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(54) Title: EXTRUDED WHOLE-GRAIN CEREAL PRODUCTS AND THEIR PROCESS OF MAKING

(57) Abstract: The present invention relates to a process for preparing an extruded cereal product with an increased amount of whole grain, and hence to a process for preparing an extruded cereal product that has an increased amount of dietary fibres. In particular, the invention relates to an extruded cereal product comprising an increased amount of whole grain, preferably without significantly compromising the mouthfeel or the expansion properties of the extruded cereal product and maintaining, or gaining, consumer preference.



EXTRUDED WHOLE-GRAIN CEREAL PRODUCTS AND THEIR PROCESS OF MAKING

TECHNICAL FIELD OF THE INVENTION

5 The present invention relates to a process for preparing an extruded cereal product comprising whole grain. The present invention also relates to a process for preparing an extruded cereal product that has a high amount of dietary fibres, without significantly compromising the mouthfeel or the expansion properties of the extruded cereal product, thereby maintaining, or gaining, consumer preference.

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BACKGROUND OF THE INVENTION

The common grains, also referred to as cereals, are comprised in many important foods and food stuff materials. Common cereals are wheat, maize, oat, rice, barley,
15 and rye. In the Western World, wheat and corn, and to a certain extent maize, are the most important cereals. Rice is the most important cereal in Asian countries. The grains are all members of the grass family, and from the grains several food products are manufactured, including pure starch, breakfast cereals, snacks / confectionary cereals, meal, and flour. From a nutritional perspective, most cereals
20 are rich in carbohydrates, proteins, fibres, vitamins and minerals, and to some extent also fat.

Whole grains consist of three parts: endosperm (mainly starches), germ and bran. Bran contains about 80-90% of the dietary fibres from whole grains. When grains are refined (e.g. to produce white flour), the bran and germ layers are generally
25 removed, leaving only the endosperm. This refining process can cause 66% loss of fibres, 92% loss of selenium, 62% loss of folate and up to 99.8% of phytochemicals from the grains. Refined cereals, such as white flour, generally have a higher glycaemic index (GI) than their wholegrain counterparts. This means that consuming

refined cereals causes a sharp rise in blood sugars, demanding a strong response from the pancreas. A diet full of high glycaemic index foods has been linked to the development of diabetes and heart disease. Studies have also found that people who eat large amounts of refined cereals do so at the expense of more nutritious
5 foods like fruits and vegetables. This increases the risk of certain diseases, such as some types of cancer.

Therefore, in an effort to recover the beneficial components of the whole grain, the refined flour is usually reconstituted by mixing the appropriate amounts (i.e. the same weight ratios as in seeds) of refined flour, germ and milled bran. However,
10 when extruding a dough which only contains high levels of whole-grain flour (natural or reconstituted) as cereal base, the extruded product has a much higher density and expands less than a dough which contains primarily refined flour as its cereal base.

The higher density and lesser expansion, have a negative effect on the “mouth-feel”
15 of the extruded product. Mouth-feel is closely related to the textural properties of the product, and is often used to describe the physical and chemical interaction in the mouth, an aspect of food rheology. Mouth-feel is evaluated through the physical and visual appearance of the product, the first bite, through mastication to swallowing and aftertaste. Positive or good mouth-feel of cereal products is often
20 related to the hardness and/or crispness of the product. The crispness of a product is associated with light, crispy texture, which again is related to the density and expansion of the product. Thus, crispy products have a relatively high expansion while at the same time maintaining a relatively low density.

The organoleptic properties in extruded whole-grain products are still less preferred
25 by consumers than those of extruded refined flours. Improving the textural properties of whole-grain products, hence improving the mouthfeel of the product, will enable to increase whole-grain content in the extruded products, and hence in the diet.

Attempts have been made in the past to identify a solution to use whole grain wheat flour in products typically made with refined wheat flour.

US2006/0073258A1 describes an ultrafine milled whole-grain wheat flour where not less than 98% of the flour passes through a cloth having an opening not larger
5 than those of woven wire cloth designated 212 mm. Such whole-grain wheat flour is obtained from an ultrafine milled coarse fraction prepared by a dry-milling process (gap milling) of the coarse fraction of the grain (germ and bran).

US 4500558 and US 4710386 (Fulger Charles V) describe extrusion of cereal bran (corn) in water in a respective weight ratios of from 5.5:1 to 10:1 (optimum ratio
10 stated as 7:1) followed by a grinding step in which the bran is ground to a particle size of below 80 µm and then reconstituted with the other parts of the grain (themselves modified) prior to being processed as a ready to eat (RTE) cereal. These documents do not suggest other methods to reduce particle size (such as wet-ball milling and/or high pressure homogenization).

15 WO 2010-000935 (Lehtomaeki Ilkka) describes dry milling of bran (oat / beta-glucan (BG)), separating the fractions and milling them further to produce a product having a particle size from 70 to 100 µm. The moisture content present during milling is from 13 to 16% by weight which indicates that this document is concerned with dry not wet milling.

20 CN 101906399 (Jiangsu Hill Country Zhenjiang Insitute of Agricultural Science) describes a process that uses a ball-mill to grind bran breaking its cellular walls and degrading the enzymes. This document does not indicate what the particle size of dietary fibre is after milling. The ball mill is rotated at a low speed of from 350 to 500 rpm. The patent also discloses the use of enzymes to degrade cellular
25 walls during milling at a temperature below 50°C.

WO 2008/040705 (Nestlé) describes co-extruded products comprising a filling and an outer shell.

Unfortunately, such solutions have not provided the desired level of expansion and crispy texture in extruded products based on the corresponding whole grain flour.

30 Additionally, particles having such small particle size prove to be particularly difficult to handle on an industrial scale as such particles tend not to flow easily when processed.

Therefore, it is an object of the invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative. In particular, it is desirable to provide a whole-grain extruded cereal product, with a density and expansion as close as possible to those of extruded cereal products based on refined
5 flour, while at the same time providing an increased content of fibres, preferably without significantly compromising the mouthfeel of the extruded cereal product, and thereby maintaining, or gaining, consumer preference. It is an additional object of the invention, to provide whole-grain extruded cereal product, which can be easily prepared in a manufacturing plant without issues associated with inadequate
10 flow of the masses in the plant.

SUMMARY OF THE INVENTION

It has been discovered by the inventors that subjecting the bran material to a wet-
15 mechanical treatment, the bran material is broken into smaller pieces, such as small sized particles. This wet-mechanical treatment of the bran material reduces the size of fibre particles in the wet-treated bran product from about 200 to 300 μm as obtained by conventional mechanical treatment of bran material to less than 160 μm as described in the present invention. Additionally, this wet-mechanical
20 treatment followed by a drying treatment leads to formation of wet-treated bran product having particles size lower than 1mm, preferably ranging between 200-500 μm . Without wishing to be bound by theory, the inventors believe that the size reduction obtained by wet-mechanical treatment improves the homogeneity of the dough containing a bran product. Thus, during extrusion, the air bubbles do not
25 collapse, which prevents an increase in density while maintaining expansion properties, resulting in an extruded whole-grain product with improved texture, especially improved crispness and mouth-feel.

Previously, bran products with reduced particle size have been provided by dry-mechanical treatment of the bran material. However, the use of such bran products doesn't result in adequate expansion properties for the dough and compromises the proper functioning of the extruded due to the fact that the powder doesn't flow
5 any more. The inventors have surprisingly found that by implementing a wet-mechanical treatment of the bran material it becomes possible to provide a bran product comprising fibre particles having an average particle size of less than 160 μm which does not, or substantially not, compromise the expansion properties of the product.

10 Accordingly, by using a wet-treated bran product comprising fibre particles with an average diameter of less than 160 μm obtained as described in the present invention, in the preparation of an extruded cereal product, an extruded cereal product can be provided that will have substantially uncompromised mouthfeel.

To this end, a first aspect of the invention relates to a process for preparing an
15 extruded cereal product as laid out in claim 1. More specifically, said process comprises the steps of:

- (i) providing a composition comprising a wet—treated bran product, which comprises fibre particles having an average particle size of less than 160 μm ,
- (ii) extruding said composition,
- 20 (iii) drying the extrudate.

In addition, a second aspect of the invention relates to an extruded cereal product, preferably as prepared according to the process described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Figure 1 shows the fibre particle size distribution of untreated bran reference (triangles), and wet-treated brans according to the present invention: extruded bran (diamonds), ball-milled bran (squares), high-pressure homogenized bran (circles),

stone-milled bran (crossed squares). Fibre particle size distribution was determined by light scattering techniques in water. See Examples 1 and 2.

Figure 2 shows the RVA (Rapid Visco Analyser) paste viscosity profiles of untreated bran reference (curve 1), and wet-treated brans according to the present invention: ball-milled bran (curve 2), high-pressure homogenized bran (curve 3) and stone-milled bran (curve 4), according to the RVA paste method. Curve T is the temperature profile as a function of time, used during the assay. See Example 3.

Figure 3 shows starch molecular size distribution of untreated bran reference (squares), high-pressure homogenized bran wet-treated according to the present invention (diamonds) and stone milled wet-treated bran according to the present invention (triangles). The peak around 20 ml elution volume corresponds to amylopectin, the smaller peak at around 37.5 ml elution volume corresponds to amylose, while the peak around 45 ml elution volume corresponds to small molecular sized carbohydrates. See Example 4.

Figure 4 shows the average diameter and Figure 5 shows the average bulk density, of extruded products based on different flours: refined wheat flour (A), whole wheat flour (B) and whole wheat flour reconstituted with bran wet-treated under high pressure homogenization (D). Two extrusion conditions were used [Condition 1 (Figure 4a, top) and Condition 2 (Figure 4b, bottom)]. See Example 5.

Figure 6 shows X-ray tomography pictures of products extruded under condition 1 or condition 2 and made with refined wheat flour (A), whole wheat flour (B), reconstituted whole wheat flour (C), whole wheat flour reconstituted with wet-treated bran under high pressure homogenization (D), or whole wheat flour reconstituted with bran wet-treated by extrusion (E). See Example 6.

Figure 7 shows the average diameter (Figure 7a), average bulk density (Figure 7b) and average porosity (Figure 7c) of extruded products under condition 1, and made with refined wheat flour (A), whole wheat flour (B), whole wheat flour reconstituted

with bran wet-treated by ball-milling (F), whole wheat flour reconstituted with bran wet-treated by jet-milling (G), or Conagra flour (H). See Example 7.

Figure 8 shows light microscopy pictures of extruded (condition 1) whole wheat (a, b), extruded reconstituted whole wheat containing wet-treated bran part by high
5 pressure homogenisation (c, d) and containing wet-treated bran part by extrusion (e, f).

DETAILED DESCRIPTION OF THE INVENTION

10 The inventors of the present invention have surprisingly found, that by providing an extruded cereal product wherein the extruded cereal product comprises a bran product which has been prepared by subjecting a bran material to a wet-mechanical treatment, the extruded cereal product comprise a high content of whole grain, while at the same time having a mouthfeel comparable to the mouthfeel of
15 conventional extruded cereal products comprising lower contents of whole grain. Accordingly, by subjecting the bran material to a wet-mechanical treatment, the bran material is broken into smaller pieces, such as small sized particles. This mechanical treatment of the bran material reduces the size of (its) fibre particles comprised in the wet-treated bran product from about 200-300 μm or more to less
20 than 160 μm as described in the process herein. Without wishing to be bound by theory, the inventors believe that the size reduction improves the homogeneity of a dough containing wet-treated bran product, and following reconstitution of the whole-grain flour product by mixing the wet-mechanical treated bran material with an endosperm material and/or a germ material, an extruded cereal product can be
25 provided, wherein during extrusion the air bubbles do not burst, which prevents density from increasing while maintaining expansion properties. This results in an extruded whole-grain cereal product with improved texture, especially improved crispness with an improved mouthfeel.

Thus, in an embodiment, the present invention relates to a process for preparing an extruded cereal product comprising whole grain, preferably without significantly compromising the mouthfeel of the extruded cereal product, said process comprising the steps of:

- 5 (i) preparing a wet-treated bran product comprising fibre particles, wherein said fibre particles have an average particle size of less than 160 μm , the process for preparing a bran product comprising the steps of: subjecting a bran material to a mechanical treatment, in the presence of a total water content of at least 16% by weight;;
- 10 (ii) mixing the bran product with a germ material and/or an endosperm material providing a reconstituted whole-grain flour product,
(iii) optionally adjusting the water content of the reconstituted whole-grain flour product, and
(iv) subjecting the reconstituted whole-grain flour product to an extrusion process
- 15 providing an extruded cereal product.

In another embodiment, the present invention relates to a process for preparing an extruded cereal product comprising bran, preferably without significantly compromising the mouthfeel of the extruded cereal product, said process comprising the steps of:

- 20 (i) preparing a wet-treated bran product comprising fibre particles, wherein said fibre particles have an average particle size of less than 160 μm , the process for preparing a bran product comprising the steps of: subjecting a bran material to a mechanical treatment, in the presence of a total water content of at least 16% by weight;;
- 25 (ii) optionally adjusting the water content of the reconstituted whole-grain flour product, and
(ii) subjecting the wet treated bran material optionally in the presence of other ingredients to an extrusion process providing an extruded cereal product.

The particle size of the wet-treated bran product also determines its flowability during transportation and extrusion. Wet-mechanical treatment of the bran material allows controlling its particle size after drying and maintaining good powder flowability and maintaining suitable pressure in the extruder. The optional
5 drying step which may follow the wet-mechanical treatment may be performed according to traditional techniques known to the person skilled in the art, for example spray drying, freeze-drying, or roller drying.

The wet-treated bran product according to the present invention may be used in subsequent extrusion processes in the liquid state as it comes out of the wet
10 mechanical treatment or after being subject to a drying step which form particles of dry wet treated bran product having a particle size lower than 1 mm.

The wet-mechanical treatment does not modify the total, soluble and insoluble dietary fibre content of the bran material. Bran and hence bran material as defined herein is a readily available low cost by-product that contains a high amount of
15 insoluble dietary fibre (40-50 % fibres). As its expansion properties is significantly improved by wet-mechanical treatment according to the present invention, bran material could be used as a dietary fibre carrier to enrich extruded products in fibres and replace the use of expensive soluble fibres such as inulin.

In one preferred embodiment of the present invention, the wet treated bran
20 product may be used to reconstitute a whole grain flour. In another embodiment of the present invention, the wet treated bran product may be used as an ingredient of a composition in extrusion applications.

In the present context, the term "extruded cereal product" identifies an extruded product which is based on cereal flour.

25 In the present context, the term "extruded whole grain cereal product" identifies an extruded product which is based on whole grain cereal flour.

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A “bran material” is to be understood as any material comprising or consisting of bran prior to treating said material as described herein by mechanical treatment.

5 Bran originates from whole grains, which are a recognised source of dietary fibres, phytonutrients, antioxidants, vitamins and minerals. The entire grain seed comprises the germ, the endosperm and the bran.

“Wet-treated bran product” or “wet-mechanical treated bran product” shall be considered equivalent expressions, referring to bran material that has undergone a
10 mechanical treatment in the presence of humidity, according to the invention.

“Wet-treated flour” refers to flour reconstituted with wet-treated bran material. Preferably, all the bran in the wet-treated flour is wet-treated bran material, although in some applications, it may be enough to use a mix of wet-treated bran material and non wet-treated bran material in various proportions. Preferably, at
15 least 50% by weight of the bran material is wet-treated bran material. Preferably, the wet-treated flour is whole-grain flour, meaning that it contains endosperm, germ and wet-treated bran, all preferably from the same cereal, in the same proportions as naturally found in that cereal.

In the present context, a “bran product” is to be understood as a a product
20 comprising bran, specifically comprising bran material previously subjected to mechanical treatment as described herein.

The bran, bran material or wet-treated bran product describe in the present invention originates from whole grains from the monocotyledonous plants of the Poaceae family (grass family) cultivated for their edible, starchy grains. Examples of
25 whole-grain cereals include barley, rice, black rice, brown rice, wild rice, buckwheat, bulgur, corn, millet, oat, sorghum, spelt, triticale, rye, wheat, wheat berries, teff, canary grass, Job’s tears and fonio. Plant species that do not belong to the grass family also produce starchy seeds or fruits that may be used in the same way as

cereal grains, are called pseudo-cereals. Examples of pseudo-cereals include amaranth, buckwheat, tartar buckwheat and quinoa. When designating cereals, this will include both cereal and pseudo-cereals.

Thus, the bran, bran material or wet-treated bran product described in the present
5 invention may originate from a whole-grain cereal or a pseudo-cereal. Thus, in an embodiment the bran, bran material or wet-treated bran product is obtained from the whole grain from a plant selected from the group consisting of barley, rice, brown rice, wild rice, black rice, buckwheat, bulgur, corn, millet, oat, sorghum, spelt, triticale, rye, wheat, wheat berries, teff, canary grass, Job's tears, fonio, amaranth,
10 buckwheat, tartar buckwheat, quinoa, other variety of cereals and pseudo-cereals and mixtures thereof. In general the source of grain depends on the product type, since each grain will provide its own taste profile.

In one embodiment of the present invention, the bran, bran material or wet-treated bran product originates from whole grains from corn, rice, barley or wheat. In a
15 certain embodiment of the present invention, the bran, bran material or wet-treated bran product originates from whole grains from wheat.

The wet-treated bran product as described in the present invention comprises, among other components, fibres, starch (carbohydrate), proteins and fat. The amount of the individual components varies according to the source of the whole
20 grain from which the bran originates, as well the refining process of the bran. Thus, in one embodiment, when the bran as described in the present invention originates from whole grains from wheat, the content of the individual components are generally as follows: Fibres 30-70% (w/w), starch 20-50% (w/w), proteins 5-20% (w/w), fat 0.5-10% (w/w). In another embodiment of the present invention, the
25 content of the individual components in the wheat bran are generally as follows: Fibres 20-50% (w/w), starch 30-40% (w/w), proteins 10-15% (w/w), fat 1-5% (w/w). In the context of the present invention the terms "%" and "% (w/w)" relate to weight percentage on a dry matter basis, unless otherwise stated.

As mentioned above, the wet-treated bran product of the present invention contains fibres. The bran obtained from the whole grains may comprise from about 40-50 % to 80-90% of the dietary fibres present in the whole grains. Refined flour contains mainly endosperm . Usually, whole-grain flour is reconstituted by mixing
5 the appropriate amounts (i.e.: the same weight ratios as in seeds) of refined flour, germ and milled bran. However, when extruding a dough which only contains whole-grain flour (natural or reconstituted) as cereal base, the extruded product has a much higher density and expands less than a dough which only contains refined flour as cereal base.

10 Reconstitution of the whole-grain flour product by mixing the wet-mechanical treated bran product with a germ material and/or an endosperm material may according to the invention be carried out under conditions wherein the germ material and/or the endosperm material has been subjected to further treatment before mixing with said wet-treated bran product. Thus, in an embodiment of the
15 present invention the endosperm may be subjected to further treatment, preferably selected from milling, cooling and/or enzymatic hydrolysis, before being mixed with the wet-treated bran product. In the present context “milling” is to be understood as any milling process used to reduce the size of the material being milled. The milling process may be a wet-milling process and/or a dry-milling process.

20 In the present context “enzymatic hydrolysis” refers to the use of hydrolytic enzymes in treatment of the material in order to breakdown the polysaccharide structure and/or the protein structure of the material. Proteases are enzymes capable of catalyzing the hydrolysis of proteins into smaller peptides or amino acids. They may be used to decrease the viscosity of the endosperm material. Alcalase 2.4L
25 (EC 3.4.21.62) from Novozymes is an example of a suitable enzyme according to the invention. Saccharidases are a class of enzymes that catalyze the hydrolysis of polysaccharides into smaller polysaccharides or carbohydrates. Amylase (EC 3.2.1.1) is an exemplary saccharidase that catalyzes the hydrolytic breakdown of starch into

smaller units (smaller polysaccharides and/or carbohydrates) which results in a decrease in the viscosity of the hydrolyzed endosperm material. In general it is to be understood that the enzymes used in the production of the hydrolyzed endosperm material (and therefore also present in the final product) are different
5 from the corresponding enzymes naturally present in the whole-grain component.

It is within the scope of the present invention that the further treatment of the endosperm material, preferably selected from coarse milling, cooling and/or enzymatic hydrolysis, may comprise more than one step, and these steps may be carried out in any order, such as coarse milling followed by enzymatic hydrolysis, or
10 coarse milling followed by cooling followed by enzymatic hydrolysis, etc.

As stated above, the germ material may likewise be subjected to treatment before mixing with the wet-treated bran product of the invention. Hence, the germ may be subjected to further treatment like toasting and/or mechanical before being mixed with the wet-treated bran product.

15 The term "toasting" may refer to any kind of toasting process known to the person skilled in the art, such as a toasting process carried out in an oven, a toasting process carried out over open fire, and/or a toasting process carried out on a stove or a stove device.

In the present context the term "particle size" is preferably used interchangeable
20 with the term "average particle size" and refers to the average diameter of the particles and determined as $D[4, 3]$. Thus, in the present context the particle size stated as μm , e.g. $140 \mu\text{m}$, means an average particle size of e.g. $140 \mu\text{m}$ determined as $D[4, 3]$. The particle size $[D4, 3]$ represents the mean volume diameter of the particles obtained by laser diffraction method.

25 The size reduction according to the present invention results in an improved homogeneity of the dough with physical properties that prevents the air bubbles present in the dough to collapse during extrusion, resulting in an extruded whole

grain product with a low density, comparable to the density of the refined flour-based extruded cereal products.

The wet-treated bran product as described in the present invention, obtained by wet-mechanical treatment, comprises fibre particles having an average particle size
5 of less than 180 μm , preferably of less than 150 μm , preferably of less than 140 μm , such as less than 125 μm , e.g. less than 100 μm , such as less than 75 μm , e.g. less than 60 μm , such as less than 50 μm , e.g. less than 40 μm . Typically, such fibre particles may have an average particle size of at least 1 μm , preferably at least 2, 3 or 4 μm , preferably at least 5 μm . Typically, such fibre particles have an average
10 particle size of between 5 μm and 180 μm , preferably of between 5 μm and 140 μm , preferably of between 5 μm and 140 μm , such as between 5 μm and 125 μm , such as between 5 μm and 100 μm , such as between 5 μm and 75 μm , such as between 5 μm and 60 μm , between 5 μm and 50 μm or between 5 μm and 40 μm .

In wet-treated bran product described in the present invention, the majority of the
15 fibre particles are preferably relatively homogenous in size. This means that the particle size distribution of the majority of the fibre particles is relatively narrow, such as between 5 μm and 200 μm , such as between 10 μm and 175 μm , e.g. between 15 μm and 150 μm , such as between 20 μm and 140 μm e.g. between 30 μm and 130 μm , such as between 40 μm and 120 μm , e.g. between 70 μm and 100
20 μm , for example between 20 μm and 70 μm , such as between 25 μm and 60 μm , e.g. between 30 μm and 50 μm , such as between 35 μm and 40 μm .

According to the present invention, the majority of the fibre particles preferably constitutes at least 75% of the total fibre particles, such as at least 85%, e.g. at least 90%, such as at least 95%, e.g. at least 99% of the total fibre particles.

25 The wet-treated bran product as described in present invention is produced by exposing the bran material to a wet-mechanical treatment which is described in detail in the Examples herein below. These processes have a remarkably and surprising effect of size reduction of the fibre particles of the wet-treated bran

product of the invention. However, the wet-mechanical treatment also has effect on other components present in the bran, including the carbohydrates, the proteins and the fat (lipids). The main carbohydrate component in the bran is starch, a polysaccharide comprised of amylopectin and amylose. In addition to the size
5 reducing effect of the fibre particles, wet-mechanical treatment of the bran material of the present invention also have effect on the molecular size distribution of the carbohydrates compared to the untreated, unprocessed bran. Hence, the wet-mechanical treatment of the bran material as described in the present invention has a depolymerizing effect on amylopectin, wherein the amylopectin are hydrolyzed to
10 smaller molecular sized polysaccharides.

Thus the wet-treated bran product as described in the present invention, in particular originating from wheat bran material, presents a normalised content of amylopectin is below 9 and/or and a normalised content of small molecular size carbohydrates is at least 4.

15 In the present context “normalised” refers to the division of multiple sets of data by a common variable in order to negate that variable's effect on the data, thus allowing underlying characteristics of the data sets to be compared. This allows data on different scales to be compared, by bringing them to a common scale.

The normalised content of amylopectin in the wet-treated bran product, in
20 particular originating from wheat bran material, of the present invention, may in an embodiment be below 7, e.g. below 5, e.g. below 3, such as below 2.

The normalised content of small molecular sized carbohydrates in the wet-treated bran product, in particular originating from wheat bran material, of the present invention, may in an embodiment be at least 5, e.g. at least 7, e.g. as at least 9.

25 The above listed content of amylopectin and small molecular size carbohydrates relate to an embodiment of the present invention, wherein the bran originates from wheat. However, in another embodiment, the bran material may originate from

other sources, e.g. corn, rice or barley, and therefore the content of amylopectin and small sized carbohydrates may differ from the above listed values.

In an embodiment, the normalised content of small molecular sized carbohydrates in the wet-treated bran product as described in the present invention is higher than
5 the normalised content of amylopectin. Preferably, the normalised content of small molecular sized carbohydrates is at least 10% higher than the normalised content of amylopectin in the wet-treated bran product, such as at least 20% higher, e.g. at least 40% higher, such as at least 60% higher, e.g. at least 80% higher, such as at least 100% higher, e.g. at least 150% higher, such as at least 200% higher, e.g. at
10 least 250% higher.

The wet-mechanical treatment of the bran material, in particular wheat bran, as described in the present invention also have a markedly effect on the pasting profile of the wet-treated bran product, compared to a reference bran which has not been subjected to wet-mechanical treatment. The pasting profiles of the wet-treated
15 bran product, in particular originating from wheat bran material, according to the RVA paste method described in the Examples herein below, thus results in a decreased paste viscosity of the wet-treated bran material compared to a reference bran material that has not been wet-treated.

Hence, for the wet-treated bran product as described in the present invention, in
20 particular wheat bran, the viscosity is at most 70 cP, e.g. at most 60 cP, such as at most 50 cP, e.g. at most 50 cP within the period from 175 seconds to 750 seconds, such as from 300 to 450 seconds, e.g. from 175 seconds to 300 seconds when measured according to the RVA paste method.

The above listed values for viscosity of a wet-treated bran product relate to the case
25 wherein the bran material originates from wheat. However, the bran material may originate from other sources, e.g. corn, rice or barley, and therefore the values for viscosity may differ from the above listed values.

In the wet-treated bran product as described in the present invention, although subjected to wet-mechanical treatment with e.g. heat, pressure, water and shear, the total dietary fibre (soluble fibres and insoluble fibres) content of the wet-mechanical treated bran material is not modified or affected, as compared to the
5 content of total dietary fibre in bran material that has not been wet-mechanical treated. Likewise, the solubility, of the dietary fibres of the wet-mechanical treated bran material, is not modified or affected, as compared to the solubility of the dietary fibre in bran material that has not been wet-mechanical treated.

In the present context the terms “wet-mechanical treatment” or simply “wet-
10 treated” is to be understood as the process of the present invention used for providing the wet treated/wet-mechanical treated bran material and hence the extruded whole grain product according to the present invention. Hence “wet-mechanical treatment” according to the invention is synonymous with “wet-treatment” or “wet-process”.

15 In the present context the phrases “wet-mechanical treatment” or “wet-mechanical process” is to be understood as a treatment or process wherein the bran is broken into smaller pieces in the presence of water. In an embodiment of the present invention water may be added to the bran material providing a wet bran material having a water content of at least 16% (w/w), for example at least 20% (w/w), such
20 as at least 25% (w/w), for example at least 35% (w/w), e.g. at least 50% (w/w), such as at least 75% (w/w). Typically, the water may be added to the bran material providing a water content of between 16% (w/w) and 95% (w/w), for example between 20% (w/w) and 95% (w/w), between 25% (w/w) and 95% (w/w), between 35% (w/w) and 95% (w/w), such as between 50% (w/w) and 95% (w/w), or between
25 75% (w/w) and 95% (w/w).

The present invention also pertains to a process for preparing a wet-treated bran product comprising fibre particles, wherein said fibre particles have an average particle size of less than 160 μm , preferably less than 140 μm , more preferably less

than 140 μm , wherein the process comprises the steps of: subjecting the wet bran material to a wet-mechanical treatment in the presence of a total water content of at least 16% by weight. The term “mechanical treatment” is to be understood as a treatment or process wherein the substance subjected to the treatment or process
5 is broken into smaller pieces.

In the present context the phrases “dry mechanical treatment” or “dry mechanical process” pertains to a mechanical treatment or mechanical process, wherein the water content is relatively low. Hence, the water content in a dry mechanical process may be less than 16% (w/w), such as less than 12% (w/w), e.g. less than 10%
10 (w/w), such as less than 5% (w/w). The dry mechanical treatment may also relate to a mechanical process that is free of water, or substantially free of water.

In an embodiment of the present invention the bran material is obtained from a whole grain, said whole grain being subjected to a dry mechanical process followed by a separation process resulting in a bran material, a germ material and an
15 endosperm material.

Preferably, the bran material may subsequently be used in the process according to the present invention.

In an embodiment of the present invention, the wet-mechanical treatment is a wet-ball milling process. In the present context the phrase “wet-ball milling” is to be
20 understood as a process wherein the bran material is subjected to milling, comprising water and beads between 0.1-5 mm in diameter, e.g. between 0.3-3 mm, for example between 0.5-2 mm, e.g. between 0.6-1.5 mm, such as 0.7-1.2 mm in diameter, e.g. between 0.8-1.0 mm in diameter. In an embodiment of the present invention the bran material, the water and the beads are subjected to wet-ball
25 milling at a speed of at least at 1,000 rpm, e.g. at least at 2,000 rpm, e.g. at least at 3,000 rpm, for example at least at 4,000 rpm, e.g. at least at 5,000 rpm, such as at least at 6,000 rpm, e.g. at least at 7,000 rpm, such as at least at 7,500 rpm, e.g. at least at 8,000 rpm, such as at least at 9,000 rpm, or at least at 10,000 rpm, e.g. in a

range of between 1,000 rpm to 15,000 rpm, between 2,000 rpm to 15,000 rpm, between 3,000 rpm to 15,000 rpm, between 4,000 rpm to 15,000 rpm, between 5,000 rpm to 15,000 rpm, between 6,000 rpm to 15,000 rpm, between 7,000 rpm to 15,000 rpm, between 8,000 rpm to 15,000 rpm, between 9,000 rpm to 15,000 rpm, or between 10,000 rpm to 15,000 rpm.

The wet-ball milling process according to the invention may be accompanied by the addition of heat to the process. Performing the wet-ball milling process at relatively high temperatures add to the efficiency of the mechanical treatment, resulting in increased amounts of the small sized fibre particles described herein above. Hence, the wet-ball milling may performed at temperatures between 20-100 °C, e.g. at least at 25 °C, such as at least at 40 °C, for example at least at 50 °C, e.g. at least at 75 °C, such as at least at 80 °C, e.g. at least at 90 °C, such as e.g. between 25 °C to 100°, between 40 °C and 100°C, between 50 °C and 100°C, between 75 °C and 100°C, between 80 °C and 100°C, or between 90 °C and 100 °C. The wet-ball milling may be performed at such a temperature during the entire wet-ball milling process or part thereof. As an example, the temperature during the wet-ball milling process may be increased from a(ny) starting temperature, e.g. an ambient temperature, such as about 20 to 25°C, to the above defined temperature of between 20-100 °C, etc., preferably at any point during the entire process of wet-ball milling. Such increase may thus at the beginning, at the end or at any point between beginning and end of the process. Alternatively, the temperature may be kept at a constant temperature throughout the entire wet-ball milling process, wherein the temperature is preferably in a region or range as defined above of between 20-100 °C, etc.

Further, the wet-ball milling process according to the invention may in one embodiment be performed for a prolonged time, such as up to 24 hours, e.g. up to 20 hours, for example up to 15 hours, such as up to 10, e.g. up to 5 hours. In a preferred embodiment the wet-ball milling process according to the invention may be performed for up to 4 hours.

It is also within the scope of the present invention that the wet-ball milling may be performed at reduced pressure, compared to normal atmospheric pressure, for example in the range of 0.2-0.9 bar, e.g. in the range of 0.3-0.8 bar, such as in the range of 0.4-0.7 bar.

- 5 In a further embodiment of the present invention, the wet-mechanical treatment is a wet corundum stone milling process. In the present context the phrase “wet corundum stone milling process” pertains to a treatment or process, wherein the bran material and water are subjected to milling between two stones. In an embodiment the distance between the two stones is in the range of 0-2 mm, such
10 as in the range of 0-1 mm, e.g. in the range of 0-0.5 mm, for example in the range of 0-0.25 mm such as in the range of 0-0.1 mm.

In an embodiment of the present invention, the wet-mechanical treatment may be a homogenisation process. Preferably the homogenisation process is a wet ultra-high pressure homogenisation process, comprising appliance of high pressure in the
15 homogenisation of bran material in aqueous solution, wherein the pressure is 500 bars or above, such as 600 bars or above, e.g. 750 bars or above, such as 1000 bars or above, e.g. 1200 bars or above. The wet high pressure homogenisation process may be repeated and thereby adding to the efficiency of the wet-mechanical process, resulting in increased amounts of the small sized fibre particles as
20 described herein above. Thus, it is within the scope of the invention that the high pressure homogenisation process may be repeated several times, such as at least 2 times, e.g. at least 3 times, such as at least 4 times, e.g. at least 5 times. It is also within the scope of the invention that the high pressure homogenisation process may comprise recirculation of the bran material in the homogenisation process for
25 up to 4 hours, such as up 2 hours, e.g. up to 1 hour, for example up to 30 minutes. Further, it is within the scope of the present invention, that the homogenisation process may comprise the addition of heat. However, owing to the nature of the

homogenisation process, comprising mechanical shear, heat may be automatically induced during the process.

The wet-mechanical treatment of the present invention comprises in a preferred embodiment a milling process and/or a homogenisation process.

- 5 It is also within the scope of the present invention that heat and/or shear and/or pressure may be used in the wet-mechanical process. Further, it is within the scope of the present invention that the wet-mechanical process involves a shear stress on the bran material. In another embodiment according to the second aspect of the invention, the wet-mechanical process may preferably not involve the use of
- 10 enzymatic hydrolysis of the fibres. In a further embodiment according to the second aspect of the invention, the process may comprise addition of enzymes after the wet-mechanical process. However, in a certain embodiment according to the second aspect of the invention, the wet-mechanical treatment does not involve the initial use of any enzymatic hydrolysis of the fibres.
- 15 The process or treatment according to the present invention may be used to prepare the wet-treated bran product as described herein.

In an embodiment the extruded whole grain product according to the present invention, is a product such as extruded snacks, breakfast cereals and baked dough

20 products, comprising the wet-treated bran product as described in the present invention. According to the invention, the baked dough products may comprise crackers, crisp bread, biscuits and the like. In a certain embodiment of the invention, the baked dough products comprise biscuits.

Normally, when increasing the amount of whole grain in cereal products to above

25 approximately 6-8 g per serving, the density of the extruded product will increase, resulting in a product with less crispness and crunchiness, and hence a product with a lesser good mouthfeel. However, much surprisingly, the inventors of the present invention found that by applying the process for preparing an extruded cereal

product as described herein above, a high-content whole-grain flour cereal product could be provided, without compromising the mouthfeel of the product.

Thus, the present invention also pertains to an extruded cereal product comprising a reconstituted whole-grain flour product wherein the extruded cereal product has
5 a whole-grain content of at least 4 g per serving. The extruded cereal product is preferably prepared by a process as described herein above and can be defined as described above or in the further below. In an embodiment of the invention the extruded cereal product has a whole-grain content of at least 6 g per serving, 8 g per serving, 10 g per serving, e.g. at least 12 g per serving, such as at least 14 g per
10 serving, e.g. at least 16 g per serving, without compromising the density, crispness, crunchiness, and hence the mouthfeel of the product.

In the present context the term “serving” is used to describe the serving size or portion size of the cereal product of the present invention. In an embodiment, the serving size is in the range of 5-50 g, such as 10-45 g, for example 15-40 g, e.g. 20-
15 35 g, such as 25-30 g. In a preferred embodiment of the present invention, the serving size is 30 g.

The mouthfeel of extruded cereal products are closely related to the crispness and crunchiness of the product, properties which again are related to the fracturability of the product. In the present context fracturability is to be understood as the force
20 applied to cause a food sample to break or fracture. Therefore, since the extruded cereal product of the invention comprising an increased amount of whole grain has density properties that do not compromise crispness and/or crunchiness, the present invention relates in an embodiment to an extruded cereal product, wherein the fracturability of the product results close to that of the corresponding product
25 comprising refined flour.

The extruded cereal product of the present invention comprises wet-mechanical treated bran material as described in the process of the invention, said bran material comprising fibre particles wherein at least 90% of the particles have an average

particle size of less than 160 μm , preferably less than 150 μm , more preferably less than 140 μm , or even less as described above. However, the reconstituted whole-grain flour product of the invention may comprise other components, such as germ and endosperm which also comprise fibre particles, wherein less than 90% of the (entire) fibre particles have an average size of 140 μm . Accordingly, the present invention relates to an extruded cereal product wherein at least 50% of the (entire) fibre particles in the extruded cereal product have a particle size of less than 140 μm . In an embodiment of the invention, the extruded cereal product comprises fibre particles wherein at least 60% of the particles, for example at least 70% of the particles, such as 80 % of the particles present in the product have an average particle size of less than 140 μm .

The extruded cereal product may comprise both wet-treated bran, as well as the bran that has not been wet-treated, and therefore the content of the small sized fibre particles described herein above in the cereal product may be variable. Accordingly, the present invention relates to an extruded cereal product wherein at least 50 % of the (entire) fibre particles in the product have a particle size of less than 150 μm , preferably less than 140 μm , such as at least 60% of the particles, for example at least 75% of the fibre particles present in the product has a particle size of less than 140 μm .

The extruded cereal product according to the invention may further comprise a pasty filling. Pasty fillings may be chosen among any suitable filling, including but not limited to fat based fillings, fruit based fillings, chocolate cream, jam, peanut butter, caramel cream or any other fat pasty filling. In an embodiment, the pasty filling is chocolate cream.

Hence, the extruded cereal product according to the invention may be a confectionary product, a breakfast product, such as a breakfast cereal, a baked dough product, preferably comprising biscuits, or a pet food.

Snacks and confectionary cereal products comprising the extruded cereal product of the invention may for example comprise pillows which are extruded cereal shells filled with a pasty filling, such as chocolate filling, as mentioned above.

It should be noted that embodiments and features described in the context of one of the aspects or embodiments of the present invention also apply to the other aspects or embodiments of the invention.

Experimental Section

10 Particle size analysis

The average particle size [D_{4, 3}] represents the mean volume diameter of the particles obtained by laser diffraction method using a Malvern optical instrument (Mastersizer 2000, Malvern, Herrenberg, Germany) equipped with MS 15 Sample Presentation Unit (Refractive Index 1.590) and water as dispersing agent for the particles. Distributions were made in duplicate for each sample, using 1 g in an aqueous suspension. Size distribution was quantified as the relative volume of particles in size bands presented as size distribution curves (Malvern MasterSizer Micro software v 5.40). Particle size distribution parameters recorded included largest particle size D[v,90], mean particle volume D[v,50] and mean particle diameter (D[4, 3]). D[v,90] represents the volume value below which 90% of the volume distribution is. D[v,50] represents the volume value below which 50% of the volume distribution is.

25 Pasting profile analysis

Rapid Visco analysis. Pasting profiles of extruded samples were evaluated using a Rapid Visco Analyzer (RVA-4, Newport Scientific, Jessup, Maryland). The ground extruded sample (< 250 µm, 20 % by weight d.m. 0.1 M AgNO₃) was left 15 min prior measurement to allow hydration of the solid material. The sample was hold 1min at

50 °C, heated to 95 °C at 11 K min⁻¹, held at 95 °C for 3 min and cooled to 50 °C at 6.5 K min⁻¹ under stirring at 160 rpm. The viscosity (η) and corresponding time was recorded using the Thermocline software (v. 2.2, Newport Scientific, Jessup, Maryland). Measurements were duplicated.

5

Determination of the internal structure of the products by microcomputed X-ray tomography and 3D image analysis

The samples were scanned using a high resolution desktop cone beam X-ray micro-
10 CT system (Scanco μ CT 35, Scanco Medical AG, Brütisellen, Switzerland), which consists of a micro-focused sealed X-ray tube operating at a voltage of 55 kV and current of 145 μ A. X-ray shadow images were acquired every 0.18° views through 360 ° of rotation. In order to get a high signal to noise ratio, the signal measured during an integration time of 300 ms, was averaged 8 times. The reconstruction
15 used a Shepp & Logan filtered back-projection extended to a cone-beam geometry. The minimum voxel size, which also corresponds to the resolution of the instrument, was 3.5 μ m. A voxel size of 6 μ m was selected in order to capture the thin cell walls while scanning statistically a significant part of each sample in a reasonable time. 3D image analyses were performed OpenVMS. For each extruded pellet, an automatic
20 wrapping was applied to select a volume of interest (VOI) delimited by its external surface. This VOI was then segmented (without either filtering or smoothing) and the porosity of the pellet calculated as the ratio of the volume of the cells to the VOI. The cell size and cell wall thickness distributions were calculated using the method developed by **Hildebrand and Rüegsegger (1997)**.

25

Examples

Example 1 – Bran wet-treatment methods**Bran extrusion**

Bran extrusion was performed modulating screw speed and feed moisture content (15 and 30%) (Clextral EV 25, 10 kg/h feed rate, screw length to diameter ratio; L/D =20, temperature profile of barrel sections: room temperature, 60 °C, 80 °C, 120 °C and 160°C, 1mm gap.

Wet-ball milling

Lab-scale wet-ball milling (90 AHM, Hosokawa-Alpine, Germany) was applied on wheat bran (10 % solids in water, 2500 rpm, 80 °C and 70 % beads volume). The samples were first treated with a colloidal mill (IKA-Werke, Germany) for 25 min at 7500 rpm. Beads of 0.8-1 mm diameters were used. Samples were taken up at different treatment durations.

15 Ultra high pressure homogenisation

Ultra high pressure homogenisation (Niro Soavi, GEA Messo, Switzerland) was applied to wheat bran in aqueous solution (Bran Fine, 16% solids, 1200 bars, 3 runs).

Corundum stone milling

A Frima-Koruma MK160 corundum stone mill was used to treat wheat bran in water solution (Bran Fine, 16% solids). The gap between the two stones was reduced to 0 mm and 15 kg of feed were introduced from above using gravity. The mill was heated with water circulation to 90-95 °C to reach about 80-85 °C at the exit. The bran was treated for 1 hr., corresponding to about 10-15 cycles (feed rate varies during treatment due to the change in viscosity).

25 The resulting particle sizes of fiber particles obtained from treating the bran by different methods are summarised in table 1. The bran reference is a wet-treated bran product mechanically treated under conventional methods.

Table 1: Summary table

μm	Bran ref	Extruded	Ball milled	High pressure homogenization	Stone Milled
D[4,3]	224 $\pm$ 6	148 $\pm$ 0.8	46.4 $\pm$ 0.2	47 $\pm$ 1	76
D[v,50]	302 $\pm$ 12	108 $\pm$ 2	34.0 $\pm$ 0.5	39 $\pm$ 1	61
D[v,90]	593 $\pm$ 5	345 $\pm$ 2	101.2 $\pm$ 0.5	91 $\pm$ 3	155

Example 2 – Bran wet-treatment effect on particle size

Among the four tested wet-treatment technologies, the wet-ball milling and high
 5 pressure homogenisation (1200 bars, 3 runs) gave the lowest fibre particle size,
 while extrusion was less efficient (Figure 1). Nevertheless, the distribution with
 homogenisation was more homogeneous.

Example 3 – Bran wet-treatment effect on viscosity according to the RVA paste

10 method

Pasting profiles of extruded samples were evaluated using a Rapid Visco Analyzer
 (RVA-4, Newport Scientific, Jessup, Maryland). The samples (20 % by weight d.m.
 0.1 M AgNO₃) was left 15 min prior measurement to allow hydration of the solid
 material. The sample was hold 1min at 50 °C, heated to 95 °C at 11 K/min, held at
 15 95 °C for 3 min and cooled to 50 °C at 6.5 K/min under stirring at 160 rpm. The
 viscosity (η) and corresponding time was recorded using the Thermocline software
 (v. 2.2, Newport Scientific, Jessup, Maryland). Measurements were duplicated
 The pasting profile of the wet-treated bran varied according to the treatment
 (Figure 2). This could be seen on the “setback from trough”, viscosity difference
 20 between the plateau reached at about 500 s and the final viscosity at around 750 s.
 This corresponds to the formation of a gel during cooling, which is likely mainly
 coming from starch and would be strong in the case of high molecular weight starch
 molecules than lower ones. Ball milling and stone milling showed similar pasting

profiles. The high pressure homogenised bran showed a higher pasting viscosity than the other samples and a peak at about 300 s that could be some remaining granular starch structures. This difference between high pressure homogenisation and the other wet-treatments may come from the lower temperature used (below
5 the starch gelatinization temperature) compared to the other wet-treatments.

Example 4 – Bran wet-treatment effect on starch depolymerisation

Starch molecular size distribution was obtained by gel permeation chromatography. Approximately 200 mg of sample were hydrated in 1 ml of deionizer water for 15
10 min and then 10 ml of dimethylsulfoxide was added. The sample was heated in a boiling water bath for 15 min and then left overnight at room temperature ($22\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$) with continuous stirring. Samples were then reheated in a boiling water bath for 15 min and after cooling, centrifuged at 12'000 g for 15 min and filtered on a 0.45 μm filter. The sample (200 μl) was injected and eluted through two HR 10/30
15 columns packed with Sephacryl S1000 connected in series with degassed 0.01 M aqueous NaOH at a flow rate of 10 ml/h, using a precision pump Pharmacia P-500. Samples were collected and the content of sugar measured with the phenol-sulfuric acid method (Dubois, Gilles, Hamilton, Rebers & Smith, 1956). The void volume and total elution volume were obtained by injecting waxy wheat starch (Sigma, S9679)
20 and glucose (Sigma, 49139), respectively.

The wet-treatment of the bran significantly modified the molecular size distribution of the unprocessed bran (Figure 3). It appears that ball milling strongly depolymerized amylopectin, generating lower molecular size polymers. The stone milling also affects amylopectin but to a lower extent.

25

Example 5 – Bran wet-treatment effect on the expansion and density of whole grain

Extrusion

Extrusion experiments were performed with an Evolum 25 extruder (Cletral, Firminy, France). Two conditions were used:

Condition 1 (120 °C, 18 % total water content in the feed and 400 rpm)

5 Condition 2 (180 °C, 22 % total water content in the feed and 800 rpm).

The reconstituted whole-grain flours with wet-mechanical treated bran using High Pressure Homogeniser were compared to the extruded refined wheat and whole wheat flour at two different extrusion conditions (a, condition 1 and b, condition 2).

The determination of the relative density (D) was based on the definition given by

10 Alvarez-Martinez et al. (1988):

$$D = \frac{\rho^*(1 - MC^*)}{\rho_s(1 - MC_s)}$$

where ρ and MC are the density and the moisture content (fraction on total wet basis) and (*) and (s) refer to the extrudate and material, respectively. The raw material density, used to estimate the melt density and the cell wall material density

15 (ρ_s) was measured by helium pycnometry (10 replicates, Accupyc 1330, Micrometrics, Verneuil en Halatte, France). The extrudate bulk density (ρ_e) was measured by beads displacement by repeating the measurement three times on 5 pieces and the average was taken. The porosity is given by $(1-D) \times 100$. The sample diameter was measured with a caliper (average of 10 points).

20

Effect on expansion

Wet-treatment of bran significantly improved expansion of corresponding extruded whole grain cereal product.

In terms of average diameter, at condition 1, extruded cereal product obtained from

25 refined wheat flour (A) showed 11.9 mm, extruded cereal product obtained from whole wheat flour (B) showed 7.7 mm and extruded cereal product obtained from

reconstituted whole grain wheat flour with treated bran according to the invention (D) showed 9.4 mm (Fig 4a).

At condition 2, extruded cereal product obtained from refined wheat flour (A) showed 4.3 mm, extruded cereal product obtained from whole wheat flour (B) showed 3.9 mm and extruded cereal product obtained from reconstituted whole grain wheat flour with treated bran according to the invention (D) showed 6.5 mm (Fig 4b).

Effect on density

10 Wet-treatment of bran significantly lowers the density of corresponding extruded whole grain cereal product.

In terms of bulk density, at condition 1, extruded cereal product obtained from refined wheat flour (A) showed 119 g/l, extruded cereal product obtained from whole wheat flour (B) showed 160 g/l and extruded cereal product obtained from reconstituted whole grain wheat flour with treated bran according to the invention (D) showed 170 g/l (Fig 5a).

At condition 2, extruded cereal product obtained from refined wheat flour (A) showed 380 g/l, extruded cereal product obtained from whole wheat flour (B) showed 470 g/l and extruded cereal product obtained from reconstituted whole grain wheat flour with treated bran according to the invention (D) showed 305 g/l (Fig 5b).

Example 6 - Cellular structure visualized by X-ray tomography

The cellular structure of the extruded samples at condition 1 and 2 are displayed in Figure 6. The mean cell size (MCS), mean cell wall thickness (MCWT) and cell density (Nc) are displayed in Table 6 and 7. Condition 2 led to a higher density of smaller cells compared to condition 1. The reconstituted whole-grain flour properties were close to the ones of the non-reconstituted one. The wet-treatment of the bran part

of the reconstituted whole grain, either by high pressure homogenization or by extrusion, increased the cell size and decreased the cell density compared to the untreated reconstituted whole grain (Table 2 and 3).

5 Table 2: Cellular structure properties of extruded samples at condition 1

Sample	MCS [μm]	MCWT [μm]	Cell density [cm^{-3}]
Refined flour	1948 ± 254	92 ± 7	29 ± 2
Whole wheat flour	852 ± 92	78 ± 1	319 ± 73
Reconstituted whole wheat flour	1016 ± 91	97 ± 2	268 ± 31
Reconstituted whole wheat flour with high press. Homog. Bran	1378 ± 97	131 ± 0	117 ± 2
Reconstituted whole wheat flour with extruded bran	1255 ± 22	229 ± 1	57 ± 2

Table 3: Cellular structure properties of extruded samples at condition 2

Sample	MCS [μm]	MCWT [μm]	Cell density [cm^{-3}]
Refined flour	212 ± 8	49 ± 0	2792
Whole wheat flour	113 ± 6	50 ± 2	6857
Reconstituted whole	103 ± 6	45 ± 1	6480
Reconstituted whole wheat flour with	603 ± 153	78 ± 4	705

Reconstituted whole wheat flour with	189 ± 11	55 ± 1	4163
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Example 7 – Effect of Wet against dry milling of the bran on the corresponding extruded cereal product

Wet-ball milling was used based on the hypothesis that water would be necessary to disrupt the dense fibre parts and release some of the fibres trapped in these structures. To validate this hypothesis, the bran was milled at around 50 µm using jet milling and compared to the bran wet-treated with wet-ball milling. The bran treated by jet milling or wet-ball milling was mixed with the endosperm and the germ to reconstitute the whole wheat flour. The reconstituted flour was extruded under condition 1. A white whole wheat flour supplied by Conagra (Ultrafine, Patent US2006/0037258A1) and with an average fibre particle size of $D[4,3] = 62$ was used for comparison and also extruded under condition 1. The results are presented in table 4 and Figure 7.

Table 4

	Extruded Refined wheat flour (A)	Whole wheat flour (B)	whole wheat flour reconstituted with bran wet-treated by ball-milling (F)	whole wheat flour reconstituted with bran wet-treated by jet-milling (G)	Conagra flour (H)
Diameter [mm]	14.5 ± 0.9	8.7 ± 0.3	11.0 ± 0.3	9.9 ± 0.3	9.4 ± 0.2
Bulk density [g l ⁻¹]	41 ± 7	99 ± 11	57 ± 6	79 ± 6	79 ± 11
Porosity [%]	97	92	95	94	94

Whole wheat grain led to a lower volumetric expansion resulting in an increase in bulk density. The sectional expansion (diameter) was also reduced. The wet-ball milled bran and the jet milled bran had close average fibre particle size ($D [4,3] = 47$ 5 μm vs. $32 \mu\text{m}$). Reducing the particle size of the bran using jet milling improved the expansion properties leading to an increase of about 15 % of diameter and a reduction of about 20 % of bulk density compared to the non-wet-treated reconstituted whole wheat flour. Nevertheless, the extruded whole wheat flour with the wet-ball milled bran showed a higher expansion with an improvement of 10 about 30 % of diameter and a reduction of about 40 % of density compared to the non-wet-treated reconstituted whole wheat flour. The Conagra Ultrafine flour (fibre particle size of $D [4,3] = 62 \mu\text{m}$) improved expansion to a similar level as the jet milled bran. This is consistent with e.g. Garber et al. (1997) and confirms the benefit on expansion of reducing the bran particle size. Nevertheless, it appears that the 15 wet-treatment brought a further benefit compared to just dry milling. This may be attributed to disruption of the dense fibre parts, increase the interactions between the fibres and the starch continuous matrix and/or modifications of the other macronutrients such as starch or proteins contained in wheat bran. No major changes in melt pressure were observed when trying the different flours (see Table 20 4).

Table 4: Melt pressure at front plate according to the different flours extruded at condition 1

		Reconstituted whole wheat			
	Refined wheat flour	With unprocessed bran	With ball milled bran	With jet milled Bran	Conagra flour

Melt pressure at front plate [MPa]	12.4 ± 0.3	12.6 ± 0.32	11.2 ± 0.1	12.4 ± 0.4	11.9 ± 0.5
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Example 8 – Light microscopy

Extruded cereal products prepared as describe din Example 5, Condition 1 were embedded in Technovit 7100 resin (Kulzer-technik A.G., Wehrheim, Germany).

5 Slices of 5 μm in the longitudinal direction (parallel to extrusion) were generated with a Microtome Leica 2055 with a tungsten knife (Leica Geosystems, AG, Heerbrugg, Switzerland). Slices were stained with Lugol 1% solution (Sigma, L6146) and Light green solution (Fluka 62110) and observed under bright field with a light microscope Zeiss Axioplan equipped with Zeiss Axicam MRc5 camera (Carl Zeiss

10 A.G., Feldbach, Switzerland).

Light microscopy was performed on the extruded cereal products at condition 1 - giving rise to the most crispy product (Figure 8). Wet-treating the bran part with extrusion led to remaining visible fibres structures, although compared to the

15 untreated fibres, the original structure and particle size were reduced (Figure 8e, 8f). With the high pressure homogenization wet-mechanical treatment the original fibre structure was totally lost and only small pieces remained. For both treatments, only very few intact fibre structure could be observed (e.g. Figure 8d) and are likely coming from the unmodified germ part or from the endosperm, containing

20 untreated fibres.

Example 9 – Mechanical properties of flour based Extruded products

Mechanical properties were measured by a three-point bending test on a TA- HDi texture analyzer (Stable Microsystems, Godalming, UK) equipped with a 50 kg load cell. The average radius (r) of 70 mm-long extruded tubes was measured with a vernier caliper (10 points). The distance between the supports was $L = 50$ mm and
 5 the crosshead speed was 1 mm/s. Rupture stress (σ) of the extruded samples was derived from the maximum force at rupture (F), the crosshead displacement corresponding to the maximum force at rupture (d) and calculated according to the following equations:

$$\sigma = \frac{FL}{\pi r^3}$$

$$E = \frac{1}{12} \frac{F}{d} \frac{L^3}{\pi r^4}$$

10

Extruded cereal products prepared as described in Example 5, Condition 1 and according to the flour ingredients reported in Table 5 where tested for their mechanical properties as above described.

15

All measurements were done on 10 pieces. Samples were equilibrated prior to testing at 30 % relative humidity in humidity cabinet (C+ 10/60, CTS A.G., Germany). The results are summarized in Table 5.

20 Table 5: Mechanical properties of extruded flours at condition 1 – at 30% relative humidity.

	Force at rupture	Stress at rupture	Elastic modulus
	[N]	[MPa]	[MPa]

Refined wheat flour	4.9 ± 1.5	0.21 ± 0.07	0.27 ± 0.08
Reconstituted untreated	3.6 ± 0.6	0.61 ± 0.11	1.65 ± 0.42
Reconstituted untreated Whole wheat flour with ball milled treated bran (wet-	4.3 ± 0.8	0.40 ± 0.07	0.90 ± 0.22
Reconstituted untreated Whole wheat flour With Jet milled bran	5.0 ± 0.7	0.66 ± 0.12	2.00 ± 0.39
Conagra Flour	4.2 ± 0.8	0.55 ± 0.11	1.43 ± 0.40

The higher the value of force at rupture and/or of stress at rupture, the harder the product is. The harder the product is, the more difficult it is to be fractured.

Results reported in table 5 indicate that the product obtained with whole grain reconstituted flour comprising bran obtained by a wet-treatment shows a behaviour in terms of mechanical properties (and as a consequence textural and sensory properties) which is much closer to that of products based on refined flour than any other product based on whole grain reconstituted flour and known in the state of the art.

- 10 In fact, the extruded product based on reconstituted whole flour containing wet-mechanical treated significantly reduced the stress at rupture with respect to extruded products based on reconstituted whole grain flour from Conagra or based on dry-treated bran product.

Claims

1. A process for preparing an extruded cereal product, said process comprising the steps of:
 - 5 (i) providing a composition comprising a wet—treated bran product, which comprises fibre particles having an average particle size of less than 160 μm ,
 - (ii) extruding said composition,
 - (iii) drying the extrudate.
- 10 2. The process according to claim 1, wherein said wet-treated bran product is prepared by subjecting a bran material to a size-reduction mechanical treatment in the presence of at least 16%w/w total water.
3. The process according to claim 2, wherein said mechanical treatment is
15 extrusion.
4. The process according to claim 2, wherein said mechanical treatment is selected from the group consisting of: high-pressure homogenisation, wet-stone milling, and wet-ball milling.
- 20 5. The process according to any one of claims 2 to 4, wherein said wet- treated bran product is dried into to form wet treated bran product particles, preferably by spray drying, freeze drying or roller drying.
- 25 6. The process according to claim 5, wherein said dried wet treated bran product particles, have an average particle size lower than 1 mm.
7. The process according to any one of claims 1 to 6, wherein at least 50wt% of the fibre particles in the wet-treated bran product have a size between 5 μm and
30 200 μm .
8. The process according to any one of claims 1 to 7, wherein, when in the dry state, the average fibre particle size is lower than 100 μm .

9. A process according to anyone of claims 1 to 8 wherein the composition of step (i) comprises a reconstituted whole grain flour wherein the bran comprises at least a portion of wet-treated bran product.
- 5 9. An extruded cereal product obtainable by a process according to any one of claims 1 to 8, wherein said extruded cereal product comprises reconstituted whole-grain flour.
10. The extruded cereal product according to claim 9, having a whole-grain
10 content of at least 4 g per serving.
11. The extruded cereal product according to any one of claims 9 to 10, wherein the extruded cereal product comprises a pasty filling.
- 15 12. The extruded cereal product according to claim 11, wherein the pasty filling is selected from the group consisting of a chocolate cream, a fat-based filling, a fruit-based filling, and a savoury filling.
13. The extruded cereal product according to any one of claims 9 to 12, wherein
20 the extruded cereal product is a confectionary product, a breakfast cereal or a pet food.

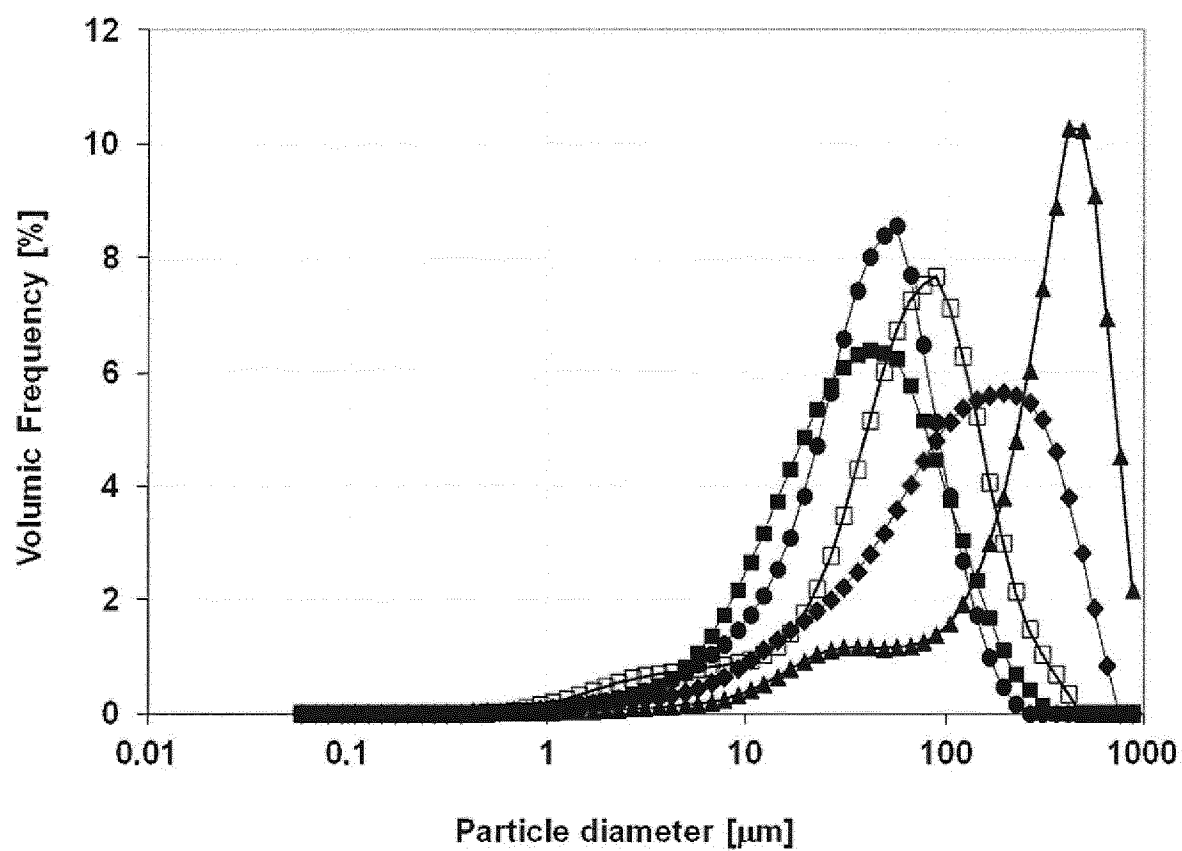


Fig. 1

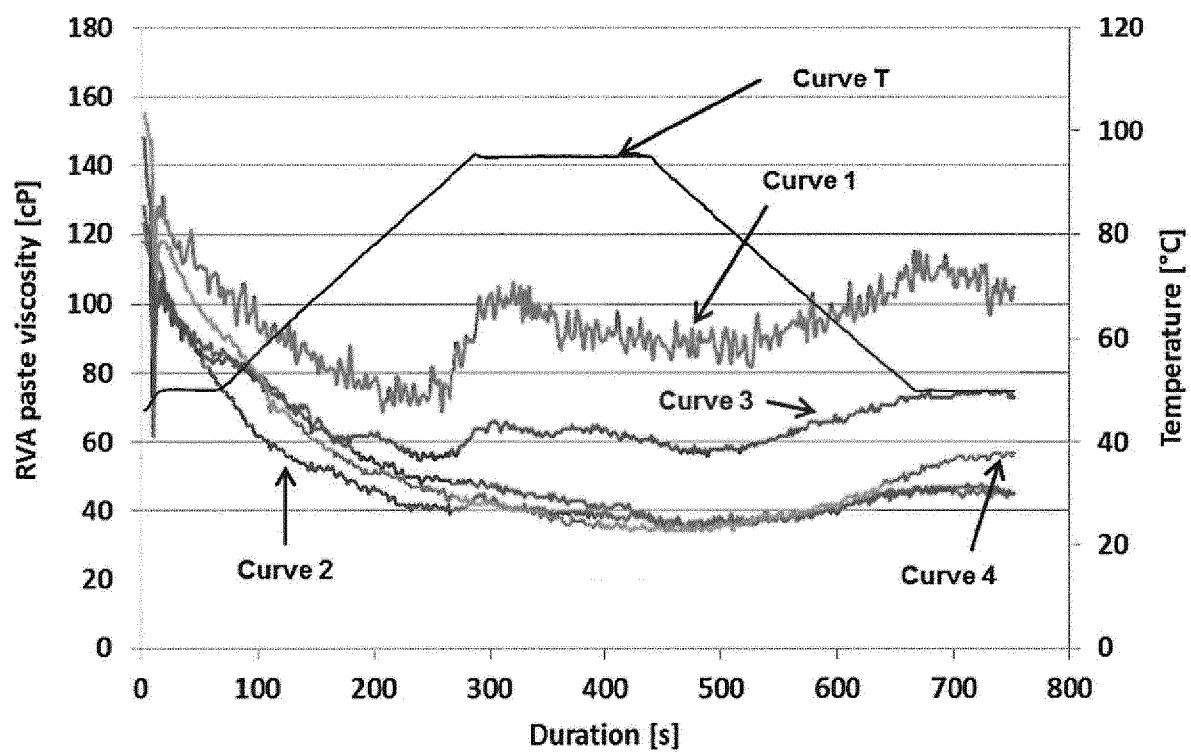


Fig. 2

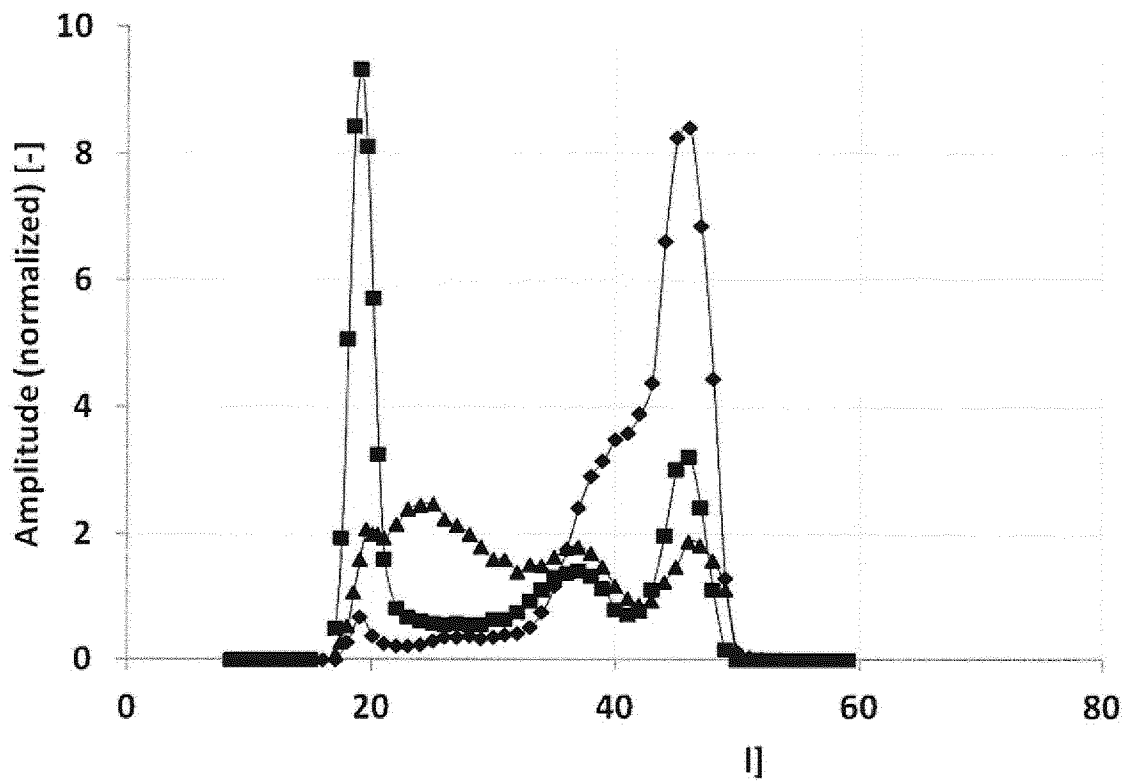


Fig. 3

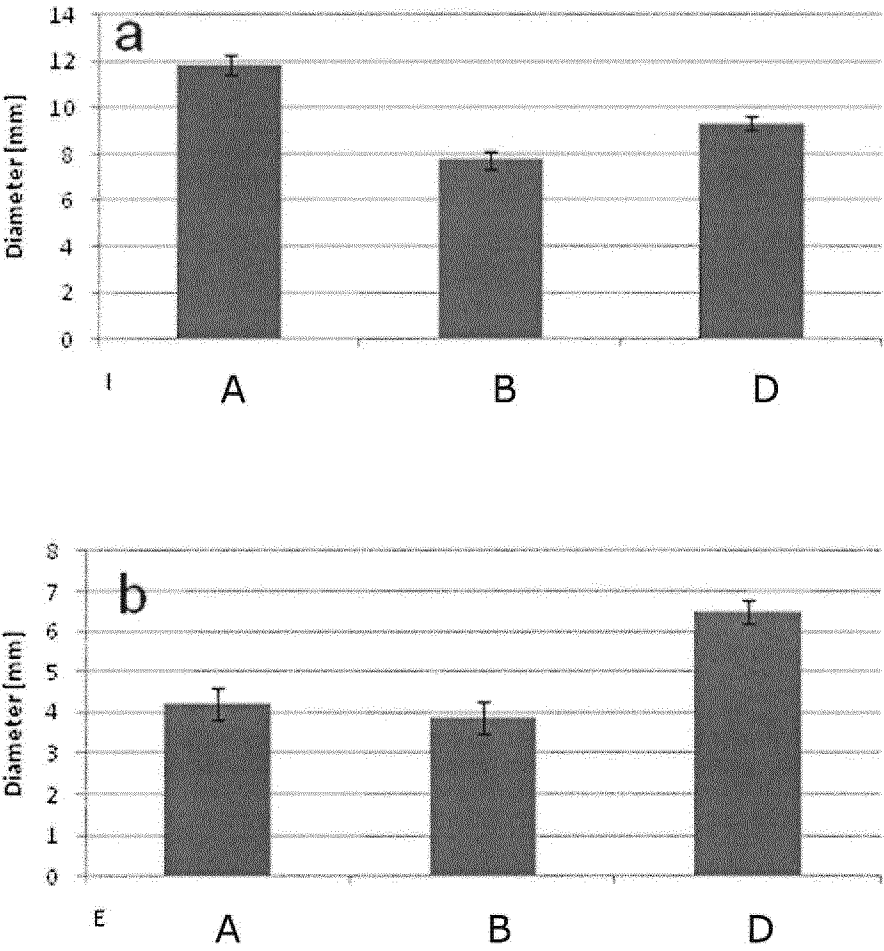


Fig. 4

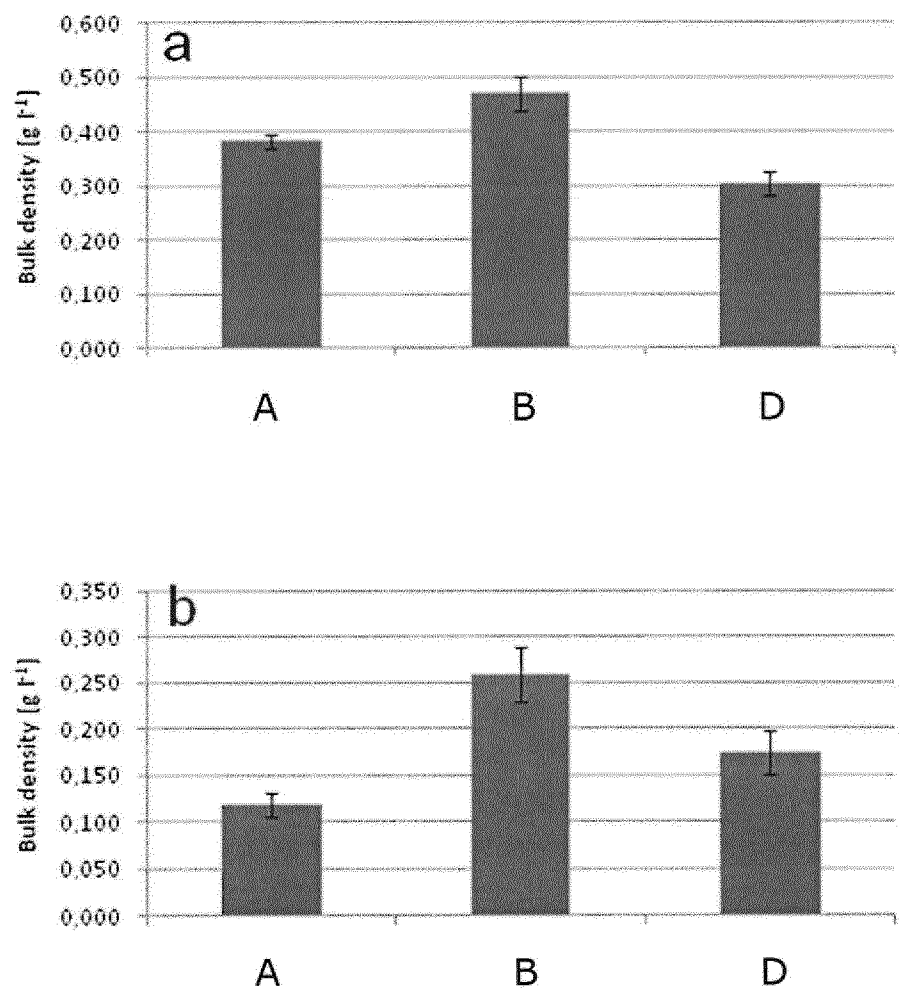


Fig. 5

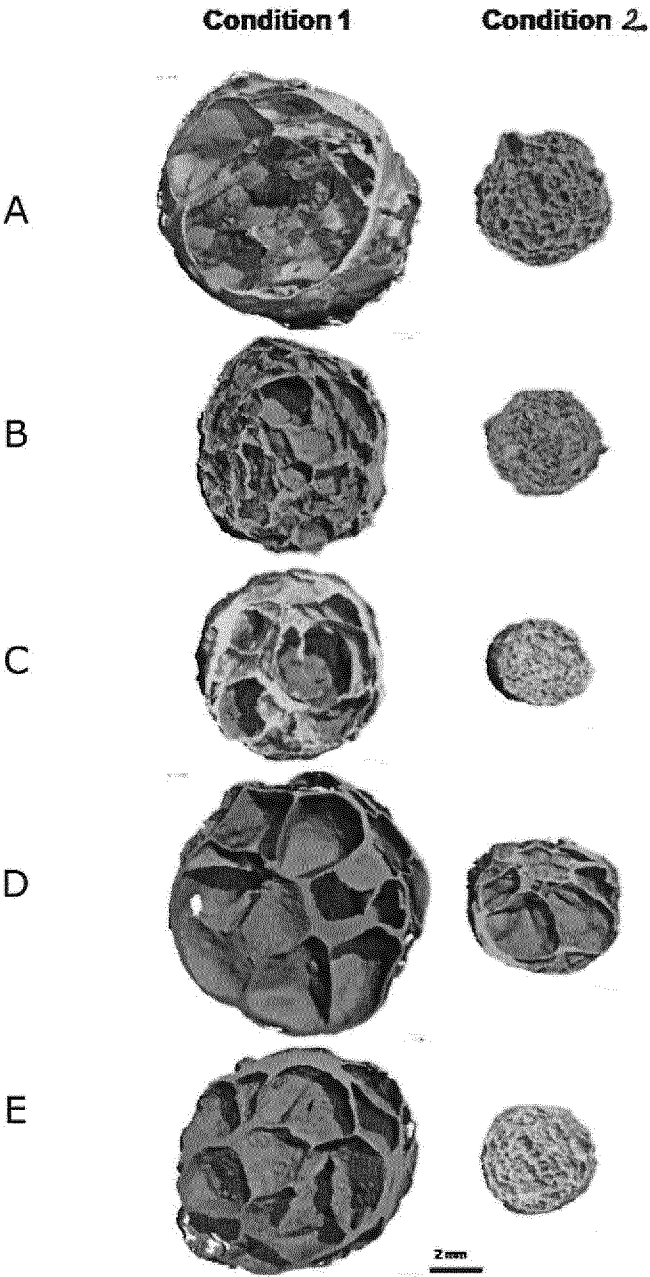


Fig. 6

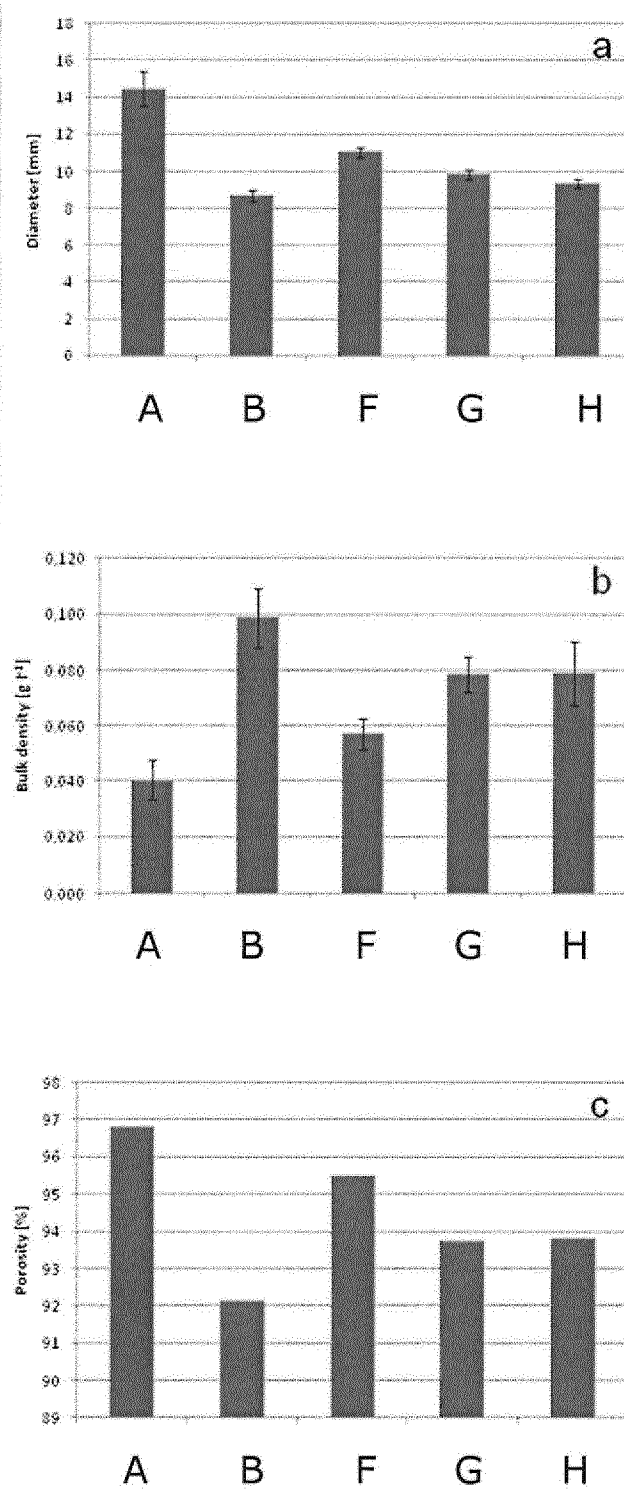


Fig. 7

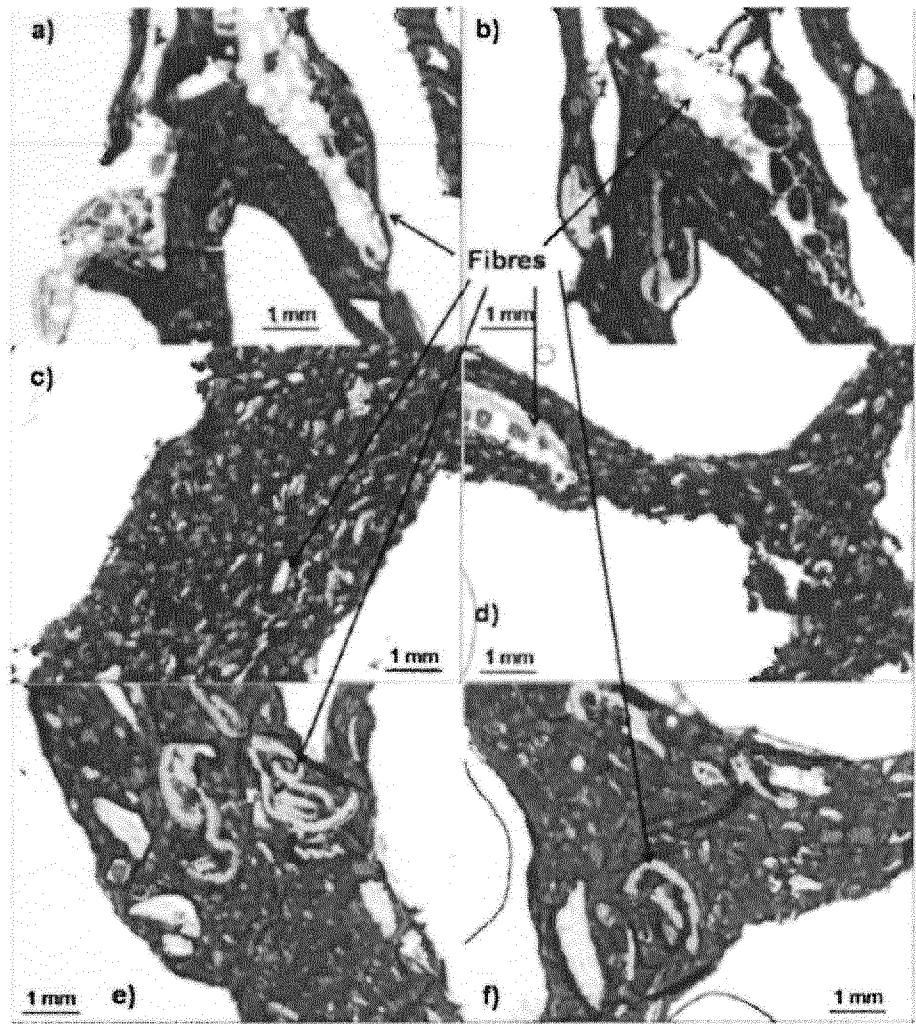


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/079129

A. CLASSIFICATION OF SUBJECT MATTER
INV. A23L7/00 A23L7/10 A23P30/20 A23K10/00
ADD.

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)
A23K A23L A23P

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 practicable, search terms used)

EPO-Internal, WPI Data, FSTA, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 710 386 A (FULGER CHARLES V [US] ET AL) 1 December 1987 (1987-12-01) cited in the application	1-3, 5-11,14
Y	column 5, line 11 - line 20 column 5, line 31 - line 37; claims 1, 14; example 1	1,2,4,6, 11-13
X	----- US 4 500 558 A (FULGER CHARLES V [US] ET AL) 19 February 1985 (1985-02-19) cited in the application	1-3,7,8, 14
Y	column 3, line 46 - line 59; claim 1	4
Y	----- CN 101 906 399 A (JIANGSU HILL COUNTRY ZHENJIANG INST OF AGRICULTURAL SCIENCE ZHENJIANG) 8 December 2010 (2010-12-08) cited in the application abstract	4
	-/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

18 February 2016

Date of mailing of the international search report

26/02/2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/079129

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2008/040705 A1 (NESTEC SA [CH]; HUET JEAN NOEL [GB]; TSLAF ALEX [IL]) 10 April 2008 (2008-04-10) cited in the application example 1 -----	12,13
Y	WO 2010/000935 A1 (LEHTOMAEMI ILKKA [FI]; MYLLYMAEMI OLAVI [FI]) 7 January 2010 (2010-01-07) cited in the application claims 1, 7, 9 -----	1,2,6,11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/079129

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