

Resistant dextrin with high dietary fiber content and preparation method thereof

Cross-Reference to Related Application

The present application claims priority to the Chinese Patent Application No. 202411813142.X filed on December 11, 2024, and the contents of the patent application is incorporated into the present application by reference in its entirety.

Technical Field

The present invention belongs to the field of functional sugar, specifically relates to a resistant dextrin with high dietary fiber content and a preparation method thereof.

Background

Dietary fiber (a food nutrient that is difficult to digest) helps maintain intestinal cleanliness and has significant effects in reducing and preventing gastrointestinal diseases, as well as controlling blood sugar. Dietary fiber includes soluble and insoluble dietary fiber. Insoluble dietary fiber has high viscosity, low solubility, and an unpleasant taste; whereas water-soluble dietary fiber has good solubility and a pleasant taste, making it widely used in the food industry and daily life, among which resistant dextrin is a representative product.

Resistant dextrin possesses excellent properties such as high solubility, low viscosity, acid stability, freeze-thaw stability, low browning tendency, and storage stability. Resistant dextrin contains α -1,3 and α -1,6 glycosidic bonds, as well as glucan and numerous irregular branched structures. The complex structure of resistant dextrin makes it difficult for human digestive enzymes to completely break it down, thereby promoting and enhancing basic human metabolism such as intestinal peristalsis and blood circulation, and stimulating the intestinal probiotics to produce more short-chain fatty acids. When added to food as a dietary fiber, resistant dextrin does not alter the final quality of the products. In addition, resistant dextrin exhibits a range of beneficial physiological functions and properties, including inhibiting rapid postprandial blood glucose spikes, regulating blood lipids, enhancing gastrointestinal function, modulating blood pressure, aiding in weight control, and providing low caloric value (only 0.5 to 1.4 kcal/g), and thus has broad application prospects in processed foods.

Currently, the production of resistant dextrin primarily involves heating corn starch, wheat starch, or potato starch at high temperatures to decompose it into pyrodextrin. The pyrodextrin is then dissolved in water and enzymatically hydrolyzed, followed by decolorization with activated carbon, desalination with ion exchange resins, and chromatographic separation, and finally

subjected to drying and other steps to obtain the finished product. However, after enzymatic decomposition, the resulting resistant dextrin has a low dietary fiber content, typically 80% to 85%, while its glucose and non-dietary fiber contents are relatively high.

Summary

In view of this, the object of the present invention is to provide a resistant dextrin with high dietary fiber content and its preparation method. The preparation method of the present invention increases the dietary fiber content in the resistant dextrin.

The present invention provides a method for preparing a resistant dextrin with high dietary fiber content, comprising the following steps:

mixing pea starch milk and a liquefying enzyme for liquefaction to obtain a liquefied liquid; wherein the liquefied liquid has a DE value of 8% to 11%;

subjecting the liquefied liquid to undergo a molecular rearrangement reaction under acidic conditions to obtain a resistant dextrin; wherein, the resistant dextrin has a dietary fiber content of $\geq 93\%$ by mass.

In some embodiments, the liquefying enzyme is used in an amount of 60 to 100 mL/ton, based on the dry basis of the pea starch milk.

In some embodiments, the liquefaction is performed at 95 to 115 °C for 40 to 60 minutes.

In some embodiments, the method further comprises, before the molecular rearrangement reaction, an enzyme inactivation step; wherein the enzyme inactivation is acidic enzyme inactivation, and the acidic enzyme inactivation is performed by adjusting the pH of the liquefied liquid to 3 to 4.

In some embodiments, the acidic condition for the molecular rearrangement reaction is pH = 1.5 to 2.

In some embodiments, the molecular rearrangement reaction is performed at 130 to 150 °C for 1.5 to 2.5 hours.

In some embodiments, the pea starch milk has a solid content of 30 to 40 wt% and a pH of 5 to 6.

In some embodiments, the method further comprises, after the molecular rearrangement reaction: sequentially subjecting the feed liquid obtained from the molecular rearrangement reaction to decolorization, desalination, concentration, and drying; wherein the decolorization is activated carbon decolorization, and the mass of activated carbon used in the activated carbon decolorization is 0.5% to 1% of the dry basis mass in the feed liquid.

In some embodiments, the desalination is ion exchange resin desalination, and the ion exchange resin desalination uses a combination of strong acid cation exchange resin D001, strong base anion exchange resin D202, and strong acid cation exchange resin D001.

The present invention further provides a resistant dextrin with high dietary fiber content obtained by the preparation method described in any of the above embodiments, wherein the resistant dextrin with high dietary fiber content has a dietary fiber content of $\geq 93\%$ by mass and a DE value of $\leq 5\%$.

Compared with the prior art, the present invention has the following beneficial effects:

The present invention provides a method for preparing a resistant dextrin with high dietary fiber content, comprising the following steps: mixing pea starch milk and a liquefying enzyme for liquefaction to obtain a liquefied liquid; wherein the liquefied liquid has a DE value of 8% to 11%; subjecting the liquefied liquid to a molecular rearrangement reaction under acidic conditions to obtain a resistant dextrin; wherein the resistant dextrin has a dietary fiber content of $\geq 93\%$ by mass. In the present invention, the DE value of the liquefied liquid is controlled to be 8% to 11%, within this DE value range, the process operation is highly controllable and repeatable, avoiding problems due to excessively low or high DE values such as insufficient reaction or excessive monosaccharides leading to violent reactions, thereby the resulting resistant dextrin has a high dietary fiber content. The present invention uses pea starch as raw material, as compared with corn starch and potato starch, pea starch has a relatively high content of slowly digestible starch (SDS), making it easier to obtain a liquefied liquid with a suitable DE value after liquefaction. The resistant dextrin prepared using this liquefied liquid has a high dietary fiber content and good resistance to digestion.

The preparation method of the present invention allows for the direct production of resistant dextrin with high dietary fiber content through the molecular rearrangement reaction of the post-liquefied crude dextrin. The resistant dextrin has a dietary fiber content of $\geq 93\%$ and a high starch conversion rate, thus eliminating the need for further enzymatic conversion and chromatographic separation of the resistant dextrin to make its components to meet the acceptance criteria. The content of small molecules such as glucose and the dietary fiber content both meet the standards. The existing technology generally involves using enzymes to hydrolyze macromolecules into small molecules, followed by chromatographic separation to remove small molecules such as glucose, thereby obtaining digestion-resistant macromolecular dextrin. The resistant dextrin prepared by the present invention has a high dietary fiber content, eliminating the need for additional removal of small molecules. The crude material liquid after molecular rearrangement is easy to refine, resulting in a product with high purity. The preparation method of the present invention is simple, with low energy consumption, low water consumption, and low cost.

Brief description of the Drawings

To more clearly illustrate the technical solutions in the examples of the present invention or the prior art, the drawings used in the examples will be briefly described below. Obviously, the drawings described below are only some examples of the present invention. For those skilled in the art, other drawings can be obtained based on these drawings without inventive effort.

Figure 1 shows a flowchart of the preparation of resistant dextrin with high dietary fiber content in the Examples.

Detailed description

The present invention provides a method for preparing a resistant dextrin with high dietary fiber content, comprising the following steps:

mixing pea starch milk and a liquefying enzyme for liquefaction to obtain a liquefied liquid; wherein the liquefied liquid has a DE value of 8% to 11%;

subjecting the liquefied liquid to undergo a molecular rearrangement reaction under acidic conditions to obtain a resistant dextrin; wherein the resistant dextrin has a dietary fiber content of $\geq 93\%$ by mass.

In the present invention, unless otherwise specified, all materials and equipments used herein are commercially available products in the art.

In the present invention, pea starch milk and a liquefying enzyme are mixed for liquefaction to obtain a liquefied liquid; and the liquefied liquid has a DE value of 8% to 11%.

In the present invention, the solid content of the pea starch milk is preferably 30 to 40 wt%, specifically may be 34 wt%, 35 wt%, or 36 wt%, and the pH value is preferably 5 to 6, specifically may be 5.2, 5.4, 5.5, or 5.6. During the slurrying process of the pea starch milk, it is preferred to use tap water at room temperature. The concentration of the pea starch milk as described in the present invention facilitates direct molecular rearrangement reaction after liquefaction, eliminating the need for additional concentration adjustment. The pH value falls within the optimal range suitable for the liquefying enzyme, allowing production of crude dextrin with a suitable DE value.

In the present invention, the liquefying enzyme is preferably a high-temperature α -amylase. Based on the dry basis of the pea starch milk, the amount of the liquefying enzyme is preferably 60 to 100 mL/ton (i.e., 60 to 100 mL/T•DS), specifically may be 80 mL/ton. The high-temperature α -amylase is preferably obtained from Shandong Lonct Enzymes Co., Ltd., with high-temperature at a range of 90 to 120 °C.

In the present invention, the liquefaction is preferably performed at a temperature of 95 to 115°C, specifically may be 100°C, the liquefaction is preferably performed for a period of 40 to 60 minutes, specifically may be 50 minutes. During the liquefaction process, starch granules absorb water and swell under heat effect, weakening the intermolecular binding of starch molecules, leading to partial disintegration of the starch granules and the formation of a homogeneous viscous liquid, i.e., dextrin. The temperature and time of liquefaction as described in the present invention facilitate controlling the DE value of the liquefied liquid to be 8% to 11%.

In the present invention, the DE value of the liquefied liquid is preferably 9% to 10%, specifically may be 8%, 9.52%, 8.31%, 10.27%, 9.48%, 9.34%, or 9.15%. The DE value (Dextrose Equivalent) refers to the percentage of reducing sugars (calculated as glucose) in dry matter, and is used to measure the degree of starch conversion into glucose. The DE value described in the present invention avoids problems such as insufficient reaction due to an excessively low DE value (below 8) or violent reaction caused by a higher amount of monosaccharides due to an excessively high DE value (above 11), thereby enabling the production of resistant dextrin with a high dietary fiber content. The liquefied liquid is a feed liquid of crude dextrin.

In the present invention, after obtaining the liquefied liquid, the liquefied liquid is subjected to a molecular rearrangement reaction under acidic conditions to obtain the resistant dextrin; wherein the resistant dextrin has a dietary fiber content of $\geq 93\%$ by mass.

In the present invention, the liquefied liquid is preferably subjected to an enzyme inactivation step before the molecular rearrangement reaction. The enzyme inactivation is preferably acidic enzyme inactivation. The acidic enzyme inactivation preferably comprises: adjusting the pH value of the liquefied liquid to 3 to 4, specifically may be 3.3, 3.4, or 3.5; wherein, the reagent for adjusting the pH is preferably hydrochloric acid. The present invention imposes no specific requirements on the concentration of the hydrochloric acid.

In the present invention, the acidic condition for the molecular rearrangement reaction is preferably at a pH value of 1.5 to 2, specifically may be 1.5, 1.8, or 2. During the molecular rearrangement reaction, acid-catalyzed decomposition of dextrin also occurs. The pH value described in the present invention avoids problems such as violent reaction of acid-catalyzed decomposition which would generate an excessive number of small molecules, and insufficient acid-catalyzed decomposition of the crude dextrin which would result in the failure to achieve the desired degree of polymerization. The pH value specified in the present invention facilitates the progress of the molecular rearrangement reaction, thereby obtaining the resistant dextrin with a high dietary fiber content. During the molecular rearrangement process, the glycosidic bonds of the dextrin molecules are rearranged to form digestion-resistant linkages.

In the present invention, the molecular rearrangement reaction is preferably performed under stirring and heating conditions. The heating is preferably performed at a temperature of 130 to 150 °C, specifically may be 140°C, and the heating is preferably performed for a period of 1.5 to 2.5 hours, specifically may be 2 hours. The stirring is preferably performed at a rotation speed of 100 to 200 rpm, specifically may be 105 rpm.

In the present invention, the molecular rearrangement reaction is preferably performed in a reaction vessel. Preferably, in the present invention, the reaction vessel is preheated before adding the enzyme-inactivated liquefied liquid. The preheating is preferably performed at a temperature of 120 to 130°C, specifically may be 125°C, with a stabilization time preferably of 15 to 20 minutes.

In the present invention, the crude resistant dextrin in the feed liquid obtained from the molecular rearrangement reaction has a DE value of $\leq 5\%$, and a dietary fiber content of $\geq 93\%$ (based on a dry basis).

In the present invention, after the molecular rearrangement reaction, the method preferably further comprises: sequentially subjecting the feed liquid obtained from the molecular rearrangement reaction to decolorization, desalination, concentration, and drying;

the decolorization is preferably activated carbon decolorization, and the activated carbon decolorization preferably comprises: mixing the feed liquid obtained from the molecular rearrangement reaction with activated carbon and heating the mixture, and then filtering to obtain a post-decolorized feed liquid; wherein the mass of the activated carbon is preferably 0.5% to 1%, specifically may be 0.8%, of the dry basis mass of the feed liquid; and the heating is preferably performed at a temperature of 78 to 82 °C, specifically may be 80°C, and with a sustained temperature for a time preferably of 30 to 40 mins;

the desalination is preferably ion exchange resin desalination, and the desalination is preferably performed by using a combination of strong acid cation exchange resin D001, strong base anion exchange resin D202 and strong acid cation exchange resin D001, wherein the feeding temperature is preferably 35 to 55 °C, specifically may be 45°C or 50°C, and the feeding rate is preferably 3 to 5 BV/h, specifically may be 4 BV/h;

the concentration is preferably performed at a temperature of 50 to 60 °C, specifically may be 55°C, and preferably a pressure of -0.1 MPa. The concentrated solid content is preferably 75% to 80%, specifically may be 76%, 77%, 77.5%, 78%, or 78.5%; the product obtained from the concentration step has an electrical conductivity of $< 50 \mu\text{S/cm}$, a light transmittance of $\geq 95\%$, and a colorless or light yellow color;

the drying is preferably vacuum drying, the drying is preferably performed at a temperature of 100 to 110 °C, and the product obtained from the drying has a moisture content of $\leq 5\%$.

The present invention also provides a resistant dextrin with high dietary fiber content prepared by the above-mentioned method, wherein the resistant dextrin with high dietary fiber content has a dietary fiber content of $\geq 93\%$ and a DE value of $\leq 5\%$.

The present invention provides a method for preparing resistant dextrin using pea starch. Using pea starch as raw material, the resistant dextrin prepared has a high dietary fiber content ($\geq 93\%$), excellent digestion resistance, improved conversion rate of starch, and broadens the application scope of the product. The process of the present invention is innovative yet simple, with precise control of the liquefaction DE value. The molecular rearrangement reaction can directly produce resistant dextrin with high dietary fiber content without enzymatic conversion or chromatographic procedures. This results in a high starch conversion rate, reduced costs, and improved efficiency.

To further illustrate the present invention, the resistant dextrin with high dietary fiber content and its preparation method are described in detail below with reference to the drawings and examples. However, these descriptions should not be construed as limiting the scope of the present invention.

Figure 1 shows a flowchart of the preparation process of the resistant dextrin with high dietary fiber content in the Examples, in which pea starch is slurried to form pea starch milk, which is then liquefied, the DE value is controlled at 8 to 11 during liquefaction. After enzyme inactivation, a molecular rearrangement reaction is performed, followed by decolorization, ion exchange desalination, concentration and drying to obtain resistant dextrin.

The present invention is now described in the following non-limiting examples.

Those skilled in the art will understand that the examples are described for illustrative purposes only and are not intended to limit the scope claimed by the present application. Unless otherwise specified, the experimental methods in the examples are conventional methods. Where specific conditions are not specified in the examples, they shall be performed under conventional conditions or conditions recommended by the manufacturers. Unless otherwise specified, all reagents and instruments used are commercially available conventional products. The invention is described below with reference to the following examples which are intended to illustrate the invention (rather than limiting the present invention).

Examples

Example 1

(1) Slurrying: weigh 200 g of pea starch, and add tap water to the pea starch to prepare starch milk with a solid content of 35% and a pH of 5.5;

(2) Liquefaction: a high-temperature α -amylase is added to the starch milk at 80 mL/T•DS, and liquefaction is performed at 100 °C for 50 minutes to obtain a liquefied liquid, and then detect the DE value;

(3) Enzyme inactivation: perform enzyme inactivation by using acidic enzyme inactivation method, after liquefaction the pH of the liquefied liquid is adjusted to 3.5;

(4) Adjustment of pH value: the feed liquid from step (3) is adjusted to pH 1.8 with hydrochloric acid;

(5) Molecular rearrangement reaction: a high-temperature reaction vessel is preheated to 125 °C and stabilized for 15 minutes, then the feed liquid from step (4) is transferred into the reaction vessel, and heated at 140 °C for 2 hours; the reaction is performed under stirring at a rotation speed of 150 rpm. After the reaction, a feed liquid of crude resistant dextrin is obtained, and its DE value and dietary fiber content are determined;

(6) Refinement: the feed liquid of crude resistant dextrin is subjected to decolorization, ion exchange desalination, concentration and drying;

wherein, the decolorization is performed by: adding 0.8% (dry basis weight) activated carbon and maintaining at 80 °C for 30 minutes to perform decolorization;

the ion exchange desalination is performed by: using a combination of D001 resin and D202-D001 resin at an ion exchange temperature of 45 °C and a flow rate of 4 BV/h;

concentration conditions: the concentration is performed at a temperature of 55 °C, and a pressure of -0.1 MPa for concentration; after the concentration, the solid content is 75%, the conductivity is 23 μ S/cm, and the transmittance is 98%;

drying conditions: the drying is performed under vacuum at a pressure of -0.1 MPa and a temperature of 100 °C; a resistant dextrin powder is obtained by pulverization, and then its DE value, dietary fiber content, and starch conversion rate are determined.

Example 2

(1) Slurrying: weigh 200 g of pea starch, and add tap water to the pea starch to prepare starch milk with a solid content of 35% and a pH of 5.6;

(2) Liquefaction: a high-temperature α -amylase is added to the starch milk at 60 mL/T•DS, and liquefaction is performed at 115 °C for 40 minutes to obtain a liquefied liquid, and its DE value is determined;

(3) Enzyme inactivation: perform enzyme inactivation by using acidic enzyme inactivation method, after liquefaction the pH of the liquefied liquid is adjusted to 3.5;

(4) Adjustment of pH value: adjust the pH of the feed liquid from step (3) to pH 1.8 with hydrochloric acid;

(5) Molecular rearrangement reaction: a high-temperature reaction vessel is preheated to 120 °C and stabilized for 20 minutes, then the feed liquid from step (4) is transferred into the reaction vessel, and heated at 140 °C for 2 hours; the reaction is performed under stirring at a rotation speed of 150 rpm; after the reaction, a feed liquid of crude resistant dextrin is obtained, and its DE value and dietary fiber content are determined;

(6) Refinement: subject the feed liquid of crude resistant dextrin to decolorization, ion exchange desalination, concentration and drying;

wherein, the decolorization is performed by: adding 0.8% (dry basis weight) activated carbon and maintaining at 80 °C for 30 minutes to perform decolorization;

the ion exchange desalination is performed by: using a combination of D001 resin and D202-D001 resin at an ion exchange temperature of 45 °C and a flow rate of 4 BV/h;

concentration conditions: the concentration is performed at a temperature of 55 °C, and a pressure of -0.1 MPa for concentration; after the concentration, the solid content is 75%, the conductivity is 32 μ S/cm, and the transmittance is 96.5%;

drying conditions: the drying is performed under vacuum at a pressure of -0.1 MPa and a temperature of 100 °C; a resistant dextrin powder is obtained by pulverization, and its DE value, dietary fiber content, and starch conversion rate are determined.

Example 3

(1) Slurrying: weigh 200 g of pea starch, and add tap water to the pea starch to prepare starch milk with a solid content of 34% and a pH of 5.4;

(2) Liquefaction: a high-temperature α -amylase is added to the starch milk at 100 mL/T•DS, and liquefaction is performed at 95 °C for 60 minutes to obtain a liquefied liquid, and its DE value is determined;

(3) Enzyme inactivation: perform enzyme inactivation by using acidic enzyme inactivation method, after the liquefaction the pH of the liquefied liquid is adjusted to 3.0;

(4) Adjustment of pH value: the feed liquid from step (3) is adjusted to pH 1.8 with hydrochloric acid;

(5) Molecular rearrangement reaction: a high-temperature reaction vessel is preheated to 125 °C and stabilized for 15 minutes, then the feed liquid from step (4) is transferred into the reaction vessel, and heated at 140 °C for 2 hours; the reaction is performed under stirring at a rotation speed of 150 rpm; after the reaction, a feed liquid of crude resistant dextrin is obtained, and its DE value and dietary fiber content are determined;

(6) Refinement: the feed liquid of crude resistant dextrin is subjected to decolorization, ion exchange desalination, concentration and drying;

wherein, the decolorization is performed by: adding 0.8% (dry basis weight) activated carbon and maintaining at 80 °C for 35 minutes to perform decolorization;

the ion exchange desalination is performed by: using a combination of D001 resin and D202-D001 resin at an ion exchange temperature of 50 °C and a flow rate of 4 BV/h;

concentration conditions: the concentration is performed at a temperature of 55 °C, and a pressure of -0.1 MPa for concentration; after the concentration, the solid content is 76%, the conductivity is 45 μ S/cm, and the transmittance is 96.6%;

drying conditions: the drying is performed under vacuum at a pressure of -0.1 MPa and a temperature of 105 °C; a resistant dextrin powder is obtained by pulverization, and its DE value, dietary fiber content, and starch conversion rate are determined.

Example 4

(1) Slurring: weigh 200 g of pea starch, and add tap water to the pea starch to prepare starch milk with a solid content of 34% and a pH of 5.5;

(2) Liquefaction: a high-temperature α -amylase is added to the starch milk at 80 mL/T•DS, and liquefaction is performed at 100 °C for 50 minutes to obtain a liquefied liquid, and its DE value is determined;

(3) Enzyme inactivation: perform enzyme inactivation by using acidic enzyme inactivation method, after liquefaction the pH of the liquefied liquid is adjusted to 3.4;

(4) Adjustment of pH value: the feed liquid from step (3) is adjusted to pH 1.5 with hydrochloric acid;

(5) Molecular rearrangement reaction: a high-temperature reaction vessel is preheated to 125 °C and stabilized for 15 minutes, then the feed liquid from step (4) is transferred into the reaction vessel, and heated at 140 °C for 2 hours; the reaction is performed under stirring at a rotation speed of 150 rpm; after the reaction, a feed liquid of crude resistant dextrin is obtained, and its DE value and dietary fiber content are determined;

(6) Refinement: the feed liquid of crude resistant dextrin is subjected to decolorization, ion exchange desalination, concentration and drying;

wherein, the decolorization is performed by: adding 1% (dry basis weight) activated carbon and maintaining at 80 °C for 40 minutes to perform decolorization;

the ion exchange desalination is performed by: using a combination of D001 resin and D202-D001 resin at an ion exchange temperature of 45 °C and a flow rate of 4 BV/h;

concentration conditions: the concentration is performed at a temperature of 55 °C, and a pressure of -0.1 MPa for concentration; after the concentration, the solid content is 78%, the conductivity is 48 $\mu\text{S}/\text{cm}$, and the transmittance is 95.8%;

drying conditions: the drying is performed under vacuum at a pressure of -0.1 MPa and a temperature of 110 °C; a resistant dextrin powder is obtained by pulverization, and its DE value, dietary fiber content, and starch conversion rate are determined.

Example 5

(1) Slurring: weigh 200 g of pea starch, and add tap water to the pea starch to prepare starch milk with a solid content of 36% and a pH of 5.2;

(2) Liquefaction: a high-temperature α -amylase is added to the starch milk at 80 mL/T•DS, and liquefaction is performed at 100 °C for 50 minutes to obtain a liquefied liquid, and its DE value is determined;

(3) Enzyme inactivation: perform enzyme inactivation by using acidic enzyme inactivation method, after the liquefaction the pH of the liquefied liquid is adjusted to 4;

(4) Adjustment of pH value: the feed liquid from step (3) is adjusted to pH 2.0 with hydrochloric acid;

(5) Molecular rearrangement reaction: a high-temperature reaction vessel is preheated to 125 °C and stabilized for 15 minutes, then the feed liquid from step (4) is transferred into the reaction vessel, and heated at 140 °C for 2 hours; the reaction is performed under stirring at a rotation speed of 150 rpm; after the reaction, a feed liquid of crude resistant dextrin is obtained, and its DE value and dietary fiber content are determined;

(6) Refinement: the feed liquid of crude resistant dextrin is subjected to decolorization, ion exchange desalination, concentration and drying;

wherein, the decolorization is performed by: adding 0.5% (dry basis weight) activated carbon and holding at 82 °C for 30 minutes to perform decolorization;

the ion exchange desalination is performed by: using a combination of D001 resin and D202-D001 resin at an ion exchange temperature of 45 °C and a flow rate of 4 BV/h;

concentration conditions: the concentration is performed at a temperature of 60 °C, and a pressure of -0.1 MPa for concentration; after the concentration, the solid content is 80%, the conductivity is 45 μs/cm, and the transmittance is 96.2%;

drying conditions: the drying is performed under vacuum at a pressure of -0.1 MPa and a temperature of 105 °C; a resistant dextrin powder is obtained by pulverization, and its DE value, dietary fiber content, and starch conversion rate are determined.

Example 6

(1) Slurrying: weigh 200 g of pea starch, and add tap water to the pea starch to prepare starch milk with a solid content of 35% and a pH of 5.5;

(2) Liquefaction: a high-temperature α-amylase is added to the starch milk at 80 mL/T•DS, and liquefaction is performed at 100 °C for 50 minutes to obtain a liquefied liquid, and its DE value is determined;

(3) Enzyme inactivation: perform enzyme inactivation by using acidic enzyme inactivation method, after the liquefaction the pH of the liquefied liquid is adjusted to 3.6;

(4) Adjustment of pH value: the feed liquid from step (3) is adjusted to pH 1.8 with hydrochloric acid;

(5) Molecular rearrangement reaction: a high-temperature reaction vessel is preheated to 125 °C and stabilized for 15 minutes, then the feed liquid from step (4) is transferred into the reaction vessel, and heated at 130 °C for 2.5 hours; the reaction is performed under stirring at a rotation speed of 100 rpm; after the reaction, a feed liquid of crude resistant dextrin is obtained, and its DE value and dietary fiber content are determined;

(6) Refinement: the feed liquid of crude resistant dextrin is subjected to decolorization, ion exchange desalination, concentration and drying;

wherein, the decolorization is performed by: adding 1% (dry basis weight) activated carbon and maintaining at 80 °C for 40 minutes to perform decolorization;

the ion exchange desalination is performed by: using a combination of D001 resin and D202-D001 resin at an ion exchange temperature of 45 °C and a flow rate of 4 BV/h;

concentration conditions: the concentration is performed at a temperature of 55 °C, and a pressure of -0.1 MPa for concentration; after the concentration, the solid content is 78.5%, the conductivity is 42 μS/cm, and the transmittance is 96.4%;

drying conditions: the drying is performed under vacuum at a pressure of -0.1 MPa and a temperature of 100 °C; a resistant dextrin powder is obtained by pulverization, and its DE value, dietary fiber content, and starch conversion rate are determined.

Example 7

(1) Slurrying: weigh 200 g of pea starch, and add tap water to the pea starch to prepare starch milk with a solid content of 35% and a pH of 5.5;

(2) Liquefaction: a high-temperature α -amylase is added to the starch milk at 80 mL/T•DS, and liquefaction is performed at 100 °C for 50 minutes to obtain a liquefied liquid, and its DE value is determined;

(3) Enzyme inactivation: perform enzyme inactivation by using acidic enzyme inactivation method, after the liquefaction the pH of the liquefied liquid is adjusted to 3.3;

(4) Adjustment of pH value: the feed liquid from step (3) is adjusted to pH 1.8 with hydrochloric acid;

(5) Molecular rearrangement reaction: a high-temperature reaction vessel is preheated to 125 °C and stabilized for 15 minutes, then the feed liquid from step (4) is transferred into the reaction vessel, and heated at 150 °C for 1.5 hours; the reaction is performed under stirring at a rotation speed of 200 rpm; after the reaction, a feed liquid of crude resistant dextrin is obtained, and its DE value and dietary fiber content are determined;

(6) Refinement: the feed liquid of crude resistant dextrin is subjected to decolorization, ion exchange desalination, concentration and drying;

wherein, the decolorization is performed by: adding 1% (dry basis weight) activated carbon and maintaining at 82 °C for 40 minutes to perform decolorization;

the ion exchange desalination is performed by: using a combination of D001 resin and D202-D001 resin at an ion exchange temperature of 45 °C and a flow rate of 4 BV/h;

concentration conditions: the concentration is performed at a temperature of 55 °C, and a pressure of -0.1 MPa for concentration; after the concentration, the solid content is 77.5%, the conductivity is 36 μ S/cm, and the transmittance is 96.2%;

drying conditions: the drying is performed under vacuum at a pressure of -0.1 MPa and a temperature of 100 °C; a resistant dextrin powder is obtained by pulverization, and its DE value, dietary fiber content, and starch conversion rate are determined.

Comparative Example 1

This comparative example is basically the same as Example 1, except that high-temperature α -amylase is added to the starch milk at 50 mL/T•DS. After concentration, the solid content is 75.5%, the conductivity is 45 μ S/cm, and the transmittance is 95%.

Comparative Example 2

This comparative example is basically the same as Example 3, except that high-temperature α -amylase is added to the starch milk at 110 mL/T•DS. After concentration, the solid content is 76.5%, the conductivity is 32 μ S/cm, and the transmittance is 96.4%.

Comparative Example 3

This comparative example is basically the same as Example 4, except that the pH of the feed liquid is adjusted to 1.4 with hydrochloric acid in step (4). After concentration, the solid content is 76.5%, the conductivity is 34 μ S/cm, and the transmittance is 96.7%.

Comparative Example 4

This comparative example is basically the same as Example 5, except that the pH of the feed liquid is adjusted to 2.2 with hydrochloric acid in step (4). After concentration, the solid content is 79%, the conductivity is 32 μ S/cm, and the transmittance is 95.3%.

Comparative Example 5

This comparative example is basically the same as Example 6, except that in step (5), the feed liquid is transferred into a reaction vessel and heated at 120 °C for reaction. After concentration, the solid content is 77.5%, the conductivity is 28 μ S/cm, and the transmittance is 96.1%.

Comparative Example 6

This comparative example is basically the same as Example 7, except that in step (5), the feed liquid is transferred into a reaction vessel and heated at 160 °C for reaction. After concentration, the solid content is 79.5%, the conductivity is 31 μ S/cm, and the transmittance is 95.8%.

Comparative Example 7

This comparative example is basically the same as Example 7, except that in step (5), the feed liquid is transferred into a reaction vessel and heated at 160 °C for 1 hour. After concentration, the solid content is 78%, the conductivity is 26 μ S/cm, and the transmittance is 95.4%.

Comparative Example 8

This comparative example is basically the same as Example 1, except that: in step (1), corn starch is weighed for slurring. After concentration, the solid content is 75.3%, the conductivity is 26 μ S/cm, and the transmittance is 95.3%.

The determination of indicators is carried out for Examples 1 to 7 and Comparative Examples 1 to 8: the liquefied liquid samples (feed liquid of crude dextrin) is detected for DE values, the feed liquid of crude resistant dextrin is detected for DE value and dietary fiber content (on dry basis), and the finished product of resistant dextrin is detected for DE value, dietary fiber content, and starch conversion rate. The results of determination are shown in Table 1 below.

Table 1: Results of determined indicators in Examples 1 to 7 and Comparative Examples 1 to 8

Example	Liquefaction DE value	DE value of crude resistant dextrin	Dietary fiber content of crude resistant dextrin	DE value of finished resistant dextrin	Dietary fiber content of finished resistant dextrin	Starch conversion rate (dry basis)
Example 1	9.52%	2.34%	97.38%	2.38%	97.46%	97.2%
Example 2	8.31%	3.21%	96.54%	3.47%	96.21%	95.8%
Example 3	10.27%	3.24%	96.07%	3.15%	96.33%	96.2%
Example 4	9.48%	4.38%	93.91%	4.28%	93.89%	93.5%
Example 5	9.34%	4.26%	94.85%	4.59%	94.16%	93.7%
Example 6	9.15%	4.37%	94.57%	4.47%	94.22%	93.8%
Example 7	9.52%	4.93%	95.22%	4.87%	95.31%	95.1%
Comparative Example 1	6.37%	9.83%	89.92%	10.23%	89.77%	88.3%
Comparative Example 2	11.28%	13.75%	85.53%	13.84%	85.23%	84.2%
Comparative Example 3	9.37%	14.13%	85.89%	14.25%	85.54%	84.3%
Comparative Example 4	9.34%	10.13%	88.94%	10.57%	88.46%	87.2%
Comparative Example 5	9.28%	15.57%	84.31%	15.34%	84.65%	84.3%
Comparative Example 6	9.33%	17.35%	82.47%	17.23%	82.17%	81.8%
Comparative Example 7	9.51%	14.01%	85.01%	14.39%	84.25%	83.8%
Comparative Example 8	9.56%	6.25%	86.02%	6.18%	86.23%	85.6%

The starch conversion rate in Table 1 refers to the amount of dietary fiber converted from 1 ton of starch dry matter. Conversion rate = mass of finished product * dietary fiber content / (mass of starch dry matter).

As shown in Table 1, compared with Example 1, the reduced amount of enzyme used Comparative Example 1 results in a lower DE value in the obtained liquefied liquid, insufficient amount of substrates such as glucose utilized during the digestion-resisted reaction (molecular rearrangement reaction), less resistant dextrin produced, and lower dietary fiber content. Compared with Example 3, the increased amount of enzyme used in Comparative Example 2 leads to a higher DE value in the obtained liquefied liquid, more substrates utilized during the digestion-resisted reaction, a more violent reaction, re-decomposition of the resistant dextrin formed by polymerization, and a lower dietary fiber content. Compared with Example 4, a lowered pH value in the digestion-resisted reaction of Comparative Example 3 results in a higher degree of acid-catalyzed decomposition of the crude dextrin, more substrates utilized during the polymerization process, a more violent reaction, re-decomposition of the resistant dextrin produced, and a lower dietary fiber content. Compared with Example 5, an increased pH value in the digestion-resisted reaction of Comparative Example 4 results in a lower degree of acid-catalyzed decomposition of the crude dextrin during the digestion-resisted reaction, a lower content of substrates, a lower degree of polymerization, and a lower dietary fiber content. Compared with Example 6, a lowered temperature of the molecular rearrangement reaction in Comparative Example 5 results in an insufficient degree of polymerization, less amount of resistant dextrin produced, and a lower dietary fiber content. Compared with Example 7, an increased temperature of the molecular rearrangement reaction in Comparative Example 6 leads to partial decomposition of the resistant dextrin formed by polymerization at the higher temperature, less amount of resistant dextrin produced, and a lower dietary fiber content. Compared with Comparative Example 6, Comparative Example 7 shows that the increased reaction temperature also results in reduction of the reaction time, therefore the prepared resistant dextrin had a high DE value yet a low dietary fiber content, this is attributed to the uncontrollable violent reaction caused by the excessively high temperature and partial decomposition of the obtained resistant dextrin at the high temperature despite the shortened reaction time. Compared with Example 1, Comparative Example 8 used corn starch, and since the slowly digestible starch (SDS) content in pea starch is higher than that in corn starch, the pea resistant dextrin prepared in Example 1 shows a higher mass content of dietary fiber.

The resistant dextrin products prepared in Examples 1 to 7 exhibit excellent properties in terms of DE value and dietary fiber content, which is primarily attributed to the reaction system of

specific starch that enables the production of resistant dextrin with better digestion resistance and higher dietary fiber content.

Although the above examples provide a detailed description of the present invention, they are merely some embodiments of the present invention, not all embodiments. Other embodiments and examples can be obtained without inventive effort based on these embodiments and examples, and all such embodiments and examples fall within the scope of the present invention.

What is claimed is:

1. A preparation method of resistant dextrin with high dietary fiber content, comprising the following steps:

mixing pea starch milk and a liquefying enzyme for liquefaction to obtain a liquefied liquid; wherein the liquefied liquid has a DE value of 8% to 11%;

subjecting the liquefied liquid to undergo a molecular rearrangement reaction under an acidic condition(s) to obtain a resistant dextrin; wherein the resistant dextrin has a dietary fiber content of $\geq 93\%$ by mass.

2. The preparation method according to claim 1, wherein, based on the dry basis of the pea starch milk, the amount of the liquefying enzyme is 60 to 100 mL/ton.

3. The preparation method according to claim 1 or 2, wherein the liquefaction is performed at 95 to 115°C for 40 to 60 minutes.

4. The preparation method according to claim 1, wherein the method further comprises: an enzyme inactivation step before the molecular rearrangement reaction; wherein the enzyme inactivation is acidic enzyme inactivation, and the acidic enzyme inactivation is performed by adjusting the pH value of the liquefied liquid to 3 to 4.

5. The preparation method according to claim 1 or 4, wherein the acidic condition for the molecular rearrangement reaction is pH value = 1.5 to 2.

6. The preparation method according to claim 1, wherein the molecular rearrangement reaction is performed at 130 to 150 °C for 1.5 to 2.5 hours.

7. The preparation method according to claim 1, wherein the pea starch milk has a solid content of 30 to 40 wt% and a pH value of 5 to 6.

8. The preparation method according to claim 1, wherein the method further comprises: after the molecular rearrangement reaction, sequentially subjecting the feed liquid obtained from the molecular rearrangement reaction to decolorization, desalination, concentration and drying; wherein the decolorization is activated carbon decolorization, and the mass of activated carbon used in the activated carbon decolorization is 0.5% to 1% of the dry basis mass in the feed liquid.

9. The preparation method according to claim 8, wherein the desalination is ion exchange resin desalination, and a combination of strong acid cation exchange resin D001, strong base anion exchange resin D202 and strong acid cation exchange resin D001 is used in the ion exchange resin desalination.

10. A resistant dextrin with high dietary fiber content prepared by the preparation method according to any one of claims 1 to 9, wherein the resistant dextrin with high dietary fiber content has a dietary fiber content of $\geq 93\%$ by mass, and a DE value of $\leq 5\%$.