

SOLID-STATE FERMENTATION SYSTEM

1. FIELD OF THE INVENTION

[0001] The present invention relates to a solid-state fermentation technology, particularly a solid-state fermentation system using a horizontal agitating
5 fermentation vessel.

2. DESCRIPTION OF THE PRIOR ART

[0002] In Solid-State Fermentation (SSF), the culture medium has lower water content, essentially in form of powder or pellets and dripping water while kneaded. At present, SSF is mainly applied to the powdered animal
10 food industry.

[0003] Humans cannot directly digest fibrous plants, such as pericarps and barks. However, the fibrous plants can be converted into eatable fungal protein if they are heated/agitated and metabolized/hydrolyzed/transformed in a solid-state fermentation vessel.

15 [0004] A solid-state fermentation vessel may be a vertical-type one or a horizontal-type one. The material may be unevenly stirred and stuck to the vessel wall during the heating and agitating process. Besides, the culture medium and the material will gradually become sticky from a solid state during hydrolysis of plant fiber, which will thus result in uneven fermentation.
20 Further, the bacteria may be killed by the heat generated in hydrolysis.

SUMMARY OF THE INVENTION

[0005] In order to solve the abovementioned problems, the present invention provides a solid-state fermentation system, which is applicable to various types of mixtures, wherein the mixing blades match with or mesh with the baffles on the inner wall of the horizontal fermentation vessel to perform a function of agitating, breaking, drying or smashing, or perform a combination of the aforementioned functions.

[0006] In order to solve the abovementioned problems, the present invention provides a solid-state fermentation system, which is applicable to various types of mixtures, wherein the rotation speeds and the rotation directions of the horizontal fermentation vessel and the mixing assembly are adjusted to perform a function of agitating, breaking, drying or smashing, or perform a combination of the aforementioned functions.

[0007] In order to achieve the abovementioned objectives, the present invention provides a solid-state fermentation system, which includes a horizontal fermentation vessel, a mixing assembly, a first rotation assembly, and a second rotation assembly. The horizontal fermentation vessel includes a vessel body and a bottom cover, which jointly define a fermentation space inside the horizontal fermentation vessel. A plurality of first baffles is intermittently disposed on the inner wall of the vessel body and protrudes into the fermentation space. The mixing assembly includes a longitudinal tubular member, a plurality of mixing blades, and a plurality of second baffles. The longitudinal tubular member, the mixing blades and the second baffles are accommodated in the fermentation space. A first end of each mixing

blade is connected with the longitudinal tubular member; one of the second baffles is disposed at a second end of the mixing blade and protrudes toward the inner wall. A first end of the longitudinal tubular member is accommodated in the vessel body; a second end of the longitudinal tubular member penetrates through the bottom cover to the exterior of the vessel body. The first rotation assembly is connected with the vessel body and used to rotate the vessel body. The second rotation assembly is connected with the mixing assembly and used to rotate the longitudinal tubular member. While at least one of the vessel body and the mixing assembly is rotating, any one of the second baffles stays between adjacent two of the first baffles or passes through adjacent two of the first baffles.

[0008] In one embodiment, the first baffles are intermittently fixed onto the inner wall in a parallel or oblique way as a whole with respect to the longitudinal tubular member.

[0009] In one embodiment, one or more openings are formed on the wall of the longitudinal tubular member.

[0010] In one embodiment, the longitudinal tubular member is a hollow structure having a supporting assembly thereinside.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig.1 is a perspective view schematically showing a solid-state fermentation system according to a first embodiment of the present invention.

[0012] Fig.2 is a lateral sectional view schematically showing a portion of

the solid-state fermentation system of the first embodiment in a first situation.

[0013] Fig.3 is a cross sectional view schematically showing a portion of the solid-state fermentation system of the first embodiment in the first situation.

5 [0014] Fig.4 is a lateral sectional view schematically showing a portion of the solid-state fermentation system of the first embodiment in a second situation.

[0015] Fig.5 is a cross sectional view schematically showing a portion of the solid-state fermentation system of the first embodiment in the second situation.

10 [0016] Fig.6 is a spread view schematically showing a portion of members of the solid-state fermentation system according to the first embodiment of the present invention.

[0017] Fig.7 is another spread view schematically showing a portion of members of the solid-state fermentation system according to the first
15 embodiment of the present invention.

[0018] Fig.8 is a spread view schematically showing a portion of members of the solid-state fermentation system according to another embodiment of the present invention.

20 **DESCRIPTION OF THE PREFERRED EMBODIMENT**

[0019] Fig.1 is a perspective view schematically showing a solid-state fermentation system according to a first embodiment of the present invention.

Fig.2 and Fig.3 are respectively a lateral sectional view and a cross sectional

view schematically showing a portion of the solid-state fermentation system of the first embodiment in a first situation. Refer to Figs.1-3. The solid-state fermentation system 1 mainly includes a horizontal fermentation vessel 2 and a mixing assembly 3. A vessel body 20 and a bottom cover 11 are joined together to form the appearance of the horizontal fermentation vessel 2. The vessel body 20 may be formed by laminating multiple layers of materials. For example, the multiple layers of materials may include a heat insulation wall 13 and a sleeve 15. The sleeve 15 and the bottom cover 11 jointly define a fermentation space 14 inside the horizontal fermentation vessel 2. Sensors (not shown in the drawings) may be installed on the bottom cover 11 to detect the environment, reactants or products inside the fermentation space 14. In the first embodiment, the shape of the vessel body 20 resembles a bell. The top of the vessel body 20 has a protrudent first coupling part 17, which is connected with a first rotation assembly and other members that are outside the horizontal fermentation vessel 2. In one embodiment, a first longitudinal rotating shaft 18 passes through a mounting member 4 and connects with a first rotary joint 19, and the first longitudinal rotating shaft 18, the mounting member 4 and the first rotary joint 19 constitute the first rotation assembly. The bottom cover 11 has a plate-like structure; the bottom cover 11, and the heat insulation wall 13 and the sleeve 15 are joined tightly. The bottom cover 11 has an opening to allow the mixing assembly 3 to pass through. The sleeve 15 adheres to the heat insulation wall 13 and functions as the inner wall of the vessel body 20. A plurality of first baffles 12 is intermittently distributed on the inner wall. A region of

the sleeve 15, which is corresponding to the first coupling part 17, has an accommodation member connected with a terminal (a first end) of a longitudinal tubular member 33. The mixing assembly 3 includes the longitudinal tubular member 33, a plurality of mixing blades 34, and a plurality of second baffles 32, wherein the mixing blades 34 and the second baffles 32 are arranged inside the fermentation space 14. A second end of the longitudinal tubular member 33 penetrates the bottom cover 11 and connects with a second longitudinal rotating shaft 38, and the second longitudinal rotating shaft 38 passes through another mounting member 4 and then connects with a second rotary joint 39. The second longitudinal rotating shaft 38, another mounting member 4 and the second rotary joint 39 constitute a second rotation assembly. Two mounting members 4 are used to suspend the horizontal fermentation vessel 2. In the first embodiment, the longitudinal tubular member 33 is a long and hollow pipe structure; one end of the longitudinal tubular member 33 is accommodated by the accommodation member of the sleeve 15; another end of the longitudinal tubular member 33 extends through the opening of the bottom cover 11 to the exterior; one or more first perforations 35 are formed on the wall of the longitudinal tubular member 33. A supporting assembly 31 is accommodated in the pipe-shape space of the longitudinal tubular member 33. The supporting assembly 31 may have but is not limited to have air supply/transfer piping and water supply/transfer piping. Gas or liquid from the supporting assembly 31 may enter into fermentation space 14 via the first perforations 35. A first end of the mixing blade 34 connects with the longitudinal tubular

member 33, and the mixing blade 34 almost vertically extends from the longitudinal tubular member 33 toward the fermentation space 14 to reach a region approaching the sleeve 15. A second end of the mixing blade 34 has the second baffle 32 that protrudes toward the sleeve 15 (the inner wall).

5 The positions and size of the second baffles 32 match the positions and size of the first baffles 12. The supporting assembly 31 may further include wires, circuit boards, and power supply elements, which are connected to the second rotary joint 39. In Fig.2, the horizontal fermentation vessel 2 or the mixing assembly 3 are not drawn or merely sketched simply. However, it is
10 not to limit the present invention but to emphasize the characteristics of the present invention.

[0020] Refer to Figs.1-3 again. The horizontal fermentation vessel 2 and the mixing assembly 3 may be respectively driven by different driving mechanisms/driving assemblies. In the first embodiment, a first motor 22 is
15 connected to the first longitudinal rotating shaft 10 through a first transmission assembly 25. In one embodiment, the first transmission assembly 25 may include belts and pulleys. In operation, the first motor 22 drives the first transmission assembly 25 to rotate the first longitudinal rotating shaft 18 and then drive the bottom cover 11, the vessel body 20 and
20 the first baffles 12 to rotate together(the rotation is indicated by Arrow A). A second motor 24 is connected to the mixing assembly 3 through a second transmission assembly 23. The second motor 24 drives the second transmission assembly 23 to rotate the second longitudinal rotating shaft 38 and then drive the longitudinal tubular member 33, the mixing blades 34 and

the second baffles 32 to rotate together (the rotation is indicated by Arrow B). In a first situation, the horizontal fermentation vessel 2 and the mixing assembly 3 are respectively driven to rotate in the same direction. For example, Arrow A and Arrow B are in the clockwise direction. While the horizontal fermentation vessel 2 and the mixing assembly 3 rotate in the same speed, the first baffles 12 match and engage with the second baffles 32 to form a continual structure along the longitudinal length L of the fermentation space, and the continual structure exists persistently for the entire period of the rotations at the same speed in the same direction. Thus, the reactants, the products or other materials (not shown in the drawings) are less likely to adhere to the sleeve 15. While the horizontal fermentation vessel 2 and the mixing assembly 3 do not rotate in the same speed, the first baffles 12 match and engage with the second baffles 32 to constitute a continual structure along the longitudinal length L of the fermentation space at specified time points. During the period that the horizontal fermentation vessel 2 and the mixing assembly 3 do not rotate in the same speed, the first baffles 12 and the second baffles 32 will approach each other gradually, match and engage with each other, and then separate from each other. Thus, the continual structure and the non-continual structure appear alternately in the horizontal fermentation vessel 2. With the variation from approaching each other, matching and engaging with each other, and then separating from each other, different actions are applied to the materials inside the fermentation space 14. Thus, a function of agitating, breaking, drying or smashing, or a combination of the aforementioned functions, is performed on the materials inside the

fermentation space 14.

[0021] Fig.4 and Fig.5 are respectively a lateral sectional view and a cross sectional view of a portion of assemblies of a solid-state fermentation system in a second situation according to a second embodiment of the present invention. Refer to Figs.1-5 simultaneously. In comparison with the situation where the first baffles 12 match and engage with the second baffles 32 in Fig.2, Fig.4 shows a situation where the first baffles 12 neither match nor engage with the second baffles 32. As shown in Fig.5, the horizontal fermentation vessel 2 and the mixing assembly 3 are respectively driven to rotate in different directions, wherein Arrow A rotates clockwise and Arrow B rotates counterclockwise, and wherein the first baffles 12 are separated from the second baffles 32 by 90 degrees at specified time points. It is easily understood: in the second type of rotation, the first baffles 12 and the second baffles 32 may also approach each other, match and engage with each other, and then separate from each other at specified time points. Therefore, the continual structure and the non-continual structure also appear alternately in the horizontal fermentation vessel 2 during the second type of rotation. Thus, different actions are applied to the materials inside the fermentation space 14, wherein a function of agitating, breaking, drying or smashing, or a combination of the aforementioned functions, is performed on the materials inside the fermentation space 14. It is easily understood: one of the horizontal fermentation vessel 2 and the mixing assembly 3 of the present invention may be set to stay stationary, and the other one may be set to rotate. For example, the horizontal fermentation vessel 2 is kept still, and the mixing

assembly 3 is rotated clockwise or counterclockwise. In such a setting, the relative position of the first baffles 12 and the second baffles 32 may still have the aforementioned variation at specified time points. According to the above description, while the mixing assembly 3 rotates singly or while the horizontal fermentation vessel 2 and the mixing assembly 3 rotate in the same direction but at different speeds, the mixing blades 34 and the second baffles 32 of the sleeve 15 may match each other or engage with each other at specified time points. While the horizontal fermentation vessel 2 and the mixing assembly 3 rotate in the same direction and at the same speed, the mixing blades 34 and the second baffles 32 of the sleeve 15 may also match each other or engage with each other. The aforementioned operation methods may flip and fling the mixtures (materials and culture media) to agitate and mix them fully. While the horizontal fermentation vessel 2 and the mixing assembly 3 rotate in different directions, they may perform a smashing function. Therefore, the solid-state fermentation system 1 of the present invention may apply to various types of mixtures and may evenly mix the materials fed into the horizontal fermentation vessel 2, the intermediate products of fermentation and the final products of fermentation. The solid-state fermentation system 1 of the present invention may apply to various types of mixtures, such as solid-state powders, slurry materials and dough-like materials. Even through the mixtures have different forms in the fermentation process, the present invention can still agitate, break, dry or smash them, or perform a combination of the aforementioned functions on them via adjusting the speed and direction of rotation.

[0022] Fig.6 is a spread view schematically showing a portion of assemblies of the solid-state fermentation system according to the first embodiment of the present invention. Refer to Figs.1-6 simultaneously. In Fig.6, the vessel body 20 is spread onto a plane, and R denotes the rotating axis of the vessel body and the mixing assembly. In the first embodiment, a plurality of first baffles 12 is arranged intermittently on a single virtual line parallel to the rotating axis R. In other words, the first baffles 12 disposed parallel to the longitudinal tubular member. While one of the vessel body 20 and the mixing assembly 3 rotates, the second baffles 32 stay between the first baffles 12 at a specified time point or more specified time points or within a continuous time interval, whereby the first baffles 12 and the second baffles 32 jointly form a straight line. In other words, the first baffles 12 and the second baffles 32 form a continual structure. It should be particularly explained: the first baffles 12 and the second baffles 32 match each in structure. For example, the first baffles 12 have a rectangular shape; the second baffles also have a rectangular shape or have a stereo 3-dimensional structure with a rectangular bottom; while the first baffle 12 stays between the adjacent second baffles 32, the gaps therebetween are either neglectable or very small. Fig.7 is another spread view schematically showing a portion of assemblies of the solid-state fermentation system according to the first embodiment of the present invention. In comparison with the first baffles 12 in Fig.6, the first baffles 12 in Fig.7 has a trapezoidal shape, wherein the larger base is fixed to the inner wall of the vessel body, and the smaller base protrudes toward the fermentation space. Thus, the second baffles 32, which

match the first baffles 12, also has a trapezoidal shape, wherein the larger base is near the inner wall of the vessel body, and the smaller base is connected with the mixing blade (not shown in the drawing), and wherein the projection area of the larger base is equal or approximate to the spacing of two adjacent first baffles 12.

[0023] Fig.8 is a spread view schematically showing a portion of assemblies of the solid-state fermentation system according to another embodiment of the present invention. In comparison with the first baffles 12 in Fig.6, the first baffles 12 in Fig.8 are fixed to the inner wall intermittently, but a single virtual line with respect to the first baffles 12 is not a parallel line but a skew line to the rotating axis R. In the embodiment shown in Fig.8, a plurality of mixing blades is arranged helically with respect to the longitudinal tubular member to make the status shown in Fig.8 appear at some time points or persist for a period of time during rotation. In other words, the second baffles 32 and the first baffles 12 form a straight line in projection, wherein the straight line is skew to the rotating axis, and while the straight line is an arc line in reality when the vessel body is a bell-like cylinder in reality. Accordingly, the first baffles 12 are fixed onto the inner wall intermittently in a parallel or oblique way as a whole with respect to the longitudinal tubular member. The first baffles 12 may be fixed to the inner wall of the vessel body 12 in an appropriate method, such as a welding method. The present invention does not constrain that the first baffles 12 must be distributed on the inner wall according to the patterns shown in the attached drawings. In the present invention, the quantity, shape and arrangement of the first baffles

12 may be adjusted according to requirement as long as the quantity, shape and positions of the second baffles 32 can match the quantity, shape and arrangement of the first baffles 12.

[0024] The substrates suitable for the solid-state fermentation (SSF) system include starchy substrates, substrates with protein, cellulosic/ lignocellulosic substrates, substrates with solvable sugar, defined media and inert carrier, and combinations of at least two of the aforementioned substrates. The starchy substrate may be but is not limited to be rice, barley, oats, cassava, wheat bran, cassava meal, corn meal, bean dregs, sweet potato residues, banana peel, or a combination of at least two of the aforementioned starchy substrates. The starchy substrates, being rich in carbohydrates (important carbon source in many microbial fermentation processes), are hydrolyzed to produce simple sugars that can be consumed easily by microorganisms. Food and agricultural-industry by-products, such as oil cakes, are ideal sources of proteinaceous nutrients. Their use as a solid substrate is highly favored in SSF. Oil cakes, being rich in proteins (important nitrogen sources in many microbial fermentation) and supported by other nutrients such as carbohydrates and minerals, offer a wide range of alternative substrates in SSF for the production of various enzymes (for example proteases, lipases, etc.) and offer a wide spectrum of secondary metabolites, biomass, organic acids and biofertilizers in other uses. Oil cake-type food and agricultural-industry by-products include pumpkin oil cake (63.52%), soybean oil cake (51.8%), sesame oil cake (48.2%), groundnut oil cake (45.6%), safflower oil cake (44.0%), rapeseed meal oil cake (42.8%), cottonseed oil cake (41.0%),

mustard oil cake (38.5%), sunflower oil cake (34.1%), canola oil cake (33.9%), linseed oil cake (32-36%), coconut oil cake (25.2%), copra oil cake (23.11%), palm kernel oil cake (20.4%), and olive oil cake (4.77%), which are the most abundant agriculture by-products.

- 5 [0025] Most agricultural residues contain high levels of cellulose or lignocellulose, which have the potential to be used as solid substrates in SSF. The agricultural residues containing high levels of cellulose or lignocellulose include sugarcane bagasse, soybean hulls, wheat bran, rice hulls, rice stover, corn cob, barley husk, sugar beet pulp, wheat straw, barley straw, and wood.
- 10 In this case, cellulolytic fungi, such as *Trichoderma*, *Trichoderma viride*, *Aspergillus niger*, *Clostridium cellulolyticum* and *Rhizopus* sp. *Streptomyces* sp., and ligninolytic fungi, such as white-rot fungi, are able to degrade complex cellulose and lignocellulose to produce simple sugars.

- [0026] Solid substrates containing significant amount of soluble sugars may
- 15 be obtained from fruit processing, such as molasses, grape pomace, apple pomace, kiwi pomace, lemon peel, lemon pulp, peach pomace, pineapple waste, sweet sorghum, fodder and sugar beets, sugar beet pulp, carob pods, and coffee pulp. There are various inert carriers that can be used to simulate the conditions of typical SSF. These inert carriers include vermiculite,
- 20 perlite, clay granules, pozzolana particles (volcanic material), hemp, amberlite, polyurethane foam (PUF) and polystyrene. The inert carrier is filled with chemically defined liquid media.

[0027] The embodiments described above are to demonstrate the technical thought and characteristics of the present invention to enable the persons

skilled in the art to understand, make, and use the present invention. However, these embodiments are only to exemplify the present invention but not to limit the scope of the present invention. Any equivalent modification or variation according to the spirit of the present invention is to be also
5 included by the scope of the present invention.

CLAIMS

What is claimed is:

1. A solid-state fermentation system, comprising:

a horizontal fermentation vessel including a vessel body and a
5 bottom cover, wherein the vessel body and the bottom cover jointly define
a fermentation space inside the horizontal fermentation vessel, and a
plurality of first baffles is intermittently disposed on an inner wall of the
vessel body and protrudes into the fermentation space;

a mixing assembly including a longitudinal tubular member, a
10 plurality of mixing blades and a plurality of second baffles, wherein the
longitudinal tubular member, the mixing blades and the second baffles are
accommodated in the fermentation space, and wherein

a first end of each of the mixing blades is connected with the
longitudinal tubular member; one of the second baffles is disposed at a
15 second end of each of the mixing blades and protrudes toward the inner
wall; and

a first end of the longitudinal tubular member is
accommodated in the vessel body; a second end of the longitudinal
tubular member penetrates through the bottom cover to exterior of the
20 vessel body;

a first rotation assembly connected with the vessel body and used to
rotate the vessel body; and

a second rotation assembly connected with the mixing assembly and
used to rotate the longitudinal tubular member, wherein while at least one

of the vessel body and the mixing assembly rotates, any one of the second baffles stays between adjacent two of the first baffles or passes through adjacent two of the first baffles.

2. The solid-state fermentation system according to claim 1, wherein the first baffles are fixed onto the inner wall intermittently in a parallel or oblique way as a whole with respect to the longitudinal tubular member.

3. The solid-state fermentation system according to claim 1, wherein one or more perforations are formed on a wall of the longitudinal tubular member.

4. The solid-state fermentation system according to claim 1, wherein the longitudinal tubular member is a hollow structure having a supporting assembly thereinside.

5. The solid-state fermentation system according to claim 1, wherein the first rotation assembly includes a first longitudinal rotating shaft connected with the vessel body, and a first rotary joint is connected with the first longitudinal rotating shaft.

6. The solid-state fermentation system according to claim 5, further comprising a first transmission assembly connected with the first longitudinal rotating shaft, and a first motor rotating the vessel body via the first transmission assembly.

7. The solid-state fermentation system according to claim 1, wherein the second rotation assembly includes a second longitudinal rotating shaft connected with the longitudinal tubular member, and a second rotary joint is connected with the second longitudinal rotating shaft.

8. The solid-state fermentation system according to claim 7, further comprising a second transmission assembly connected with the second longitudinal rotating shaft, and a second motor rotating the longitudinal tubular member via the second transmission assembly.

5 9. The solid-state fermentation system according to claim 1, further comprising two mounting members respectively connected with the first rotation assembly and the second rotation assembly for suspending the horizontal fermentation vessel.