METHOD FOR PRODUCING ETHANOL FROM ROOT AND TUBER CROPS

Fig. 1

A method for producing ethanol from root and tuber crops comprises the following steps of: (a) removing skin of root and tuber crops by using a peeling device which comprises a pedestal, a roller rotatably fitted on the pedestal and having a feed inlet and a material discharge hole, a spiral feeder located within the roller and fixedly connected with the inner wall of the roller, and a driving device, wherein raw material of root and tuber crops is fed into the roller via the feed inlet, and the driving device drives the roller and the spiral feeder to rotate together; (b) pulverizing the peeled material obtained in step (a); (c) mixing the pulverized material obtained in step (b) with enzyme, and subjecting the mixture to enzymolysis; and (d) fermenting the enzymolysis product obtained in step (c). The method can improve ethanol yield.
Method for producing ethanol from root and tuber crops

Technical Field
The present invention relates to a production method of ethanol, and particularly relates to a method for producing ethanol from root and tuber crops.

Technical Background
Root and tuber crops, such as sweet potato, potato, and cassava etc., are rich in starch, and thus are widely used in production of sugar by fermentation and production of starch. Cassava is tropical and subtropical perennial, or temperate annual shrub belonging to Manihot Mill., originated from South America, and is suited to grow in low latitude area with average temperature of 25-29°C and annual average precipitation of 1,000-1,500mm. Before about 1820, cassava was introduced to southern China, and mainly planted in Guangdong, Guangxi, and Hainan. Nowadays it has been expanded to other provinces, such as Yunnan, Fujian, and Guizhou, etc. Cassava may be divided into two types: bitter cassava (toxic cassava) and sweet cassava (nontoxic cassava). Water is the primary chemical component of fresh root tuber of cassava, and carbohydrate is the second; additionally, cassava also contains a small amount of protein, fat, and pectin. The starch content of fresh cassava can reach 25-30wt%.

Ripe cassava has diameter of about 4-8cm, and length of 20-30cm, which is podgy and in shape of short cylinder. Cassava has structure of flesh and skin from inner to outer, wherein the skin comprises inner skin and outer skin. The outer skin is in dark brown color, and has spaced white circular strips, and the inner skin and flesh are in white color.

The skin of cassava, particularly inner skin, contains cyanide and cyanogenic glycoside, linamarin, which is capable of causing food poisoning. Linamarin can generate hydrocyanic acid after being hydrolyzed. Hydrocyanic acid and cyanide are both extremely toxic and can cause acute poisoning. If cyanide toxin is not removed, it may lead to inactivation of enzyme during enzymlolysis and inactivation of yeast during fermentation, and thus subsequent enzymlolysis and fermentation processes are affected. Therefore, available methods for producing ethanol from root and tuber crops, particularly cassava, generally comprise removing skin of root and tuber crops, and then pulverizing, enzymlizing, and fermenting.

Presently, manual or simple mechanical skin-removing methods are adopted to remove cassava skin through friction or pare the cassava. As cassava skin, particularly inner skin, is tightly attached on cassava flesh, skin-removing effect is not desirable when friction is adopted for skin removal, and a considerable amount of skin is left on cassava surface; therefore residual cyanide content in cassava is high (removal rate of cyanide is about 40-50%), which leads to inactivation of enzyme during enzymlolysis and inactivation of yeast during fermentation, and hence influences ethanol yield. On the other hand, when the cassava is pared, cassava flesh is likely to be removed together with the skin, and hence a large amount of raw material is wasted, which inevitably reduces ethanol yield. Therefore, ethanol yield
of available methods for producing ethanol from root and tuber crops is low.

Summary of the Invention
To overcome the disadvantage of the available methods for producing ethanol from root and tuber crops that their ethanol yield is low, the present invention provides a method for producing ethanol from root and tuber crops with effectively increased yield.

The present invention provides a method for producing ethanol from root and tuber crops, comprising the steps of:
(a) removing skin of root and tuber crops by using a skin-removing device which comprises a pedestal 1, a rotary drum 2 rotatably fitted on the pedestal 1 and having an inlet 4 and a outlet 5, a helical screw feeder 3 provided in the rotary drum 2 and fixedly connected with the inner wall of the rotary drum 2, and a driving unit for driving the rotary drum 2 and the helical screw feeder 3 to rotate together, wherein raw material of root and tuber crops is fed into the rotary drum 2 via the inlet 4, and the driving unit drives the rotary drum 2 and the helical screw feeder 3 to rotate together;
(b) pulverizing the skin-removed material obtained in step (a);
(c) mixing the pulverized material obtained in step (b) with enzyme, and subjecting the resulting mixture to enzymolysis; and
(d) fermenting the enzymolysis product obtained in step (c).

By removing skin of root and tuber crops such as cassava through the method according to the present invention, the cyanide removal rate can reach 75% or higher, and raw material loss rate can be kept below 5wt%, which are beneficial for ethanol yield increase.

Brief Description of the Accompanying Drawings
Fig. 1 shows the front view of the skin-removing device for root and tuber crops used in the method according to the present invention;
Fig. 2 shows the longitudinal section view of the skin-removing device;
Fig. 3 shows the cross section view representing connection relationship of the chain wheel and the rotary drum.

Embodiments
The method for producing ethanol from root and tuber crops comprising the steps of:
(a) removing skin of root and tuber crops by using a skin-removing device;
(b) pulverizing the skin-removed material obtained in step (a);
(c) mixing the pulverized material obtained in step (b) with enzyme, and subjecting the resulting mixture to enzymolysis; and
(d) fermenting the enzymolysis product obtained in step (c).

As shown in Fig. 1 and Fig. 2, the skin-removing device comprises:
a pedestal 1;
a rotary drum 2 rotatably fitted on the pedestal 1 and having an inlet 4 and a outlet 5;
a helical screw feeder 3 provided in the rotary drum 2 and fixedly connected with the inner wall of the rotary drum 2; and a driving unit for driving the rotary drum 2 and the helical screw feeder 3 to rotate together.

The step of removing skin comprises feeding raw material of root and tuber crops into the rotary drum 2 via the inlet 4, and allowing the driving unit to drive the rotary drum 2 and the helical screw feeder 3 to rotate together. The rotation speed of the rotary drum 2 and the helical screw feeder 3 can be 2-50 rpm, preferably 5-25 rpm. Under push action of the helical screw feeder 3, the raw material is continuously moved forward, and at the same time the raw material rotates along with the rotary drum 2 and the helical screw feeder, so as to remove the skin of the raw material; and the skin-removed material is discharged from the outlet 5.

The rotary drum 2 can be made from various wear-resistant materials, such as steel, rubber, or rigid plastics. The rotary drum 2 can be further provided with spraying unit therein. The spraying unit can be fixedly fitted on the inner wall of the rotary drum, and located close to the inlet of the rotary drum. The spraying unit can be various common spraying units. According to the invention, the method can further remove dirt (such as soil or impurities) on the raw material by spraying water on the material via the spraying unit. There is no special limitation on the amount of sprayed water, as long as it is sufficient to remove dirt on the raw material.

Preferably, as shown in Fig. 1, the rotary drum 2 comprises, from inlet end to outlet end, a first section rotary drum 2a and a second section rotary drum 2b which are communicated with each other, and a spraying unit is provided in the second section rotary drum 2b. The spraying unit can be fixedly fitted on the inner wall of the second section rotary drum 2b, and located close to the inlet of the second section rotary drum.

According to the method in the present invention, a friction structure may be further provided on the inner wall of the rotary drum 2 in order to achieve better skin-removing effect. The friction structure can be various structures with rough surface, preferably one or more ribbed steel bars, more preferably multiple ribbed steel bars. The ribbed steel bar has transversal ribs, and can be various conventional hot rolled ribbed steel bar and cold rolled ribbed steel bar, such as ribbed steel bar complying with Chinese National Standard GB 1499-1998. The nominal diameter of the ribbed steel bar can be 6-25 mm, preferably 8-20 mm. The interval between the transversal ribs can be 3-16 mm, preferably 4-12 mm. The grade of the ribbed steel bar includes, but is not limited to, HRB335, HRB400 and HRB500. The ribbed steel bar is fixedly connected with the inner wall of the rotary drum 2, such that it can exert friction action to the raw material during rotation of the rotary drum. For easily fixedly connecting the ribbed steel bar onto the inner wall of the rotary drum 2, preferably the ribbed steel bar is parallel to the central axis of the rotary drum.

The rotary drum 2 can be horizontally or obliquely installed on the pedestal 1. When the rotary drum is horizontally installed, the raw material is moved forward under push action of the helical screw feeder 3, and finally discharged via the outlet of the rotary drum. When the rotary drum is obliquely installed, since the position of the inlet is higher than that of the outlet, the raw material can be moved downward under its own gravity action (i.e. moved forward) as well. The inclination angle of the
rotary drum 2 can be 0-15 degrees, preferably 5-10 degrees. The length of the rotary
drum 2 can be 2-10 m, preferably 3.5-7 m. When the rotary drum comprises the first
section rotary drum and the second section rotary drum, the length refers to sum of
lengths of the first section rotary drum and the second section rotary drum. The
inclination angle refers to included angle between the central axis of the rotary drum
and the horizontal line. There is no special limitation on inner diameter of the rotary
drum, which can be selected according to the amount of the raw material to be
processed. For example, generally, the inner diameter of the rotary drum is 1-2 m.

The helical screw feeder 3 can be various common helical screw feeders in the
mechanical field. The helical screw feeder 3 can be connected on the inner wall of the
rotary drum 2 via various fixed connection means. For example, as shown in Fig. 2,
the helical screw feeder 3 is fixedly connected on the inner wall of the rotary drum 2
via a fastener 8. To achieve better skin-removing effect, the pitch of the helical
screw feeder 3 is preferably 0.3-0.8m, and the height of the screw thread is preferably
0.1-0.4m. The helical screw feeder can be made of various wear-resist materials,
such as steel, rubber, or nylon, etc.

The present invention has no special limitation on the driving unit, as long as it can
drive the rotary drum 2 and the helical screw feeder 3 to rotate together. For
example, the driving unit may comprise a driving source, a transmission chain, and a
chain wheel 6. As shown in Fig. 3, the chain wheel may be fixed on the rotary drum
2. When the rotary drum 2 comprises the first section rotary drum 2a and the second
section rotary drum 2b, the chain wheel 6 is preferably fitted between the first section
rotary drum 2a and the second section rotary drum 2b. As the rotary drum 2 is
rotatably fitted on the pedestal 1, the chain wheel can drive the rotary drum to rotate
when the transmission chain transfers the driving power of the driving source to the
chain wheel. The rotatable fitting manner can be realized by various common
methods, for example, support roller or frame can be adopted to fit the rotary drum on
the pedestal to allow the rotary drum to rotate around the central axis. The driving
source can be various units capable of generating power, such as motor.

For the convenience of feeding, the skin-removing device may further comprise a
windmill feeder 7. As shown in Fig. 1 or 2, the windmill feeder 7 is fitted at the inlet
4 of the rotary drum. The windmill feeder 7 can be various common windmill
feeders in the mechanical field.

The skin-removing device in the present invention utilizes friction action among raw
material and between the raw material and the rotary drum wall to remove skin of the
raw material. By removing the skin of cassava material according to the method of
the present invention, the cyanide removal rate can reach 75% or higher, and raw
material loss rate can be kept below 5wt%; thus ethanol yield is significantly
increased.

The root and tuber crops may be various, such as sweet potato, potato, and cassava,
etc. In the embodiment of the present invention, cassava is adopted as root and tuber
crops. As the raw material may contain soil, sand/stone, and iron impurities which
may cause damage to the skin-removing device, the raw material is preferably
subjected to pretreatment process before removing the skin. The pretreatment
process may be conventional method, and usually comprises removing impurities and
cleaning. For example, after harvest of fresh cassava, soil, root, whisker, xylem part
and sand/stone on the cassava are removed; and cassava is cleaned by using the
equipment and method well known to those skilled in the arts.
According to the present invention, in the step of pulverizing, various pulverization methods conventionally used in the field may be used, as long as texture of cassava can be destroyed, and fine starch particles can be disintegrated and separated from the cassava root tuber. For example, dry or wet pulverization method can be adopted, and the major difference between the two methods is whether cassava is mixed with water. Wet pulverization comprises mixing the skin-removed cassava and water, and carrying out pulverization for one or more times. The resulting pulverized material may have an average particle size of 1.5-10 mm. The weight ratio of cassava to water can be 1:0.2-5, preferably 1:0.5-2. Various common pulverizers can be used, such as SFSP series hammer-type pulverizers.

The enzymolysis procedure can be carried out by common methods in the field, for example, the procedure may comprise adding enzyme-producing microbes and/or enzyme into the pulverized material, and incubating at the growth temperature of the enzyme-producing microbes or activation temperature of the enzyme. The enzyme-producing microbes are those capable of secreting amylase. The said enzyme comprises amylase.

As microbes will produce byproduct during growth, it is preferred to add enzyme directly. The effect of enzymolysis will be better if more amount of enzyme is used. In consideration of cost, the usage amount of amylase is preferably 4-50 enzyme activity units, more preferably 10-30 enzyme activity units per gram of pulverized material (on dry basis).

The enzyme activity unit in the present invention is defined as below: one enzyme activity unit is the amount of enzyme required for converting starch 1 mg into glucose within 1 min at 70°C and pH of 6.0.

The enzymolysis can be carried out at any temperature suitable for amylase to exert action, generally 50-90°C, more preferably 60-70°C. Theoretically, the effect of enzymolysis will be better if the enzymolysis is carried out longer. For the sake of equipment utilization efficiency, the enzymolysis time is 20-240 min, more preferably 30-120 min. The pH of enzymolysis can be any pH suitable for amylase to exert action, generally 3.0-7.0, more preferably 5.0-6.0. As little pH fluctuation occurs during enzymolysis, pH of enzymolysis can be adjusted before addition of enzyme by known methods in the field. For example, pulverized material is mixed with water or culture medium (usually enzyme is mixed with water, and enzyme-producing microbes are mixed with the culture medium for the microbes). Usually the resulting mixture has solid content of 20-40wt%, and pH of the mixture to be enzymolized is adjusted to 3.0-7.0, preferably 5.0-6.0 by using sulfuric acid or sodium hydroxide.

Amylase generally refers to a kind of enzymes capable of decomposing starch glycosidic linkage, and the may comprise α-amylase, β-amylase, glucoamylase, and isoamylase.

α-Amylase, also called 1,4-α-D-glucan glucanohydrolase, can arbitrarily and irregularly cleave α-1, 4-glycosidic linkage in starch chain, and hydrolyze starch into maltose, oligosaccharide with 6 glucose units, and oligosaccharide with side chain. The microbes producing α-amylase mainly comprise Bacillus subtilis, Aspergillus niger, Aspergillus oryzae, and Rhizopus spp.

β-Amylase, also called 1,4-α-D-glucan maltohydrolase, can cleave 1, 4-glycosidic linkage from non-reducing end of starch molecule to produce maltose. The product
resulted from action of the enzyme on starch is maltose and limit dextrin. The enzyme is mainly produced by Aspergillus spp., Rhizopus spp., and Endomycoses spp.

Glucoamylase, also called α-1,4-Glucan glucohydrolase, sequentially acts on α-1, 4-glucosidic linkage in starch molecule from non-reducing end with glucose as unit to yield glucose. The product resulted from action of the enzyme on branched starch is glucose and oligosaccharide with α-1, 6-glucosidic linkage, while the product resulted from action of the enzyme on linear starch is almost glucose. The microbe producing the enzyme mainly comprises Aspergillus niger (Aspergillus usamii, and Aspergillus awamori), Rhizopus spp. (Rhizopus niveue, and Rhizopus delemar), Endomycopsis spp., and Monascus spp.

Isoamylase, also called Glucan 1,6-α-glucosidase or branching enzyme, acts on α-1, 6-glucosidic linkage of branching spot of branched starch molecule, and cleaves off the whole side chain of the branched starch to give linear starch. The microbes producing the enzyme mainly comprise anaerobic Bacillus spp., Bacillus spp., and certain Pseudomonas spp.

Preferably the enzymes adopted in the enzylolysis further comprise phosphatase. As phosphatase can hydrolyze phosphorylated dextrin, which is formed from the esterification of phosphoric acid and alcoholic hydroxyl, into glucose while releasing phosphoric acid, it has significant liquefying ability. Therefore, the enzyme adopted in the enzyolysis includes phosphatase in order to fully hydrolyze starch to increase ethanol yield.

All microbes capable of fermenting monosaccharide (such as glucose and/or fructose) and oligosaccharide (such as sucrose and/or galactose) can be used in the fermentation process of the present invention. Saccharomyces cerevisiae is preferably used in the present invention, because it is widely adopted microbe for hexose fermentation with ethanol resistance, less byproducts, and high ethanol yield.

Relative to per gram of enzymolysis product, the inoculation amount of the said yeast used in the fermentation is about $10^3$-$10^8$ colony forming units, more preferably $10^4$-$10^6$ colony forming units.

The said colony forming unit is defined as below: microbial unicells in a certain amount of diluted microbial liquid are dispersed on a culturing medium plate by casting or coating the liquid on the medium plate, and each unicell forms one colony after cultivation, i.e. unicell number contained in each millimeter of microbial liquid.

The yeast used in the fermentation of the present invention can be commercial yeast solid preparation (such as dry yeast powder) or yeast strain, such as Rasse II yeast (also called Germany II yeast), Rasse XII (also called Germany XII yeast), Yeast K, Nanyang V yeast (1300), and Nanyang mixed yeast (1308). The colony forming unit of the yeast can be determined according to known methods in the field, such as plate count using methylene blue dye, the detail of which comprises:

dissolving dry yeast powder 1g in sterile water 10ml, or diluting strain activation liquid with sterile water to 10ml; adding 0.1wt% methylene blue 0.5ml; holding at 35°C for 30min; and counting viable bacteria (viable bacteria will not be dyed while dead bacteria will be dyed) in the solution by using blood cell counting plate and 10x optical microscope to give number of viable bacteria in 1g of the dry yeast or 1ml of the strain activation liquid, i.e. the number of colony forming units.

The yeast can be inoculated by routine methods, such as adding seed liquid 5-15vol%
into enzymolysis product. The seed liquid can be either aqueous solution or culturing medium solution of dry yeast, or activation seed liquid of dry yeast or commercial strain.

The fermentation temperature can be any suitable for yeast growth, preferably 30-36 °C, more preferably 30-33 °C. And the fermentation pH may be 4-6, preferably 4-4.5. The fermentation time is the time from inoculation to occurrence of decline phase of the yeast growth (i.e. the fermentation time is the sum of lag phase, log phase, and stable phase), which is preferably 55-70hr, more preferably 60-70hr. The ethanol as fermentation product can be subjected to separation and refinement, such as distillation, concentration, and dewatering, according to requirement of different industrial products (for example fuel ethanol is required to have a purity of 99% or higher).

The present invention will be described in further details through following examples.

In the examples, the cassava material is fresh cassava harvested in same batch, with diameter of 4-8cm, length of 20-30cm, and water content of about 65wt%.

Example 1

In the present example, the method for producing ethanol from cassava according to the present invention is described.

(1) Skin-removing and pulverization of cassava raw material

The skin-removing device is shown in Fig. 1, 2, and 3.

A rotary drum 2 includes a first section rotary drum 2a and a second section rotary drum 2b from up to down, the first section rotary drum 2a and the second section rotary drum 2b are communicated, and the lengths of the first section rotary drum 2a and the second section rotary drum 2b are respectively 1.8m and 1.6m. The rotary drum 2 is made of steel, with inner diameter of 1.6m. 40 hot-rolled ribbed steel bars (Grade No. HRB335, and nominal diameter of 12mm) are fixed on the inner wall of the first section rotary drum 2a, parallel to the central axis of the rotary drum, and distributed at equal interval of 0.125m along circumference of the rotary drum inner wall. 50 hot-rolled ribbed steel bars (Grade No. HRB500, and nominal diameter of 16mm) are fixed on the inner wall of the second section rotary drum 2b, parallel to the central axis of the rotary drum, and distributed at equal interval of 0.1m along circumference of the rotary drum inner wall. The rotary drum 2 is obliquely fitted on a pedestal 1 at inclination angle of 5 degrees. A helical screw feeder 3, which is made of rubber, and has pitch of 0.5m, and screw thread height of 0.2m, is fixedly connected on the inner wall of the rotary drum 2 via a fastener 8. A driving device comprises a motor, a transmission chain, and a chain wheel 6. The chain wheel is fixed on the rotary drum 2, the transmission chain transfers the power of the motor to the chain wheel, and the motor has a power of 5.5kW.

The motor is started to drive the rotary drum 2 and the helical screw feeder 3 to rotate around the central axis of the rotary drum at 7rpm. The harvested cleaned fresh cassava 100kg are continuously fed into the rotary drum 2 via the inlet 4, and the skin-removed cassava is discharged from the outlet 5 to obtain skin-removed cassava material 96kg.

The skin-removed cassava material 96kg is cleaned, cut into about pieces 1 cm thick,
and pulverized by using SFSP series hammer pulverizer. The pulverization method comprises pulverizing the skin-removed cassava to obtain 96kg of pulverized product with average particle size of 6mm, wherein the particle size is determined by using AccuSizerTM 780 optical particle size meter (PPS Co., US).

20g of aforementioned pulverized product is provided for determination of cyanide content (labeled as Cl) by EPA335.3 standard test method of US Environmental Protection Agency.

Original cleaned fresh cassava without skin-removing is pulverized into slurry (average particle size of 0.8mm), and 20g of the slurry is taken out, and added with 180g of distilled water to give sample to be tested. And then the sample is subjected to determination of cyanide content (labeled as C2) by EPA335.3 standard test method of US Environmental Protection Agency.

Following equation is used for calculating cyanide removal rate after skin-removing process:

\[ \varepsilon_2 = \frac{(C2-0.96C1)}{C2} \times 100\% \]

The calculated cyanide removal rate is 76%.

(2) Enzymolysis

The pulverized product from step (1) is mixed with 35kg of water, heated to 80°C after regulating pH to 5, added with \( \alpha \)-amylase (commercially available from Novozymes) at 20 enzyme activity units per gram dry pulverized product, and held at 80°C for 60min to give enzymolysis product.

(3) Fermentation

The enzymolysis product is cooled to 33°C, and inoculated with distillery yeast (Angel super alcohol active dry yeast, Hubei Angel Yeast Co., Ltd., China) at 10^5 colony forming units per gram enzymolysis product. The resulting mixture is cultivated at 33°C in fermentation tank for 65 hr with stirring. The fermentation product is distilled at 100°C, and then the obtained distillation fraction is redistilled at 78.3°C to obtain ethanol 13.9kg. The ethanol yield can be calculated according to the equation as below:

Ethanol yield = 100% X ethanol weight/weight of fresh cassava raw material

And the calculated ethanol yield is 13.9%.

Comparison example 1

In this comparison example, the method for producing ethanol from cassava material of prior art is described.

Ethanol is produced by the same method in the example 1 to obtain ethanol 12.6kg, except that manual skin-removing method is adopted in step (1) to remove inner skin of the cassava raw material by knife to obtain skin-removed cassava material 96kg. The ethanol yield is calculated by the method same as that in the example 1, and is 12.6%. The cyanide contents before and after skin-removing are determined according to the method in the example 1, and the calculated cyanide removal rate is 62%.
It can be observed from the aforementioned result, the ethanol yields of the example 1 and the comparison example 1 are respectively 13.9% and 12.6%. Compared with the comparison example 1, the ethanol yield in the example 1 is increase by 10.3%. With regard to cyanide removal rate, the example 1 has cyanide removal rate of 76%, while the comparison example has cyanide removal rate of only 62%. Therefore, the inventive method can dramatically improve ethanol yield.
Claims

1. A method for producing ethanol from root and tuber crops, comprising the steps of:
   (a) removing skin of root and tuber crops by using a skin-removing device which comprises a pedestal (1), a rotary drum (2) rotatably fitted on the pedestal (1) and having an inlet (4) and an outlet (5), a helical screw feeder (3) provided in the rotary drum (2) and fixedly connected with the inner wall of the rotary drum (2), and a driving unit for driving the rotary drum (2) and the helical screw feeder (3) to rotate together, wherein raw material of root and tuber crops is fed into the rotary drum (2) via the inlet (4), and the driving unit drives the rotary drum (2) and the helical screw feeder (3) to rotate together;
   (b) pulverizing the skin-removed material obtained in step (a);
   (c) mixing the pulverized material obtained in step (b) with enzyme, and subjecting the resulting mixture to enzymolysis; and
   (d) fermenting the enzymolysis product obtained in step (c).

2. The method according to claim 1, wherein a friction structure is provided on the inner wall of the rotary drum (2).

3. The method according to claim 2, wherein the friction structure is one or more ribbed steel bars.

4. The method according to claim 3, wherein the ribbed steel bar is parallel to the central axis of the rotary drum (2).

5. The method according to claim 1, wherein the rotary drum (2) has inclination angle of 0-15 degrees, and length of 2-10 m; and the rotation speed of the rotary drum (2) and the helical screw feeder (3) is 2-50 rpm.

6. The method according to claim 1 or 5, wherein the helical screw feeder (3) has a pitch of 0.3-0.8 m, and a screw thread height of 0.1-0.4m.

7. The method according to claim 1, wherein the driving unit comprises a driving source, a chain wheel (6) fixed on the rotary drum (2), and a driving chain for transferring the power of the driving source to the chain wheel.

8. The method according to claim 1, wherein the pulverized material has an average particle size of 1.5-10 mm.

9. The method according to claim 1, wherein the enzyme used in step (c) comprises amylase of which the usage amount is 4-50 enzyme activity units per gram of dry raw material of root and tuber crops; and the enzymolysis is carried out at temperature of 50-90°C and pH of 5-6 for 20-240min.

10. The method according to claim 9, wherein the amylase is one or more of α-amylase, glucoamylase, transglucosidase, and phosphatase.

11. The method according to claim 1, wherein the inoculation amount of yeast
used in the fermentation is $10^3$-$10^8$ colony forming units per gram of enzymolysis product, and the fermentation is performed at temperature of 30-33 °C for 50-75 hr.
### A CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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

### B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**IPC: C12P;A23N; C12R**

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)

WPI; EPODOC; PAJ; CPRS; CNKI; BIOSIS; MEDLINE and keywords: root, tuber, crop?, potato+, ferment+, peel+, ethanol, skin+, remove+, roller?, spiral, helical, friction, feeder?, enzym+, device? et al.

### C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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* Further documents are listed in the continuation of Box C

**\* Document member of the same patent family**

Date of the actual completion of the international search

24 Mar. 2009 (24.03. 2009)

Date of mailing of the international search report

09 Apr. 2009 (09.04.2009)

Name and mailing address of the ISA/CN

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Form PCT/ISA/210 (second sheet) (April 2007)
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<td>Y</td>
<td>CN 10 104 1849 A (Hunan Southward Potato Industrialization Hard Technology LTD) 26 Sep. 2007(26.09.2007) the whole document</td>
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INTERNATIONAL SEARCH REPORT

CLASSIFICATION OF SUBJECT MATTER

C12P 7/64 (2006.01) i
A23N 7/02 (2006.01) i
C12R 1/865(2006.01) n

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