[Patent Document 6] US 2004/0033573

[Patent Document 7] JP 6-279577 A

[Patent Document 8] JP 7-133344 A

[Patent Document 9] JP 8-188642 A

[Patent Document 10] JP 9-31170 A

SUMMARY

PROBLEMS TO BE SOLVED

[0012]

One of the objects of the embodiments disclosed herein is to provide a method for producing lactic acid with high productivity, which lactic acid can be applied to industrial-scale production of a polylactic acid by direct polymerization and can be used for high-yield synthesis of lactide; and methods for producing lactide and a polylactic acid using the lactic acid. Further, the present disclosure aims to obtain a polylactic acid having excellent thermal stability, mechanical strength and hue, and to provide lactic acid in which the amounts of specific impurities are not more than certain amount, and lactide and a polylactic acid obtained using the lactic acid as a raw material.

MEANS FOR SOLVING THE PROBLEMS

[0013]

The present inventors intensively studied to solve the above problems and discovered that culturing of a microorganism having an ability to produce lactic acid in a continuous culture apparatus using a porous membrane enables to obtain lactic acid in the permeate at a high yield and at a high production rate, and, by providing the obtained permeate for a nanofiltration step and a distillation step, lactic acid which is applicable to direct polymerization and allows high-yield synthesis of lactide can be obtained. Further, the present inventors discovered that, by using lactic acid, in which the amounts of particular impurities are not more than particular

levels, as a raw material for a polylactic acid, lactide having excellent hue and a polylactic acid having excellent thermal stability, mechanical strength and hue can be obtained at high yields, thereby completing the present disclosure.

[0014]

That is, the present disclosure is constituted by the following (1) to (15).

[0015]

(1) A method for producing lactic acid, the method comprising the Steps (A) to (C) below:

(A) a step of continuous fermentation wherein a fermentation culture medium of a microorganism having an ability of lactic acid fermentation is filtered through a porous membrane having an average pore size of not less than 0.01 μm and less than 1 μm with a transmembrane pressure difference within the range of 0.1 to 20 kPa, and the permeate is collected, while retaining the non-permeated liquid in or returning the non-permeated liquid to the culture medium, and adding a fermentation feedstock to the culture medium;

(B) a step of filtering the permeate obtained in Step (A) through a nanofiltration membrane; and

(C) a step of distilling the permeate obtained in Step (B) under a pressure of not less than 1 Pa and not more than atmospheric pressure, at not less than 25°C and not more than 200°C to recover lactic acid.

[0016]

(2) A method for producing lactic acid according to (1), wherein the pH of the permeate obtained in the Step (A) is adjusted to not less than 2 and not more than 4.5, followed by providing the permeate for the Step (B).

[0017]

(3) The method for producing lactic acid according to (1) or (2), wherein the Step (A) is a step of continuous fermentation in the presence of a calcium salt, and a

[0029]

(14) A polylactic acid obtained by using the lactic acid according to (11) or (12) or the lactide according to (13) as a raw material.

[0030]

(15) A polylactic acid obtained by direct dehydration polycondensation using the lactic acid according to (11) or (12) as a raw material.

In an aspect, there is provided a lactic acid composition having optical purity of not less than 95%, whose 90% aqueous lactic acid solution contains methanol at a concentration of not more than 70 ppm, pyruvic acid at a concentration of 200 to 500 ppm, furfural at a concentration of not more than 15 ppm, 5-hydroxymethylfurfural at a concentration of not more than 15 ppm, methyl lactate at a concentration of not more than 600 ppm, acetic acid at a concentration of not more than 500 ppm and 2-hydroxybutyric acid at a concentration of not more than 500 ppm.

In another aspect, there is provided a method for producing lactide, using the lactic acid composition as defined herein as a raw material.

In another aspect, there is provided a method for producing polylactic acid, using the lactic acid composition as defined herein as a raw material.

In another aspect, there is provided a method for producing polylactic acid, using the lactic acid composition as defined herein as a raw material and polymerizing by direct dehydration polycondensation.

EFFECT

[0031]

By the present disclosure, high-quality lactic acid can be produced, and the productivity of a polylactic acid, which is a biodegradable general-purpose plastic, can be improved. Further, by using lactic acid, in which the amounts of specific impurities are not more than certain amount, as a raw material for a polylactic acid, a polylactic acid having excellent thermal stability, mechanical strength and hue can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

Fig. 1 is a schematic diagram showing an embodiment of the continuous culture apparatus used in the present invention.

Fig. 2 is a diagram showing the concentration of lactic acid accumulated and the production rate of lactic acid during the continuous culture carried out in Example 1 of the present invention.

Fig. 3 is a schematic diagram showing an embodiment of the nanofiltration membrane separation apparatus used in the present invention.

Fig. 4 is a schematic diagram showing an embodiment of the cross-sectional view of the cell in which a nanofiltration membrane was placed, in the nanofiltration membrane separation apparatus used in the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

CLAIMS

1. Lactic acid composition having optical purity of not less than 95%, whose 90% aqueous lactic acid solution contains methanol at a concentration of not more than 70 ppm, pyruvic acid at a concentration of 200 to 500 ppm, furfural at a concentration of not more than 15 ppm, 5-hydroxymethylfurfural at a concentration of not more than 15 ppm, methyl lactate at a concentration of not more than 600 ppm, acetic acid at a concentration of not more than 500 ppm and 2-hydroxybutyric acid at a concentration of not more than 500 ppm.

2. The lactic acid according to claim 1, having an optical purity of not less than 99%.

3. A method for producing lactide, using the lactic acid composition according to claim 1 or 2 as a raw material.

4. A method for producing polylactic acid, using the lactic acid composition according to claim 1 or 2 as a raw material.

5. A method for producing polylactic acid, using the lactic acid composition according to claim 1 or 2 as a raw material and polymerizing by direct dehydration polycondensation.