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(71) Applicant (for AE, AG, AU, BB, BH, BN, BW, BZ, CA, CY, EG, GB, GD, GH, GM, IE, IL, IN, JO, KE, KN, KW, LC, LK, LS, MT, MW, MY, NA, NG, NZ, OM, PG, QA, RW, SA, SC, SD, SG, SL, SZ, TT, TZ, UG, VC, ZA, ZM, ZW only): **UNILEVER PLC** [GB/GB]; a company registered in England and Wales under company no. 41424 of Unilever House, 100 Victoria Embankment, London Greater London EC4Y 0DY (GB).

(71) Applicant (for all designated States except AE, AG, AU, BB, BH, BN, BW, BZ, CA, CY, EG, GB, GD, GH, GM, IE, IL, IN, JO, KE, KN, KW, LC, LK, LS, MT, MW, MY, NA, NG, NZ, OM, PG, QA, RW, SA, SC, SD, SG, SL, SZ, TT, TZ, UG, US, VC, ZA, ZM, ZW): **UNILEVER N.V.** [NL/NL]; Weena 455, 3013 AL Rotterdam (NL).

(71) Applicant (for US only): **CONOPCO, INC., D/B/A UNILEVER** [US/US]; 700 Sylvan Avenue (A4), Englewood Cliffs, New Jersey 07632 (US).

(72) Inventors: **BLIGH, Heather, Frances, Jennifer**; Unilever R&D Colworth, Sharnbrook Bedfordshire MK44 1LQ (GB). **GIBBS, Sally, Elizabeth**; Unilever R&D Colworth, Sharnbrook Bedfordshire MK44 1LQ (GB). **THIRUGANANAM, Saravanakumar**; Hindustan Unilever Limited Research Centre, 64, Main Road, Whitefield, Bangalore 560066 (IN). **VARDAM DHONDURAM, Amey**; Hindustan Unilever Limited Research Centre, 64 Main Road, Whitefield, Bangalore 560066 (IN).

(74) Agent: **WARNER, Guy, Jonathan**; Unilever Patent Group Colworth House, Sharnbrook, Bedford Bedfordshire MK44 1LQ (GB).

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(54) Title: METHOD FOR PROCESSING PEARL MILLET, FOOD PRODUCT COMPRISING IT AND ITS USE

(57) Abstract: A process comprising the steps of: Cooking pearl millet by boiling; then Drying the boiled pearl millet; then Milling the dried pearl millet between two cylindrical rollers moving cooperatively wherein the rollers have a gap between them and wherein the rollers move at different speeds characterised in that the gap between the rollers is from 0.25 mm to 1 mm and in that the speed differential of the rollers is from 5000 cm/minute to 50,000 cm/minute is provided.

PROCESSING OF PEARL MILLET

TECHNICAL FIELD OF THE INVENTION

The present invention relates to the processing of pearl millet. In particular, the present invention relates to a process that provides processed pearl millet capable of reducing the Glycaemic Index of foods to which it is added.

BACKGROUND OF THE INVENTION

One of the major challenges of the 21st Century is feeding the world's exponentially increasing population. However, it is not only the availability of food that matters, but also the access to nutritious food that will allow people to maintain their health. Given that grains account for at least 50% of all calories consumed in the world on a daily basis, one of the key aspects of this challenge lies in improving the nutritional quality of grains. One of the reasons grains are so popular is that they are high in carbohydrates which provide energy. However, a diet rich in quick releasing carbohydrates can lead to other health problems including type II diabetes mellitus, a chronic non-communicable disease which is caused when the body cannot recognise, or effectively use, the insulin it produces; usually resulting from excess intake of sugars and physical inactivity. Health complications that arise from the disease include: vision loss, heart attack, kidney failure and limb amputation. The latest figures suggest that in India alone >69 million people are now living with the disease and this number is expected to almost double by 2040. Consequently, it is crucial for public health that people are given access to a wide variety of foods with good nutritional properties.

Dietary modification at the individual level is one of the easiest ways of controlling diabetes. Products designed to control the glycaemic response are needed and will have a large potential market in vulnerable populations. In developed markets there is strong public awareness and understanding of how functional foods, particularly those which have a low Glycaemic Index (GI), can help prevent and ameliorate problems associated with type 2 diabetes. In developing markets, public understanding of glycaemic response is less established but steadily growing.

Studies have also shown that a diet with a high overall Glycaemic Load (GL) increases the relative risk of onset of type 2 diabetes by about 1.5 times, or by about 2.4 times when accompanied by a low dietary fibre intake. The risk of coronary heart disease in diabetics has also been directly linked to dietary GL.

5

It is therefore clear that the lowering of a food's GI, (and hence the GL) is desirable. GI may be reduced by slowing the conversion of carbohydrates into blood sugar. One way of doing this is to increase the viscosity of stomach fluids to slow the rate at which carbohydrates are digested. Alternatively, controlling constriction of the pylorus can
10 reduce the rate at which the stomach empties. The viscosity of stomach fluids may be increased by increasing the consumption of dietary fibre, whilst constriction of the pylorus is achieved by the addition of low molecular weight organic acids, such as acetic acid (vinegar) or citric acid (lemon juice), to the diet.

15 Another means to lower GI is to inhibit the enzymes catalysing the breakdown of carbohydrate in the intestine. Two enzymes principally responsible for this are glucosidase and α -amylase. The activity of these enzymes determines the rate at which glucose is produced from dietary polysaccharides and therefore the rate at which the glucose is absorbed into the blood.

20

Hyperglycemia is treated by lowering the GI of foods using the drug Acarbose. This drug is a complex oligosaccharide which delays digestion of ingested carbohydrates, by inhibiting intestinal enzymes (-glucosidases). Acarbose has maximal inhibitory activity against sucrase. Acarbose is also known to inhibit amylases.

25

It is an aim of this invention to find a natural and sustainable way to reduce GI, ideally by utilising existing foodstuffs. In this regard, a dose-finding study ("The Effects of Fat and Protein on Glycemic Responses in Nondiabetic Humans Vary with Waist Circumference, Fasting Plasma Insulin, and Dietary Fiber Intake", J. Nutr. 136: 2506–2511, 2006) has
30 previously been carried out to determine the dose-response effects of 0–30 g protein and fat, alone and in combination, on the glycaemic response elicited by 50 g glucose in nondiabetic humans and to see whether the effects were influenced by subjects' insulin sensitivity and diet. The study concluded that, across the range of 0–30 g, protein and

fat reduce the glycaemic response elicited by oral glucose independently from each other, with a linear dose response and a 2–3 times greater effect from protein than fat. High fiber intake and high waist circumference were associated with an increased effect of protein, whereas a high fasting plasma insulin was associated with a reduced effect of fat. However, these conclusions may not apply to solid meals and further studies were needed to determine the mechanisms for these effects.

“The Effect of Dietary Fibre on Reducing the Glycaemic Index of Bread” was also previously reviewed (British Journal of Nutrition (2013), 109, 1163–1174). The review concluded that substituting whole grains for refined grains would provide benefits not only from fibre but also from the other unique health-promoting components of whole grains, also resulting in a better strategy for reducing the GI of bread. However, when fibres or whole grains are included in bread making to affect the glycaemic response, the manufacturing protocol needs to reconsider several technological parameters in order to obtain high-quality and consumer acceptable breads.

There therefore remains the need for food components that are capable of lowering GI.

Brennan et al., in “Amaranth, millet and buckwheat flours affect the physical properties of extruded breakfast cereals and modulates their potential glycaemic impact” (Starch/Stärke. Volume 64, Issue 5, 19 January 2012, pp 392-398), investigated the potential utilisation of pseudo-cereals as alternatives to conventional cereal products in extruded snacks and evaluate their potential in modulating the glycaemic response to these food items.

In “Potential Functional Implications of Pearl millet (*Pennisetum glaucum*) in Health and Disease” (Journal of Applied Pharmaceutical Science, 1(10) · December 2011, pp 62-67), Nambiar et al. reviewed the health benefits of pearl millet.

We have surprisingly found that by processing pearl millet in a specific way the resulting processed pearl millet is capable of lowering the GI of foods to which it is added.

SUMMARY OF THE INVENTION

Accordingly, in a first aspect, the invention provides a method for processing pearl millet which delivers a pearl millet capable of reducing the Glycaemic Index of other food components.

5 The process comprises the steps of

- Cooking pearl millet by boiling; then
- Drying the boiled pearl millet; then
- Milling the dried pearl millet between two cylindrical rollers moving cooperatively

- 10 o wherein the rollers have a gap between them and
- o wherein the rollers move at different speeds
- characterised in that
- o the gap between the rollers is from 0.25 mm to 1 mm and in that
- o the speed differential of the rollers is from 5000 cm/minute to 50,000
- cm/minute.

15

Preferably the pearl millet is boiled for from 10 to 120 minutes, more preferably 20 to 80 minutes, even more preferably 30 to 60 minutes, more preferably still 40 to 50 minutes.

20 Preferably the boiled pearl millet is dried after boiling for from 1 to 12 hours, more preferably 2 to 8 hours, even more preferably 3 to 6 hours, more preferably still 4 to 5 hours.

25 Preferably the boiled pearl millet is dried after boiling to a moisture content of from 5 to 35 wt%, more preferably 10 to 30 wt%, even more preferably 15 to 25 wt%, more preferably still 18 to 20 wt%.

30 Preferably the boiled pearl millet is dried after boiling at a temperature of from 15 to 80°C, more preferably 20 to 70°C, even more preferably 30 to 60°C, more preferably still 35 to 45°C.

30

Preferably the gap between the rollers is from 0.25 to 0.75 mm, more preferably 0.25 to 0.6 mm, even more preferably 0.30 to 0.4 mm, more preferably still 0.325 to 0.375 mm.

Preferably the speed differential of the rollers is from 5,000 to 40,000 cm/minute, more preferably 10,000 to 30,000 cm/minute, even more preferably 15,000 to 25,000 cm/minute, more preferably still 17,500 to 22,500 cm/minute.

- 5 Preferably the milled pearl millet is dried for from 8 to 20 hours, more preferably 10 to 18 hours, even more preferably 12 to 16 hours, more preferably still 13 to 15 hours.

Preferably the milled pearl millet is dried at a temperature of from 15 to 80°C, more preferably 20 to 70°C, even more preferably 30 to 60°C, more preferably still 35 to 45°C.

10

Preferably the milled pearl millet is dried to a moisture content of from 3 to 14 wt%, more preferably 4 to 12 wt%, even more preferably 5 to 10 wt%, more preferably still 6 to 8 wt%.

- 15 In a second aspect the invention provides processed pearl millet obtainable by the process of the first aspect.

In a third aspect the invention provides a food product comprising carbohydrate, and also comprising the processed pearl millet of the second aspect wherein from 1-50 wt% of
20 the available carbohydrate in the food product comes from the processed pearl millet.

Preferably the food product comprises carbohydrate from grains other than pearl millet, more preferably the food product comprises carbohydrate from wheat semolina.

- 25 Preferably the food product comprises 5-75 wt% of available carbohydrate in total, more preferably 10 to 70 wt%, even more preferably 15 to 65 wt%, more preferably still 20 to 45 wt%, yet more preferably 25 to 35 wt%.

Preferably from 5-50 wt% of the available carbohydrate in the food product comes from
30 the processed pearl millet, more preferably 10 to 40 wt%, even more preferably 15 to 35 wt%, more preferably still 20 to 30 wt%, yet more preferably 22.5 to 27.5 wt%.

Preferably the food product has a glycaemic index of up to 99 excluding the GI provided by the processed pearl millet of the second aspect, more preferably up to 90, even more preferably up to 80, more preferably still up to 70, yet more preferably up to 60.

- 5 Preferably the food product has a glycaemic index of at least 20.

The food product may be a cereal-based product such as a breakfast cereal or a meal comprising cereal grains. The food product may also be a frozen confection such as an ice cream.

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In a fourth aspect the invention provides for the use of the processed pearl millet of the second aspect for use in a food product for the reduction of the GI of the food product.

- 15 In a fifth aspect the invention provides a method of delaying digestion by an animal or a human of carbohydrates in food, comprising administering an effective amount of the processed pearl millet of the second aspect.

DETAILED DESCRIPTION OF THE INVENTION

Pearl Millet

- 20 Pearl millet (*Pennisetum glaucum*) is the most widely grown type of millet. Although it has been grown in Africa and the Indian subcontinent since prehistoric times it is now grown throughout the world. The centre of diversity, and suggested area of domestication, for the crop is in the Sahel zone of West Africa.
- 25 With ovoid grains typically 3 – 4 mm in length pearl millet has the largest kernels of all varieties of millet (not including sorghum) can be nearly white, pale yellow, brown, grey, slate blue or purple. The 1000-seed weight can be about 2.5 to 14 g with a mean of about 8 g. The height of the plant ranges from around 0.5 m to 4 m.
- 30 Pearl millet is well adapted to growing areas characterized by drought, low soil fertility, and high temperature. It performs well in soils with high salinity or low pH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal

crops, such as maize or wheat, would not survive. Pearl millet is a summer annual crop well-suited for double cropping and rotations.

Pearl millet is grown on over 260,000 km² of land worldwide. It accounts for
5 approximately 50% of the total world production of millets.

Common names

Pearl millet is also known by in different countries/regions by the following names. In Africa: gero (Hausa), Arum (Borno Kanuri), Uwele (Kiswahili), Oka (Yoruba), mahangu
10 (Namibia), sajo (Bambara), gawri (Fula), babala, nyoloti, dukkin, souna, petit mil (French), heyne (Zarma), masago (Somali), mexoeira (Mozambique), biltug (Tigrinya), biltug (Blin), mhunga (Shona, Zimbabwe), inyawuthi (Northern Ndebele, Zimbabwe), lebelebele (Setswana, Botswana), zembwe (Ikalanga, Botswana). In Australia: bulrush millet. In Brazil: milheto. In Europe: candle millet, dark millet. In USA: cattail millet
15 (*Pennisetum americanum*). In India: Kambu in Tamil, Kambam in Malayalam, Bajri in Rajasthani, Gujarati and Marathi, kambu in Kannada, Bajra in Hindi, Urdu and Punjabi, sajjalu in Telugu, and bajra in Bengali. In Pakistan: Baajra in Urdu, Kashmiri, Balochi, Pashto, Punjabi.

20 Nutritional Properties of Pearl Millet

Various investigations and reviews have been performed into the nutritional properties of pearl millet including "Millet Grains: Nutritional Quality, Processing, and Potential Health Benefits" (Comprehensive Reviews in Food Science and Food Safety, Vol. 12, 2013, pp 281-295) in which it was noted that various different types of millets have been
25 investigated in relation to diabetics. In "Nutrient and antinutrient composition of pearl millet grains as affected by milling and baking" (1997, Nahrung, 41: 105–107) a study was conducted to analyse the effects of milling and baking on nutrient and antinutrient composition of pearl millet grain and found that milling and heat treatment during chapatti-making lowered polyphenols and phytic acid but actually improved protein and
30 starch digestibility to a significant extent.

Pearl Millet Processing

Pearl millet is typically not palatable unless cooked, milled, or a combination of both. When eaten as a whole grain, pearl millet is cooked in the presence of water prior to consumption using various approaches, typically by boiling, pressure cooking or steaming. Pearl millet can also be milled to a flour using the usual milling equipment and
5 then used to make products such as breads and the like.

In the present invention we have surprisingly found that if pearl millet is boiled as opposed to steamed, and is then milled using a specific piece of equipment under certain conditions as described in the following sections, then the resulting processed pearl
10 millet is actually capable of reducing the GI of foods to which it is added

Roller Mills

Milling of grains typically uses milling machinery, and roller mills are widely used. Roller mills use cylindrical rollers, either in opposing pairs or against flat plates, to crush or grind
15 various materials, such as grain. Roller grain mills are an alternative to traditional millstone arrangements in gristmills. The present invention utilises two-roller mills in which material is crushed between two rollers. The spacing between these two rollers can be adjusted with thinner spacing leading to material being crushed into smaller pieces. The rollers move cooperatively, that is to say that one roller moves clockwise,
20 the other anticlockwise. For the sake of understanding, in a typical configuration material is fed into the rollers from above and the milled material exits at the bottom. If the rollers of such a configuration are viewed end-on it will be seen that the left roller will be rotating clockwise, the right roller will be rotating anti-clockwise.

25 Crucially, the present invention utilises two-roller mills in which not only can the gap between the rollers be adjusted but also the speed of the rollers can be varied independently of each other so each roller can be set to rotate at a different speed. Materials moving between rollers rotating at different speeds are subjected not only to compression (which is a function of the gap) but also a shearing or stretching force as
30 well (which is a function of the speed difference). The difference in speed between the rollers can be expressed as the "Roller Speed Differential (RSD)". The units of the RSD may be expressed as revolutions per minute or can also be expressed as an actual

speed differential since one revolution per minute (RPM) is a movement equivalent to the circumference of the rollers in a minute.

Glycemic Index (GI)

5 GI is a measure of how a given food affects postprandial blood sugar levels. It relates principally to foods that are high in carbohydrates, since proteins and fats have relatively little effect on blood sugar. GI values indicate how quickly the carbohydrates in a given food are broken down in the intestine and converted to blood sugar. A value of 100 represents the standard, an equivalent amount of pure glucose. The GI represents the
10 rise in a person's blood sugar level two hours after consumption of the food. The glycemic effect of foods depends on a number of factors, such as the type of starch, physical entrapment of the starch molecules within the food, fat and protein content of the food and organic acids or their salts in the meal. The GI is useful for understanding how the body breaks down carbohydrates and takes into account only the available carbohydrate
15 in a food.

Available carbohydrate

Available carbohydrate represents that fraction of carbohydrate that can be digested by human enzymes, absorbed, and enter into intermediary metabolism. It does not include
20 dietary fibre, which can be a source of energy only after fermentation. Available carbohydrate can be arrived at in two different ways: it can be estimated by difference, or analysed directly. To calculate available carbohydrate by difference, the amount of dietary fibre is analysed and subtracted from total carbohydrate. Alternatively, available carbohydrate can be derived by summing the analysed weights of individual available
25 carbohydrates.

Glycemic Load

The glycemic index is usually applied in the context of the quantity of the food and the amount of carbohydrate in the food that is actually consumed. A related measure, the
30 glycemic load (GL) factors this in by multiplying the glycemic index of the food in question by the carbohydrate content of the actual serving. For example, watermelon has a high glycemic index, but a low glycemic load for the quantity typically consumed.

Processing for reduction of GI

As stated, in the present invention we have found that if pearl millet is processed in a particular way, first by cooking, then by milling using the equipment described above set to have a certain specific gap range and RSD range, then the resulting processed pearl
5 millet is actually capable of reducing the GI of foods to which it is added.

In the present invention, the process involves the step of cooking the pearl millet by boiling. By boiling is meant cooking the pearl millet in an amount of water that covers the pearl millet. Preferably the pearl millet is boiled for from 10 to 120 minutes, more
10 preferably 20 to 80 minutes, even more preferably 30 to 60 minutes, more preferably still 40 to 50 minutes. The temperature of the water will be about 100°C but may be as low as 95°C, or 90°C, or 85°C, or 80°C due to boiling at low atmospheric pressure such as in locations of high altitude. The temperature of the water may be as high as 120°C, or 115°C, or 110°C, or 105°C due to boiling under conditions of pressure such as in a
15 pressure cooker.

After boiling, the pearl millet is dried. By dried is meant removing moisture from the boiled pearl millet. Preferably the boiled pearl millet is dried after boiling to a moisture content of from 5 to 35 wt%, more preferably 10 to 30 wt%, even more preferably 15 to 25 wt%,
20 more preferably still 18 to 20 wt%. Preferably the boiled pearl millet is dried after boiling for from 1 to 12 hours, more preferably 2 to 8 hours, even more preferably 3 to 6 hours, more preferably still 4 to 5 hours. Preferably the boiled pearl millet is dried after boiling at a temperature of from 15 to 80°C, more preferably 20 to 70°C, even more preferably 30 to 60°C, more preferably still 35 to 45°C. Drying can take place under any suitable
25 conditions to achieve the desired moisture removal, such as in drying ovens.

The dried pearl millet is then milled between two cylindrical rollers moving cooperatively. As described above, by milling is meant the process by which the pearl millet is passed through a two-roller mill in which material is crushed between two rollers, the spacing
30 between which can be adjusted and also the speed of the rollers can be varied independently of each other so each roller can be set to rotate at a different speed. When materials are milled between rollers rotating at different speeds they are subjected not only to compression due to the size of the gap between the rollers but also a shearing or

stretching force which is caused by the speed difference. As set out above, the difference in speed between the rollers is expressed as the RSD, the units of which may be expressed as RPM or can also be expressed as an actual speed differential since one RPM is a movement equivalent to the circumference of the rollers per minute.

5

It has surprisingly been found that if the gap between the rollers is from 0.25 mm to 1 mm and if the speed differential of the rollers is from 5000 cm/minute to 50,000 cm/minute then the resulting processed pearl millet is capable of reducing the GI of foods to which it is added.

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The gap between the rollers may be from 0.25 to 0.75 mm, more preferably 0.25 to 0.6 mm, even more preferably 0.30 to 0.4 mm, more preferably still 0.325 to 0.375 mm. Preferably the speed differential of the rollers is from 5,000 to 40,000 cm/minute, more preferably 10,000 to 30,000 cm/minute, even more preferably 15,000 to 25,000 cm/minute, more preferably still 17,500 to 22,500 cm/minute.

15

After milling, the milled pearl millet is dried, preferably to a moisture content of from 3 to 14 wt%, more preferably 4 to 12 wt%, even more preferably 5 to 10 wt%, more preferably still 6 to 8 wt%. The milled pearl millet may be dried for from 8 to 20 hours, more preferably 10 to 18 hours, even more preferably 12 to 16 hours, more preferably still 13 to 15 hours. Preferably the milled pearl millet is dried at a temperature of from 15 to 80°C, more preferably 20 to 70°C, even more preferably 30 to 60°C, more preferably still 35 to 45°C. This drying can take place under any suitable conditions to achieve the desired moisture removal, such as in drying ovens.

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The invention provides for processed pearl millet that is obtainable by the process of the first aspect of the invention. In addition, the invention may also provide for processed pearl millet that is obtainable from the process of the first aspect of the invention.

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As stated, it has surprisingly been found that processed pearl millet of the invention is capable of reducing the GI of foods to which it is added. Therefore a further aspect of the invention provides a food product comprising carbohydrate, and also comprising the processed pearl millet of the present invention. For the sake of clarity, the carbohydrate

in the food product is not the same as the carbohydrate from the added processed pearl millet. The added processed pearl millet actually reduces the GI of the carbohydrate in the food product.

- 5 The food product may comprise normal pearl millet (i.e. that is to say pearl millet prepared using a process not according to the invention) to which the processed pearl millet of the invention has been added. It may also comprise other sources of carbohydrates other than normal pearl millet and so preferably the food product comprises carbohydrate from grains other than normal pearl millet, more preferably the
10 food product comprises carbohydrate from wheat semolina.

- In the food product, 1-50 wt% of the available carbohydrate in the food product comes from the processed pearl millet, preferably from 5-50 wt%, more preferably 10 to 40 wt%, even more preferably 15 to 35 wt%, more preferably still 20 to 30 wt%, yet more
15 preferably 22.5 to 27.5 wt%.

- Preferably the food product comprises 5-75 wt% of available carbohydrate in total (i.e. the available carbohydrate from both the food product itself and the added processed pearl millet), more preferably 10 to 70 wt%, even more preferably 15 to 65 wt%, more
20 preferably still 20 to 45 wt%, yet more preferably 25 to 35 wt%.

- The reduction of glycaemic index is especially required in high GI foods, therefore preferably the food product has a glycaemic index of up to 99 excluding the GI provided by the processed pearl millet of the invention, more preferably up to 90, even more
25 preferably up to 80, more preferably still up to 70, yet more preferably up to 60. Preferably the food product has a glycaemic index of at least 20.

- The food product may be a cereal based product such as a breakfast cereal or a meal comprising cereal grains because such products may have a high GI that can be reduced
30 by the processed pearl millet of the present invention. Frozen confections such as ice creams, and beverages such as sugary carbonated drinks may also have particularly high GIs. Therefore, the food product may also be a frozen confection such as an ice cream, or a beverage.

The invention also provides for the use of the processed pearl millet of the second aspect for use in a food product for the reduction of the GI of the food product.

- 5 The invention also provides a method of delaying digestion by an animal or a human of carbohydrates in food, comprising administering an effective amount of the processed pearl millet of the invention.

10 **EXAMPLES**

The examples that follow are intended to illustrate the invention and are not intended to limit the invention to those examples per se.

Glycaemic Index Study Protocol

- 15 A glycaemic index study was carried out to assess the effect that dietary carbohydrates have on blood sugar by measuring the glycaemic index. The glycaemic index was a comparison between the effect of equal amounts of carbohydrate from a test food compared to a standard on blood sugar.
- 20 The samples below were tested in human subjects consuming amounts containing the equivalent of 50 g available carbohydrate.

- The study was a randomized cross-over controlled trial: the order of the test samples was randomized by an independent internet-based program; each participant was asked
- 25 to consume all the products; the test food was compared with a control (in this case glucose).

Subjects

- 12 subjects were tested. They were healthy subjects with no chronic diseases, diabetes
- 30 or glucose impairment. Subjects had a BMI between 18.5-27kg/m² and were aged 18 to 65 years old. Pregnant women did not take part.

Reference food

The reference food was 50 g glucose powder dissolved in 250ml water.

Test foods

The samples were prepared as set out below. Samples were consumed on separate occasions as a portion providing 50g of available carbohydrate.

Protocol

Subjects were tested in the morning after a 10-12h overnight fast. Three fasting blood samples were taken (-5 min, -3 min, -1 min) 2 minutes apart after which subjects consumed the test meal or reference food at an even rate over 15 min. All subjects recorded the time it took in minutes to consume the test food/reference. Further blood samples were taken at 15, 30, 31, 32, 45, 60, 90 and 120 min after the beginning of the meal. The test meal and reference food were consumed with a 250ml drink of water.

Blood sampling

Blood was obtained by finger-pricking using disposable Unistix needles and instant glucose analysers were used.

GI calculation

The incremental area under the blood glucose response curve (iAUC), ignoring area beneath the baseline, was calculated. In individual subjects, the GI value was the iAUC for each sample expressed as a percentage of the mean iAUC of the reference food. The GI of the test food is the mean GI $\pm$ Standard Error of the Mean (SEM) of the 12 subjects. Up to two outliers (an outlier is an individual whose GI differed from the mean by more than two SD) could be excluded from the data set. SEM was within 20% of the mean.

Pearl Millet Processing

Pearl millet, commercial variety HHB67-improved was sourced from Shakti Vardhak Hybrid seeds Pvt Limited, India. It is noted that although commercial variety HHB67-improved was sourced from an Indian company, it is also available from elsewhere in the world. Initially, the pearl millet was tested for microbiological and mycotoxin

contaminants and no contamination was detected. The pearl millet was subjected to four different processing methods which varied in the way in which the pearl millet was cooked and how it was milled.

- 5 Milling of the pearl millet was carried out using a two-roller mill Miag Vario Roller Mill 'C' Model ("Vario Roller Mill"), from Muhlenbau und Industrie GmbH, Braunschweig, Germany. The Vario Roller Mill had a roll width (active surface) of 11.5cm and a roll diameter of 25.0cm, equating to a circumference of 78.5cm.
- 10 The gaps between the rollers of the Vario Roller Mill could be varied. The speed of each roller could also be independently varied so that the rollers could be set to rotate at different speeds. As a consequence, materials moving between rollers rotating at different speeds were subjected not only to compression but also a shearing or stretching force as well.

15

The difference in speed between the rollers is expressed as the "Roller Speed Differential (RSD)". As can be appreciated, one RPM is equivalent to a speed at the face of the roller of 78.5 cm/min. Therefore, if one roller is moving at 1 RPM and the other is moving at 11 RPM, the differential is 10RPM (11-1) and the RSD is therefore 785 cm/min.

20

The four different processing methods A to D are given below and a summary is provided in Table 1.

Process	Cooking	Milling Parameters	
		Roller Gap (mm)	Roller Speed Differential (rpm (cm/min))
A	Boiled	0.2	20 (1,570)
B	Steamed	0.35	150 (11,775)
C	Not cooked	0.75	0 (0)
D	Boiled	0.35	250 (19,625)

25

Table 1 – Summary of Processing Methods A to D

Process A:

- Pearl millet was boiled in excess water for 45 min.
- Boiled pearl millet was drained then spread out on plastic bags on metal trays in a Mitchell dryer at 40°C for 4-5 hours. Moisture content after initial drying was 18-20%.
- Pearl millet was then stored overnight in a wheat store at 12°C in sealed plastic bags.
- Pearl millet was then milled on the Vario Roller Mill set as follows:
 - o Gap between rollers = 0.2mm,
 - o Speed of fast roller = 520 rpm, speed of slow roller = 500 rpm.
- After milling, samples were dried down in the Mitchell dryer for 13-15 hours (overnight) to a moisture content of 6-8%.

Process B:

- Pearl millet was steamed for 30 min then left to cool.
- Moisture content after steaming was 22.0%.
- Steamed pearl millet was then stored overnight in the wheat store at 12°C in sealed plastic bags.
- Pearl millet was then milled on the Vario Roller Mill set as follows:
 - o Gap between rollers = 0.35mm
 - o Speed of fast roller = 300 rpm, speed of slow roller = 150 rpm.
- After milling, samples were dried down in the Mitchell dryer for 13-15 hours (overnight) to a moisture content of 6-8%.

Process C:

- Process C did not use cooking, the pearl millet was milled straight from the bag.
- Raw pearl millet had a moisture value of 10.9%.
- Pearl millet was milled on the Vario Roller Mill set as follows:
 - o Gap between rollers = 0.75mm
 - o Speed of fast roller = 250 rpm, speed of slow roller = 250 rpm
- After milling, samples were dried down in the Mitchell dryer for 13-15 hours (overnight) to a moisture content of 6-8%.

Process D:

- Pearl millet was boiled in excess water for 45 min.
- Boiled pearl millet was drained then spread out on plastic bags on metal trays in a Mitchell dryer at 40°C for 4-5 hours. Moisture content after initial drying was 18-20%.
- Pearl millet was then stored overnight in a wheat store at 12°C in sealed plastic bags.
- Pearl millet was then milled on the Vario Roller Mill set as follows:
 - o Gap between rollers = 0.35mm,
 - o Speed of fast roller = 500 rpm, speed of slow roller = 250 rpm.
- After milling, samples were dried down in the Mitchell dryer for 13-15 hours (overnight) to a moisture content of 6-8%.

A HACCP analysis was performed to assess the safety of the grain for consumption at all stages, from processing to cooking. Prior to the GI testing, the pearl millet flakes were further tested for pesticide and heavy metal contaminants and microbiological contaminants. No contaminants were detected.

Samples of the pearl millet from processes A to D were subjected to sensory analysis and at this point the pearl millet from C was deemed un-palatable so was therefore not investigated in the sections that follow.

GI of Un-milled Pearl Millet Meal vs Processed Pearl Millet Meals

- The following samples were prepared for a GI study in order to ascertain the effect of the above processes A, B and D on the pearl millet:
- Control Meal – containing standard, un-milled pearl millet
 - Meal A – containing pearl millet from Process A with Seasoning
 - Meal B – containing pearl millet from Process B with Seasoning
 - Meal D – containing pearl millet from Process D with Seasoning

The composition of the samples is given in Table 2 and the method of cooking is given in Table 3. Each sample was designed to contain a total of 50g available carbohydrate

(AC), hence the differing amounts of pearl millet. In these samples, 100% of the grain-based AC was from pearl millet, plus the carbohydrate from the yoghurt (which was the same for all samples).

Sample	Ingredients (g)		
	Pearl Millet	Yoghurt	Seasoning*
Control Meal	82.00 (Standard)	150	-
Meal A	79.50 (Process A)	150	2.5
Meal B	79.16 (Process B)	150	2.5
Meal D	88.11 (Process D)	150	2.5
* Seasoning: 80% Salt, 20% Roasted cumin seed			

5

Table 2 – Composition of Standard Pearl Millet Meal vs Processed Pearl Millet Meals

Sample	Cooking Method
Control Meal	82 g of the whole pearl millet was soaked in 200 ml of water over night Another 250ml of water was added to the soaked pearl millets and the water and millet were then placed in a pressure cooker (pressure cooking was required to make the un-milled whole pearl millet palatable). The millet was pressure-cooked and then set it aside to cool (the cooking water was not drained from the pearl millet). 100g of water was mixed with the 150g of yoghurt. The water/yoghurt mixture was combined with the cooled millet and 1g salt was added.
Meal A	79.5g of the pearl millet obtained from process A was added to 400ml of water, boiled for 5 minutes and left to cool for 10 minutes (the cooking water was not drained from the pearl millet). 150g of water was mixed with the 150g of yoghurt. The water/yoghurt mixture was combined with the cooled millet.

Meal B	79.16g of the pearl millet obtained from process B was added to 400ml of water, boiled for 5 minutes and left to cool for 10 minutes (the cooking water was not drained from the pearl millet). 150g of water was mixed with the 150g of yoghurt. The water/yoghurt mixture was combined with the cooled millet.
Meal D	88.11g of the pearl millet obtained from process D was added to 400ml of water, boiled for 5 minutes and left to cool for 10 minutes (the cooking water was not drained from the pearl millet). 150g of water was mixed with 150g of the yoghurt. The water/yoghurt mixture was combined with the cooled millet.

Table 3 – Method of Cooking of Un-milled Pearl Millet Meal and Processed Pearl Millet Meals

5

The results of the GI study on the un-milled_pearl millet meal and the processed pearl millet meals are shown in Table 4. It can be seen that the GI of the pearl millet samples from processes A, B and D were are not significantly different from the GI of un-milled pearl millet alone (Control Meal), indicating that the processing has not had a significant effect on the GI of the processed pearl millets themselves. In fact, the processing appears to cause the meals containing the processed pearl millet (Meal A, Meal B, Meal D) to have a higher GI than the Control Meal.

10

Sample	Glycaemic Index	Standard Error of the Mean
Control Meal	66.1	8.6
Meal A	70.2	6.5
Meal B	79.5	14.6
Meal D	74.9	7.9

15

Table 4 - Results of GI Study on Un-milled Pearl Millet Meal and the Processed Pearl Millet Meals A, B, and D

However, as demonstrated below, we have surprisingly found that when a particular one of these processed pearl millets is added to a further carbohydrate source, then the GI of that carbohydrate source is greatly reduced.

5

Analysis of Ability of Processed Pearl Millets to Reduce GI

Pearl millets obtained from processes A, B and D were investigated for their ability to reduce the GI of a different carbohydrate source as follows. In this experiment a wheat-based semolina cereal, seasoned with oils and spices, was used as the base meal.

10

Five samples, each containing 50g available carbohydrate (AC) were prepared:

- Control 1 – Semolina (100% of AC) (no seasoning)
- Control 2 – Semolina (100% of AC)
- Example A – Semolina (75% of AC) + pearl millet from Process A (25% of AC)
- 15 - Example B – Semolina (75% of AC) + pearl millet from Process B (25% of AC)
- Example D – Semolina (75% of AC) + pearl millet from Process D (25% of AC)

The composition of the samples is given in Table 5 and the method of cooking is given in Table 6.

20

Sample	Ingredients (g)		
	Wheat Semolina	Pearl Millet	Seasoning [#]
Control 1	86.52	-	-
Control 2	86.52	-	20
Example A	64.89	19.87 (Process A)	20
Example B	64.89	19.79 (Process B)	20
Example D	64.89	22.03 (Process D)	20
[#] Seasoning: Roasted Mustard seed (2.13%), Roasted cumin seed (2.13%), Curry leaves - dry roasted (0.85%), Asafoetida (0.43%), Edible Vegetable fat – Palm (21.28%), Chilli powder (0.85%), Onion minced (42.55%), Edible common Salt (21.28%), Dehydrated Carrot bits (8.51%)			

Table 5 – Composition of Control 1, Control 2, Example A, Example B, and Example D

Sample	Cooking Method
Control 1	86.52g of the Wheat Semolina was added to 450ml of boiling water in a pan and cooked for 5 minutes with regular whisking
Control 2	86.52g of the Wheat Semolina and 20g of the seasoning was added to 450ml of boiling water in a pan and cooked for 5 minutes with regular whisking
Example A	64.89g of the Wheat Semolina, 19.87g of the pearl millet from Process A, and 20g of the seasoning was added to 450ml of boiling water in a pan and cooked for 5 minutes with regular whisking
Example B	64.89g of the Wheat Semolina, 19.79g of the pearl millet from Process B, and 20g of the seasoning was added to 450ml of boiling water in a pan and cooked for 5 minutes with regular whisking
Example D	64.89g of the Wheat Semolina, 22.03g of the pearl millet from Process D and 20g of the seasoning was added to 450ml of boiling water in a pan and cooked for 5 minutes with regular whisking

5 Table 6 – Method of Cooking of Control 1, Control 2, Example A, Example B, and
Example D

As set out above, of the 50g of available carbohydrate 75% was from wheat semolina
10 and 25% was from the pearl millet process A, B, or D. It was therefore expected that the
GI of the 100% wheat controls would be ~100. The results of this experiment (as provided
in Table 7) shows that Control 1 (Semolina (100% of AC) (no seasoning)) and Control 2
(Semolina (100% of AC)) did indeed both have a GI of around 100. The addition of oils
and spices to the wheat semolina of Control 2 did not significantly raise the GI compared
15 to Control 1.

Sample	Glycaemic Index	Standard Error of the Mean
Control 1	91.3	11.2
Control 2	102.4	12.7
Example A	95.0	8.8
Example B	117.6	16.4
Example D	64.8	9.2

Table 7 – Results of Ability of Processed Pearl Millet to Reduce GI

5

In addition, the GI of Example A containing pearl millet from Process A was not significantly different from the Controls. The GI of Example B containing pearl millet from Process B was actually higher than the Controls.

10 However, it can surprisingly be seen that the GI of Example D containing pearl millet from Process D was significantly lower than the Controls and was even lower than the GI of Examples A and B.

15 It has therefore been demonstrated that the addition of pearl millet that has been processed according to the present invention is capable of reducing the GI of the food to which it is added.

Area Under the Curve

20 In order to further understand why Example D had an improved GI over Control 2, Example A and Example B, the area under the curve (AUC) for these samples was investigated. The Cmax values, which are at the 30 minute interval, for Control 2, Example A, Example B, and Example D were not significantly different from each other. However, by the 60 minute interval the mean blood glucose value for Example D started
25 to separate from the others with the error bars only just overlapping at this time point. By the 90 minute interval the mean blood glucose level for Example D was significantly lower than the other 3 samples.

Physical Properties of the Processed Pearl Millet

Scanning electron micrograph images of the processed grain were taken to identify
5 whether starch was more or less available as a result of processing.

The images of flakes produced by process A show that the seed coat of the grain has been largely torn open though had not completely lost its structure. A stronger magnification on this grain showed lots of holes in the surface of the seed coat where
10 starch granules appear to be escaping. This suggested that the starch has become slightly more available as a result of processing.

Process B caused much greater destruction in the integrity of the seed coat than process A. It was observed that the grain had been broken up into heavily damaged fragments,
15 exposing the starch within and large quantities of starch molecules were escaping from fractures in the seed coat. Some of the exposed starch grains were spherical in shape, whilst others are polygonal – a trait arising as a result of the grains having been tightly pressed together inside the plant cells.

20 Process D provided pearl millet grains that appeared to have remained largely intact. There were a few fractures in the seed coat still and some evidence of starch grains escaping, though not to the same extent that was observed for processes A and B.

Although there appears to be some difference between the physical properties of the
25 pearl millet obtained from process D compared to A and B, it is not obvious how that difference would deliver the GI reducing properties delivered by the pearl millet of Process D.

Rheological analyses

30 The physical qualities of pearl millet processed according to A, B and D (Samples A, B and D respectively) were further assessed with rheological analyses for dough hardness, moisture loss and shear rate. Compression is a common texture test for food products,

the dough is placed on a flat surface and an upper compressor is lowered onto the sample, the force measured is that required to penetrate or puncture the dough.

5 Samples A and D formed a dough with 6ml water, whereas Sample B was unable to absorb that amount. When the volume of water was reduced to 3ml, the consistency of Sample B remained pasty rather than hard, consequently, reliable data for dough hardness could not be obtained for this sample. Samples A and D had a similar dough hardness, both collapsing at a compression force of ~1200 g.

10 The processed pearl millets were also analysed for moisture loss. Sample B had the lowest level of water loss suggesting that the structure of this grain is able to “lock in” water molecules more easily than samples A and D. This result is supported by the microscopy images described previously, which indicate that the extent of damage to grains processed by method B was far greater than the damage to grains processed by
15 methods A and D. The extra damage to the grain may have resulted in greater exposure of the starch granules within, making them better able to soak up excess moisture.

The final rheological analysis of the different samples was to measure the dough shear rate. Structural formation in dough systems is the result of an interplay between
20 processing conditions and subsequent interaction in the protein phase. The analysis showed that there was very little difference between structural formations across the different processing methods; all samples behaved very similarly.

In summary, the variation in the processing methods used to make these prototypes are
25 not causing large changes in the rheological properties of the grains. It is unsurprising that A and D should behave more alike as the processing method is very similar for these samples whilst the processing method for sample B is very different. However, the subtle differences observed in the dough hardness and moisture loss analyses suggest that processing the pearl millet via processes A and D is favourable to process B. It is
30 therefore not obvious how the various rheological properties of the different processed pearl millets would result in the GI reducing properties delivered by the pearl millet of Process D.

Claims

1. A process comprising the steps of
 - Cooking pearl millet by boiling; then
 - Drying the boiled pearl millet; then
 - Milling the dried pearl millet between two cylindrical rollers moving cooperatively
 - o wherein the rollers have a gap between them and
 - o wherein the rollers move at different speedscharacterised in that
 - o the gap between the rollers is from 0.25 mm to 1 mm and in that
 - o the speed differential of the rollers is from 5000 cm/minute to 50,000 cm/minute.
2. A process according to claim 1 wherein the pearl millet is boiled for from 10 to 120 minutes.
3. A process according to claim 1 or claim 2 wherein the boiled pearl millet is dried after boiling to a moisture content of from 5 to 35 wt%.
4. A process according to any of claims 1 to 3 wherein the gap between the rollers is from 0.25 to 0.75 mm.
5. A process according to any of claims 1 to 4 wherein the speed differential of the rollers is from 5,000 to 40,000 cm/minute.
6. A process according to any of claims 1 to 5 wherein the milled pearl millet is dried to a moisture content of from 3 to 14 wt%.
7. Processed pearl millet obtainable by the process of any of claims 1 to 6.
8. A food product comprising carbohydrate, and also comprising the processed pearl millet of claim 7 wherein from 1-50 wt% of the available carbohydrate in the food product comes from the processed pearl millet.

9. A food product according to claim 8 comprising carbohydrate from grains other than pearl millet.
10. A food product according to claim 8 or claim 9 comprising carbohydrate from wheat semolina.
11. A food product according to any of claims 8 to 10 comprising 5-75 wt% of available carbohydrate in total.
12. A food product according to any of claims 8 to 11 having a glycaemic index of up to 99 excluding the GI provided by the processed pearl millet of claim 7.
13. A food product according to any of claims 8 to 12 wherein the food product is a cereal-based product.
14. Use of the processed pearl millet of the claim 7 for use in a food product for the reduction of the GI of the food product.
15. A method of delaying digestion by an animal or a human of carbohydrates in food, comprising administering an effective amount of the processed pearl millet of claim 7.

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. A23L7/10
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)
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 practicable, search terms used)

EP0-Internal, BIOSIS, FSTA, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	S CHOWDHURY ET AL: "Nutrient and antinutrient composition of pearl millet grains as affected by milling and baking", NAHRUNG - FOOD, vol. 41, no. 2, 1 January 1997 (1997-01-01), pages 105-107, XP055398018, XX ISSN: 0027-769X, DOI: 10.1002/food.19970410210 abstract page 106, column 2, last paragraph ----- -/--	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

24 August 2018

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Heirbaut, Marc

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/068721

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	AHMED S.M. SALEH ET AL: "Millet Grains: Nutritional Quality, Processing, and Potential Health Benefits : Millet grains...", COMPREHENSIVE REVIEWS IN FOOD SCIENCE AND FOOD SAFETY, vol. 12, no. 3, 8 April 2013 (2013-04-08), pages 281-295, XP055397597, US ISSN: 1541-4337, DOI: 10.1111/1541-4337.12012 page 7, paragraph 2 - page 8, paragraph 3 -----	1-15
A	MARGARET A. BRENNAN ET AL: "Amaranth, millet and buckwheat flours affect the physical properties of extruded breakfast cereals and modulates their potential glycaemic impact", STARCH: INTERNATIONAL JOURNAL FOR THE INVESTIGATION, PROCESSING AND USE OF CARBOHYDRATES AND THEIR DERIVATIVES, vol. 64, no. 5, 19 January 2012 (2012-01-19), pages 392-398, XP055397810, DE ISSN: 0038-9056, DOI: 10.1002/star.201100150 abstract table 2 -----	1-15
A	Vanisha S Nambiar ET AL: "Potential Functional Implications of Pearl millet (Pennisetum glaucum) in Health and Disease", Journal of Applied Pharmaceutical Science, 1 January 2011 (2011-01-01), XP055398068, Retrieved from the Internet: URL:http://imsear.li.mahidol.ac.th/bitstream/123456789/151028/1/japs2011v1n10p62.pdf [retrieved on 2017-08-10] abstract page 65, column 2, paragraph 3 -----	1-15