal dispersion or gel, derived from an insoluble fiber material that has been enzymatically hydrolyzed and then subjected to mechanical disintegration, comprising the steps of:

a) adding an enzymatically-treated insoluble fiber material to a food formulation; and

b) subjecting the product of step (a) to mechanical disintegration to decrease particle size of the enzyme-treated fiber material,

thereby producing a food formulation containing a stable, homogenous colloidal dispersion or gel having low water and oil absorption properties.

22. A process of preparing a food formulation comprising incorporating therein the stable, homogeneous colloidal dispersion or gel of Claim 1.

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 96/05213

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A23L1/308 A23L1/05

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A23L

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 537 554 (ASAHI CHEMICAL IND) 21 April 1993 see page 2, line 1 - line 9 see page 4, line 25 - page 5, line 20	1-22
Y	see page 4, line 19 - line 24 ---	1-22
X	US,A,5 175 275 (DOBASHI SHOZABURO ET AL) 29 December 1992 see column 2, line 10 - line 29 see column 3, line 67 - column 4, line 4 ---	1-22
X	GB,A,1 013 522 (FMC CORPORATION) 15 December 1965 see page 1, line 44 - line 54	1-22
Y	see page 3, line 45 - line 48 --- -/--	1-22

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

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
31 July 1996	29. 08. 96

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Inter bnal Application No
PCT/US 96/05213

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO,A,90 10392 (ALKO AB OY) 20 September 1990 see claim 1	1-22
Y	GB,A,961 398 (FMC CORPORATION) 24 June 1964 see page 3, line 126 - page 4, line 5 see page 5, line 2 - line 16 see page 7, line 99 - line 105	1-22

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