

[Name of the invention] Method for producing shikimic acid, method for producing shikimic acid aqueous solution, method for purifying shikimic acid, steam distillation apparatus, and equipment for producing shikimic acid

[Technical field]

[0001]

This disclosure relates to a method for producing shikimic acid, method for producing shikimic acid aqueous solution, method for purifying shikimic acid, steam distillation apparatus, and equipment for producing shikimic acid.

[Background technology]

[0002]

Shikimic acid is known as a raw material compound for the influenza treatment drug oseltamivir. Shikimic acid is a natural organic compound contained in various plants. Conventionally, methods for producing shikimic acid from plants containing shikimic acid have been considered. For example, Patent Document 1 discloses a method for producing shikimic acid, which includes a step of obtaining an extract containing shikimic acid from a crushed product of a plant containing shikimic acid, and then treating the extract with an enzyme to obtain a solution containing shikimic acid. This document describes how shikimic acid can be obtained in good yield by fractionating the solution obtained as described above using a hydrophobic synthetic adsorbent, a strongly basic anion exchange resin, and an amphoteric ion exchange resin, and then concentrating and drying the fraction.

[Prior art documents]

[Patent documents]

[0003]

[Patent document 1] International Publication No. 2019/039553

[Summary of the invention]

[Problems to be solved by the invention]

[0004]

According to the study by the present inventors, the method described in Patent Document 1 had room for improvement in terms of the running time and energy efficiency of the entire process. That is, in the method described in Patent Document 1, the extraction of shikimic acid, deoiling (removal of essential oils), enzyme treatment, and concentration and drying take more than 50 hours, and the entire process takes more than 110 hours. Since these steps are carried out while heating the treated material, energy has to be consumed for a long time.

[0005]

The present disclosure has been made in consideration of the above problems, and provides a method for producing high-purity shikimic acid with a sufficiently short running time and a sufficiently small energy input. The present disclosure also provides a method for producing an aqueous shikimic acid solution, a method for purifying shikimic acid, and a steam distillation apparatus and equipment for producing shikimic acid, which are useful for producing high-purity shikimic acid with a sufficiently short running time and a sufficiently small amount of energy input.

[Means for solving the problems]

[0006]

One aspect of the present disclosure relates to a method for producing shikimic acid. This production method comprises a step of producing an aqueous shikimic acid solution (steps (a) and (b)) and a step of purifying shikimic acid (steps (c) to (e)). Steps (a) to (e) are as follows:

- (a) A step of extracting essential oil from a raw material containing shikimic acid and essential oil components by steam distillation.
- (b) A step of obtaining an aqueous solution containing shikimic acid by contacting water with the raw material in which shikimic acid remains after step (a).
- (c) A step of contacting the aqueous solution with an anion exchange resin to adsorb the shikimic acid contained in the aqueous solution to the anion exchange resin.
- (d) A step of eluting the shikimic acid adsorbed on the anion exchange resin.
- (e) A step of contacting the aqueous solution containing shikimic acid obtained through the above step (d) with a cation exchange resin.

[0007]

One aspect of the present disclosure relates to a method for producing an aqueous solution of shikimic acid. This production method includes the steps of (a) extracting an essential oil from a raw material containing shikimic acid and essential oil components by steam distillation, and (b) obtaining an aqueous solution containing shikimic acid by contacting the raw material containing remaining shikimic acid with water after the above step (a).

[0008]

The present inventors have found that in order to efficiently extract shikimic acid from a raw material containing shikimic acid and essential oil components, it is useful to first extract the essential oil components from the raw material in step (a) and separate them from the shikimic acid in advance, and this makes it possible to suppress the generation of emulsion in step (b) and efficiently produce high-purity shikimic acid. In step (a), the raw material only needs to be roughly crushed to an extent that the essential oil components can be extracted, and the time and energy required for crushing can be saved. In addition, since the manufacturing method according to the present disclosure does not require the use of enzymes, the time and energy required for enzyme treatment are not necessary.

[0009]

It is preferable that steps (a) and (b) are carried out in a state in which the raw material is contained in a tank, as described below. That is, in step (a), the raw material is contained on a support plate that is provided at a position separated from the bottom surface of the tank and has a plurality of through holes, and it is preferable that steam is supplied to the raw material through the through holes of the support plate, and the steam containing the vaporized essential oil components and the steam is cooled outside the tank to extract the essential oil. In addition, it is preferable that in step (b), steam is supplied to the raw material through the through holes of the support plate, and the water generated by cooling the steam outside the tank is returned to the tank, and an aqueous solution containing shikimic acid is obtained at the bottom of the tank.

[0010]

One aspect of the present disclosure relates to a method for purifying shikimic acid. In the course of investigating

the process of purifying shikimic acid extracted from plants, the present inventors found that raw materials containing shikimic acid also contain amino acids. Shikimic acid has a carboxyl group, while amino acids have amino and carboxyl groups. Therefore, in the purification method according to the present disclosure, an anion exchange resin and a cation exchange resin are used in combination. That is, the purification method according to the present disclosure includes the steps of (c) contacting an aqueous solution containing shikimic acid, amino acids, and impurities (e.g., the aqueous solution obtained through the above step (b)) with an anion exchange resin to adsorb the shikimic acid and amino acids contained in the aqueous solution to the anion exchange resin, (d) eluting the shikimic acid and amino acids adsorbed to the anion exchange resin, and (e) contacting the aqueous solution containing shikimic acid and amino acids obtained through the above step (d) with a cation exchange resin.

[0011]

By passing through the above step (d), an aqueous solution containing amino acids in addition to shikimic acid is obtained. Then, by carrying out the above step (e), amino acids having amino groups are adsorbed to the cation exchange resin and removed from the aqueous solution. In addition, the cation exchange resin replaces sodium, magnesium, calcium, and other cations contained in the aqueous solution with hydrogen ions (H⁺). The above cations cause scale generation in the aqueous solution concentration step, so by using an anion exchange resin in step (d) in combination with a cation exchange resin in step (e), it is possible to use a reverse osmosis membrane in the concentration step. In other words, the purification method according to the present disclosure may further include a step (f) of concentrating the aqueous solution using a reverse osmosis membrane to obtain a shikimic acid concentrate. Note that the elution of shikimic acid in the above step (d) is preferably carried out using hydrochloric acid, since it is easy to use a reverse osmosis membrane in the concentration step. [0012] One aspect of the present disclosure relates to a steam distillation apparatus. This apparatus is capable of storing raw materials containing shikimic acid and essential oil components, and is equipped with a tank for distilling the raw materials using steam, a first cooler for cooling the steam discharged from the tank to obtain essential oil and water, a second cooler for cooling the steam discharged from the tank to obtain water, a valve for switching the destination of the steam from the tank to the first cooler or the second cooler, and a return line for supplying water from the second cooler into the tank. This steam distillation apparatus preferably has a function for adjusting the temperature of the water returned from the second cooler into the tank.

[0013]

One aspect of the present disclosure relates to a shikimic acid production facility. This facility is equipped with the above-mentioned steam distillation apparatus, an anion exchange resin column to which the shikimic acid aqueous solution from the steam distillation apparatus is supplied, and a cation exchange resin column to which the aqueous solution from the anion exchange resin column is supplied. This shikimic acid production facility may further include a reverse osmosis membrane for concentrating the aqueous solution from the cation exchange resin column.

[Effects of the Invention]

[0014]

According to the present disclosure, a method for producing high-purity shikimic acid with a sufficiently short running time and a sufficiently small energy input is provided. In addition, according to the present disclosure, a method for producing an aqueous shikimic acid solution and a method for purifying shikimic acid, as well as a steam distillation apparatus and a shikimic acid production facility are provided, which are useful for producing high-

purity shikimic acid with a sufficiently short running time and a sufficiently small energy input.

[Brief Description of the Drawings]

[0015]

[Figure 1] Figure 1 is a flow diagram showing one embodiment of a method for producing shikimic acid according to the present disclosure.

[Figure 2] Figure 2 is a cross-sectional view showing a schematic diagram of a steam distillation apparatus used in the shikimic acid extraction process.

[Figure 3] Figure 3 is a cross-sectional view showing a schematic diagram of reflux extraction using the steam distillation apparatus shown in Figure 2.

[Figure 4] Figure 4 is a schematic diagram showing one embodiment of a shikimic acid production facility according to the present disclosure.

[Form for carrying out the invention]

[0016]

Below, the embodiment of the present disclosure will be described in detail with reference to the drawings as necessary. Note that the present invention is not limited to the following embodiment.

[0017]

[Method for producing shikimic acid]

The method for producing shikimic acid according to this embodiment is composed of an extraction process for obtaining a shikimic acid aqueous solution from a raw material containing shikimic acid and essential oil components, a purification process for obtaining a purified shikimic acid liquid from the shikimic acid aqueous solution, and a concentration process for obtaining shikimic acid from the purified shikimic acid liquid (see FIG. 1). Each process will be described below.

[0018]

<Extraction process>

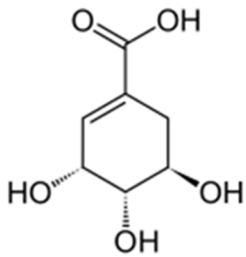
The extraction process is a process for producing a shikimic acid aqueous solution from a raw material containing shikimic acid and essential oil components. This process includes the following steps.

- (1) A step of crushing a raw material containing shikimic acid and essential oil components to obtain a crushed product.
- (2) A step of extracting essential oil from the crushed product by steam distillation.
- (3) After the above step (2), a step of contacting the ground material containing residual shikimic acid with water to obtain an aqueous solution of shikimic acid.

[0019]

Shikimic acid is a compound represented by the following chemical formula and is an ionic compound having a carboxy group.

[Chemical formula 1]



[0020]

There are no particular limitations on the raw material as long as it contains shikimic acid, but according to the inventors' investigations, many plants containing shikimic acid also contain essential oil components and amino acids, and such plants can be used as raw materials. Specific examples of raw materials include the fruit of *Illicium verum*; the fruit and leaves of Santa Maria (*Calophyllum brasiliensis*); and the leaves of conifers such as *Pinus thunbergii* and *Abies sachalinensis*. *Illicium verum* is an evergreen tree belonging to the Schisandraceae family, *Illicium* genus, and its fruit is called star anise or star anise. Santa Maria is a broadleaf tree belonging to the *Calophyllum* genus of the Hypericaceae family. *Pinus thunbergii* is an evergreen tree belonging to the Pinaceae family, *Pinus* genus. The Japanese Sakhalin fir is an evergreen tree belonging to the genus *Abies* in the family Pinaceae.

[0021]

The above-mentioned raw materials are suitable for the extraction process according to this embodiment in that they contain a large amount of essential oil components that volatilize due to the heat of steam and have a small amount of non-volatile oil. As long as the raw materials satisfy these conditions, the extraction process can be applied to any raw material, not limited to the above-mentioned raw materials.

[0022]

In step (1), the raw material is crushed roughly enough to efficiently extract the essential oil components in step (2). For example, if the raw material is dried star anise, the particle size of the crushed material may be about 2 to 5 mm. With such a degree of crushing, a commercially available crusher can be used to crush 100 kg of dried star anise in about one hour or less.

[0023]

In step (2), for example, a steam distillation device 10 shown in FIG. 2 is used to extract the essential oil from the crushed material. The steam distillation device 10 includes a tank 1, a support plate 2 provided in the lower part of the tank 1, a baffle plate 3 provided in the upper part of the tank 1, first and second coolers 4a, 4b, a valve 5 for switching the flow path of steam from the tank 1, and a return path 6 for supplying water from the second cooler 4b into the tank 1.

[0024]

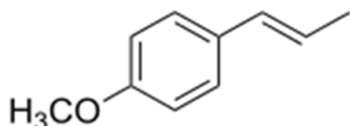
The crushed material C is stored in the tank 1 on the support plate 2. Steam is introduced from a boiler (not shown) to the bottom 1a of the tank 1 (the area between the bottom surface 1b and the support plate 2). Steam is supplied to the ground material C through a large number of through holes 2a provided in the support plate 2. Steam flows from below to above the ground material C. Arrow S in FIG. 2 indicates the flow direction of the steam. The steam comes into contact with the ground material C, and the essential oil components contained in the ground material C are extracted. The steam discharged from the tank 1 through the flow path L1 contains steam and essential oil

components. The steam is supplied to the first cooler 4a through the valve 5. The essential oil EO and water W generated by cooling in the first cooler 4a are collected in the container 7. Prior to the step (3), the generation of emulsion can be suppressed by extracting the essential oil components from the ground material in the step (2), and ultimately, high-purity shikimic acid can be efficiently produced. Note that water may be stored in the bottom 1a of the tank 1, and the water may be heated to generate steam.

[0025]

According to the inventors' research, the essential oil components contained in star anise contain, for example, trans-anethol, which is represented by the following chemical formula:

[Chemical formula 2]



If trans-anethole and other aromatic compounds contained in the essential oil components form an emulsion with shikimic acid, it becomes difficult to extract shikimic acid. As described above, the generation of emulsions can be suppressed by first extracting the essential oil components by steam distillation in step (2). For example, if the crushed material is 100 kg of star anise, the capacity of tank 1 may be about 500 L, and the amount of steam generated may be 500 to 750 kg/hour. In this case, about 10 L of essential oil is recovered in container 7 by distillation for about 4 hours.

[0026]

After step (2), step (3) is performed. That is, after the recovery of the essential oil by distillation, valve 5 is switched and steam from tank 1 is supplied to second cooler 4b. The steam from tank 1 is mainly water vapor. The steam is cooled in second cooler 4b, and the water generated by this is supplied into tank 1 through return line 6. This water is dripped onto crushed material C through a large number of through holes 3a provided in baffle plate 3. The arrow W in FIG. 3 indicates the direction of water flow. Meanwhile, water is stored in the bottom 1a of the tank 1, and steam is generated by heating this water. The arrow S in FIG. 3 indicates the direction of steam flow. Water is supplied from above to the ground material C in the tank 1 while being heated by steam supplied from below. When the water dripping from the through holes 3a of the baffle plate 3 comes into contact with the ground material C, shikimic acid is extracted into the water, and the shikimic acid aqueous solution Sw accumulates at the bottom 1a. For example, when the ground material is 100 kg of star anise, about 200 L of shikimic acid aqueous solution can be obtained by reflux extraction for about 2 hours.

[0027]

The temperature of the water refluxed to the tank 1 is preferably 45 to 98° C, more preferably 80 to 98° C, from the viewpoint of efficient extraction of shikimic acid. It is preferable that the steam distillation device 10 has a function of adjusting the temperature of the refluxed water. In the steam distillation apparatus 10, for example, the second cooler 4b may have a temperature adjustment function, or a temperature controller (not shown) may be provided in the return line 6.

[0028]

<Purification process>

The purification process is a process for obtaining a purified shikimic acid solution from an aqueous shikimic acid solution. This process includes the following steps:

- (4) A step of adjusting the concentration of the aqueous shikimic acid solution as necessary.
- (5) A step of bringing the aqueous shikimic acid solution into contact with an anion exchange resin, thereby adsorbing the shikimic acid and amino acids contained in the aqueous shikimic acid solution onto the anion exchange resin.
- (6) A step of eluting the shikimic acid and amino acids adsorbed onto the anion exchange resin.
- (7) A step of bringing the aqueous solution containing shikimic acid and amino acids obtained through step (6) into contact with a cation exchange resin, thereby adsorbing the amino acids onto the cation exchange resin.
- (8) A step of bringing the aqueous solution containing shikimic acid obtained through step (7) into contact with a hydrophobic synthetic adsorbent.

[0029]

In step (4), the concentration of the shikimic acid aqueous solution is adjusted as necessary so that it is suitable for treatment with the anion exchange resin used in step (5). When diluting the shikimic acid aqueous solution, for example, deionized water may be used.

[0030]

In the purification process according to this embodiment, as described above, an anion exchange resin is used in step (5), and then a cation exchange resin is used in step (7). According to the inventors' investigation, 100 kg of star anise (dried material) may contain about 86 mol of shikimic acid and about 14 mol of amino acids. By using an anion exchange resin and a cation exchange resin in combination, shikimic acid and amino acids can be separated. Amino acids are a general term for compounds that have a carboxy group and an amino group. Since amino acids have a carboxy group, they are also adsorbed to the anion exchange resin. For example, when the ground material is 100 kg of star anise, the treatment can be completed in about 2 hours.

[0031]

In step (5), the shikimic acid aqueous solution is brought into contact with the anion exchange resin, so that the shikimic acid and amino acids contained in the shikimic acid aqueous solution are adsorbed onto the anion exchange resin. In addition, by treating the shikimic acid aqueous solution with the anion exchange resin, all nonionic compounds can be removed, as well as all water-insoluble substances (such as fine particles). By using particles with a particle size of about 0.5 to 0.6 mm as the anion exchange resin, the column will not be clogged even if the shikimic acid aqueous solution contains fine particles (particle size of about 10 μ m).

[0032]

The anion exchange resin is a resin that has a crosslinked polymer as the resin matrix and has an anion exchange group. For example, an anion exchange resin that has a styrene resin as the matrix and has quaternary ammonium groups or amino groups as the anion exchange group can be used. The anion exchange resin may be of either a gel type or a macroporous type, but is preferably of a gel type. The anion exchange resin may be a commercially available OH-type resin as is, or a Cl-type resin may be converted to the OH-type using an aqueous solution of sodium hydroxide or the like. Examples of anion exchange groups include amino groups, trimethylammonium groups, and dimethylethanolammonium groups. Resins whose anion exchange groups are

dimethylethanolammonium groups are preferred because they are easy to regenerate (i.e., convert Cl to OH).

[0033]

Specific examples of anion exchange resins include Diaion (registered trademark) SA20A, Diaion (registered trademark) PA408, Diaion (registered trademark) PA412, and Diaion (registered trademark) PA418 (all manufactured by Mitsubishi Chemical Corporation), Dowex (registered trademark) Marathon A2 (manufactured by Dow Chemical Company), Amberlite (registered trademark) IRA410J, Amberlite (registered trademark) IRA411, Amberlite (registered trademark) IRA910CT (all manufactured by Organo Corporation), Purolite (registered trademark) A200, Purolite (registered trademark) A300, Purolite (registered trademark) A510 (all manufactured by Purolite Corporation), and Duolite (registered trademark) A116 (manufactured by Sumika Chemtex Corporation).

[0034]

By carrying out step (6), the shikimic acid and amino acids adsorbed on the anion exchange resin are eluted. It is preferable to use hydrochloric acid for eluting shikimic acid and amino acids. By using hydrochloric acid in step (6), it is possible to use a reverse osmosis membrane in the subsequent concentration process. The concentration of hydrochloric acid may be, for example, 1 mol/L (1N). For example, when the crushed material is 100 kg of star anise, the treatment can be completed in about 2 hours.

[0035]

After step (6), step (7) is carried out. That is, the aqueous solution obtained through step (6) is brought into contact with a cation exchange resin, so that the amino acids contained in the aqueous solution are adsorbed onto the cation exchange resin. As a result, the amino acids are removed from the aqueous solution, and the sodium, magnesium, calcium and other cations contained in the aqueous solution are replaced with hydrogen ions (H⁺) by the action of the cation exchange resin. These cations cause scale formation in the aqueous solution concentration process, but by using an anion exchange resin in step (5) and a cation exchange resin in step (7) in combination, it is possible to use a reverse osmosis membrane in the concentration process.

[0036]

Cation exchange resins are resins that have a crosslinked polymer as the resin matrix and have cation exchange groups. Examples of cation exchange resins include resins that have acid groups such as carboxyl groups (-COOH) and sulfo groups (-SO₃H) on the side chains of the polymer chain. Among these, cation exchange resins that have sulfo groups on the side chains of the resin and exhibit strong acidity are preferred because they can speed up the reaction. Commercially available cation exchange resins include Amberlite, a strong acid cation exchange resin manufactured by Organo Corporation.

[0037]

After step (7), step (8) is carried out. That is, the aqueous solution obtained through step (7) is brought into contact with a hydrophobic synthetic adsorbent to remove colored components and other phenolic compounds contained in the aqueous solution. This results in a purified shikimic acid solution. Since components other than shikimic acid have been sufficiently removed by the time of step (8), the load on the hydrophobic synthetic adsorbent can be sufficiently reduced, and the frequency of regeneration treatment of the hydrophobic synthetic adsorbent can be

sufficiently reduced. For example, when the crushed material is 100 kg of star anise, about 50 L of shikimic acid purified liquid is obtained.

[0038]

The hydrophobic synthetic adsorbent is a hydrophobic adsorbent composed of a crosslinked polymer having a porous structure, and has the property of adsorbing various organic substances in a solution due to the physical interaction between the pores and the adsorbed substance. From the viewpoint of sufficiently removing trans-anethole and other aromatic compounds, it is preferable to use an aromatic synthetic adsorbent. The aromatic synthetic adsorbent is a synthetic adsorbent in which the crosslinked polymer constituting the synthetic adsorbent has an aromatic ring group such as a benzene ring. An example of an aromatic synthetic adsorbent is a porous body made of a styrene-divinylbenzene copolymer.

[0039]

The pore volume of the hydrophobic synthetic adsorbent is, for example, 0.5 to 3 mL/g, preferably 1 to 3 mL/g, and more preferably 1 to 2 mL/g. The hydrophobic synthetic adsorbent is usually spherical, and it is preferable that 90% or more of the particle size is 250 μ m or more. Specific examples of hydrophobic synthetic adsorbents include DIAION (registered trademark) HP20 and DIAION (registered trademark) HP21 (both manufactured by Mitsubishi Chemical Corporation).

[0040]

<Concentration process>

The concentration process is a process in which shikimic acid purified liquid is concentrated to obtain high-purity shikimic acid. This process includes the following steps:

(9) A step of concentrating the shikimic acid purified liquid using a reverse osmosis membrane.

(10) A step of obtaining shikimic acid by volatilizing the water content of the shikimic acid concentrated liquid obtained through step (9).

[0041]

In step (9), by using a reverse osmosis membrane, a concentration system can be constructed relatively inexpensively. In addition, since reverse osmosis membranes do not require heating, the energy required for concentration can be significantly reduced. Systems using reverse osmosis membranes are widely used, for example, as seawater desalination systems, and have the advantage of being easily enlarged. When the ground material is 100 kg of star anise, for example, by constructing a system with a processing capacity of 400 GPD (1,520 L/day), 20 L of shikimic acid concentrate can be obtained from 50 L of shikimic acid purified liquid in about 2 hours.

[0042]

In step (10), powdered shikimic acid is obtained, for example, by drying using a spray dryer. When the ground material is 100 kg of star anise, about 1 kg of powdered shikimic acid can be obtained from about 20 L of shikimic acid concentrate by drying using a spray dryer for about 4 hours. According to the production method of this embodiment, it is possible to stably produce shikimic acid with a purity of 98% by mass or more.

[0043]

According to the inventors' study, the manufacturing method according to this embodiment has the following advantages over the manufacturing method described in Patent Document 1.

-While the manufacturing method described in Patent Document 1 required more than 110 hours per batch, the manufacturing method according to this embodiment can be carried out in about 24 hours per batch.

-The manufacturing method according to this embodiment can significantly reduce the energy required for heating.

-The manufacturing method according to this embodiment can sufficiently reduce the frequency of regeneration treatment of each column of anion exchange resin, cation exchange resin, and hydrophobic synthetic adsorbent.

-The manufacturing method according to this embodiment does not require the use of both ion exchange resins.

[0044]

[Shikimic Acid Manufacturing Equipment]

The manufacturing equipment for carrying out the manufacturing method according to this embodiment will be described. Figure 4 is a schematic diagram showing the configuration of the manufacturing equipment according to this embodiment. The shikimic acid production equipment 100 includes a grinder 8, a steam distillation device 10, an anion exchange resin column 20, a cation exchange resin column 30, a hydrophobic synthetic adsorbent column 40, a reverse osmosis membrane 50, and a spray dryer 60.

[0045]

According to the shikimic acid production method and production equipment according to this embodiment, it is possible to produce high-purity shikimic acid with a sufficiently short running time and a sufficiently small energy input.

[0046]

Although the embodiments of the present disclosure have been described in detail above, the present invention is not limited to the above embodiments. For example, in the above embodiments, the fruits and leaves of plants that contain at least shikimic acid and essential oil components and further contain amino acids are exemplified as raw materials, but other materials may be used as raw materials. For example, foods (e.g., mushrooms) or food residues (e.g., koji) that contain shikimic acid may be used as raw materials.

[0047]

In the above embodiment, the water obtained by cooling the water vapor from tank 1 in second cooler 4b is returned to tank 1 via return line 6. However, for example, a spray capable of spraying water may be installed at the top of tank 1, and shikimic acid contained in pulverized material C may be extracted using the water sprayed from the spray.

[Explanation of symbols]

[00]

1...tank, 1a...bottom, 1b...bottom surface, 2...support plate, 2a...through hole, 3...baffle plate, 3a...through hole, 4a...first cooler, 4b...second cooler, 5...valve, 6...return line, 7...container, 8...crusher, 10...steam distillation apparatus, 20...anion exchange resin column, 30...cation exchange resin column, 40...hydrophobic synthetic adsorbent column, 50...reverse osmosis membrane, 60...spray dryer, 100...shikimic acid manufacturing equipment, C...crushed material, EO...essential oil, L1...flow path, Sw...shikimic acid aqueous solution, W...water.