(12) STANDARD PATENT (11) Application No. **AU 2003204155 B8**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Slowly digestable starch product

(51) International Patent Classification(s)
A23L 1/10 (2006.01) ***C08B 30/00*** (2006.01)
A21D 2/18 (2006.01) ***C08B 30/06*** (2006.01)
A23L 1/09 (2006.01) ***C08B 30/12*** (2006.01)

(21) Application No: **2003204155** (22) Date of Filing: **2003.05.13**

(30) Priority Data

(31) Number	(32) Date	(33) Country
10/145,302	**2002.05.14**	**US**

(43) Publication Date: **2003.12.04**
(43) Publication Journal Date: **2003.12.04**
(44) Accepted Journal Date: **2007.12.06**
(48) Corrigenda Journal Date: **2008.06.05**

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(56) Related Art
WO 1993/03629
US 5409726
US 6352733

ABSTRACT

this patent pertains to a slowly digestable starch prepared by debranching low amylose starches, particularly by isoamylase. Such slowly digestable starches are useful in edible products, including nutritional supplements.

P/00/011
Regulation 3.2

AUSTRALIA

Patents Act 1990

COMPLETE SPECIFICATION

FOR A STANDARD PATENT

ORIGINAL

TO BE COMPLETED BY APPLICANT

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Invention Title: SLOWLY DIGESTABLE STARCH PRODUCT

The following statement is a full description of this invention, including the best method of performing it known to :-

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Slowly Digestible Starch Product

BACKGROUND OF THE INVENTION

The present invention relates to a slowly digestible starch product prepared by enzymatically debranching low amylose starches and allowing the resultant linear short chains to crystallize to a highly crystalline form.

Starch is a major source of energy in the typical American diet. Refined starches are mostly eaten cooked, and in this form generally have a high glycemic index, being quickly and substantially digested. Some refined starches resist enzymatic hydrolysis in the small intestine, such that the starch is not substantially broken down until it reaches the large intestine where it is utilized by resident microorganisms (resistant starch).

A need has been recognized for a slowly digestible starch, one which provides the consumer with glucose over an extended time period. Such slowly digestible starch would thus be useful for both food and drug applications.

Such slowly digestible starch would be an excellent carbohydrate for use in foods, including medical foods and dietary supplements, for both diabetic and prediabetic individuals. Such slowly digestible starch would also be useful for healthy individuals wishing to moderate their glucose response or achieve sustained energy release via consumption in foods.

Research literature indicates a role for slowly digestible starches in health, as a result of glucose release over an extended time period. Research suggests health-related benefits may include increased satiety for longer time periods (i.e. for use in weight management), sustained energy release (i.e. for enhancing athletic performance including training), and improvements in concentration maintenance and memory.

Such slowly digestible starches could also be useful as drugs, e.g. for reducing the risk of developing diabetes. Further, the slowly digestible starches may be useful for the treatment of hyperglycemia, insulin resistance, hyperinsulinemia, dyslipidemia, and dysfibrinolysis. It may also be useful for treating obesity.

Surprisingly, it has now been discovered that a slowly digestible starch may be prepared by enzymatically debranching low amylose containing starches.

SUMMARY OF THE INVENTION

This patent pertains to a slowly digestible starch product prepared by debranching low amylose starches and allowing the resultant linear short chains to crystallize to a highly crystalline form. The slowly digestible starches provide sustained energy release with a low Glycemic Index.

As used herein, the term rapidly digestible starch is intended to mean a starch or portions thereof which are digested within 20 minutes of digestion.

As used herein, the term resistant starch is intended to mean a starch, or the fraction thereof, which is not digested in the small intestines, as described by Englyst et al, 1992 (Englyst et al, European Journal of Clinical Nutrition, 1992, 46,S33-S50).

As used herein, the term slowly digestible starch is intended to mean a starch, or the fraction thereof, which is neither rapidly digestible starch or resistant starch, as described by Englyst et al, 1992 (Englyst et al, European Journal of Clinical Nutrition, 1992, 46,S33-S50).

As used herein, the term short chain amylose refers to linear polymers containing from about 5 to 65 anhydroglucose units linked by alpha-1,4-D-glucoside bonds.

Fully or completely debranched starch, as used herein, is intended to mean that which theoretically comprises 100%, by weight, of short chain amylose and, in practice, that which is so highly debranched that further enzyme activity produces no measurable change in the percentage of short chain amylose.

Glycemic Index, as used herein, is intended to mean the incremental area under the blood glucose response curve of a 50g carbohydrate portion of a test food expressed as a percent of the response to the same amount of carbohydrate from a standard food taken by the same subject. Typically, carbohydrate is on an available basis and either white bread or glucose is used as the standard food. See Carbohydrates in human nutrition, FAO Food and Nutrition Paper 66, Report of a Joint FAO/WHO Expert Consultation, Rome, 14-18 April 1997.

DETAILED DESCRIPTION OF THE INVENTION

This patent pertains to a slowly digestible starch product prepared by enzymatically debranching low amylose starches and allowing the resultant linear short chains to crystallize to a highly crystalline form. The slowly digestible starches provide sustained energy release with a low Glycemic Index.

Starch, as used herein, is intended to include all starches derived from any native source, any of which may be suitable for use herein. A native starch as used herein, is one as it is found in nature. Also suitable are starches derived from a plant obtained by standard breeding techniques including crossbreeding, translocation, inversion, transformation or any other method of gene or chromosome engineering to include variations thereof. In addition, starch derived from a plant grown from artificial mutations and variations of the above generic composition, which may be produced by known standard methods of mutation breeding, are also suitable herein.

Typical sources for the starches are cereals, tubers, roots, legumes and fruits. The native source can be a waxy variety of corn (maize), pea, potato, sweet potato, banana, barley, wheat, rice, oat, sago, amaranth, tapioca (cassava), arrowroot, canna, and sorghum particularly maize, potato, cassava, and rice. As used herein, the term "waxy" or "low amylose" is intended to include a starch containing no more than about 10% by weight amylose. Particularly suitable in the invention are those starches which contain no more than about 5% amylose by weight.

The starch is enzymatically debranched using techniques known in the art. Suitable enzymes are isoamylase and other endo-alpha-1,6-D-glucanohydrolases which are capable of achieving the desired amount of debranching.

The amount of enzyme used is dependent upon the enzyme source and activity and base material used. Typically, the enzyme is used in an amount of from about 0.05 to about 2.0%, particularly from about 0.2 to about 0.5%, by weight of the starch.

The optimum parameters for enzyme activity will vary depending upon the enzyme used. The rate of enzyme degradation depends upon factors known in the art, including the enzyme type and concentration, substrate concentration, pH, temperature, the presence or absence of inhibitors, and the degree and type of

modification if any. These parameters may be adjusted to optimize the digestion rate of the starch base.

The starch is gelatinized using techniques known in the art before enzyme debranching. Techniques known in the art include those disclosed for example in U.S. Patent Nos. 4,465,702, 5,037,929, 5,131,953, and 5,149,799. Also see, Chapter XXII- "Production and Use of Pregelatinized Starch", Starch: Chemistry and Technology, Vol. III- Industrial Aspects, R.L. Whistler and E.F. Paschall, Editors, Academic Press, New York 1967. The gelatinization process unfolds the starch molecules from the granular structure, thereby permitting the enzyme to more easily and uniformly degrade the starch molecules.

Generally the enzyme treatment is carried out in an aqueous or buffered slurry at a starch solids level of about 10 to about 40%, depending upon the base starch being treated. A solids level of from about 15 to 35% is particularly useful, from about 18 to 30% more particularly useful, in the instant invention. In the alternative, the process may utilize an enzyme immobilized on a solid support.

Typically, enzyme digestion is carried out at the highest solids content feasible without reducing reaction rates in order to facilitate any desired subsequent drying of the starch composition. Reaction rates may be reduced by high solids content as agitation becomes difficult or ineffective and the starch dispersion becomes more difficult to handle.

The pH and temperature of the slurry should be adjusted to provide effective enzyme hydrolysis. These parameters are dependent upon the enzyme to be used and are known in the art. In general, a temperature of about 25 to about 70°C is used, particularly from about 50 to about 60°C. In general, the pH is adjusted to about 3.0 to about 6.0, particularly from about 3.5 to about 4.5, using techniques known in the art.

The enzyme reaction is continued until a slowly digestible starch is achieved. In general, the enzyme reaction will take from about 1 to about 24 hours, particularly about 4 to about 12 hours. The time of the reaction is dependent upon the type of starch used, the type and amount of enzyme used, and the reaction parameters of solids percent, pH, and temperature.

The amount of hydrolysis may be monitored and defined by measuring the concentration of reducing groups which are freed by alpha-1,6-D-glucanohydrolase activity by methods well known in the art. Other techniques

such as monitoring the change in viscosity, iodine reaction, or the change in molecular weight may be used to define the reaction end point. When the starch is completely debranched, the monitored measurement will no longer change. The resultant starch must be at least about 90%, particularly at least about 95%, more particularly at least about 98%, most particularly at least about 99% debranched. The debranched starch will typically have less than about 0.2%, particularly less than about 0.1% alpha-1,6-D-glucosidic bonds (linkages).

Optionally, the enzyme may be deactivated (denatured) by any technique known in the art such as heat, acid or base deactivation. For example, acid deactivation may be accomplished by adjusting the pH to lower than 3.0 for at least 30 minutes or heat deactivation may be accomplished by raising the temperature to from about 80 to about 90°C and maintaining it at that temperature for at least about 20 minutes to fully deactivate the enzyme.

The starch may also be further modified, either before or after the enzymatic hydrolysis. Such modification may be physical, enzyme, or chemical modification. Physical modification includes by shearing or thermal-inhibition, for example by the process described in U.S. Patent No. 5,725,676.

Chemical modification includes without limitation, crosslinking, acetylation and organic esterification, hydroxyalkylation, phosphorylation and inorganic esterification, cationic, anionic, nonionic, and zwitterionic modifcations, and succination. Such modifications are known in the art, for example in Modified Starches: Properties and Uses, Ed. Wurzburg, CRC Press, Inc., Florida (1986).

The starches may be converted, and is intended to include fluidity or thin-boiling starches prepared by oxidation, acid hydrolysis, enzyme hydrolysis, heat and or acid dextrinization. These processes are well known in the art.

Any base starch having suitable properties for use herein may be purified by any method known in the art to remove starch off flavors and colors that are native to the polysaccharide or created during processing. Suitable purification processes for treating starches are disclosed in the family of patents represented by EP 554 818 (Kasica, et al.). Alkali washing techniques are also useful and described in the family of patents represented by U.S. 4,477,480 (Seidel) and 5,187,272 (Bertalan et al.). The debranched starch may also be purified using this method.

The resultant solution is typically adjusted to the desired pH according to its intended end use. In general, the pH is adjusted to from about 3.0 to about 6.0, particularly from about 3.5 to about 4.5, using techniques known in the art. Further, any short chain amylose which precipitated out of the starch dispersion may be redispersed. If purification of the debranched starch composition is desired, reaction impurities and by-products may be removed by dialysis, filtration, centrifugation or any other method known in the art for isolating and concentrating starch compositions. For example, the degraded starch may be washed using techniques known in the art to remove soluble low molecular weight fractions, such as oligosaccharides, resulting in more highly crystalline starch.

The debranched starch is allowed to crystallize by methods known in the art, for example by allowing the starch to stand and retrograde. The starch is then recovered using methods known in the art, particularly by filtration or by drying, including spray drying, freeze drying, flash drying or air drying, more particularly by filtration or flash drying. It is important to control the crystallization, typically by controlling retrogradation and drying, in order to obtain the high degree of crystallinity essential to the present invention. It is further important that the method of drying and other post-crystallization processes do not substantially destroy the crystals.

The resultant starch is in the form of highly crystalline short chain amylose from the debranched starch and is uniquely functional as a slowly digestible starch. The starch is characterized by a melting point temperature, T_p, as measured by DSC using the procedure described infra, of at least about 70°C, particularly at least about 80°C; more particularly at least about 90°C, and an enthalpy, ΔH, as measured by DSC using the procedure described infra, of at least about 25J/g, particularly at least about 30 J/g. Such DSC values are indicative of the highly crystalline nature of the product.

The debranched starch is further characterized by a dextrose equivalent (DE) of at least about 5.0, more particularly of at least 6.0. However, a lower dextrose equivalent (e.g. a DE of at least about 4.0) may be achieved by altering the processing conditions, particularly by removing the low molecular weight hydrolysis products. Dextrose equivalent, as used herein, is intended to mean the reducing power of the hydrolysate. Each starch molecule has one reducing end;

therefore DE is inversely related to molecular weight. The DE of anhydrous D-glucose is defined as 100 and the DE of unhydrolyzed starch is virtually zero.

The resultant debranched starch is slowly digestible in that it has sustained digestion, particularly over at least a two hour time period, more particularly over at least a four hour time period, yet is significantly digested by about 6 hours after ingestion. In particular, less than about 60%, more particularly less than about 50%, most particularly less than about 30%, is digested in the first twenty minutes following consumption and at least about 20%, particularly at least about 30%, is digested between 20 minutes and two hours following consumption, as measured using the digestion procedure described infra. In additional, at least about 50%, particularly at least about 60%, is digested within two hours following consumption. Starch digestion typically continues beyond two hours.

Starch may be consumed in its raw state, but is typically consumed after processing under high or low moisture conditions. Therefore, the invention is intended to include those starches which have the advantage of being slowly digested in the state in which it is consumed. Such state is modeled by the methods described in the examples, *infra*.

Further, the resultant slowly digestible starch does not produce a large rapid increase in blood glucose levels typical of high glycemic index starches, but instead provides a more moderate increase above the baseline which is sustained for a longer time period. It is also process tolerant in that the slowly digestible portion does not substantially decrease upon cooking and/or other typical food processing conditions.

The starch may be used in a variety of edible products including, but not limited to: cereal, bars, pizza, pasta, dressings, including pourable dressings and spoonable dressings; pie fillings, including fruit and cream fillings; sauces, including white sauces and dairy-based sauces such as cheese sauces; gravies; lite syrups; puddings; custards; yogurts; sour creams; beverages, including dairy-based beverages; glazes; baked goods, including crackers, breads, muffins, bagels, biscuits, cookies, pie crusts, and cakes; condiments, confectioneries and gums, and soups.

Edible products also is intended to include nutritional foods and beverages, including dietary supplements, diabetic products, products for sustained energy release such as sports drinks, nutritional bars and energy bars.

The present starch may be added in any amount desired or necessary to obtain the functionality of the composition. In general, the starch may be added in an amount of from about 0.01% to about 100%, particularly from about 1 to about 50%, by weight of the composition. The starch may be added to the food or beverage in the same manner as any other starch, typically by mixing directly into the product or adding it in the form of a sol.

EXAMPLES

The following examples are presented to further illustrate and explain the present invention and should not be taken as limiting in any regard. All percents used are on a weight/weight basis.

The following test procedures are used throughout the examples:

Differential scanning calorimetry – Differential scanning calorimetry measurements were performed in a Perkin-Elmer DSC-7 (Norwalk, CONN., U.S.A). The instrument was calibrated with indium. Samples of approximately 10mg starch at a starch:water ratio of 1:3 are prepared and heated at 10°C/min from 5°C to 160°C. An empty stainless steal pan is used as a reference.

Chain Length and Linearity - The debranched starch samples were analyzed using NMR to determine the average chain length and alpha-1,4 to alpha-1,6 linkage ratios. The NMR samples were prepared by suspending 5-6 mg of the starch in 2.5 mL of D_2O/TSP (sodium trimethyl silyl propionate) and pressure cooking the suspensions for approximately 1 hour. The resulting clear solutions were transferred to 5mm NMR tubes and kept hot on a steam bath until the NMR spectra were acquired. This procedure for the handling of the samples insured that the crystalline starch material remained in solution. The proton NMR spectra were acquired at 90°C. on a Bruker DPX-400 spectrometer at 400 MHz.

The chemical shift assignments (relative to TSP at 90°C.) for the resonance of interest were as follows. The alpha-1,4 mid-chain linkages had a chemical shift of 5.38 ppm, the alpha-1,6 mid-chain (branch points) at 4.96 ppm, the alpha-form of the reducing end groups at 5.23 ppm, and the beta-form of the reducing end groups at 4.65 ppm.

The average chain length for the starch samples was calculated from the ratio of the reducing end groups to the mid-chain resonance. The percentage of alpha-1,6 linkages (branch points) were calculated from the amount of alpha-1,6 linkages versus alpha-1,4 linkages.

Dextrose Equivalent (DE) - For in-process DE measurement, the Fehling Volumetric Titration Method was used. A 500 ml Erlenmeyer flask was rinsed with deionized (D.I.) water. 50 ml of D.I. water was then added. The addition of 5 ml each of Fehling Solutions A and B, and 2 drops of methylene blue with two boiling chips followed. After determination of the reaction solids using a refractometer, a starch solution containing 2-4 percent starch solids was

prepared using D.I. water by diluting the reaction solution in a beaker. Before proceeding to the next step, the solids were checked by a refractometer to make sure the solution was prepared correctly. The beaker with starch solution was weighed and the weight recorded. 15 grams of the starch solution was added into the Erlenmeyer flask with prepared Fehlings solution. After they were boiled under agitation for 2 minutes on a hot plate, a bluish tint normally appeared. Starch solution from the beaker was added using a pipette gradually until the bluish tint disappeared and a distinctive reddish cuprous oxide formed. The starch solution was continuously stirred with a plastic pipette to keep the solution uniform. When the reddish endpoint was reached, the beaker containing the starch solution was weighed again to determine the weight of starch consumed. The calculation of D.E. can be seen from the following equation:

$$D.E. = \frac{[\text{Fehling factor} \times 100]}{[(\text{grams required from starch solution}) \times (\text{conc. of starch solution})]}$$

Simulated Digestion - (Englyst et al, European Journal of Clinical Nutrition, 1992, 46,S33-S50) - Food samples are ground/minced as if masticated. Powder starch samples are screened to a particle size of 250 microns or less. A 500-600 mg ± 0.1 mg of sample is weighed and added to the sample tube. 10 ml of a pepsin (0.5%), guar gum (0.5%), and HCl (0.05 M) solution is added to each tube.

Blank and glucose standard tubes are prepared. The blank is 20 ml of a buffer containing 0.25 M sodium acetate and 0.02% calcium chloride. Glucose standards are prepared by mixing 10 ml sodium acetate buffer (described above) and 10ml of 50 mg/ml glucose solution. Standards are prepared in duplicate.

The enzyme mix is prepared by adding 18 g of porcine pancreatin (Sigma P-7545) to 120 ml of deionized water, mixing well, then centrifuging at 3000g for 10 minutes. The supernatant is collected and 48mg of dry invertase (Sigma I-4504) and 0.5 ml AMG 400 (Novo Nordisk) are added.

The sample tubes are pre-incubated at 37°C for 30 min, then removed from the bath and 10 ml of sodium acetate buffer is added along with glass balls/marbles (to aid in physical breakdown of the sample during shaking).

5 ml of the enzyme mixture is added to the samples, blank, and standards. The tubes are shaken horizontally in a 37°C waterbath at approximately 180 strokes/min. Time "zero" represents the first addition of the enzyme mixture to the first tube.

After 20 and 120 minutes, 0.5-ml aliquots are removed from the incubating samples and placed into a separate tube of 20ml 66% ethanol (to stop the reaction). After 1 hour, an aliquot is centrifuged at 3000g for 10 minutes.

The glucose concentration in each tube is measured using the glucose oxidase/peroxidase method (Megazyme *Glucose Assay Procedure* GLC9/96). This is a colorimetric procedure. HPLC may also be used to detect glucose as disclosed in previous literature using this experiment.

The degree of starch digestion is determined by calculating the glucose concentration against the glucose standards, using a conversion factor of 0.9. Results are given as "% starch digested" (dry weight basis) after 20 and 120 minutes. SDS (slowly digestible starch) is the 120-minute value minus the 20-minute value.

Every sample analysis batch includes a reference sample of uncooked cornstarch. The accepted range of % digestion values for cornstarch are:

Sample	s20	s120	SDS
Cornstarch[1]	17.5 ± 2.5	80 ± 5	approx. 62.5

[1]Melogel® starch, commercially available from National Starch and Chemical Company, Bridgewater, NJ, USA.

Cooked models - Two general models are used to mimic commercial food processes: high moisture; and low moisture. The high moisture food model uses starch in water at 20% solids, cooked in a steam bath at 90°C. for 5 minutes. This cook is then frozen in a dry ice/acetone bath, freeze-dried, ground, and tested for digestion. The low moisture food starch in water at 50% solids, and bakes the paste in an oven at 190°C. for approximately 20 minutes. The sample was then ground and screened to a particle size of 250 microns or less.

Example 1

Preparation of the Crystalline Starch Using Isoamylase for Uncooked Digestion Study

A. 4 kg of waxy maize starch was slurried in 10.8 liter of water and the pH was adjusted to 4.0 using 3:1 water:hydrochloric acid. The starch was jet-cooked with full steam at 310-315°F. (154.4-157.2°C.) and a back-pressure of 80 psi (5.52 x 10^5 Pa) to completely cook out the starch. 0.2% isoamylase (commercially available from Hayashibara Inc., Japan) based on the weight of the starch, was added after the cooked starch was cooled to 55°C. The debranching reaction was stopped when the sample D.E. (Dextrose Equivalent) reached 6.0. At this point, the pH was adjusted to 2.0 for 30 minutes at 55°C. to denature the enzyme. The starch solution was then cooled to room temperature after the pH was re-adjusted to 6.0, and allowed to crystallize overnight (16 hours) at room temperature. The crystallized product was recovered by spray drying with an inlet temperature of 210°C and an outlet temperature of 116°C.

B. 500 lbs of acid converted waxy maize starch was slurried in 1500 lbs of water and the pH was adjusted to 4.0 using 3:1 water:hydrochloric acid. The starch was steam-batch-cooked. 0.2% isoamylase enzyme was added under constant agitation after the cooked starch temperature was maintained at 55°C. After the reaction proceeded for 8 hours, the enzyme was denatured by lowering pH to 2.0 at 55°C. for 30 minutes. The starch solution was then cooled to room temperature after pH was re-adjusted to 6.0, and allowed to crystallize at room temperature until the filtrate soluble leveled off. The crystallized product was de-watered and flash-dried. The resultant debranched starch has a dextrose equivalent of 7.0.

C. The method of Example 1A was repeated with the exception that the base starch was an acid converted waxy maize and the reaction proceeded overnight (16 hours). After the crystallization, the product was spray-dried with an inlet temperature of 210°C and an outlet temperature of 116°C.

D. The method of Example 1A was repeated with the exception that the debranching reaction was stopped when the sample D.E. reached 5.3. At this point, the pH was adjusted to 2.0 for 30 minutes at 55°C. to denature the enzyme. The starch solution was then cooled to room temperature after pH was re-adjusted

to 6.0, and allowed to crystallize overnight at room temperature. The crystallized product was filtered and air-dried.

DSC and digestion results as well as the calculated SDS contents for the samples in Example 1 are shown in Table 1.

Table 1.

DSC and digestion results

Sample	20min	120min	SDS	DSC			
				To(°C.)	Tp(°C.)	Tc(°C.)	ΔH(J/g)
1A	49.6	73.2	23.6	44.6	80.6	95.7	28.3
1B	22.7	48.6	25.9	47.2	96.2	127.7	32.0
1C	42.4	65.0	22.6	47.3	76.1	93.4	25.9
1D	25.0	50.3	25.3	53.8	77.0	89.9	28.3

The samples all contained more than 20% SDS.

Example 2

Preparation of Isoamylase Debranched and Crystallized Samples for Cooked Digestion Study

A. 4 kg of waxy maize starch was slurried in 12 liters of water. The sample was jet-cooked and cooled to 55°C. and pH was adjusted to 4.0 by adding 3:1 water:HCl. At this point, 0.2% isoamylase based on starch weight was added to start the debranching reaction. After 5 hours of reaction, the sample pH was raised to 6.0 using 3% NaOH and heated to 85°C. for 20 minutes to kill the enzyme. The sample was then cooled to room temperature and crystallized overnight at that temperature. The sample was recovered by filtration and air-dried. The resultant debranched starch had a dextrose equivalent of 6.7.

B. The method of Example 2A was repeated with the exception that the sample was cooled to 40°C. and crystallized at 40°C. overnight.

Digestion studies of sample 2A and 2B in Example 2 and sample 1C and 1D in Example 1 were conducted following subjection of the starches to either high moisture (HM) or low moisture (LM) cook models. Table 2 summarizes digestion results as well as the calculated SDS contents for these samples. DSC results for raw samples are also included.

Table 2.

Digestion results for cooked samples and raw material DSC

Sample	Cook	20m	120m	SDS	DSC			
					To(°C)	Tp(°C)	Tc(°C)	ΔH(J/g)
2A	HM	31.0	65.0	34.0	55.8	87.1	99.7	33.2
2B	HM	36.0	65.0	29.0	82.9	112.1	129.4	35.0
1C	LM	39.8	69.2	29.4	47.3	76.1	93.4	25.9
1D	LM	31.1	66.7	35.6	53.8	77.0	89.9	28.3

All samples in this example demonstrated higher than 20% SDS content.

Example 3

Food Product Containing Debranched Starch

Crackers were made using the following formulations and methods.

Ingredient	Sample 3A Amount (%w/w)	Sample 3B Amount (%w/w)	Sample 3C Amount (%w/w)
Cake flour	45.3	14.4	14.4
Starch Example 1D	0.0	0.0	39.0
Waxy maize starch	0.0	39.0	0.0
Sugar	12.0	3.9	3.9
Baking soda	0.71	0.71	0.71
Calcium phosphate	0.71	0.71	0.71
Salt	0.44	0.44	0.44
Malted barley flour	0.57	0.57	0.57
Shortening	6.56	6.56	6.56
High fructose corn syrup	1.7	1.7	1.7
Ammonium bicarbonate	1.11	1.11	1.11
Water	30.6	30.6	30.6

The dry ingredients were mixed together for one minute. The shortening, corn syrup and water were then added and the mixture was kneaded into a dough. The dough was rolled and cut into crackers of approximately 2 inch (50.8mm)

squares of 0.25 (6.35mm) inches thick. The crackers were baked for 15 minutes at 400°F. (204.4°C.).

The crackers were ground as if masticated and tested for digestibility. The results are shown in Table 3.

Table 3.

Sample	20 min	120 min	SDS
3A	77.0	91.3	14.3
3B	72.5	89.0	16.5
3C	49.6	75.5	25.9

As can be seen from Table 3, the cracker baked with the slowly digestible starch retained such slow digestibility.

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The claims defining the invention are as follows:

1. A starch composition prepared from low amylose starch comprising crystalline linear α-glucans characterized by:

a) at least about 20% slowly digestible starch;

b) less than about 60% rapidly digestible starch;

c) a melting point temperature, T_p as measured by DSC, of at least about 70°C; and

d) an enthalpy, ΔH as measured by DSC, of at least about 25J/g, wherein the composition is at least about 90% debranched, wherein at least about 50% is digested within two hours as measured by simulated digestion.

2. The starch composition of claim 1, wherein at least about 60% is digested within two hours of digestion as measured by simulated digestion.

3. The starch composition of claim 1, whereby the starch composition is prepared from a low amylose starch selected from the group consisting of maize, potato, cassava, and rice.

4. The starch composition of claim 1, wherein the melting point temperature is at least about 80°C.

5. The starch composition of claim 1, wherein the melting point temperature is at least about 90°C.

6. The starch composition of claim 1, wherein the enthalpy is at least about 30J/g.

7. The starch composition of claim 1, characterized by at least about 30% slowly digestible starch.

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8. The starch composition of claim 1 consisting essentially of crystalline linear α-glucans.

9. The starch composition of claim 1, wherein the composition has a dextrose equivalent of at least about 4.0.

10. The starch composition of claim 1, wherein the composition has a dextrose equivalent of at least about 5.0.

11. The starch composition of claim 1, wherein the starch is debranched at least about 95%.

12. The starch composition of claim 1, wherein the starch is debranched at least about 98%

13. A process of making the starch composition of claim 1 comprising:

a) debranching a low amylose starch, wherein the starch is debranched at least about 90%;

b) allowing the debranched starch to crystallize; and

c) drying the highly crystallized debranched starch.

14. The process of claim 13, wherein the starch composition is debranched using isoamylase.

15. The process of claim 13, wherein the starch composition is completely debranched.

16. The process of claim 13, wherein the starch is debranched at least about 95%.

17. The process of claim 13, wherein the starch is debranched at least about 98%.

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18. An edible product comprising the starch composition of claim 1.

19. The product of claim 18, wherein the product is a nutritional food.

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