



US 20110282085A1

(19) **United States**

(12) **Patent Application Publication**
Cantrell et al.

(10) **Pub. No.: US 2011/0282085 A1**

(43) **Pub. Date: Nov. 17, 2011**

(54) **METHODS OF PROCESSING ETHANOL BYPRODUCTS AND RELATED SUBSYSTEMS**

(60) Provisional application No. 60/602,050, filed on Aug. 17, 2004.

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Publication Classification

(51) **Int. Cl.**
C11B 13/00 (2006.01)

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(52) **U.S. Cl.** **554/177**

(21) Appl. No.: **13/107,197**

(57) **ABSTRACT**

(22) Filed: **May 13, 2011**

Related U.S. Application Data

(63) Continuation of application No. 11/241,231, filed on Sep. 30, 2005, now Pat. No. 8,008,516, Continuation of application No. 12/559,136, filed on Sep. 14, 2009, now Pat. No. 8,008,517, which is a continuation of application No. 11/122,859, filed on May 5, 2005, now Pat. No. 7,601,858.

In one aspect of the invention, a method recovers oil from a concentrated byproduct, such as evaporated thin stillage formed during a dry milling process used for producing ethanol. The method includes forming a concentrate from the byproduct and recovering oil from the concentrate. The step of forming the concentrate may comprise evaporating the byproduct. Further, the step of separating the oil from the concentrate may comprise using a centrifuge and, in particular, a disk stack centrifuge. Other aspects of the invention include related methods and subsystems for recovering oil from thin stillage.

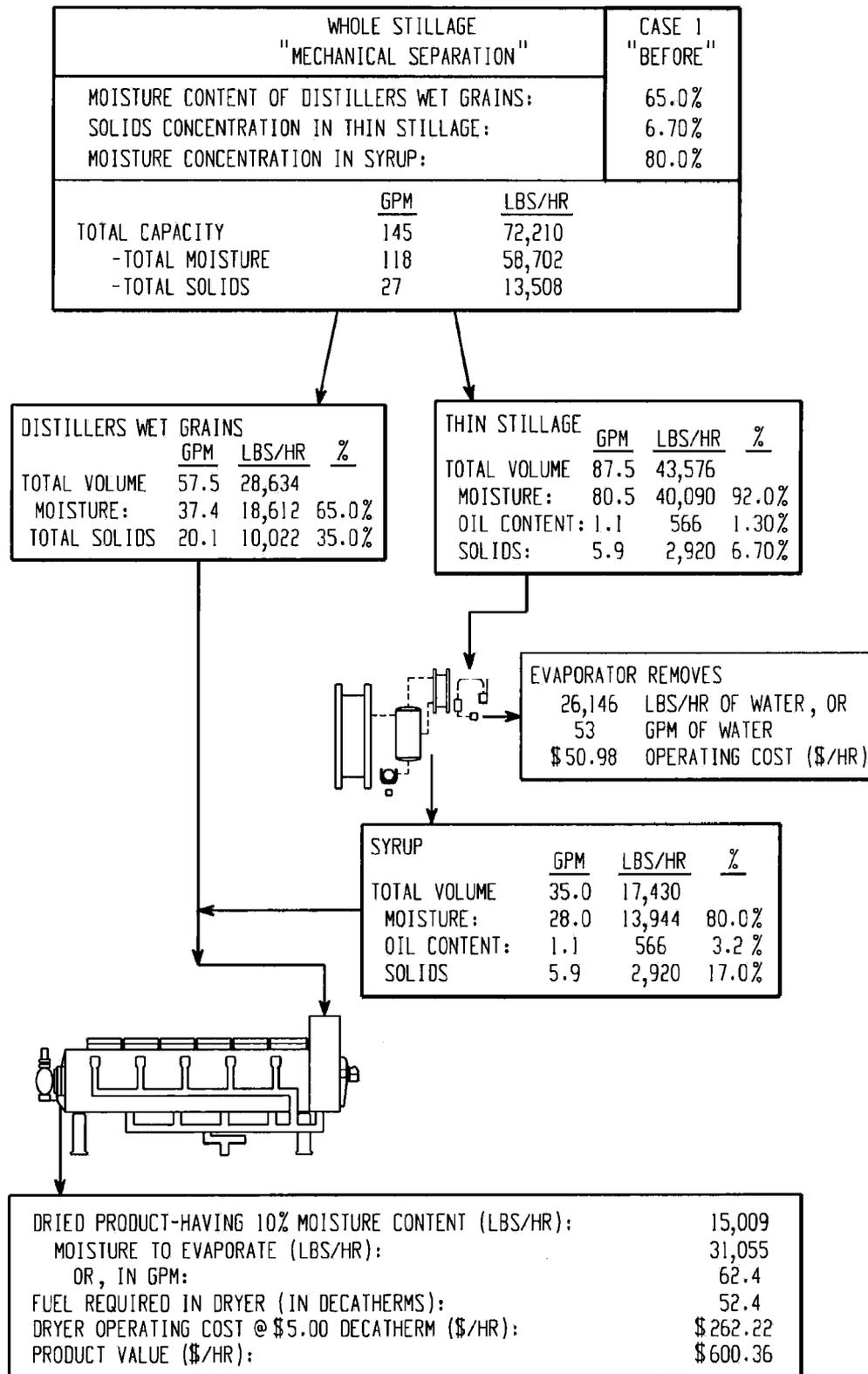


Fig. 1

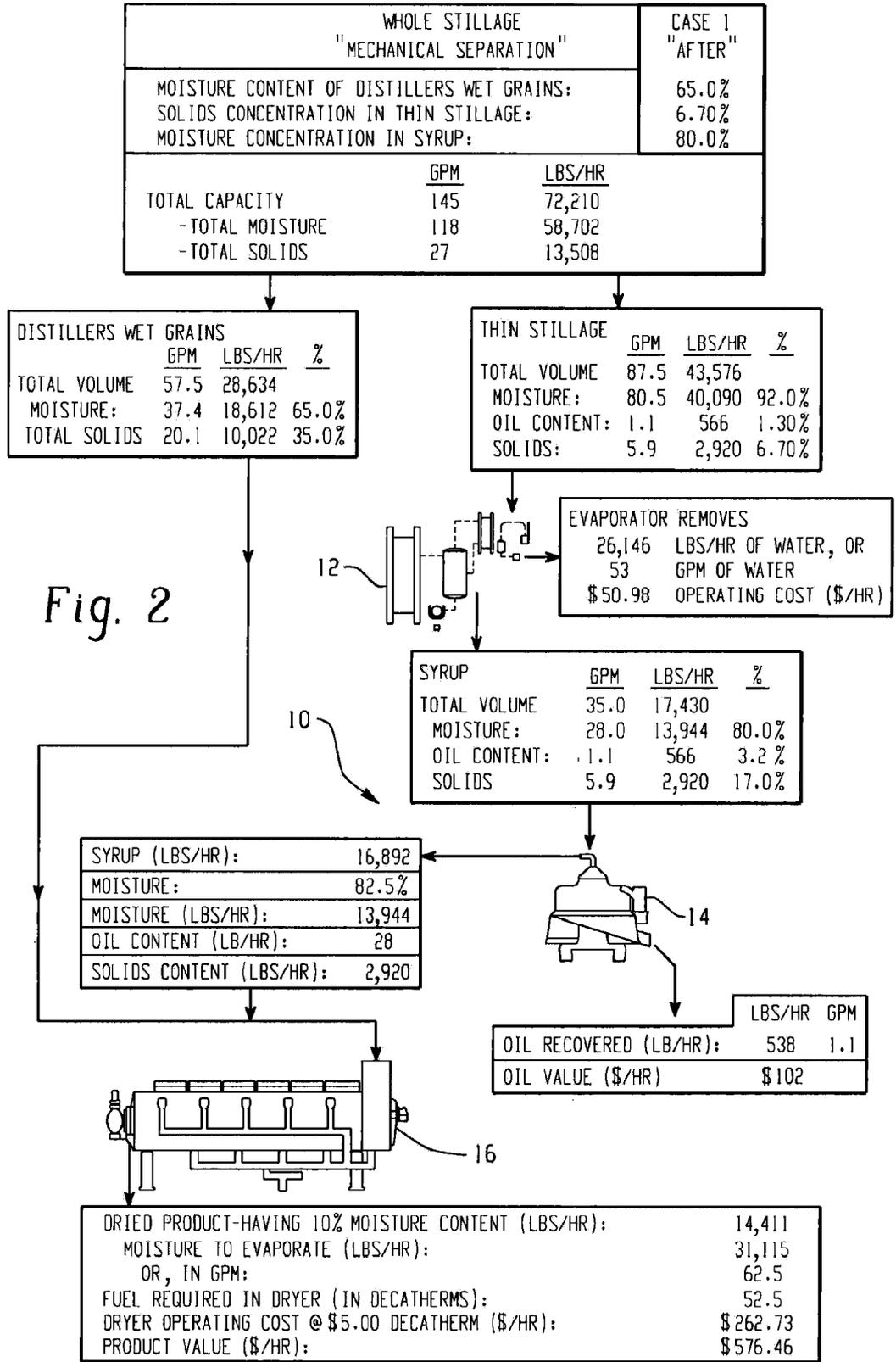


Fig. 2

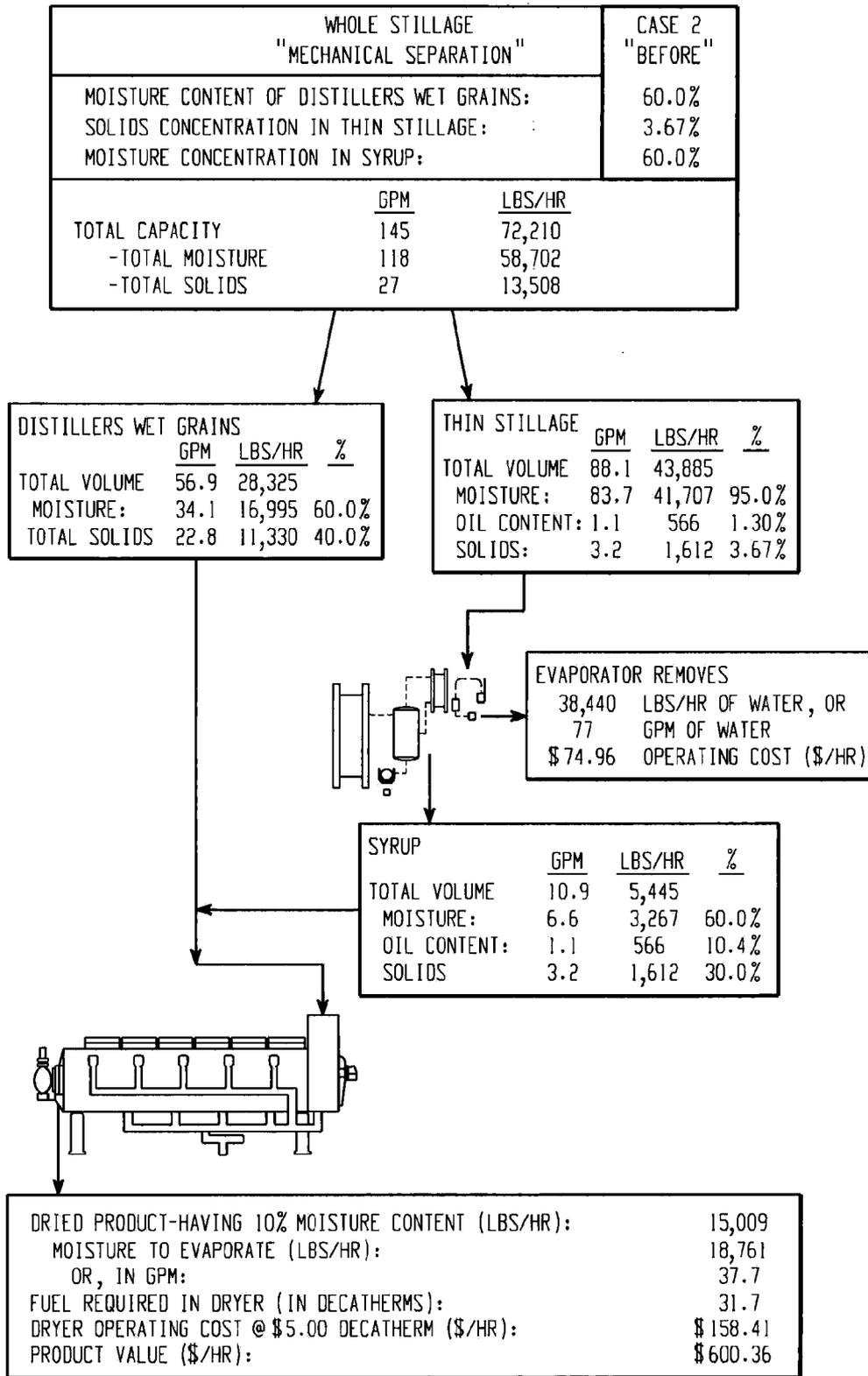


Fig. 3

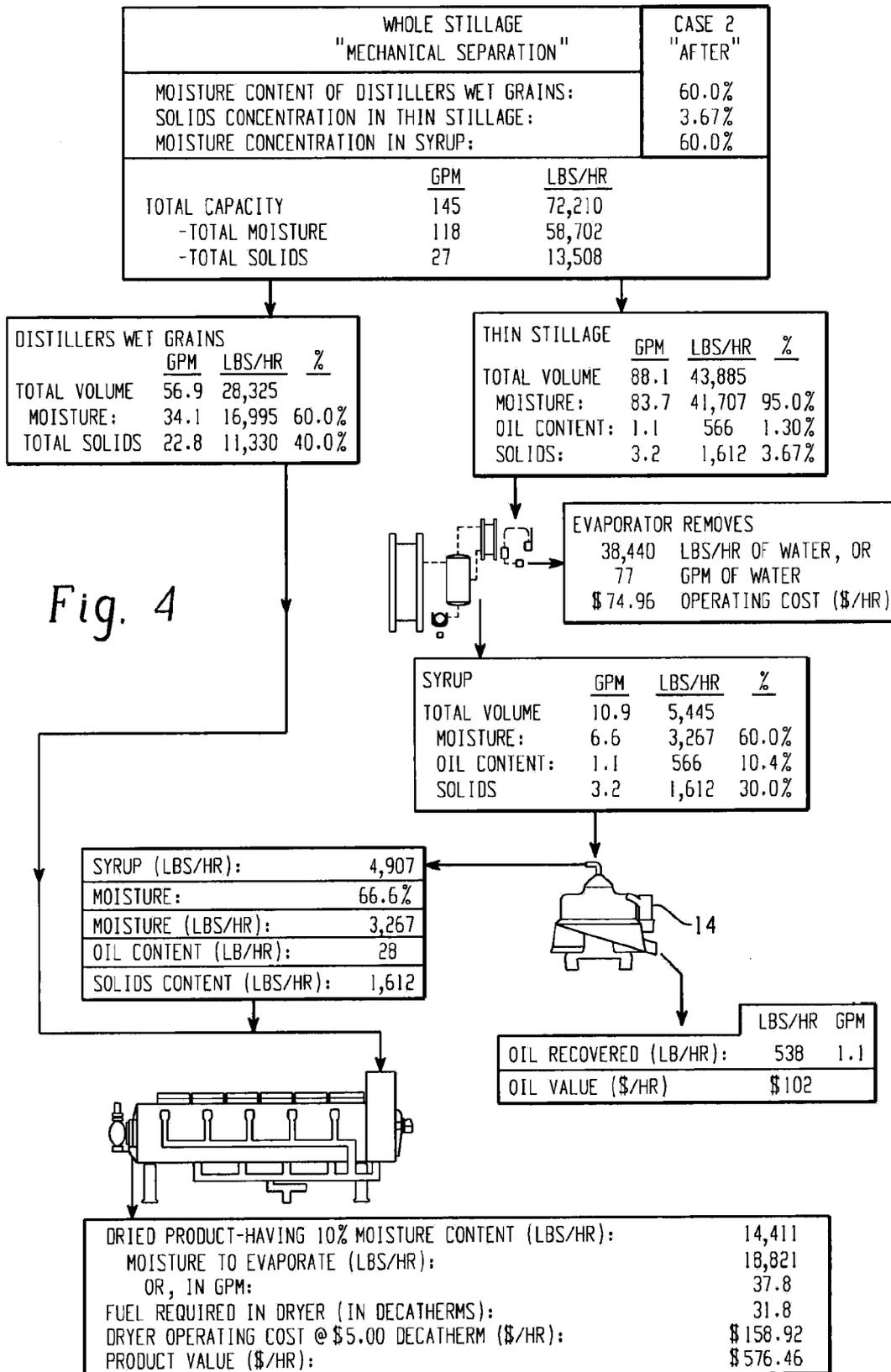


Fig. 4

METHODS OF PROCESSING ETHANOL BYPRODUCTS AND RELATED SUBSYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation of U.S. patent application Ser. No. 11/241,231, filed on Sep. 30, 2005 and U.S. patent application Ser. No. 12/559,136 filed on Sep. 14, 2009, which are continuations of U.S. Pat. No. 7,601,858, filed on May 5, 2005 and which claims the benefit of priority under 35 USC 119(e) to U.S. Provisional Application No. 60/602,050, filed on Aug. 17, 2004. The present application is also related to U.S. patent application Ser. No. 12/475,781 filed on Jun. 1, 2009, which has been abandoned and is a continuation of U.S. Pat. No. 7,601,858; all of which are incorporated by reference in their entireties.

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TECHNICAL FIELD

[0003] The present invention relates generally to recovering oil and, more particularly, to recovering oil from a byproduct of the dry milling process used to form ethanol.

BACKGROUND OF THE INVENTION

[0004] Over the past thirty years, significant attention has been given to the production of ethyl alcohol, or "ethanol," for use as an alternative fuel. Ethanol not only burns cleaner than fossil fuels, but also can be produced using grains such as corn, which are of course renewable resources. At present, approximately sixty-nine "dry milling" plants in the United States produce over two billion gallons of ethanol per year. Additional plants presently under construction are expected to add over four hundred million gallons to this total in an effort to meet the current high demand.

[0005] As noted in the foregoing discussion, a popular method of producing ethanol is known as "dry milling," and in the United States is typically practiced using corn. As is well known in the industry, the dry milling process utilizes the starch in the corn or other grain to produce the ethanol through fermentation, and creates a waste stream comprised of byproducts termed "whole stillage" (which may be further separated into products known as distillers wet grains and "thin stillage"). Despite containing valuable oil, this whole stillage has for the most part been treated as waste and used primarily to supplement animal feed (mostly in the form of distillers dried grains with solubles (DDGS), which is created by evaporating the thin stillage, recombining the resulting concentrate or syrup with the distillers wet grains, and drying the product to have a low moisture content; see, e.g., U.S. Pat. Nos. 5,662,810 and 5,958,233, the disclosures of which are incorporated herein by reference).

[0006] Efforts to recover the valuable oil from this byproduct have not been successful in terms of efficiency or economy. For example, one approach involves attempting to separate the oil from the thin stillage before the evaporation stage, such as using a centrifuge. However, spinning the thin

stillage at this stage does not produce usable oil, but rather merely creates an undesirable emulsion phase requiring further processing. Moreover, the volume of thin stillage present is generally 2 to 10 times greater than the syrup, which requires considerable capital to purchase the number of centrifuges required. Together, these obstacles make attempts to recover oil from thin stillage highly inefficient and uneconomical.

[0007] U.S. Pat. No. 5,250,182 (the disclosure of which is incorporated herein by reference) describes the use of filters for removing substantially all solids and recovering lactic acid and glycerol from the thin stillage without the need for evaporation. Despite eliminating a step in the conventional process, the proposal results in a more complicated arrangement requiring multiple filtration steps. Wholesale elimination of the evaporator in the vast majority of existing plants is also unlikely and otherwise uneconomical. Filters, and especially the microfiltration and ultrafiltration types proposed in this patent, are also susceptible to frequent plugging and thus disadvantageously increase the operating cost. For these reasons, the filtration process proposed in this patent has not gained widespread commercial acceptance.

[0008] Accordingly, a need exists for a more efficient and economical manner of recovering oil from a byproduct containing it, such as thin stillage created during the dry milling process used to produce ethanol.

SUMMARY OF THE INVENTION

[0009] In accordance with one aspect of the invention, a method of processing a concentrated byproduct of a dry milling process for producing ethanol, such as by using corn, is disclosed. In its most basic form, the method comprises recovering oil from the concentrated byproduct.

[0010] In one embodiment, the byproduct comprises thin stillage, and the method includes the step of evaporating the thin stillage to form a concentrate. The recovering step may further comprise separating the oil from the concentrate using a disk stack centrifuge. Preferably, the recovering step comprises: (1) providing the concentrated byproduct at a temperature of between about 150 and 212° F. and, most preferably, at a temperature of about 180° F.; and/or (2) providing the concentrated byproduct having a pH of between about 3 and 6 and, most preferably, between about 3.5 and 4.5. Additionally, it is preferred that the concentrated byproduct have a moisture content greater than 15% by weight, more preferably a moisture content greater than 50% and less than 90% and, most preferably, a moisture content between about 60-85%. The step of recovering the oil from the concentrated byproduct produces syrup, and the method may further include the step of recovering oil from the syrup.

[0011] In accordance with another aspect of the invention, a more specific method of processing concentrated thin stillage created by a dry milling process for producing ethanol, such as from corn, is disclosed. The method comprises recovering oil from the concentrated thin stillage having a moisture content of less than about 90% by weight.

[0012] In one embodiment, the recovering step comprises separating the oil from the concentrate using a disk stack centrifuge. The method may further include the step of drying the concentrate after the removing step.

[0013] In accordance with still another aspect of the invention, a method of recovering oil from thin stillage is disclosed. The method comprises evaporating the thin stillage to create a concentrate having a moisture content of greater than 15%

by weight and less than about 90% by weight. Oil is then recovered by centrifuging the concentrate, preferably using a disk stack centrifuge.

[0014] In accordance with yet another aspect of the invention, a method of processing whole stillage is disclosed. The method comprises recovering thin stillage including oil and solids from the whole stillage, concentrating the thin stillage including the solids, and recovering oil from the concentrate.

[0015] In one embodiment, the step of recovering the thin stillage includes using a separator selected from the group consisting of a press, extruder, a decanter centrifuge, and a screen centrifuge. The concentrating step may comprise processing the thin stillage to a temperature of between about 150 and 212° F., a pH of between about 3 and 6, and a moisture content of less than 90%. The step of recovering oil comprises separating the oil from the concentrate using a centrifuge. The recovering and concentrating steps may be performed in a continuous fashion. The method may further include drying the concentrate after recovering oil.

[0016] In accordance with a further aspect of the invention, a subsystem for use in a system for producing ethanol by dry milling and creating thin stillage as a byproduct is disclosed. The subsystem comprises an evaporator for evaporating the thin stillage to form a concentrate, and a centrifuge for receiving the concentrate and recovering oil therefrom. Preferably, the concentrate has a moisture content of less than about 90% by weight, and the centrifuge is a disk stack type.

[0017] Still a further aspect of the invention is a subsystem for use in a system for producing ethanol by dry milling and creating thin stillage as a byproduct. The subsystem comprises an evaporator for evaporating the thin stillage to form a concentrate and means for recovering oil from the concentrate. In one embodiment, the recovering means comprises a centrifuge and, most preferably, a disk stack centrifuge.

[0018] Yet a further aspect of the invention is the combination of a concentrate formed from thin stillage including oil and a centrifuge for removing at least a portion of the oil from the concentrate. Preferably, the concentrate has a moisture content of greater than 15% by weight and less than about 90% by weight, and the centrifuge is a self-cleaning bowl type of disk stack centrifuge, a nozzle bowl disk stack centrifuge, or a horizontal centrifugal decanter

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is a partially schematic flow chart illustrating the processing of co-products formed during the ethanol extraction process;

[0020] FIG. 2 is a partially schematic flow chart illustrating the recovery of oil from a syrup formed by evaporating the thin stillage;

[0021] FIG. 3 is a schematic view similar to FIG. 1; and

[0022] FIG. 4 is a schematic view similar to FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

[0023] In accordance with one aspect of the invention, a method recovers oil from a byproduct resulting from the production of ethanol using a dry milling technique (which is extensively described in the above-referenced '182 patent). The byproduct, known as "thin stillage," is recovered by separating the distillers wet grain from the "whole stillage" leftover after fermentation is complete. As is known in the art, this mechanical separation may be accomplished using a press/extruder, a decanter centrifuge, or a screen centrifuge.

Moisture is then removed from the unfiltered thin stillage to create a concentrate or syrup, such as through evaporation. Advantageously, usable oil is then easily recovered from this concentrated form of the byproduct through relatively simple mechanical processing, without the prior need for multiple stages of filtration or other expensive and complicated undertakings.

[0024] In one embodiment, oil is recovered from the concentrate by passing it through a centrifuge and, in particular, a disk stack centrifuge (and most preferably a self-cleaning bowl type). Preferably, the concentrate fed to the disk stack centrifuge is at a temperature of between about 150 and 212° F. (and ideally 180° F.) and a pH of between about 3 and 6 (ideally between about 3.5 and 4.5). As a result of the preceding evaporation step, the concentrate has a moisture content of greater than 15% and less than about 90%, more preferably between 30% and about 90%, and ideally about 60-85% by weight. Under these process conditions, the disk stack centrifuge is able to separate the oil in usable form from the concentrate in an efficient and effective manner, despite the relatively high level of solids present (which may be recovered from the centrifuge in a continuous or intermittent fashion, depending on the particular process conditions).

[0025] Besides creating usable oil, the concentrate or syrup recovered from the disk stack centrifuge is considered more valuable. This is because the post-evaporation processing to recover or remove the oil improves the efficiency of the drying process used on the combined concentrate syrup and distillers wet grains. A stable, flowable product for supplementing animal feed results, which thus further complements the value of the oil recovered.

[0026] Two examples are presented below to demonstrate the efficacy of the above-described method.

Example 1

[0027] Reference is made to FIGS. 1 and 2 to illustrate schematically a first example demonstrating the efficacy of the present method.

[0028] FIG. 1 represents one technique for processing whole stillage resulting from dry milling corn to create distillers dried grains with solubles. The whole stillage leftover after deriving the ethanol is mechanically separated into distillers wet grains (approx. 35% solids) and thin stillage (approx. 6.7% solids), such as by using a centrifugal decanter. The thin stillage is then introduced to an evaporator to create a syrup having a moisture content of approximately 80% by weight and about 17% solids by weight. The syrup is then recombined with the distillers wet grains, introduced to a drum dryer, and dried to reduce the overall moisture content to approximately 10% by weight. An estimated total value of the resulting distillers dried grains with solubles is \$600.36 per hour.

[0029] FIG. 2 represents the inventive method and a related subsystem 10 for implementing it. Initial processing of the whole stillage is done in the same fashion, and the mechanically separated thin stillage is delivered to the evaporator 12 forming part of the subsystem 10. The resulting concentrate or syrup having a moisture content of approximately 80% by weight and a solids content of approximately 17% by weight is delivered to a disk stack centrifuge 14, and preferably a "solids ejecting" one, such as an Alfa Laval Model No. AFPX510, AFPX513, or AFPX617 or equivalent device. At an infeed rate of approximately 35 gallons per minute, this centrifuge 14 recovers usable oil at a rate of 538 pounds per

hour and produces syrup having a having a moisture content of 82.5% by weight, but with far less oil in view of the preceding recovery step.

[0030] Recombining the syrup (which is substantially free of oil) from the centrifuge **14** with the distillers wet grains and drying in a drum dryer **16** to a moisture content of 10% by weight results in a product having a value of \$576.46 per hour. However, the 538 pounds per hour of oil recovered has a product value of approximately \$102 per hour. Accordingly, the total product value using the inventive method is \$678.46 per hour, which is approximately 12% greater than the \$600.36 per hour product value resulting from use of the conventional set-up shown in FIG. 1. Moreover, removal of the majority of the oil before the drying step makes the process more efficient, and results in an estimated energy savings of approximately 10%, or \$26.27 per hour. As a result, product value per hour (\$678.46) less the estimated dryer operating cost (\$236.46 per hour with the 10% savings) and less the estimated evaporator operating cost (\$50.98 per hour) is about \$391.02 per hour.

Example 2

[0031] Reference is made to FIGS. 3 and 4, which illustrate a prophetic comparison between one processing method and the inventive method. The set-up is essentially the same as shown in FIGS. 1 and 2, but a more effective centrifugal decanter is used than the one used in Example 1. As a result, the syrup introduced to the disk stack centrifuge **14** would have a moisture content estimated at 60% by weight. While this does not impact the product value figures, the syrup from the centrifuge **14** has a moisture content of only 66.6% by weight, as compared to 82.5% by weight in Example 1. As a result, the cost per hour of drying this syrup when combined with the distillers wet grains to achieve an end product having a moisture content of less than 10% is only \$158.92, or approximately 40% less. Assuming a savings in dryer efficiency of 10%, the product value per hour (\$678.46) less the estimated dryer operating cost (\$143.03 per hour) and less the estimated evaporator operating cost (\$74.96 per hour) is \$460.46 per hour. This represents an approximate 15% increase over the corresponding value calculated for Example 1.

[0032] As should be appreciated, the above-described method and subsystem of the preferred embodiment essentially require the addition of a centrifuge downstream of the evaporator in the conventional system for processing thin stillage (which centrifuge may thus be considered a "means for" recovering oil from thin stillage). Accordingly, instructions on how to implement the above-described method (including the optimum process variables) may be provided along with a centrifuge for use in an ethanol plant for forming the novel subsystem **10** disclosed herein. Such instructions result in the most efficient implementation of the method, as compared to the situation where the scientists or engineers at the plant must experiment with the centrifuge to determine the optimum process conditions required to achieve a favorable result.

[0033] The foregoing description provides illustration of the inventive concepts. The descriptions are not intended to be exhaustive or to limit the disclosed invention to the precise form disclosed. Modifications or variations are also possible in light of the above teachings. For example, the syrup recovered from the centrifuge may be evaporated and processed again in a further effort to recover oil before drying. More-

over, in addition to a self-cleaning bowl type of disk stack centrifuge, a nozzle bowl disk stack centrifuge would work as a means for recovering oil from the concentrate, as would a horizontal centrifugal decanter (which may be especially beneficial when the moisture content of the concentrate is less than 50% by weight) or other like devices for separating oil from a substance including suspended solids. Moreover, besides corn, the present invention may have utility with any other grain used in a dry milling process for producing ethanol, such as for example, milo. The embodiments described above were chosen to provide the best application to thereby enable one of ordinary skill in the art to utilize the inventions in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention.

1. A method of recovering oil from thin stillage; the method consisting essentially of, in sequence:

- evaporating water from the thin stillage to form a thin stillage concentrate, wherein the thin stillage concentrate has a moisture content of greater than 30% and less than 90% by weight before the recovering step;
- mechanically processing the thin stillage concentrate to separate oil from the thin stillage concentrate;
- recovering the separated oil; and
- drying the thin stillage concentrate to reduce the moisture content in the thin stillage concentrate.

2. The method of claim 1, wherein the mechanically processing the thin stillage concentrate to separate the oil from the thin stillage concentrate comprises introducing the thin stillage concentrate to a disk stack centrifuge.

3. The method of claim 1, wherein the recovering the oil is performed on the thin stillage concentrate at a temperature of between about 150 and 212° F.

4. The method of claim 1, wherein the recovering the oil is performed on the thin stillage concentrate at a temperature of about 180° F.

5. The method of claim 1, wherein the recovering the oil is performed on the thin stillage concentrate having a pH of between about 3 and 6.

6. The method of claim 1, wherein the recovering the oil is performed on the thin stillage concentrate having a pH of between about 3.5 and 4.5.

7. The method of claim 1, further comprising recovering an additional amount of oil from the thin stillage concentrate after drying the thin stillage concentrate.

8. A method of processing whole stillage, comprising, in sequence:

- separating distiller wet grains and thin stillage from the whole stillage, the thin stillage including oil and solids;
- concentrating the thin stillage including the solids to form a thin stillage concentrate having a moisture content of greater than 30% and less than 90% by weight;
- disc stack centrifuging oil from the thin stillage concentrate to form a substantially oil free concentrate; and
- drying the thin stillage concentrate to reduce the moisture content in the thin stillage concentrate.

9. The method of claim 8, wherein the mechanically processing the thin stillage concentrate to separate the oil from the thin stillage concentrate comprises introducing the thin stillage concentrate to a disk stack centrifuge.

10. The method of claim 8, wherein the recovering the oil is performed on the thin stillage concentrate at a temperature of between about 150 and 212° F.

11. The method of claim 8, wherein the recovering the oil is performed on the thin stillage concentrate at a temperature of about 180° F.

12. The method of claim 8, wherein the recovering the oil is performed on the thin stillage concentrate having a pH of between about 3 and 6.

13. The method of claim 8, wherein the recovering the oil is performed on the thin stillage concentrate having a pH of between about 3.5 and 4.5.

14. The method of claim 8, wherein the thin stillage concentrate has a moisture content between about 60-85%.

15. The method of claim 8, further comprising recovering an additional amount of oil from the thin stillage concentrate after drying the thin stillage concentrate.

16. A method of recovering oil from thin stillage, comprising, in sequence:

evaporating the thin stillage to create a thin stillage concentrate having a moisture content of greater than 30% by weight and less than about 90% by weight;

centrifuging the thin stillage concentrate to recover oil; and drying the thin stillage concentrate to reduce a moisture content in the thin stillage concentrate.

17. The method according to claim 16, wherein the step of centrifuging the concentrate comprises using a disk stack centrifuge.

18. The method of claim 16, further comprising recovering an additional amount of oil from the thin stillage concentrate after drying the thin stillage concentrate.

19. A method of recovering oil from thin stillage, the method comprising, in sequence:

evaporating the thin stillage to remove water and form a concentrated byproduct, wherein the concentrated byproduct has a moisture content of greater than 30% and less than 90% by weight;

recovering oil from the concentrated byproduct by heating and mechanically processing the concentrated byproduct to separate the oil from the concentrated byproduct; and

drying the concentrated byproduct to reduce the moisture content in the concentrated byproduct.

20. The method of claim 19, wherein the mechanically processing the thin stillage concentrate to separate the oil from the concentrated byproduct comprises introducing the thin stillage concentrate to a disk stack centrifuge.

21. The method of claim 19, wherein the recovering the oil is performed on the thin stillage concentrate at a temperature of between about 150 and 212° F.

22. The method of claim 19, wherein the recovering the oil is performed on the thin stillage concentrate at a temperature of about 180° F.

23. The method of claim 19, wherein the recovering the oil is performed on the thin stillage concentrate having a pH of between about 3 and 6.

24. The method of claim 19, wherein the recovering the oil is performed on the thin stillage concentrate having a pH of between about 3.5 and 4.5.

25. The method of claim 19, further comprising recovering an additional amount of oil from the thin stillage concentrate after drying the thin stillage concentrate.

26. The method of claim 1, wherein the drying of the thin stillage concentrate to reduce the moisture content in the thin stillage concentrate further comprises combining the thin stillage concentrate with wet distillers grains prior to the drying.

27. The method of claim 8, wherein the drying of the thin stillage concentrate to reduce the moisture content in the thin stillage concentrate further comprises combining the thin stillage concentrate with wet distillers grains prior to the drying.

28. The method of claim 16, wherein the drying of the thin stillage concentrate to reduce the moisture content in the thin stillage concentrate further comprises combining the thin stillage concentrate with wet distillers grains prior to the drying.

29. The method of claim 19, drying the concentrated byproduct to reduce the moisture content in the concentrated byproduct further comprises combining the concentrated byproduct with wet distillers grains prior to the drying.

30. A method of recovering oil from thin stillage; the method comprising

evaporating water from the thin stillage to form a thin stillage concentrate, wherein the thin stillage concentrate has a moisture content of greater than 30% and less than 90% by weight;

mechanically processing the thin stillage concentrate to separate oil from the thin stillage concentrate; and recovering the separated oil.

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