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ley William; 19907 State Route V, Helena, Missouri 64459 (US). WILLIAMSON, Aaron; 310 North First Street, Colwich, Kansas 67030 (US).

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(74) Agent: SCHEIFERSTEIN, Gregory; Snell & Wilmer LLP, One E. Washington Street, Suite 2700, Phoenix, Arizona 85004 (US).

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(71) Applicant: ICM, INC. [US/US]; 310 North First Street, Colwich, Kansas 67030 (US).

(72) Inventors: GALLOP, Charles C.; 109 Somerset Drive, Gower, Missouri 64454 (US). GERKEN, Christopher Ri-

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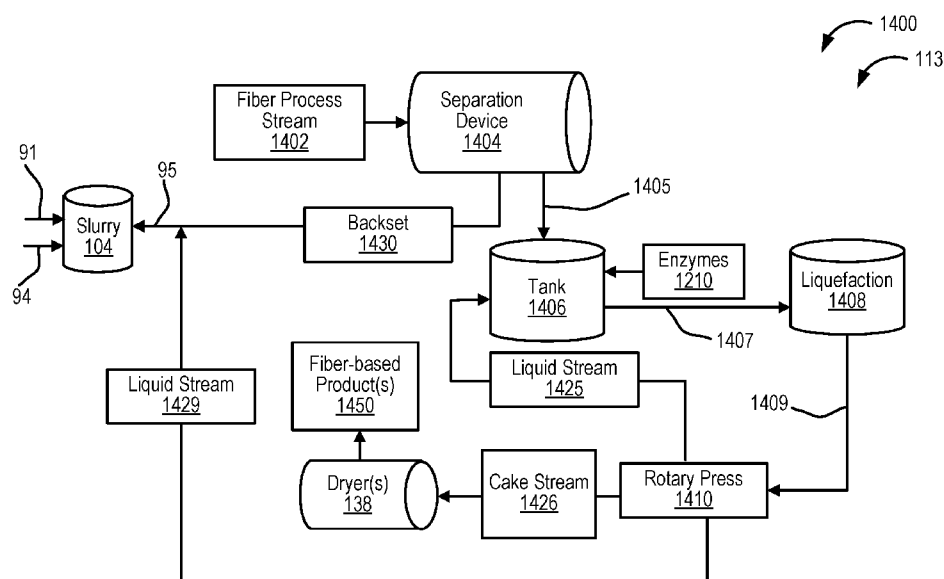


FIG. 14B

(57) Abstract: An advanced processing method to produce protein feed products from dry grind cereal grains comprises separating a process stream into a fiber process stream and a defiber process stream, sending the fiber process stream through a fiber concentration system that outputs a fiber cake stream that is enhanced in fiber relative to the fiber process stream, and sending the defiber process stream through a feed processing system and a solids separation system to produce animal feed products. The advanced processing method can ferment and distil the defiber process stream or ferment and distill the process stream prior to the separating the process stream into the fiber process stream and the defiber process stream.

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**TITLE: ADVANCED PROCESSING METHODS TO PRODUCE
HIGH PROTEIN FEEDS AND/OR LOW-FAT FIBER
PRODUCTS FROM DRY GRIND CEREAL GRAINS**

**INVENTORS: CHARLES C. GALLOP
CHRISTOPHER RILEY WILLIAM GERKEN
AARON WILLIAMSON**

ASSIGNEE: ICM, INC.

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a non-provisional of, and claims priority to, U.S. Provisional Application Serial No. 63/472,573, filed June 12, 2023, titled “METHODS TO LOWER FAT COMPOSITION OF CORN FIBER,” (hereinafter the ‘573 Application). The ‘573 Application is hereby incorporated by reference in its entirety for all purposes.

FIELD

[0002] The subject matter of this disclosure relates to methods of separating a whole stillage process stream, a defiber process stream, and or a fiber process stream in a production facility for biofuels and producing valuable feed products from these separated process streams. In particular, the subject matter is directed to using separation devices to separate components in the process stream and to recover the various components used to produce valuable feed products, such as a high protein animal product with a protein content greater than 45% and/or a low-fat fiber product. These methods help remove suspended solids, recover components, reduce the amount of energy needed for downstream processing, reduce greenhouse gas emissions and/or carbon emissions, and increase overall efficiency of processes in the production facility.

BACKGROUND

[0003] The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in and of themselves may be inventions.

[0004] Various types of feed stock can be produced from processing of grain. During such processing, fiber, syrup, oil, and protein can be produced. Such processes can include a variety of steps, such as separation steps, at varying times during processing. In these processes, fermentable carbohydrates may be used during production of syrup, oils, and protein from the grain, however, the use of such fermentable carbohydrates in the process can interfere with separation of fiber.

[0005] It is desirable to find methods to reduce greenhouse gas (GHG) emissions and/or to reduce carbon-intensity (CI), which includes finding more efficient technologies. For instance, there are known techniques to separate solids from liquids in process streams. However, these techniques are not very efficient. For instance, one method uses gravity separation with the process streams to separate and to recover various components. Problems are that gravity separation may not separate components very well and requires a long time.

[0006] Other methods may not adequately separate solids from liquids in the process streams, are very expensive to operate, require frequent maintenance and repair, and require a higher skill set to operate and to maintain. The process streams may contain high amounts of solids that cause fouling of the evaporators. Also, the solids may have high moisture content, which increases the operating costs to transport and to dry the solids downstream. The equipment may create high levels of emissions from the plants, as well as increase capital and operating costs. Moreover, none of the above methods may be easily integrated into a production facility or capitalize on producing products and feed products.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. A more complete understanding of the present disclosure, however, may best be obtained by referring to the following detailed description and claims in connection with the following drawings. While the drawings illustrate various embodiments employing the principles described herein, the drawings do not limit the scope of the claims.

[0008] FIG. 1 illustrates a flow chart of a process performed in an ethanol plant, in accordance with various embodiments.

[0009] FIG. 2 illustrates a flow chart of a process performed in an ethanol plant, in accordance with various embodiments.

[0010] FIG. 3 illustrates a flow chart of a process performed in an ethanol plant, in accordance with various embodiments.

[0011] FIG. 4 illustrates a flow chart of a process performed in an ethanol plant, in accordance with various embodiments.

[0012] FIG. 5A illustrates a flow chart of a process performed in an ethanol plant, in accordance with various embodiments.

[0013] FIG. 5B illustrates a flow chart of a process performed in an ethanol plant, in accordance with various embodiments.

[0014] FIG. 6 illustrates a flow chart of a fiber separation system in an ethanol plant, in accordance with various embodiments.

[0015] FIG. 7 illustrates a flow chart of a feed processing system in an ethanol plant, in accordance with various embodiments.

[0016] FIG. 8 illustrates a flow chart of a feed processing system in an ethanol plant, in accordance with various embodiments.

[0017] FIG. 9 illustrates a flow chart of a feed processing system in an ethanol plant, in accordance with various embodiments.

[0018] FIG. 10 illustrates a flow chart a solids separation system in an ethanol plant, in accordance with various embodiments.

[0019] FIG. 11A illustrates a flow chart a solids separation system in an ethanol plant, in accordance with various embodiments.

[0020] FIG. 11B illustrates a flow chart a solids separation system in an ethanol plant, in accordance with various embodiments.

[0021] FIG. 12 illustrates a flow chart of an enzyme addition process in an ethanol plant, in accordance with various embodiments.

5 [0022] FIG. 13 illustrates a flow chart of an enzyme addition process in an ethanol plant, in accordance with various embodiments.

[0023] FIG. 14A illustrates a flow chart of a fiber concentration system, in accordance with various embodiments.

10 [0024] FIG. 14B illustrates a flow chart of a fiber concentration system, in accordance with various embodiments.

[0025] FIG. 15 illustrates a flow chart of a fiber concentration system, in accordance with various embodiments.

[0026] FIG. 16 illustrates an advanced processing method to produce protein feed products from dry grind cereal grains, in accordance with various embodiments.

15 [0027] FIG. 17 illustrates a method for enhancing a fiber concentration of a fiber process stream, in accordance with various embodiments.

DETAILED DESCRIPTION

[0028] The following detailed description of various embodiments herein refers to the accompanying drawings, which show various embodiments by way of illustration. While these various embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosure, it should be understood that other embodiments may be realized and that changes may be made without departing from the scope of the disclosure. Thus, the detailed description herein is presented for purposes of illustration only and not of limitation. Furthermore, any reference to singular includes plural embodiments, and any reference to more than one component or step may include a singular embodiment or step. Also, any reference to attached, fixed, connected, or the like may include permanent, removable, temporary, partial, full or any other possible attachment option. Additionally, any reference to without contact (or similar phrases) may also include reduced contact or minimal contact. It should also be understood that unless specifically stated otherwise, references to “a,” “an” or “the” may include one or more than one and that reference to an item in the singular may also include the item in the plural. Further, all ranges may include upper and lower values and all ranges and ratio limits disclosed herein may be combined.

[0029] Disclosed herein are systems and methods for reducing an overall mass of a process stream prior to fermentation, distillation, and formation of various animal feed products by removing individual components (e.g., distillers corn oil, carbohydrates, and/or proteins) from a fiber process stream (e.g., a corn fiber process stream), and re-slurrying a liquid stream separated therefrom at a front end of a dry grind process. As described further herein, the systems and methods to remove these components can include the additions of an enzyme that reduces fat and protein to the fiber process stream, applying shear forces to the fiber process stream with the enzymes, and washing the fiber process stream with the enzymes prior to re-introducing a liquid stream that is output therefrom back into a front end of the dry grind process.

[0030] In various embodiments, methods of fiber separation technology, specifically to lower fat composition of fiber are disclosed herein. Fiber separation technology is used to remove grain fiber during the cook process at a front end, rather than letting that fiber pass through the entire processing plant. The removal of fiber allows for

increased fermentation and distillation capacities, production of diversified feed products, increased distilled grain oil production, and less energy and chemical use in the process.

[0031] The fiber separation process can include intaking and milling the grain, producing a slurry with appropriate enzymes, several liquefaction and separation screening apparatus steps, followed by reduction of water therein with a mechanical separation device, such as a rotary press or roller mill. For higher oil yields, a biological component is added in a specific liquefaction tank. The biological component can be an enzyme mixture, such as including proteases, xylases, beta glucanase, pectinase, and/or other enzymes. The use of such biological components, which are isolated to a particular tank in the process, allows for production of lower fat composition grain fiber, and isolated oil.

[0032] In the fiber separation process, a fiber process stream is separated post-liquefaction. The fiber process stream bypasses an entire ethanol production process. In this regard, the bypassed fiber does not undergo oil solvency during fermentation (e.g., when fermentation is bypassed) or in the beer well (e.g., when distillation is bypassed). Accordingly, due to the fiber separation process being at a front end of an ethanol plant, corn oil yields can be lower. Fiber can be removed in the front end to concentrate proteins through the ethanol process.

[0033] The use of proteolytic enzymes (proteases), which are enzymes that break down protein, typically lower protein concentration, and are a contradiction to the benefit of fiber separation. For example, by removing fiber at a front end of a production process (e.g., prior to fermentation and distillation), significantly higher protein products can be formed from the defiber process stream that is sent through fermentation and distillation, as described further herein. Yet, if a protease enzyme (or a pectinase enzyme) is introduced into a process stream without proper consideration of potential downstream effects, a protein content of the animal feed products formed from the defiber process stream that would otherwise be increased, could end up being significantly reduced, which would in turn significantly reduce a value of the animal feed product, and defeating the purpose of separating the fiber from the process stream prior to fermentation and distillation. Accordingly, as described further herein, to introduce a protease enzyme (or another enzyme that potentially breaks down protein, such as a pectinase enzyme), the process should carefully ensure that the protease enzyme does not remain active when a

respective process stream that was exposed to the protease enzyme is reintroduced into a slurry tank prior to fermentation and distillation.

[0034] The process described herein utilizes proteolytic enzymes (and/or pectinase enzymes) and shear forces via mixing to degrade an oleosome from corn germ, which remove distillers corn oil from the isolated corn fiber in a respective fiber process stream and then deactivates (or allow the enzyme to naturally die/deactivate) the protease enzyme (e.g., post-shearing) before integration of the water back into the dry grind process, in accordance with various embodiments. In this regard, by ensuring the protein degrading enzyme (e.g., a protease enzyme and/or a pectinase enzyme) is deactivated (or allowed to die naturally) prior to re-slurrying one or more slurry tanks at a front end of a dry grind process, the protein degrading enzyme will not cause any negative downstream effects, such as degrading protein during fermentation and/or distillation, in accordance with various embodiments.

[0035] In the fiber separation process, fiber can be concentrated by a specialty equipment (e.g., multi-zoned screening apparatus (MZSA), a paddle screen, a rotary press, or any combination of specialty equipment) after a liquefaction step. The fiber is then re-slurried with fresh (clean) water, treated for a set period of time (e.g., 1 to 8 hours) with proteolytic enzymes, and/or mixed via high shear mixing at high temperatures (e.g., between 170 °F (77 °C) and 205 °F (96 °C)). After the high shear mixing, a resultant fiber process stream is concentrated again by a specialty equipment (e.g., MZSA, a paddle screen, a rotary press, or a combination of specialty equipment) and the water is collected. The collected water is heated (e.g., >250 °F (>121 °C)) to deactivate the proteolytic enzymes and then is sent back to a slurry tank. In this regard, an energy recovery on the process stream can be utilized, prior to the slurry tank. The resultant low-fat fiber process stream can then be re-slurried with cleaner water at high temperature (e.g., between 170 °F (77 °C) and 205 °F (96 °C)) and the low-fat fiber process stream can be concentrated by another specialty equipment (e.g., multi-zoned screening apparatus (MZSA), a paddle screen, a rotary press, or any combination of specialty equipment).

[0036] The fiber separation methods discussed herein have several advantages, some of which are unexpected. In various embodiments, the fiber separation methods herein can allow for higher yields. For example, the fiber separation methods herein impact

processes downstream in a positive way. The fiber separation methods can remove approximately 4.5 pounds of fiber per bushel. This can allow for a capacity increase in the process downstream.

[0037] In various embodiments, the fiber separation methods herein reduce the burden on operators and equipment: the user heat exchangers are relatively easy to clean, decreasing likelihood of contamination. Moreover, there is less overall wear and tear on the equipment. For example, the load on centrifuges downstream is reduced. These methods also allow for more efficient use of electricity and reduce the burden on the pumps during processing.

[0038] Overall, the systems and methods disclosed herein can help guard against damage of downstream protein production, while produced fiber cakes have a reduction of cake fat content, a starch content, and a protein content.

ILLUSTRATIVE ENVIRONMENTS

[0039] FIGs. 1-5B are flow process diagrams showing example environments that may be used with the process for lowering a fat composition of a fiber process stream. The process may be performed using a combination of different environments and/or types of equipment. Any number of the described environments, processes, or types of equipment may be combined in any order to implement the method, or an alternate method. There may be less or more equipment than shown and may be in any order. Moreover, it is also possible for one or more of the provided steps or pieces of equipment, chemical, enzymes, or other processes to be omitted.

[0040] Referring now to FIG. 1, a process 100 implementing a series of operations in a dry grind mill of an alcohol production facility is illustrated, in accordance with various embodiments. The process 100 in the dry grind mill may operate in a continuous manner. In other implementations, the process 100 may operate in a batch process or a combination of batch and continuous processes. The present disclosure is not limited in this regard. Furthermore, although described herein as being utilized in an ethanol production process, the present disclosure is not limited in this regard. For example, one skilled in the art may recognize various other applications for use of a fiber concentration system as disclosed herein and would still be within the scope of this disclosure.

[0041] In various embodiments, the process 100 includes a series of steps, including milling (or grinding) a feedstock 102 (e.g., a grain), fiber separation (e.g., via a fiber separation system 108), feed optimization processing (e.g., via a feed processing system 122), and solids separation (e.g., via a solids separation system 124), among other steps. The processes discussed herein can allow for production of feed with a desired protein content.

[0042] The process 100 can be used to receive feedstock 102 of a grain and produce one or more products (e.g., Hi-Pro 140, Enrich Yeast Hi-Pro 144, dried distillers grains (DDG) 142, dried distillers grains with solubles (DDGS) 146, condensed distillers solubles (CDS) 130, fiber & CDS 132, oil 136, and/or any other product that may be readily apparent to one skilled in the arts), in addition to sending certain separated components to produce ethanol 118. The process 100 can additionally include various types of equipment as described further herein.

[0043] In various embodiments, the process 100 is performed by a system 101. The system 101 can include a particulate reduction station 103 (e.g., a milling station, a grinding station, or any other particle reduction station known in the arts), one or more slurry tanks 104, one or more liquefaction tanks 106, a fiber separation system 108, a fiber concentration system 113, an ethanol processing system 117 with one or more fermentation tanks 110, one or more distillation devices 112, and one or more dehydration apparatuses 114, feed processing system 122 (e.g., with one or more separation devices as described further herein), a solids separation system 124 (e.g., with a preparation technology and a separation device as described further herein), one or more evaporators 128, and one or more dryers 138.

[0044] As described further herein the overall system 101 can combine the beneficial use of a fiber concentration system 113 with an ethanol processing system 117, a feed processing system 122, and/or a solids separation system 124, to separate and produce various high quality animal feed products (e.g., Hi-Pro 140, DDG 142, Enrich Yeast Hi-Pro 144, DDGS 146) and/or other high-quality products (e.g., fiber & CDS 132, oil 136). Another example of a system for processing grain can be found in U.S. Provisional Patent Application Serial No. 63/444,487, the disclosure of which is incorporated herein in its entirety by reference.

[0045] The process 100 may receive feedstock 102 of a grain that includes, but is not limited to, barley, beets, cassava, corn, cellulosic feedstock, grain, milo, oats, potatoes, rice, rye, sorghum grain, triticale, sweet potatoes, lignocellulosic biomass, wheat, and the like, or pulp. Lignocellulosic biomass may include corn fiber, corn stover, corn cobs, cereal straws, sugarcane bagasse and dedicated energy crops, which are mostly composed of fast growing tall, woody grasses, including, but not limited to, switch grass, energy/forage sorghum, miscanthus, and the like. Also, the feedstock may further include, grain fractions or by-products as produced by industry, such as hominy, wheat middlings, soy meal, corn gluten feed, distillers dried grains with solubles (DDGS), and the like. The feedstock may include, an individual type, a combined feedstock of two-types, of multiple types, or any combination or blend of the above grains. The feedstock may include, but is not limited to, one to four different types combined in various percentage ranges. The feedstock may be converted into different types of products and co-products that may include, but is not limited to, ethanol, sugar, syrup, distiller's oil, distiller's dried grains, distiller's dried grains with solubles, condensed distillers solubles, wet distiller's grains, and the like. Disclosed herein are systems and methods for producing significant volume of feed products, enriched yeast products, fiber products, and other types of products. For instance, a bushel of corn may produce about 17-19 pounds of ethanol, about 17-18 pounds of DDGS, and 17-18 pounds of carbon dioxide. The carbon dioxide can be captured and compressed into liquid carbon dioxide or dry ice for commercial applications, in accordance with various embodiments.

[0046] For brevity purposes, the process 100 of using a single stream of feedstock will be described with reference to FIG. 1. As an example, corn may be used as a single feedstock in the dry grind process. Corn may be broken down into its major components of endosperm, germ, bran, and tip cap. Each of these major components may be further broken down to their smaller components. The endosperm, the germ, the bran, and the tip cap each contains varying amounts of starch, protein, oil, fiber, ash, sugars, etc. For example, the amounts of the components in corn may include, but are not limited to, about 70 to 74% starch, about 7 to 9% protein, about 3 to 4% oil, about 7 to 9% fiber, about 1 to 2% ash, about 1 to 2% sugars, and others.

[0047] One skilled in the art understands that inspecting and cleaning of the

corn occurs initially. At feedstock 102, the process 100 initially mills (or grinds) the feedstock 102 (e.g., via the particulate reduction station 103) into a meal, a powder, or a flour to achieve an appropriate particle size. The process 100 may grind (or mill) the feedstock 102 by using hammer mills or roller mills. This grinding (or milling) serves to break an outer coating of the corn kernel and increases a surface area to expose starch for penetration of water in cooking. This initial grinding (or milling) of the feedstock 102 affects the particle size further down the processes. This is critical to have a good grind profile, not too fine particle sizes.

[0048] In various embodiments, the process 100 grinds the feedstock 102 with a hammer mill, a roller mill, or any other mill known in the art. For example, the process 100 can grind (or mill) the feedstock 102 with the particulate reduction station 103 (e.g., a #8 hammer mill) to create ground material 91 (e.g., a meal, a powder, a flour, or any other ground material having average particle sizes), in accordance with various embodiments. The hammer mill is a cylindrical grinding chamber with a rotating drum, flat metal bars, and a screen. The screen size may be, but is not limited to, 4/64 to 12/64 inch-hole sizes. An example hammer mill may have screen openings that are sized 7/64 inch, or about 2.78 millimeters (mm) to create small particles that are sized between about 0.02 inches (0.5 mm) and about 0.12 inches (3 mm). In various embodiments, the process 100 can grind the feedstock 102 with a roller mill to create the meal, the powder, the flour or the ground material. The roller mill receives the feedstock 102, sends the feedstock 102 between two or more rolls or wheels, and crushes the feedstock 102 to create ground material. One roll may be fixed in position while the other roll may be moved further or closer towards the stationary roll. The roll surfaces may be grooved to help in flaking of the corn. The example rolls may be about 9 inches to about 12 inches (23 cm to 30.5 cm) in diameter, with a ratio of length to diameter that may be about 4:1. The small particles may be sized between about 0.02 inches (0.5 mm) and about 0.12 inches (3 mm).

[0049] The process 100 sends the ground material 91 to one or more slurry tanks 104. Next, the process 100 adds cook water (e.g., water, backset, and/or enzymes from the fiber concentration system 113 or from any other upstream system or process) to the feedstock 102 that has been ground and sent to the one or more slurry tanks 104 to form the slurry 92 that is sent to the one or more liquefaction tanks 106. In various embodiments,

the process 100 adds a liquefying enzyme, such as alpha-amylase to this mixture in the one or more liquefaction tanks 106. The alpha-amylase enzyme hydrolyzes and breaks starch polymer into short sections, dextrins, which are a mix of oligosaccharides. The process 100 maintains a temperature between about 60 °C to about 100 °C (about 140 °F to about 212 °F, about 333 K to about 373 K) in the one or more slurry tanks 104 to cause the starch to gelatinize and a residence time of about 30 to about 60 minutes to convert insoluble starch in the slurry to soluble starch. The slurry may have suspended solids content of about 26% to about 40%, which includes starch, fiber, protein, and oil. Other components in the one or more slurry tanks 104 may include, grit, salts, and the like, as is commonly present on raw incoming grain from agricultural production, as well as recycled waters that contain acids, bases, salts, yeast, and enzymes. The process 100 adjusts the pH of the slurry to about 4.5 to 6.0 (depending on enzyme type) in the one or more slurry tanks 104.

[0050] In various embodiments, the one or more slurry tanks 104 may be heated to further reduce viscosity of the ground grain. The parameters include heating for longer periods and/or at higher temperatures. In some embodiments, there may be two or more slurry tanks used for an additional residence time and a viscosity reduction.

[0051] In various embodiments, the process 100 pumps the slurry in the one or more slurry tanks 104 to jet cookers to cook the slurry. Jet cooking may occur at elevated temperatures and pressures. For example, jet cooking may be performed at a temperature of about 104 °C to about 150 °C (about 220 °F to about 302 °F) and at an absolute pressure of about 1.0 to about 6.0 kg/cm² (about 15 to 85 lbs/in²) for about five minutes. Jet cooking is another method to gelatinize the starch.

[0052] The process 100 sends the slurry from the one or more slurry tanks 104 to one or more liquefaction tanks 106, which converts the slurry to a mash. The process 100 uses a temperature range of about 80 °C to about 150 °C (about 176 °F to about 302 °F, about 353 K to about 423 K) to hydrolyze the gelatinized starch into maltodextrins and oligosaccharides to produce a liquefied mash. Here, the process 100 produces a mash stream, which has about 26% to about 40% total solids content. The mash may have suspended solids content that includes protein, oil, fiber, grit, and the like. In embodiments, the one or more liquefaction tanks are used for liquefaction of the slurry to the mash.

[0053] The process 100 may add another enzyme, such as glucoamylase in the

one or more liquefaction tanks 106 to break down the dextrins into simple sugars. Specifically, the glucoamylase enzyme breaks the short sections into individual glucose. The process 100 may add the glucoamylase enzyme at about 60 °C (about 140 °F, about 333 K) before fermentation starts, known as saccharification, or at the start of a fermentation process. In an embodiment, the process 100 further adjusts the pH to about 5.0 or lower in the one or more liquefaction tanks 106. In another embodiment, saccharification and fermentation may also occur simultaneously.

[0054] At the one or more liquefaction tanks 106, the process 100 obtains the process stream or a mixture from the one or more slurry tanks 104. In other embodiments, the process 100 may obtain a process stream or mixture as slurry from a slurry tank, from a jet cooker, from a first liquefaction tank, from a second liquefaction tank, or after a pretreatment process in cellulosic production facility.

[0055] The liquefaction from the one or more liquefaction tanks 106 generates a cooked stream 93, which is sent to the fiber separation system 108, which separates the cooked stream 93 into a fiber process stream 109 and a defiber process stream 111. In various embodiments, a cook water stream 94 from the liquefaction in the one or more liquefaction tanks 106 can be re-purposed and sent back to the one or more slurry tanks 104. The defiber process stream 111 is then sent through the ethanol processing system 117, whereas the fiber process stream 109 is sent to the fiber concentration system 113. In various embodiments, the fiber separation system 108 can allow for more fermentable carbohydrates to be loaded into each batch for fermentation in the one or more fermentation tanks 110.

[0056] For illustrative purposes in FIG. 1, a fiber separation system 108 (e.g., SMT V2 FST NEXT GEN) is presented at a high level in a front end of the production facility. SMT V2 refers to technology name of Selective Milling Technology V2 process and FST NEXT GEN refers to technology name of Fiber Separation Technology Next Gen process. Details of embodiments of the processes for patented SMT V2 FST NEXT GEN will be discussed later with reference to FIG. 6. The process in SMT V2 FST NEXT GEN may be included with any process as part of the dry grind process or any type of process in a production facility. Specifically, SMT V2 FST NEXT GEN helps to increase starch recovery from grain and to remove the fiber, to form two separate process streams: (1) a

fiber process stream 109, which is sent to a fiber concentration system 113, and (2) a defiber process stream 111 that is sent to one or more fermentation tanks 110. The process sends the fiber process stream 109 to a fiber concentration system 113, which will be described further herein.

5 **[0057]** In various embodiments, as described further herein, the fiber concentration system 113 is configured to receive the fiber process stream 109 and increase a concentration of fiber in the respective fiber process stream 109. In this regard, the fiber concentration system 113 is configured to reduce a fat concentration in the fiber process stream 109 and/or a protein concentration in the fiber process stream 109 to form a fiber
10 enriched stream 115 relative to the fiber process stream 109 that is received by the fiber concentration system 113. The fiber enriched stream 115 can then be sent to the one or more dryers 138 to form an animal feed product (e.g., a fiber-rich feed product), a portion of an animal feed product (e.g., as a fiber component of fiber and condensed distillers solubles (CDS) 132), or any other fiber rich product, such as paper manufacture, cellulosic
15 ethanol/alcohol, renewable natural gas, renewable nitrogen, for example.

[0058] In various embodiments, the fiber separation system 108 obtains the process stream or a mixture from the one or more liquefaction tanks 106. However, the present disclosure is not limited in this regard. For example, in other embodiments, the fiber separation system 108 can obtain the process stream or mixture as slurry from the one
20 or more slurry tanks 104, from a jet cooker, from a first of the one or more liquefaction tanks 106, from a second of the one or more liquefaction tanks 106, after a pretreatment process in cellulosic production facility, or any other process stream that may be readily apparent to one skilled in the art. The present disclosure is not limited in this regard.

[0059] At fermentation, the process 100 adds a microorganism to the mash for
25 fermentation in a the one or more fermentation tanks 110. The process 100 may use a common strain of microorganism, such as *Saccharomyces cerevisiae* to convert the simple sugars (i.e., maltose and glucose) into alcohol with solids and liquids, carbon dioxide (CO₂), and heat. In various embodiments, excess carbon dioxide can be released at this stage. The process 100 may use a residence time in each of the one or more fermentation
30 tanks 110 as long as about 50 to about 60 hours. However, variables such as a microorganism strain being used, a rate of enzyme addition, a temperature for fermentation

in the one or more fermentation tanks 110, a targeted alcohol concentration, and the like, may affect fermentation time. In various embodiments, one or more fermentation tanks may be used in the process 100.

5 **[0060]** The process 100 creates alcohol, solids, liquids, microorganisms, and various particles through fermentation in the one or more fermentation tanks 110. Once completed, the mash is commonly referred to as beer, which may contain about 10% to about 20% alcohol, plus soluble and insoluble solids from the grain components, microorganism metabolites, and microorganism bodies. The microorganism may be recycled in a microorganism recycling step, which is an option. The part of the process 100
10 that occurs prior to distillation in the one or more distillation devices 112 may be referred to as the “front end,” and the part of the process 100 that occurs after distillation in the one or more distillation devices 112 may be referred to as the “back end.”

[0061] Turning the one or more distillation devices 112 (e.g., one or more distillation columns, work with beer columns, side stripper, and the like), the process 100
15 distills the beer to separate the alcohol from the non-fermentable components, solids and the liquids by using a distillation process. The process 100 pumps the beer through the one or more distillation devices 112, which is boiled to vaporize the alcohol or produce concentrated stillage. The process 100 condenses the alcohol vapor in the one or more distillation devices 112 where liquid alcohol exits through a top portion of each of the one
20 or more distillation devices 112 at about 90% to about 95% purity ethanol, 5% water which is about 190 proof. In embodiments, the distillation columns and/or beer columns may be in series or in parallel.

[0062] The process 100 removes any moisture from the 190 proof alcohol by going through dehydration via the one or more dehydration apparatuses 114. The one or
25 more dehydration apparatuses 114 may include one or more drying column(s) packed with molecular sieve media to yield a product of nearly 100% alcohol, which is 200 proof alcohol.

[0063] At holding tank 116, the process 100 adds a denaturant to the alcohol. Thus, the alcohol is not meant for drinking, but to be used for motor fuel purposes. At 118,
30 an example product that may be produced is ethanol, to be used as fuel or fuel additive for motor fuel purposes. Ethanol without denaturant may be used for human consumption,

industrial purposes, a process solvent, a feedstock such as ethylene, or any other purpose that may be readily apparent to one skilled in the art.

[0064] Turning back to the one or more distillation devices 112, the water-rich product remaining is now referred to as a distilled defiber process stream 120, which may include but is not limited to, starches, soluble organic and inorganic compounds, suspended solids containing protein, carbohydrate, dissolved solids, water, oil, fat, protein, minerals, acids, bases, recycled yeast, non-fermented carbohydrates, by-products, small amount of fiber, and the like. Defiber is defined as having a minimum or small amount of fiber. For example, a fiber concentration in a defiber process stream can comprise crude fiber between 1% and 19% on a dry basis, crude fiber between 1% and 17% on a dry basis, crude fiber between 1% and 15% on a dry basis, or crude fiber between 1% and 13% on a dry basis. The distilled defiber process stream 120 falls to the bottom of the one or more distillation devices 112 and passes through a feed processing system 122 process to create a high protein feed product.

[0065] For illustrative purposes in FIG. 1, feed processing system 122 is presented at a high level in a back end of the production facility. Details of embodiments of the processes for the feed processing system 122 will be discussed later with reference to FIGs. 7-9. The process in the feed processing system 122 may be included with any process as part of the dry grind process or any type of process, steep process, or wet milling in a production facility. Specifically, the feed processing system 122 helps to create a high protein animal feed product and other products that may be sold.

[0066] The liquid stream 122B from the feed processing system 122 may need further processing due to its total solids composition. The liquid stream 122B could contain high amounts of suspended solids. Thus, the liquid stream 122B may contain high amounts of suspended solids that may cause efficiency problems in the evaporators. Furthermore, this processing step of evaporating to concentrate solids in high water content streams requires a significant amount of energy. Thus, the amount of energy required increases the operating costs. The evaporator capacity may be a bottleneck in the plant. The process 100 sends this liquid stream 122B to solids separation system 124 (e.g., a fractionated stillage system) for further processing.

[0067] For illustrative purposes in FIG.1, the solids separation system 124 is

presented at a high level here, shown in the back end of the production facility. Details of embodiments of solids separation system 124 will be discussed with reference to FIGs. 10 and 11. Solids separation system 124 may be included with any process as part of the dry grind process or any type of process in a production facility. Specifically, solids separation system 124 helps to improve the separation of solids from liquids in an efficient manner, improve evaporator operation, increase throughput, provide feed streams for further processing to produce valuable animal feed products and/or oil, and to reduce GHG or carbon emissions. Other embodiments may include solids separation system 124 process being located after whole stillage or after any of the evaporators (i.e., after one, two, three, last, and the like). An example solids separation system 124 is shown and discussed in U.S. Patent Applications Nos. 17/672,493, 16/624,836, 16/624,831, 16/624,824, 17/683,011, and 16/624,811, which are herein incorporated in their entirety.

[0068] The process 100 sends a liquid stream from the solids separation system 124 to the one or more evaporators 128 to boil away liquids from this stream. This creates a thick syrup, condensed distillers solubles, CDS 130 (i.e., about 25% to about 50% dry solids), which contains soluble or dissolved solids, suspended solids (generally less than 50 μm) and buoyant suspended solids from fermentation.

[0069] The one or more evaporators 128 may represent multiple effect evaporators, such as any number of evaporators, from one to about twelve evaporators. Some process streams may go through a first effect evaporator(s) from the one or more evaporators 128, which includes one to four evaporators and operates at higher temperatures, such as ranging to about 210 °F (about 99 °C or about 372 K). While other process streams may go through a second effect evaporator(s) from the one or more evaporators 128, which operates at slightly lower temperatures than the first effect evaporator(s), such as ranging from about 130 °F to about 188 °F (about 54 °C to about 87 °C or about 328 K to about 360 K). The second effect evaporator(s) from the one or more evaporators 128 may use heated vapor from the first effect evaporator(s) from the one or more evaporators 128 as heat or use recycled steam. In other embodiments, there may be three or four effect evaporator(s) (e.g., each with different heating parameters and/or control sequences or with the same heating parameters and/or control sequence parameters), which operate at lower temperatures than the second effect evaporator(s). In

embodiments, the multiple effect evaporators may range from one effect up to ten effects or more. This depends on the plants, the streams being heated, the materials, and the like. In embodiments, the evaporators may be in series or in parallel.

5 **[0070]** The process 100 sends the CDS 130 (AAFCO 2017 Official Publication at 27.7) from the one or more evaporators 128 to become combined with the fiber enriched stream 115 that is dried by the one or more dryers 138 to form the Fiber & CDS 132 as an animal feed product. In various embodiments, the Fiber & CDS 132 may also be referred to as a fiber & syrup product.

10 **[0071]** In another embodiment, the process 100 sends the syrup, which is concentrated having about 20% to about 45% by weight of total solids, to be sold as CDS 130 (AAFCO 2017 Official Publication at 27.7). This may be sold at a very low price. The CDS 130 may contain fermentation by-products, moderate amounts of fat, spent yeast cells, phosphorus, potassium, sulfur and other nutrients. The moisture content for the CDS 130 may range from about 55% to about 80%.

15 **[0072]** In another embodiment, the process 100 may send a stream from the one or more evaporators 128 to a process for oil recovery 134, which removes oil from solids separation system 124 to recover oil (e.g., oil recovery 134). As a result, the process 100 produces a product of oil 136 of back-end oil and solids. The process 100 may send solids, water, and the like from the oil recovery 134 back to the one or more evaporators 128 for
20 further processing.

[0073] Returning to the feed processing system 122, the process sends a cake stream 122A to the one or more dryers 138. The one or more dryers 138 are dryers for removing moisture from the feed products. The one or more dryers 138 may include one or multiple dryers, which are not limited to, a rotary drum dryer, a steam tube dryer, a
25 scrape surface rotary contact dryer, a flash dryer, a ring dryer, a thin film steam dryer, a spray dryer, a freeze dryer, and any other dryer that may be readily apparent to one skilled in the art.

[0074] The process 100 dries these materials to create a very high protein product (e.g., Hi-Pro 140) having protein content ranging from approximately 47% to
30 approximately 64% dry basis. The process 100 may receive a yeast enriched stream 126 from solids separation system 124 to be combined with material from the feed processing

system 122 to create a combined product (e.g., an Enrich Yeast Hi-Pro 144), which is dried animal feed product, that is yeast enriched and has high protein over 46%. The yeast may be approximately 25% based on mass balance calculations. The process 100 also blends fiber and syrup and some very high protein from Hi-Pro 140 together to achieve 26% protein content for DDG 142. The process 100 combines individual ingredients of the fiber enriched stream 115 from fiber concentration system 113, CDS 130 from the one or more evaporators 128, very high protein (e.g., Hi-Pro 140) from the feed processing system 122 and yeast enriched stream 126 (e.g., a yeast cake) from solids separation system 124 to create DDGS 146. For brevity purposes, the products produced will use similar names and identifiers in the following figures, but may be produced from different processes or equipment.

[0075] In the process 100, enzymes may be added in a single step or in multiple steps at different process locations to process streams (not shown). The enzymes will solubilize fiber with minimal impact to protein solubilization and/or protein precipitation to achieve oil and fiber removal from insoluble protein in the centrifugal process. Furthermore, as described further herein, enzymes may be added in the fiber concentration system 113 in a counterintuitive manner to remove protein and/or fat from the fiber process stream 109 to form the fiber enriched stream 115, in accordance with various embodiments.

[0076] In various embodiments, the fiber concentration system 113 further outputs a liquid stream 95 that is sent back to the one or more slurry tanks 104. The liquid stream 95 can be carrying with it liberated fat, starch, and solubilized proteins. In various embodiments, by recycling the liquid stream 95 back into the one or more slurry tanks 104, which is separated from the fiber enriched stream 115 that is output from the fiber concentration system 113, a yield of the oil 136 and a yield of ethanol 118 that is produced by the process 100 can be improved. For example, the fiber process stream 109 can include a corn germ that is predominately protein and fat and is located in the oleosome. In response to traversing the fiber concentration system 113, the outer membrane of the oleosome is softened and degraded, and thus releases an oil disposed therein. Accordingly, the liquid stream 95 can include the oil released from the oleosome of the germ, which otherwise would not be included in the defiber process stream 111 that is output from the fiber separation system 108. Stated another way, the liquids that are released from the oleosome

of the germ are recycled back into the one or more slurry tanks 104 as an element of the liquid stream 95. Then, the liquids that were released from the oleosome are included in the defiber process stream 111 after the fiber separation system 108, since the liquids have been separated from the oleosome. These liquids can then contribute to an increase in yield of ethanol 118 via the ethanol processing system 117 and an increase in yield of oil 136 via the remaining processing steps of the process 100, in accordance with various embodiments.

[0077] Referring now to FIG. 2, a flow chart of a process 200 with like numerals depicting like elements is illustrated in accordance with various embodiments. The process 200 is similar to FIG. 1, except the process 200 is an alternative embodiment to the process 100 of FIG. 1. The process 200 includes the feed processing system 122 without the solids separation system 124 from FIG. 1. In this regard, without the solids separation system 124 from FIG. 1, there will be fewer products produced by the feed processing system 122 as shown in FIG. 2 relative to FIG. 1.

[0078] Referring now to FIG. 3, a flow chart of process 300 with like numerals depicting like elements is illustrated, in accordance with various embodiments. The process 300 can include a mechanical separating device 302 downstream from the one or more distillation devices 112 that is combined with the feed processing system 122 to further enhance a protein concentration. The mechanical separating device 302 may be inserted as an example, after whole stillage 119, or could be in other process locations and would still be within the scope of this disclosure.

[0079] The mechanical separating device 302 may further screen out finer fiber, small sized particles that may slip through the process of fiber separation system 108 to create a more refined, defiber process stream 306 (e.g., a distilled defiber process stream) post-fermentation (e.g., downstream from the one or more fermentation tanks 110 and one or more distillation devices 112). The mechanical separating device 302 may improve fiber capture, and may further increase protein and starch component weight/weight dry matter mass in a filtrate (e.g., in the defiber process stream 306). For example, the mechanical separating device 302 may capture fiber and send a fiber process stream 309 (e.g., a distilled fiber process stream) to be combined with the fiber process stream 109 in the fiber concentration system 113 and/or directly combined with CDS 130 to form the Fiber &

CDS 132, in accordance with various embodiments.

[0080] The mechanical separating device 302 that may be used, includes, but is not limited to, a pressure screen, a DSM screen, a multi-zoned screening apparatus (“MZSA”), a paddle screen, a vibratory screener, fine rotary press screen, or any type of fine screening apparatus could be used to exclude particulate size from passing into the filtrate. The DSM screens may be a metal wedge wire screen or with round hole. MZSA and/or paddle screens use wedge wire or round hole metal screens. Vibratory screener is typically a woven metal or polymeric screen. The mechanical separating device 302 will screen out particles relevant to the screen size to separate any particles not desired in downstream processes, in accordance with various embodiments.

[0081] Experiments have been conducted using 600 um sieve pans, which increased the amount of protein by 14-18% relative or about 4% w/w dry protein in the final Hi-Pro 140. The captured fiber content from the 600 μm sieve screen had approximately 30% protein w/w dry matter in the substrate after copious amount of washing with hot water. Experiments were also conducted using metal sieve pan screens in the laboratory.

[0082] In another experiment, smaller screens may increase the fine fiber capture and increase the Hi-Pro product protein concentration, diverting desirable protein mass. One sample was screened, washed with water, and centrifuged to form a washed cake. It was solvent extracted in the laboratory. The sample was analyzed to be 78% protein w/w dry matter.

[0083] Referring now to FIG. 4, a flow chart of process 400 with like numerals depicting like elements is illustrated, in accordance with various embodiments. FIG. 4 is similar to FIG. 1, except the fiber separation system 108 occurs in the back end of the process 400 after whole stillage 119, as opposed to on the front end before fermentation (e.g., upstream from the one or more fermentation tanks 110 in process 100, 200, 300 from FIGs. 1-3). The fiber separation system 108 will separate out the fiber to form a fiber process stream 409 to be concentrated in the fiber concentration system 113 and create the defiber process stream 406 (e.g., a distilled defiber process stream) to be used in the feed processing system 122. In this regard, the input the fiber process stream 409 to the fiber concentration system 113 can be fiber that is separated prior to fermentation and/or

distillation (e.g., upstream from the one or more fermentation tanks 110 and/or the one or more distillation devices 112 as shown in process 100 from FIG. 1 and process 200 from FIG. 2), after fermentation (e.g., downstream from the one or more fermentation tanks 110 and/or one or more distillation devices 112 as shown in process 400 from FIG. 4), or a combination of before and after fermentation (e.g., upstream and downstream from the one or more fermentation tanks 110 and/or the one or more distillation devices 112 as shown in process 300 from FIG. 3).

[0084] Referring now to FIG. 5A, a flow chart of process 500 with like numerals depicting like elements is illustrated, in accordance with various embodiments.

FIG. 5 is similar to FIG. 4, except the fiber separation system 108 from the process 400 of FIG. 4 is replaced with a specialty equipment 502. In this regard, instead of routing an output from the whole stillage 119 through the fiber separation system 108 as shown in the process 400 from FIG. 4, the output from the whole stillage 119 can be routed through a specialty equipment 502 configured to separate the whole stillage 119 into a defiber process stream 506 (e.g., a distilled defiber process stream) and a fiber process stream 509 (e.g., a distilled defiber process stream). The fiber process stream 509 can be routed to the fiber concentration system 113 in a similar manner to the fiber process stream 409 from the process 400, fiber process stream 309 and fiber process stream 109 from the process 300, and fiber process stream 109 from process 100 from FIG. 1 and process 200 from FIG. 2.

[0085] Specialty equipment 502 occurs in the back end of the process 500 after whole stillage 119. The specialty equipment 502 can be used to further separate the components in the process stream. For instance, the specialty equipment 502 can include, but is not limited to, a multi-zoned screening apparatus (MZSA), a paddle screen, a rotary press, any combination of the equipment, in accordance with various embodiments.

[0086] In various embodiments, the process 500 may use the specialty equipment 502, such as the MZSA to dewater and to separate the components in the whole stillage 119 and to send the fiber process stream 509 to the fiber concentration system 113 to enrich the fiber and form the fiber enriched stream 115. The process 500 also creates a defiber process stream 506 (similar to the defiber process stream 406 from the process 400 of FIG. 4) to be used in the feed processing system 122. The MZSA is described in U.S. Pat. No. 9718006, entitled “Multi-Zoned Screening Apparatus” and in Pat. Application

Publication No. 20190374883, entitled “Mechanical Separation Device”, both are incorporated by reference in their entireties.

[0087] In various embodiments, instead of the MZSA, the specialty equipment 502 can comprise a paddle screen to dewater and to separate the components in the whole stillage 119 process stream. In various embodiments, the specialty equipment 502 can include a paddle screen used in combination with a rotary press.

[0088] Referring now to FIG. 5B, a flow chart of process 501 with like numerals depicting like elements is illustrated, in accordance with various embodiments. FIG. 5A, except the specialty equipment 502 is disposed immediately downstream from the one or more distillation devices 112 and the specialty equipment separates the distilled stream into the fiber process stream 509 and the whole stillage 119 whole stillage 119.

EXAMPLE OF FIBER SEPARATION SYSTEM 108

[0089] Referring now to FIG. 6, a flow chart for a process 600 performed by the fiber separation system 108 from FIGs 1-5B is illustrated, in accordance with various embodiments. A process performed by the fiber separation system 108 is fully described in U.S. Pat. No. 9,376,504 and U.S. Pat. Application Publication No. 2017/0145377, entitled “Hybrid Separation”, both are incorporated by reference herein in their entireties. In the fiber separation system 108 and corresponding process 600, the fiber can be removed from the process stream 602 (e.g., at post liquefaction, post-distillation), and incorporated as desired. For example, the process 600 sends a process stream 602 (e.g., received from one or more liquefaction tanks 106 in process 100, 200, 300 from FIGs. 1-3, received from whole stillage 119 in process 300 and/or 400, 500 from FIGs. 4-5) through a separation device 604. In various embodiments, the process stream 602 can be sent from the one or more liquefaction tanks 106, whole stillage 119, a combination of from the one or more liquefaction tanks 106 and whole stillage 119, or from any other process stream that may be readily apparent to one skilled in the art.

[0090] The separation device 604 in the process 600 produces a liquids and fine suspended particles stream 606 (e.g., defiber process stream 111 from FIGs. 1-3, defiber process stream 406 from FIG. 4, or the defiber process stream 506 from FIG. 5) and a large suspended solids stream 608. The process 600 sends smaller sized particles, such as the liquids and fine suspended particles stream 606 (e.g., defiber process stream 111 from

FIG. 1 or the defiber process stream 306, 406, 506 from FIGs. 3-5) to a subsequent system (e.g., the one or more fermentation tanks 110 for process 100, 200, 300 from FIGs. 1-3, feed processing system 122 for process 400, 500 from FIGs. 4-5, or any other subsequent system). However, the larger sized particles, such as the large suspended solids stream 608
5 may still contain starch, fiber, and/or the food grade protein. Thus, the process 600 may flake and wash the starch from the fiber through a flaking device 610 combined with a series of mechanical separation devices. Any type of device may be used. For instance, the process 600 may include one or more flaking devices that provide different amounts of flaking. However, the present disclosure is not limited in this regard, and the large
10 suspended solids stream 608 can be sent directly to a tank 614 without being sent through the flaking device 610 and would still be within the scope of this disclosure. In this regard, the process 600 can be configured to recover starch (e.g., via the flaking by the flaking device 610) for conversion to ethanol and allow for available oil recovery.

[0091] The separation device 604 can include, but is not limited to, paddle
15 screen, MZSA, pressure screen, DSM screen, and any other mechanical separation device that may be readily apparent to one skilled in the art. The flaking device 610 can include, but is not limited to, roller mill, centrifugal pump, venturi jet, hydroheater, an attrition mill, and any other flaking device that may be readily apparent to one skilled in the art. Other devices that mill, such as pin mill, impact mill or disc mill may also be used to grind the
20 particles, rather than flake the particles. In various embodiments, with a roller mill, one roll may be fixed in position while the other roll may be moved further or closer towards the stationary roll. The two roll surfaces may be smooth or grooved to help in flaking of the particles. The flaking device 610 can comprise one, two, or more sets of roller mills used to flake the particles, in accordance with various embodiments.

[0092] The process 600 sends the flaked suspended solids stream (e.g., fiber
25 cakes stream 612) to a tank 614. In various embodiments, the process 600 can also send liquids from backset, condensate, thin stillage, and the like to the tank 614. The tank 614 sends the stream to a liquefaction tank 616, which can send the stream 618 to a second mechanical separation device 620. In various embodiments, the tank 614 can send the
30 stream to one or more liquefaction tanks in series (e.g., a first of the liquefaction tank 616 then a second of the liquefaction tank 616). In this regard, with one of the liquefaction

tanks 616, the process stream can be treated as a single process step. However, when there are more than one of the liquefaction tanks 616 disposed in series, operational parameters, such as pH, temperature, mixing, use of process aids, and shear can be different for each respective liquefaction tank 616 that is disposed in series. Accordingly, different types/classes of enzymes can be introduced at different stages so as not to mix enzymes in a single stage, in accordance with various embodiments, as described further herein. However, the present disclosure is not limited in this regard. For example, the tank 614 in the process 600 can send the stream directly to the fiber concentration system 113 and would still be within the scope of this disclosure.

[0093] In various embodiments, the second mechanical separation device 620 separates the stream 618 received from the liquefaction tank 616 into a liquid stream 622 and the fiber process stream 624 (e.g., fiber process stream 109 of process 100, 200, 300 from FIGs. 1-3, fiber process stream 409 of process 400 from FIG. 4, or fiber process stream 509 of process 500 from FIG. 5). The liquid stream 622 can be re-purposed (e.g., as backset) and sent to any prior system or process step (e.g., one or more slurry tanks 104 for process 100, 200, 300 from FIGs. 1-3, whole stillage 119 from process 400, 500 from FIGs. 4 and 5, a combination of the one or more slurry tanks 104 and whole stillage 119, the one or more liquefaction tanks 106, or any other prior process step that may be readily apparent to one skilled in the art). The fiber process stream 109 (or the fiber process stream 309, 409, 509) can be sent to the fiber concentration system 113 as described further herein. In this regard, responsive to traversing through the fiber concentration system 113, the fiber process stream 109 and/or the fiber process stream 309, 409, 509 can be enriched with fiber by reducing a fat concentration and/or protein concentration to generate the fiber enriched stream 115 as described further herein. The fiber enriched stream 115 can then be combined with the CDS 130 to form the fiber & CDS 132 product, or the fiber enriched stream 115 can be utilized in any other animal feed product or fiber-based product, in accordance with various embodiments.

[0094] As shown, the one or more evaporators 128 can process a solids separation system 124 received from the feed processing system 122 and the stream 634 (e.g., a liquid evaporative condensate) from the one or more evaporators 128 can be utilized in the fiber concentration system 113 as described further herein. From solids separation

system 124, there may be a stream of backset, condensate, or thin stillage that is sent to the one or more liquefaction tanks 106. However, the present disclosure is not limited in this regard.

EXAMPLES OF FEED PROCESSING SYSTEM 122

5 **[0095]** Referring now to FIGs. 7-9, a flow chart of process 700, 800, 900 performed by the feed processing system 122 is illustrated, in accordance with various embodiments. With reference now to FIG. 7, the process 700 begins with a defiber process stream 702. In various embodiments, the defiber process stream 702 of the process 700 comprises a defiber process stream that has been previously fermented and distilled, such
10 as distilled defiber process stream 120 of process 100, 200, 300 from FIGs. 1-3, defiber process stream 406 of process 400 from FIG. 4, or defiber process stream 506 of process 500 from FIG. 5. In this regard, the defiber process stream 702 may be received from any of the processes shown in FIGs. 1-6. The defiber process stream 702 may be subjected to processes through fiber separation system (e.g., fiber separation system 108 from FIG. 4),
15 a mechanical separating device (e.g., mechanical separating device 302 from FIG. 3), or specialty equipment (e.g., specialty equipment 502 from FIG. 5), which remove the majority of the fiber from the process stream. In various embodiments, the defiber process stream 702 can be received directly from distillation where the fiber was previously separated via a fiber separation system (e.g., from the one or more distillation devices 112
20 from FIGs. 1 and 2). The present disclosure is not limited in this regard. For example, other possible starting process streams for the feed processing system 122 may include, but are not limited to, whole stillage, centrate, thin stillage, mid stillage, backset, post liquefaction dilution, syrup, any type of process streams or mixtures in any type of production facilities, and would still be within the scope of this disclosure.

25 **[0096]** The defiber process stream 702 may comprise about 4% to about 19% total solids, which may include about 3% to about 9% dissolved solids and about 2% to about 10% suspended solids (i.e., insoluble solids). The amount of fat in the defiber process stream 702 may range from about 8% to about 37% fat and range from around 10% to about 30% protein.

30 **[0097]** The process 700 may use two or more separation devices in series, in parallel, or a combination. The process 700 may use one separation device in a first pass,

another single device in a second pass, another single device in a third pass, may use two separation devices in parallel in a first pass, two separation devices in parallel in a second pass, may use two separation devices in series in a first pass, two separation devices in series in a second pass, and the passes may be in series. Any number of combinations of separation devices, passes, series or parallel may be used. For instance, the process may use one to eight separation devices, any number of passes may be used ranging from one to five, in parallel or in series. These variables depend on the production capacity of the plant.

[0098] The process 700 sends the defiber process stream 702 in a first pass to a separation device 704 (e.g., a first separation device) to separate liquids 704A, which are sent to a first liquid tank (e.g., liquid tank 708) and to separate solids 704B, which are sent to a wet cake 710 (i.e., insoluble solids such as protein, fiber, fat, and liquids). In parallel, the process 700 also sends the defiber process stream 702 to a second separation device (e.g., separation device 706) to separate the liquids 706A, which are sent to a first liquid tank (e.g., liquid tank 708) and to separate solids 706B, which are sent to a first wet cake (e.g., wet cake 710). The wet cake 710 includes solids such as wet cake, fat, protein, organics, organic acids, glycerol, and the like. Not to be bound by theory, the protein content is believed to be at least 45% at this time. The total solids range from approximately 34% to approximately 47% in 704B.

[0099] The process 700 sends the wet cake 710 to a mix tank 712, which may be approximately 4 to approximately 6 pounds of high protein content, having about 45% to about 48% protein. The mix tank 712 may receive one to four components, such as water, chemicals (e.g., processing aids, additives, or any other chemical utilized in ethanol plants that may be readily apparent to one skilled in the art), or enzymes. The addition of these components will wash the components from the first wet cake or dilute the wet cake significantly. For instance, the percent of wet cake will be diluted down or refer to as dilution washing. In another embodiment, the process 700 uses displacement washing by spraying minimum amount of water to wash the solids, which may be followed with centrifugation.

[00100] In various embodiments, the mix tank 712 in the process 700 receives the first wet cake (e.g., wet cake 710), receives distillate from the one or more distillation

devices 112 and evaporate condensate from the one or more evaporators 128. The process 700 may retain the combined streams in the mix tank 712 for 1 minute to 240 minutes, may agitate with an agitator or may not require any agitation, may be kept at room temperature or be heated ranging from approximately 180 °F (82 °C) to 212 °F (100 °C), and could
5 include processing aids or one or more chemicals 799, which are generally regarded as safe (GRAS) approved in the mix tank 712.

[00101] In various embodiments, the water added to the mix tank 712 may include, but is not limited to, clean water from process scrubber (VOC, ethanol, clean water), distillate from distillation, side stripper bottoms, carbon dioxide scrubber (CO₂
10 bottoms), centrate produced from a separation device, evaporate condensate from evaporator, or any other potential water source that may be readily apparent to one skilled in the art.

[00102] The one or more chemicals 799 added to the mix tank 712 may include, but are not limited to, polymers, such as synthetic water-soluble polymers, dry polymers,
15 emulsion polymers, inverse emulsion polymers, latex polymers, dispersion polymers, chitin, chitosan, chitinase, chitobiose, chitodextrin, lysozyme, polyacrylamide and its derivatives, or an acrylamide and its derivatives. The polymers have a specific average molecular weight (i.e., chain length) and a given molecular distribution. For instance, polyacrylamides have the highest molecular weight among synthetic chemicals, ranging
20 from about 1 to about 20 million Daltons. There are other polymers with specific properties that may be used under specific conditions include, but are not limited to, polyethylene-imines, polyamides-amines, polyamines, polyethylene-oxide, and sulfonated compounds, and the like. Chitin is a long-chain polymer of N-acetylglucosamine, which is a derivative of glucose. The polymers may carry a positive (i.e., cationic), a negative charge (i.e.,
25 anionic), or no charge (i.e., nonionic). Polymers with charges may include, but are not limited to, cationic flocculants, cationic coagulants, anionic coagulants, and anionic flocculants. The cationic (i.e., positive charge) and anionic (i.e., negative charge) polymers may have an ionic charge of about 10 to about 100 mole percent, more preferably about 40 to 80 mole percent. There are mineral flocculants that are colloidal substances, such as
30 activated silica, colloidal clays, and metallic hydroxides with polymeric structure (i.e., alum, ferric hydroxide, and the like). An example is an active modified polyacrylamide.

An example may include an acrylamide-acrylic acid resin $C_6H_9NO_3$ (i.e., hydrolyzed polyacrylamide, prop-2-enamide; prop-2-enoic acid). The enzymes that may be added to the mix tank 712 are described further herein.

[00103] In various embodiments, one or more chemicals 799 can be added to the mix tank 712 can include a surfactant, which is configured to reduce the surface tension of a liquid in which it is dissolved. For example, the chemical added to the mix tank 712 can comprise polyethylene sorbitol ester and/or carboxylates. Surfactants, such as polysorbates are typically used as an emulsifier. However, in low dosage, the polysorbates can have a de-emulsifying effect on solids and water, which unexpected and can help separate solids from liquids in the second pass separation device(s), in accordance with various embodiments.

[00104] Next, the process 700 sends the combined stream 714 from the mix tank 712 to two or more separation devices in parallel in a second pass. For example, the process 700 sends a first portion of the combined stream 714 to a third separation device (e.g., separation device 716) to separate liquids stream 716A, which are sent to a second liquid tank (e.g., liquid tank 720), which are sent further to the fiber separation system 108 as described previously herein. The process 700 separates the solids 716B, which are sent to a second wet cake (e.g., wet cake 722). At the same time, the process 700 starts and sends in parallel in the second pass, a second portion of the combined stream 714 to a fourth separation device (e.g., separation device 718) to separate liquids stream 718A, which are sent to a second liquid tank (e.g., liquid tank 720) and to separate solids 718B, which are sent to the second wet cake (e.g., wet cake 722). The second wet cake (e.g., wet cake 722) includes solids same as wet cake, fat, protein, organics, organic acids, glycerol, and the like. It is believed the protein content at this stage is approximately 46% to approximately 64%. The total solids range from approximately 35% to approximately 45% in 704B.

[00105] The process 700 further sends the second wet cake (e.g., wet cake 722) through the one or more dryers 138 to produce a product (e.g., very high protein Hi-Pro 140 which has a high protein content ranging from approximately 45% to approximately 64% dry basis). Based on the size of a plant, this second wet cake (e.g., wet cake 722) may be approximately 4 to 6 pounds of material to be dried alone and/or portions may be combined with 1.5 to 2 pounds per bushel of feedstock 102 from FIG. 1 of product from

solids separation system 124.

[00106] The separation devices used in the process 700 (e.g., separation device 704, separation device 706, separation device 716, separation device 718, and any other separation devices utilized in the process 700) may be any type of dynamic or static mechanical processor that separates out heavier suspended solids from other lighter solids, solids from liquids, and the like by density. Each separation device may include, but is not limited to, a multi-zoned screening apparatus, a decanter centrifuge, a sedicanter centrifuge, a tricanter centrifuge, a disk stack centrifuge, a cyclone, a hydrocyclone, a settling tank, and the like. The type of separation device to be used depends on factors, such as type of process streams, liquid and solid goals at start and at end of process, the type of solids, density of materials, desired reduction of carbon intensity, desired reduction of GHG emissions, and the like. Other types of separation devices that may be used include a pressure screen, a screw press, or a rotary vacuum filter. The separation device may increase solids content from about 10% to about 15% total solids to about 25% to about 45% total solids.

[00107] In various embodiments, each separation device (or a set of separation devices) may be Flottweg's Tricanter® for continuous separation of solids, oil and water from a liquid-solids mixture at adjustable RPMs from 0-4200 based upon machine and feed characteristics. The light phase liquid discharges without pressure by flowing over an internal phase separation disc. The heavy phase liquid discharges under pressure via an automated variable impeller. The variable impeller allows changes to the pond depth inside the machine while it is running.

[00108] In various embodiments, each separation device (or a set of separation devices) may be Flottweg's Decanter®, which provides centrifugal force between 3,000 and 6,500 g for an efficient separation and clarification continuously. The centrifugal force is generated by rotation, which separate the finely distributed solid particles from the suspension. The Decanter® is cylindrical shaped having a conveyer scroll located inside a bowl, both rotating at slightly different speeds. The solids and liquids may travel in the same direction (co-current) along the long zone. In various embodiments, the solids and liquids may travel in opposite directions (e.g., a counter flow). The present disclosure is not limited in this regard. An adjustable weir changes the liquid level, which affects the

pressure on the solids.

[00109] In various embodiments, the separation device may be Flottweg Sedicanter®, a horizontal, double-conical solid bowl centrifuge for continuous separation of a liquid and a difficult-to-dewater fine solid suspension, operating at up to 7000 g. The clarified liquid phase is discharged under pressure using an automatic adjustable impeller at the conical end. The externally adjustable impeller allows for the quick and precise adjustment of the pool depth inside the bowl during operation to accommodate changing process conditions and allows for effective cleaning. The dewatered solids are conveyed to the conical end of the bowl where they are discharged through ports via a combination of hydraulic pressure, internal scroll, and high G-force.

[00110] The centrifuge separates the solid phase and one or two liquids from one another. The solid phase collects at the bowl wall due to its higher density. The transport screw moves the solid continuously to the outlet openings. The liquid phase(s) flows along the transport screw, which is a specialty-designed interior scroll. Other types of separation devices manufactured by other companies may be used, that are similar in design and performance to the ones described above.

[00111] The transport screw may include a specialty-designed scroll inside the bowl. The specialty-designed scroll rotates with a differential speed (in relation to the bowl) and transports the settled solids towards the conically narrowing end of the bowl. A pitch of the scroll occurs between the scroll blades of a helical turn, performed by the scroll during one rotation. The pitch helps in transport performance of the scroll. The scroll has another design feature of a loading point to separate the media, as it enters the bowl. The scroll differs in design based on the type of material to be separated.

[00112] The specialty-designed scroll may be designed to have multiple designs, similar to the letter “S” in multiple configurations to help transport the materials inside the separation device. In another embodiment, the specialty-designed scroll may have multiple rows, multiple dividers to help move the materials, to increase throughput. Examples include a basic scroll, a slotted scroll, an xelletor scroll or other similar like scrolls from different manufacturers would be applicable.

[00113] In various embodiments, the first pass separation device(s) (e.g., separation device 704 and separation device 706) are different separation device(s) relative

to the second pass separation device(s) (e.g., separation device 716 and separation device 718). For example, the first pass separation device(s) (e.g., the separation device 704 and the separation device 706) can each be a centrifuge and the second pass separation device(s) (e.g., the separation device 716 and separation device 718) can be an MZSA. In this regard, the first pass separation device(s) can be configured to have a higher dewatering force relative to the second pass separation devices. For example, the dewatering force of the first pass separation device(s) can be at least 10% more, or between 10% and 40% more, [please provide range of objective percentage increase in pressure e.g., 20%] than the dewatering force of the second pass separation device(s).

[00114] In various embodiments, the first pass separation device(s) include a first processing aid and the second pass separation device(s) include a second processing aid that is different from the first processing aid.

[00115] In various embodiments, the second pass separation device(s) include enzyme additions whereas the first pass separation device(s) do not include any enzyme additions.

[00116] In various embodiments, an operating temperature of the first pass separation device(s) is different from an operating temperature of the second pass separation device(s).

[00117] In various embodiments, the pH of the first pass separation device(s) can be different than the pH of the second pass separation device(s). For example, the pH of the first separation device(s) can be between 2.5 pH and 3.5 pH, or between 2.75 pH and 3.25 pH at a temperature between 195 °F (91 °C) to 205 °F (96 °C), whereas the pH of the second separation device can be between 3.5 pH and 4.5 pH, or between 3.75 pH and 4.25 pH at a lower temperature (e.g., between 175 °F (79 °C) and 195 °F (91 °C), or between 180 °F (82 °C) and 190 °F (88 °C)).

[00118] In various embodiments, the first pass separation device(s) and the second pass separation device(s) are each configured to help facilitate separation of suspended solids from the dissolved solids and liquids from the specific incoming stream. The oil can be considered both a suspended solid and a liquid in during the processing in the respective separation device(s).

[00119] The second wet cake (e.g., wet cake 722) includes a cake like

consistency and small amount of liquids or water. The wet cake 722 may include protein, zein, germ, insoluble fiber, insoluble starch, non-fermentable carbohydrates, inorganic acids (i.e., acetic acid, lactic acid, butyric acid), by-products, microorganisms, and dissolved solids. The wet cake 722 may comprise about 10% to about 40% total solids, which may include about 1% to about 5% dissolved solids and about 10% to about 40% suspended solids. The wet cake 722 may include about 2% to about 15% fat and approximately 45% to 64% protein.

[00120] The second liquid tank (e.g., liquid tank 720) may include water, oil, microorganisms, protein, zein, germ, insoluble fiber, insoluble starch, non-fermentable carbohydrates, inorganic acids (i.e., acetic acid, lactic acid, butyric acid), by-products, and dissolved solids. The liquid tank 720 may comprise about 4% to about 12% total solids, which may include about 3% to about 7% dissolved solids and about 1% to about 5% suspended solids. The liquid tank 720 may include about 12% to about 36% fat.

[00121] Total solids refer to the components in the process stream that are not liquids. Dissolved solids (also referred to as solubles in water) refer to solid particles mixed with liquid in a process stream, which do not separate from the process stream during mechanical processing. Suspended solids (also referred to as insolubles) refer to suspended particles mixed with liquid in a process stream, which will separate from the process stream during mechanical processing. These terms are used to refer to, by weight.

[00122] The process 700 will increase the concentration of the solids content in the process stream. As a result, the amount of natural gas and electricity used for evaporating and/or drying the insoluble solids downstream is greatly reduced, and the amount of GHG and/or carbon emissions from the evaporators and dryers are reduced as well.

[00123] Referring now to FIG. 8, a flow chart of the process 800 performed by the feed processing system 122 is illustrated with like numerals depicting like elements, in accordance with various embodiments. In various embodiments, the process 800 can output a process stream 802 from the liquid tank 708 into the solids separation system 124.

[00124] In this regard, a portion of the solids separation system 124 can be sent as a liquids stream 806 a mixer 808 to combine with the wet cake 722 and/or a portion of the solids separation system 124 can be sent as a solids stream 804 to the one or more

dryers 138.

[00125] In various embodiments, the process stream 802 can include fiber, some solids from solids separation system 124 process and syrup solids, which can be combined to produce DDG 142 from FIGs. 1-5B. In various embodiments, the process 800 sends a solids stream 804 from the solids separation system 124 process to be dried in the one or more dryers 138 and sends a liquids stream 806 or (e.g., thin stillage stream) from the solids separation system 124, which may be a yeast enriched stream to a mixer 808. The process 800 combines the liquids stream 806 (e.g., thin stillage stream), which may be yeast enriched with the wet cake 722. In various embodiments, the process 800 can produce one or more animal feed products 810. For example, the process 800 sends the combined stream from the mixer 808 to the one or more dryers 138 to create very high protein Hi-Pro 140 with high protein product having content of approximately 45% to approximately 64% protein dry basis, Enrich Yeast Hi-Pro 144 which has the same or greater amount of protein as the Hi-Pro but also includes the enriched yeast product, of approximately 25% yeast, and/or DDGS 146 from FIGs. 1-5B as described previously herein.

[00126] Referring now to FIG. 9, a flow chart of the process 900 performed by the feed processing system 122 is illustrated with like numerals depicting like elements, in accordance with various embodiments. In various embodiments, the process 800 can output a process stream 802 from the liquid tank 708 that received one or more chemicals 902 therein prior to being sent into the solids separation system 124. With brief reference back to FIG. 5A and FIG. 5B, the one or more chemicals 902 can also be added to the whole stillage 119 that is output from the one or more distillation devices 112 in the process 500 or output from the specialty equipment 502 in the process 501 from FIG. 5B. In various embodiments, the one or more chemicals 902 can also be added to the mix tank 712.

[00127] For example, in various embodiments, the first liquid tank (e.g., liquid tank 708) in the feed processing system 122 from FIGs. 1-5B, the process 900 adds one or more chemicals 902. The one or more chemicals 902 may be configured to remove the suspended solids, reduce the surface tension of water, and/or may reduce the viscosity. The one or more chemicals 902 may include, but is/are not limited to, polymers, such as synthetic water-soluble polymers, dry polymers, emulsion polymers, inverse emulsion polymers, latex polymers, and dispersion polymers. The polymers may carry a positive

(i.e., cationic), a negative charge (i.e., anionic), or no charge (i.e., nonionic). Polymers with charges may include, but are not limited to, cationic flocculants, cationic coagulants, anionic coagulants, and anionic flocculants. The cationic (i.e., positive charge) and anionic (i.e., negative charge) polymers may have an ionic charge of about 10 to about 100 mole percent, more preferably about 40 to 80 mole percent. There are mineral flocculants that are colloidal substances, such as activated silica, colloidal clays, and metallic hydroxides with polymeric structure (i.e., alum, ferric hydroxide, and the like).

[00128] In various embodiments, the one or more chemicals 902 may be based on a polyacrylamide and its derivatives or an acrylamide and its derivatives. An example is an active modified polyacrylamide. An example may include an acrylamide-acrylic acid resin C₆H₉NO₃ (i.e., hydrolyzed polyacrylamide, prop-2-enamide; prop-2-enoic acid). The polymers have a specific average molecular weight (i.e., chain length) and a given molecular distribution. For instance, polyacrylamides have the highest molecular weight among synthetic chemicals, ranging from about 1 to about 20 million Daltons. There are other polymers with specific properties that may be used under specific conditions include, but are not limited to, polyethylene-imines, polyamides-amines, polyamines, polyethylene-oxide, and sulfonated compounds.

[00129] The one or more chemicals 902 may be chitin, chitosan, chitinase, chitobiose, chitodextrin, lysozyme, and the like. Chitin is a long-chain polymer of N-acetylglucosamine, which is a derivative of glucose. The one or more chemicals 902 used is GRAS approved, meaning it satisfies the requirements for the United States' FDA category of compounds that are "Generally Recognized as Safe." Since the chemicals 902 are GRAS approved, it does not need to be removed and may be included in the distiller's grains and be fed to livestock and/or other animals when used within the dosage and application guidelines established for the particular product formulation. Also, the chemicals 902 may be considered a processing aid under the government agencies, such as the U.S. Food and Drug Administration, the Center for Veterinary Medicine, and the Association of American Feed Control Officials based on their standards.

[00130] In various embodiments, the one or more chemicals 902 added to the mix tank 712 can include a surfactant, which is configured to reduce the surface tension of a liquid in which it is dissolved. For example, the chemical added to the mix tank 712 can

comprise polyethylene sorbitol ester and/or carboxylates. Surfactants, such as polysorbates are typically used as an emulsifier. However, in low dosage, the polysorbates can have a de-emulsifying effect on solids and water, which is unexpected and can help separate solids from liquids in the second pass separation device(s), in accordance with various
5 embodiments.

[00131] The process 900 adds an effective amount of the one or more chemicals 902 to the process 900 in an inline static mixer or in a tank (e.g., liquid tank 708). Other possible ways of adding the chemicals 902 include, but are not limited to fed into a clarifier, a thickener feed well, and the like. A dosage amount of the one or more chemicals 902 may
10 range from about 10 to about 10,000 parts per million (ppm). Another dosage may be used in concentrations of about 0.05% to about 10% of the one of the one or more chemicals 902 according to standard practices for downstream applications. One of the one or more chemicals 902 may be added at varying concentrations, at different stages of the process, and the like. The dosage amount of each of the one or more chemicals 902 depends on
15 reducing the amount of suspended solids, reducing the viscosity, and the like.

EXAMPLE OF FRACTIONATED STILLAGE

[00132] Referring now to FIGs. 10 and 11, a process 1000, 1100 performed by the solids separation system 124 from FIGs. 1, 3-6, 8, and 9 is illustrated, in accordance with various embodiments.

[00133] In various embodiments, the solids separation system 124 may be used
20 with feed processing system 122 from FIGs. 7-9. For example, process performed by the solids separation system 124 is fully described in PCT International Pat. Application No. PCT/US2018/038352, US Patent Appl. No. 16/624,811, PCT International Pat. Application No. PCT/US2018/038353, US Patent Appl. No. 16/624,831, entitled
25 “Fractionated Stillage”, which are expressly incorporated by reference herein in their entireties.

[00134] With reference now to FIG. 10, the process 1000 comprises sending a process stream 1002 that includes a mixture of one or more solids and one or more liquids (e.g., a stream from the feed processing system 122 from FIGs. 1, 3-5, and 6, from liquid
30 tank 708 in feed processing system 122 from FIG. 8, or from liquid tank 708 in feed processing system 122 from FIG. 9) through a preparation technology 1004 to a separation

device 1006. The process stream 1002 can be a stream that includes a mixture of one or more solids and one or more liquids from a production facility, such as from the example process 100 of FIG. 1. In various embodiments, the process stream 1002 is the liquid stream 122B from the feed processing system 122 as shown in process 100 from FIG. 1. However, the present disclosure is not limited in this regard. For example, those of skill in the art will appreciate that other possible process streams may include, but are not limited to, whole stillage, centrate, thin stillage, mid stillage, backset, post liquefaction dilution, syrup, any type of process streams or mixtures in any type of production facilities, and the like.

[00135] In various embodiments, the process stream 1002 may comprise about 4% to about 12% total solids, which may include about 3% to about 7% dissolved solids and about 1% to about 5% suspended solids (i.e., insoluble solids). The amount of fat in the process stream 1002 may range from about 12% to about 37% fat and range from around 40% to about 60% protein.

[00136] The process 1000 applies a preparation technology 1004 to be used with a separation device 1006 to provide a separated solids stream 1008 (also referred to simply as “separated solids stream 1008”) and a separated liquids stream 1010 (also referred to simply as “separated liquids stream 1010”). The preparation technology 1004 may include non-condensable media, including, but not limited to, air or oxygen, carbon dioxide, nitrogen, other gases, and the like, which may be compressed or not. Other gases may include but are not limited to, hydrogen, helium, argon, and neon group Members in the Group 16/VIA, referred to as chalcogens, have similar properties, such as sulfur and selenium are the next two elements in the group, and they react with hydrogen gas (H₂) in a manner similar to oxygen. Air may be composed of 78% of nitrogen, 21% oxygen and with lesser amounts of argon, carbon dioxide, and other gases. The process 1000 adds the preparation technology 1004 to the process stream 1002 through online injection, diffusers, or aeration, which causes the liquids to have a lower density than the solids. The density differential of the separated liquids stream 1010 relative to the separated solids stream 1008 assist in the separation efficiency of the separation device 1006.

[00137] The separation device 1006 may be any type of dynamic or static mechanical processor that separates out heavier suspended solids from other lighter solids, solids from liquids, and the like. The separation device 1006 may include, but is not limited

to, a decanter centrifuge, a disk stack centrifuge, a cyclone, a hydrocyclone, a settling tank, filtration devices, and the like. The type of separation device 1006 to be used depends on factors, such as type of process streams, liquid and solid goals at start and at end of process, the type of solids, density of materials, desired reduction of carbon intensity, desired reduction of GHG emissions, and the like.

[00138] The separation device 1006 may provide centrifugal force between 3,000 and 10,000 x g for an efficient separation and clarification. The separated solids stream 1008 include cake like consistency and small amount of liquids or water. The separated solids stream 1008 may include protein, zein, germ, insoluble fiber, insoluble starch, non-fermentable carbohydrates, inorganic acids (i.e., acetic acid, lactic acid, butyric acid), by-products, microorganisms, and dissolved solids. The separated solids stream 1008 may comprise about 10% to about 40% total solids, which may include about 1% to about 5% dissolved solids and about 10% to about 40% suspended solids. The separated solids stream 1008 may include about 2% to about 15% fat and about 20% to about 64% protein.

[00139] The separated liquids stream 1010 include water, oil, microorganisms, protein, zein, germ, insoluble fiber, insoluble starch, non-fermentable carbohydrates, inorganic acids (i.e., acetic acid, lactic acid, butyric acid), by-products, and dissolved solids. The separated liquids stream 1010 may comprise about 4% to about 12% total solids, which may include about 3% to about 7% dissolved solids and about 1% to about 5% suspended solids. The separated liquids stream 1010 may include about 12% to about 36% fat.

[00140] Total solids refer to the components in the process stream that are not liquids. Dissolved solids (also referred to as solubles in water) refer to solid particles mixed with liquid in a process stream, which do not separate from the process stream during mechanical processing. Suspended solids (also referred to as insolubles) refer to suspended particles mixed with liquid in a process stream, which will separate from the process stream during mechanical processing. These terms are used to refer to, by weight.

[00141] The process 1100 sends the separated solids stream 1008 to a mixer 808 to be mixed with the components from feed processing system 122. The process 1000 sends this stream to the one or more dryers 138 to create an animal feed product (e.g., the very high protein Hi-Pro 140).

[00142] With reference now to FIG. 11A, a flow chart of the process 1100 performed by the solids separation system 124 with like numerals depicting like elements, in accordance with various embodiments. In various embodiments, the process 1100 adds one or more enzymes 1102 which are combined with the separated solids stream 1008 for hydrolysis 1104 (i.e., enzymatic hydrolysis). Hydrolysis 1104 is a chemical breakdown of a compound due to reaction with water. The process 1100 sends the hydrolysate from hydrolysis 1104 to a mixer 808, which combines the product from the feed processing system 122 (e.g., wet cake 722 from FIGs. 7-9) with the separated solids stream 1008, which can contain a high concentration of protein. The process 1100 sends this combined product to one of the one or more dryers 138 to create an animal feed product (e.g., Hydrolyzed Yeast Hi-Pro 1110), in accordance with various embodiments.

[00143] With reference now to FIG. 11B, a flow chart of the process 1101 performed by the solids separation system 124 with like numerals depicting like elements, in accordance with various embodiments. In various embodiments, the process 1101 is similar to the process 1100 from FIG. 11A with the addition of a second of the separation device 1006 disposed between an output of the hydrolysis 1104 and an input of the mixer 808. In this regard, the separation device 1006 can be configured to output a solids stream to the mixer 808 and a liquid stream to at least one of the one or more evaporators 128 or the one or more dryers 138.

[00144] The addition of the enzymes may help digest carbohydrates, break down fat, or help reduce the viscosity by concentrating the process stream to a higher total solids. The enzymes may include, but are not limited to, alpha-amylase, beta-glucanase, beta-glucosidase, endoglucanase, glucanase, lipase, magnesium peroxidase, peroxidase, cellulase, hemicellulase, ligninase, oxido-reductase, phytase, protease, pectinase, peroxidase, pectinase, xylanase, a mixture, and the like. The enzymes may be added in an amount ranging from 0.01% to 0.5% weight of enzymes to dry weight of total solids, depending on the concentration of the enzymes or its substrate, activity of an enzyme, of active cells, and the like. Factors affecting the enzyme reactions include, but are not limited to, temperature, pH, enzyme concentration, substrate concentration, presence of inhibitors or activators, and the like.

[00145] The protease enzyme is known as an enzyme that performs proteolysis,

a protein catabolism by hydrolysis of peptide bonds. The protein hydrolysis is the breakdown of protein into smaller peptides and free amino acids. The amount of protease enzyme added may range from 0.003% to 0.15% w/w% (depending on specific activity of enzyme formulations) of incoming grain and added at temperature ranges from about 20 °C to about 100 °C. The pH of the hydrolysis may be adjusted from about 4.0 to about 6.5.

ADDITION OF ENZYMES

[00146] Referring now to FIGs. 12 and 13, a process 1200, 1300 for adding enzymes into the process 100 from FIG. 1 is illustrated, in accordance with various embodiments. While enzymes are shown in FIGs. 12 and 13, processing aids may be used that were described with reference to FIG. 7 (e.g., instead of or in addition to the enzymes). FIG. 12 illustrates enzymes that may be added in a single step or in multiple steps in the front end of the process 1200. The addition of the enzymes may help reduce the viscosity by concentrating the process stream to a higher total solids.

[00147] As shown, the process 1200 may add enzymes in any of these process steps (e.g., one or more enzymes 1202 can be added to one or more slurry tanks 104, one or more enzymes 1204 can be added to the one or more liquefaction tanks 106, one or more enzymes 1206 can be added via the fiber separation system 108, one or more enzymes 1208 can be added during fermentation in the one or more fermentation tanks 110, and/or one or more enzymes 1210 can be added to the fiber concentration system 113). The process 1200 with enzymes added (e.g., an enzyme enriched process stream) can continue throughout a remainder of the process 1200. Stated another way, the enzyme enriched process stream can traverse through fermentation in the one or more fermentation tanks 110 and distillation in the one or more distillation devices 112 to form the distilled defiber process stream 120, which can be fed to the feed processing system 122 as described previously herein.

[00148] In various embodiments, the one or more enzymes 1202, 1204, 1206, and 1208 do not include a protease enzyme. In this regard, as described previously herein, if the protease enzyme were added to the process stream with any of the one or more enzymes 1202, 1204, 1206, and 1208, the protease enzyme could counteract the benefits of increased protein content that the fiber separation system 108 produces by defibering the process stream prior to sending the process stream through the one or more fermentation tanks 110 and the one or more distillation devices 112 as described previously

herein.

[00149] FIG. 13 illustrates adding enzymes in the back-end process 1300. In this instance, the process 1300 adds enzymes that may be in a single step, two steps, or in multiple steps at multiple locations. The process 1300 can add enzymes 1302 to the one or more distillation devices 112, can add enzymes 1304 to post distillation (e.g., distilled defiber process stream 120), can add enzymes 1306 via the feed processing system 122, or use any combination of adding enzymes. The enzymes in the feed processing system 122 can be added in the mix tank 712 from FIGs. 7-9 as described previously herein. The enzymes can be added in single or multiple steps in feed processing system 122 and in various locations.

[00150] The enzymes can include, but are not limited to, acid proteases, acid phosphatases, alpha-amylase, arabinose, beta-glucanase, beta-glucosidase, glucanase, endoglucanase, cellulase, esterase, gluco-amylase, hemicellulase, laccase, lipase, oxidoreductase, magnesium peroxidase, peroxidase phytase, protease, pectinases, protease, phosphor-lipases, phosphatase, xylanase, a mixture, and the like. The dosage of the enzymes may be from 0.001-15 mg-EP/g-TS, optimally 0.002-5 mg-EP/g-TS, and more optimally 0.003-1 mg-EP/g-TS. The temperature of the enzymes may range from approximately 25 °C to approximately 105 °C, optimally 45-95 °C, and more optimally 50-90 °C. The amount of time for contact with the process stream may vary from approximately 0.33 of one hour to 12 hours, optimally 1 to 8 hrs., and more optimally 2 to 6 hrs. The pH for the process stream may range from 4.0 to 7.0, optimally 4.2 to 5.5, and more optimally 4.3 to 5.2. There are different optimal ranges for temperature and pH, which can limit certain of these enzymes to lower temperature areas of the process, such as fermentation.

[00151] The pH through the entire process would be suitable for most of these enzymes with activities in the pH of 5 range, such as acid protease, acid phosphatase, all cellulase and xylanase, etc. The main consideration is temperature due to two discreet temperature windows at 185 °F (85 °C) and 90 °F (32 °C), excluding the FOT process feed tank. In that tank, there may be some additional flexibility to augment temperature as this will be a new tank to the process with the feed processing system 122.

[00152] It is important to not convert the oligomers all the way to fermentable

sugars (which will also be process area dependent based on applications), such as arabinose and xylose as this will increase the contamination potential in the process through the water washing system in feed processing system 122, which can further limit the applicable enzymes and could be key to claims of enzyme type and mode of action.

5 **[00153]** In various embodiments, the enzymes may be added in an amount ranging from 0.01% to 0.5% weight of enzymes to dry weight of total solids, depending on the concentration of the enzymes or its substrate, activity of an enzyme, of active cells, and the like. Factors affecting the enzyme reactions include, but are not limited to, temperature, pH, enzyme concentration, substrate concentration, presence of inhibitors or
10 activators, and the like.

[00154] The biological, nonpolar/polar aprotic/polar protic solvents, and or thermochemical aids may be used to increase protein content by solubilizing undesirable or targeted fractions found within the substrate composition may be employed. Instead of enzymes, the additions may be aids, which may include the following: alcohol, alkane,
15 alkene, carboxylic acids (organic acids), diol, glycol, furan, ferrulic acid, ketone, mineral acid (inorganic acids), and strong and weak bases.

[00155] The thermochemical treatments and solvent extractions methods would be specific to the wet cake at 50% protein, whereby the cake would be isolated and treated by chemical means or dilute solvents. These treatments and solvent extractions could occur
20 during processing in the feed processing system 122, such as in a feed tank.

[00156] The beta-glucanase enzyme breaks down beta-linked glucose polymers that are associated with grains. The β -1, 3 glucanase breaks down β -1, 3-glucans (1 $\rightarrow$ 3), a polysaccharide made of glucose sub-units. The β -glucan break down may occur randomly of the molecule. The β -1, 6 glucanase enzyme breaks down β -1, 6-glucans. Furthermore,
25 there are beta-glucanase enzymes that break down β -1, 4-glucans. The amount of beta-glucanase added may range from 0.003% to 0.15 w/w% (depending on specific activity of enzyme formulations) of incoming grain and added at temperature ranges from about 20 °C to about 95 °C. The beta-glucanase does not need a low temperature, so the risk of bacterial contamination is avoided.

30 **[00157]** Beta-glucanase has been found to be particularly effective with some larger chains, as it attacks (1 $\rightarrow$ 3), (1 $\rightarrow$ 4) - β -glucan fiber to liberate smaller fragments (i.e.,

a cell wall modification). The rate of modification is determined by contents of the cell walls of beta-glucan. Beta-glucanase hydrolyzes beta D-glucan component and breaks down the beta-linked glucose polymers that are often associated with cereal grains. Beta-glucanase has a high degree of stability that makes it durable to pH extremes.

5 **[00158]** The protease enzyme is known as an enzyme that performs proteolysis, a protein catabolism by hydrolysis of peptide bonds. The protein hydrolysis is the breakdown of protein into smaller peptides and free amino acids. The amount of protease enzyme added may range from 0.003% to 0.15% w/w% (depending on specific activity of enzyme formulations) of incoming grain and added at temperature ranges from about 20
10 °C to about 100 °C. The pH of the hydrolysis may be adjusted from about 4.0 to about 6.5. The enzyme may be retained for about 16 to about 32 hours in a process stream.

[00159] In various embodiments for the one or more slurry tanks 104, the one or more liquefaction tanks 106, or the fiber separation system 108, the temperature may range from approximately 160 °F (71 °C) to approximately 195 °F (91 °C) with a retention time
15 may range from approximately one hour to approximately three hours. Enzymes may include the list as described above, and are not limited to: amylase, laccase (lignin solubilization), beta-glucanase, pectinase, protease, mixture, and the like.

[00160] In various embodiments, for adding enzymes to fermentation in the one or more fermentation tanks 110, the temperature may range from approximately 70 °F (21
20 °C) to approximately 110 °F (43 °C) with a long retention time that may range from approximately 36 hours to approximately 50 hours. In various embodiments for adding enzymes to fermentation, the enzymes mixture does not include protease enzymes as described previously herein. In various embodiments, for adding enzymes to fermentation, the enzyme mixture may not include pectinase.

25 **[00161]** In various embodiments, for adding enzymes to the distilled defiber process stream 120, the temperature may range from approximately 160 °F (71 °C) to approximately 200 °F (93 °C) where a retention time may range from approximately one hour to approximately three hours.

[00162] In various embodiments, for adding enzymes to the feed processing
30 system 122, the temperature may range from approximately 100 °F (38 °C) to approximately 205 °F (96 °C) where a retention time may range from approximately one

hour to approximately three.

Fiber Concentration System 113

[00163] Referring now to FIG. 14A, a flow chart for a process 1400 performed by the fiber concentration system 113 from FIGs. 1-6 and 12 is illustrated with like numerals depicting like elements, in accordance with various embodiments. The process 1400 (e.g., a fiber concentration and/or enrichment process) discussed herein can include concentration of fiber by one or more separation apparatuses (e.g., a filtering multi-zone separation apparatus, a centrifuge, paddle screens). The fiber can then be suspended (e.g., re-slurried) in clean water, in contrast with re-purposed water as described previously herein, and treated with enzymes at both high shear (e.g., via a high-shear mixer) and high temperature (e.g., a temperature of 165 °F (74 °F) to 210 °F (96 °C)). In this regard, the fiber process stream is again concentrated, and water collected. The collected water, now containing enzymes, can then be heated sufficiently to denature the enzymes. The cooked water can then be sent back to the one or more slurry tanks. The fiber process stream itself can be liquefied (e.g., re-slurried) with clean water at a high temperature. Finally, the resultant fiber process stream can be further concentrated, such as by rotary press or other mechanical device for dewatering the fiber process stream, in accordance with various embodiments.

[00164] As described previously herein, the fiber process stream 1402 can be the fiber process stream 109 of process 100, 200, 300 from FIGs. 1-3. In this regard, the fiber separation system 108 can facilitate removal of fiber from the respective process stream prior to fermentation in the one or more fermentation tanks 110 from FIGs. 1-3. In this regard, the defiber process stream 111 of process 100, 200, 300 from FIGs. 1-3 allows for fermentable carbohydrates being loaded into each batch for fermentation. Specifically, in system 101, 201, 301 from FIGs. 1-3, the fiber can be removed during the cook process, rather than letting the fiber pass through the entire system 101, 201, 301. This can allow for production of diversified feed products, increased fermentation and distillation capacities, increased distillers oil production, less energy per gallon of ethanol production for distillation and drying, and less chemicals per gallon of ethanol production for heat exchangers and beer column cleaning, in accordance with various embodiments. However, the present disclosure is not limited in this regard. For example, the fiber process stream

1402 can be received from a process stream that is post fermentation and distillation (e.g., fiber process stream 309 from the process 300 of FIG. 3, fiber process stream 409 of process 400 from FIG. 4, or fiber process stream 509 from FIGs. 5A or 5B), in accordance with various embodiments.

5 **[00165]** Liquid from the fiber concentration system 113 can be recycled and used elsewhere in the plant. For example, cook water can be diverted through the fiber concentration system 113 as described further herein and used as wash water makeup. Additionally, the use of a mechanical device for dewatering, such as a rotary press, in the fiber concentration system 113 can help remove more moisture from fiber cakes more than
10 a standard decanter. The concentration of fiber as discussed herein also allows for a smaller hydraulic load on dryers, in accordance with various embodiments.

[00166] In various embodiments, with fiber isolated via the fiber concentration system 113, there is a reduced volume of liquids output from the fiber concentration system 113 to treat with enzymes, processing aids, pH adjustments, and/or temperature
15 adjustments. In this regard, by recycling the liquid that is output from the fiber concentration system 113 back into the one or more slurry tanks 104 in the process 100 from FIG. 1, a cost of additive can be reduced and/or an increased efficiency of washing can be achieved, in accordance with various embodiments.

[00167] In some embodiments, the separation of fiber prior to fermentation (e.g.,
20 as shown in process 100, 200, 300 from FIGs. 1-3 via fiber separation system 108) can allow for a better pressure differential across heat exchangers in the ethanol processing system 117, and an increase in heat exchange therein due to less solids in the larger process (e.g., the fiber is removed). This can also allow for pump capacity increase in the ethanol processing system 117, and decanter settings to be reduced for a defiber process stream
25 111 as shown in Figs. 1-3.

[00168] The fiber concentration system 113 can comprise a separation device 1404, one or more mixing tanks 244, one or more liquefaction tanks 246, and a rotary press 1410. In various embodiments, the separation device 1404 comprises a multi-zone separation apparatus. However, the present disclosure is not limited in this regard, and
30 other separation devices, such as filtration or size exclusion apparatus, a centrifuge, a paddle screen, or any other separation devices as discussed previously herein could be

utilized and would still be within the scope of this disclosure. The fiber concentration system 113 can further comprise a jet cooker 1414 and a flash processing system 1416. The fiber concentration system 113 is a sub-system of the systems described previously herein and is configured to work in conjunction with the one or more slurry tanks 104 and
5 the one or more dryers 138, among other components.

[00169] The fiber concentration system 113 can receive a fiber process stream 1402 (e.g., a fiber process stream 109 of process 100, 200, 300 from FIGs. 1-3 that is pre-fermentation and distillation, a fiber process stream 309 of process 300 from FIG. 3 that is post-fermentation, a fiber process stream 409 of process 400 from FIG. 4 that is post-fermentation, a fiber process stream 509 of process 500, 501 from FIGs. 5A or 5B that is post-fermentation) or any other fiber process stream described herein, which is processed to produce fiber cakes (e.g., fiber cake stream 1426) and liquids with protein, oil, and sugar (e.g., liquid stream 1428). The one or more slurry tanks 104 that receive the ground material 91 and cook water stream 94 described previously herein can further receive a backset 1430
10 from the separation device 1404 and a liquid stream 1428 from a back end of the fiber concentration system 113 as described further herein.

[00170] With combined reference to FIGs. 6 and 14, the separation device 604 (e.g., a multi-zone separation apparatus) can produce a liquids and fine suspended particles stream 606 (e.g., the defiber process stream 111, the defiber process stream 306, 406, 506) and fiber cakes stream 612. The liquids and fine suspended particles stream 606 can be sent to the ethanol processing system 117 from FIG. 1 and bypass further fiber treatment in the fiber concentration system 113. The fiber cakes stream 612 can be sent to the tank 614, by way of a roller mill or other compression apparatus. At the tank 614, the fiber cakes stream 612 can be re-slurried with the addition of clean water (e.g., as opposed to backset, cook water, or any other re-purposed water) to produce the fiber process stream 109 and/or the fiber process stream 309, 409, 509, which can be sent to the fiber concentration system 113.
20 25

[00171] When fiber process stream 1402 (e.g., the fiber process stream 109 and/or the fiber process stream 309, 409, 509) enters the fiber concentration system 113, it can be concentrated at the separation device 1404 (e.g., a fiber multi-zone separation apparatus). In various embodiments, the separation device 604 and the separation device
30

1404 are each a multi-zone separation apparatus. The separated fiber stream 1405 can be channeled to the mix tank 1406 (e.g., a fiber solids mix tank). At the mix tank 1406, enzymes 1210 can be added to the separated fiber stream 1405 along with liquids (e.g., liquid stream 1424 described further herein and/or other liquids, such as clean water). The liquid stream 1424 can come, for example, from the rotary press 1410, discussed in detail below. The separated fiber received from the separation device 1404 can be slurried with the liquids (e.g., one or more enzymes 1210, liquid stream 1424, clean water, and/or any other liquids supplied to the mix tank 1406). A fiber slurry 1407 formed from the mix tank 1406 (e.g., the mixture of the fiber, liquids, and the one or more enzymes 1210) can be moved to a liquefaction tank 1408.

[00172] The fiber slurry 1407 can be treated at a high temperature and shear along with the enzymes 1210. For example, the fiber can be treated in the mix tank 1406 at a temperature of between 165 °F (74 °C) to 210 °F (99 °C), or from 170 °F (77 °C) to 205 °F (96 °C), or from 175 °F (79 °C) to 200 °F (93 °C), or from 180 °F (82 °C) to 195 °F (91 °C). In various embodiments, the fiber slurry formed in the mix tank 1406 can be treated in the mix tank 1406 at a temperature of more than 165 °F (74 °C), or more than 170 °F (77 °C), or more than 175 °F (79 °C). In various embodiments, the high shear mixing can be sufficient enough to cause the enzymes to not be immobilized. For example, the shear can cause the enzymes to not permanently attach to the fiber in the fiber slurry. This can aid in allowing the enzymes to attach to more than one fiber therein. In various embodiments, high shear mixing refers to a mixing tank that generates shear forces by pushing parts of a mixture in a first direction and pushing another part of a mixture in the opposite direction to generate high shear forces. For high shear mixing, the higher the shear force, the better the fiber slurry can incorporate the different components together (e.g., the separated fiber, the one or more enzymes 1210, the liquid stream 1422, and/or any clean water). In various embodiments, a high shear mixer (e.g., mix tank 1406) as described herein can have a high-speed rotor that forces the mixture (e.g., the fiber slurry) outward against a stator to generate shear. The mix tank 1406 mix, rotate, and/or aggregate the fiber slurry formed therein.

[00173] In various embodiments, the one or more enzymes 1210 can include a mixture or cocktail of appropriate enzymes, such as xylanases, proteases, pectinase, α -

amylases, cellulases, xylanases, lipases, phytases, and combinations thereof. In various embodiments, the one or more enzymes comprises at least one of a protease enzyme and a pectinase enzyme.

5 **[00174]** In various embodiments, the one or more enzymes 1210 can be provided in an amount of about 10% total solids, or of between 8% and 12% total solids, or between 7% and 13%, or between 5% and 15% total solids. The enzymes can be provided in an amount of about 0.06 wt% enzyme dose, or between 0.03 wt% to 0.09 wt% enzyme dose, or between 0.04 wt% to 0.08 wt% enzyme dose, or between 0.05 wt% to 0.07 wt% enzyme dose.

10 **[00175]** In various embodiments, the fiber slurry 1407 that is output from the mix tank 1406 and sent to the liquefaction tank 1408 can be maintained in the liquefaction tank 1408 with the enzymes for a first time period (e.g., between 1 hours and 8 hours, or between 2 hours and 8 hours, or between 3 hours and 7 hours, or between 4 hours and 6 hours). In various embodiments, the liquefaction tank 1408 could be replaced with a second
15 of the mix tank 1406 (e.g., in a batch process or a continuous process). In various embodiments, if a batch process is utilized, two or more of the mix tank 1406 could be disposed in series. In this regard, while one of the two or more mix tanks is filling, the other of the two or more mix tanks can be hydrolyzing the process stream disposed therein for the set period of time (e.g., between 1 hours and 8 hours, or between 2 hours and 8
20 hours, or between 3 hours and 7 hours, or between 4 hours and 6 hours). In various embodiments, the lower the dose rate, the longer the time in the liquefaction tank 1408 or a second of the mix tank 1406, in accordance with various embodiments.

[00176] The mix tank 1406 including the fiber slurry with the one or more enzymes 1210 can be configured to maintain an acidic pH between 4.8 and 6.2, or between
25 5.0 and 6.0, in accordance with various embodiments. In various embodiments, the fiber slurry 1407 that is output from the mix tank 1406 can be concentrated again by another separation device (e.g., a multi-zone separation apparatus), as described further herein.

[00177] In various embodiments, a fiber slurry stream 1409 including a mixture of the separated fiber stream, liquids (e.g., from the liquid stream 1424 and/or clean water),
30 and the one or more enzymes 1210), can be routed to the rotary press 1410. At the rotary press 1410, the fiber can be concentrated into a fiber cake stream 1426 to be sent to the one

or more dryers 138. The rotary press 1410 can act to press (or restrict) the fiber from the fiber slurry stream 1409, separating the fiber cake (e.g., the fiber cake stream 1426) from the liquid (e.g., the liquid stream 1422 and/or the liquid stream 1424) therein. This can be accomplished in the rotary press 1410 through sliding and shearing of the fiber cake therein, and by increased friction and pressure on the material. In an example, the rotary press can include one or more rotating wheels or restrictor arms that can increase friction and pressure, or provide back pressure to create opposing forces therein. In various embodiments, the fiber cake stream 1426 is enriched in fiber relative to the fiber process stream 1402.

[00178] In various embodiments, a rotary press 1410 can be used as the mechanical separation device to reduce water content in the fiber cake stream 1426. In various embodiments, the parameters of the rotary press 1410 can be adjusted depending on the particular fiber being processed. For example, an increased wheel speed can produce a fiber cake stream 1426 that is less dry. Similarly, increased inlet pressure can produce a fiber cake stream 1426 that is less dry. In contrast, an increased restrictor arm pressure can increase dryness of the fiber cake stream 1426. The rotary press 1410 can be controlled, for example, through hydraulic components and/or bellows. The amount of carbohydrates in the load can also adjust the wheel speed and restrictor pressure, resulting in adjusted dryness of the fiber cake stream 1426.

[00179] In various embodiments, the rotary press 1410 can include an open area divided by one or more baffles, such as having between 15% and 40% open area, or between 20% and 35% open area. The rotary press 1410 can optionally have one or more wash bars therein. Internally, the rotary press 1410 can include holes for filtering, with diameters of between 250 μm and 2,000 μm , or between 500 μm and 1,500 μm , or between 750 μm and 1,250 μm . In various embodiments, the rotary press 1410 can include an inlet with a diameter between 0.1 inches (0.25 cm) and 1 inch (2.54 cm), or between 0.3 inches (0.76 cm) and 0.8 inches (2.03 cm). In various embodiments, the rotary press 1410 can have a wash water flow of between +15 gpm (57 liters per minute) to +35 gpm (132 liters per minute), or between +20 gpm (75.7 liters per minute) to +30 gpm (113.6 liters per minute) at between 40 psig (276 KPa) and 60 psig (414 KPa), or between 45 psig (310 KPa) and 55 psig (379 KPa).

[00180] From the rotary press 1410, a liquid stream 1424 can be sent back to the mix tank 1406 for additional use and/or a liquid stream 1422 can be treated and sent along the back end of the system for use in earlier slurries such as the one or more slurry tanks 104 described previously herein. Although illustrated as two distinct streams (e.g., liquid stream 1422 and liquid stream 1424), the present disclosure is not limited in this regard. For example, the liquid stream 1422, 1424 could be output as a single stream and break off into separate streams thereafter, in accordance with various embodiments. Alternatively, only one of the liquid stream 1424 could be utilized (e.g., liquid stream 1424 or liquid stream 1422). The present disclosure is not limited in this regard.

[00181] In various embodiments, the liquid stream 1422 is heated to deactivate the one or more enzymes 1210 that were previously introduced. For example, the liquid stream 1422 can be heated to at between 225 °F (107 °C) and 325 °F (163 °C), or between 250 °F (121 °C) and 300 °F (149 °C), such as to sufficiently denature the enzymes. In various embodiments, the liquid stream 1422 can be heated with steam or vapor 1412 (e.g., from the one or more evaporators 128 from FIG. 1 described previously herein), sent through a jet cooker 1414, and/or sent through a flash processing system 1416 prior to being sent back to the one or more slurry tanks 104 for use to slurry with incoming ground material 91 and the cook water stream 94. In various embodiments, the liquid stream 1428 that is treated can be combined with backset 1430 that is output from the separation device 1404.

[00182] In various embodiments, the liquid stream 1422 can be, for example, heated with the jet cooker 1414 (e.g., a cook tube) and then flash heated with the flash processing system 1416 to produce the liquid stream 1428 which can include protein, oil, and sugar. In various embodiments, the flash processing system 1416 is configured to heat the liquid stream that is received from the jet cooker at very high temperatures for a short period of time. For example, the flash processing system 1416 is configured to heat the liquid stream 1422 between 65 °C and 100 °C for between 1 minute and 30 minutes, or between 1 minute and 20 minutes. In various embodiments, by flowing the liquid stream 1422, the liquid stream 1422 can be rapidly subcooled for efficiently providing the liquid stream 1422 back into the one or more slurry tanks 104.

[00183] In various embodiments, steam or vapor 1412 can be used prior to, or

with, the jet cooker 1414 to heat the liquid stream 1422 prior to the flash processing system 1416. After the enzymes have been denatured, the resulting liquid stream 1428 can be sent back along backset 1430. Meanwhile, the fiber cake stream 1426 from the rotary press 1410 can be dried at the one or more dryers 138.

5 **[00184]** Although described herein as including the jet cooker 1414, an injection of steam or vapor 1412, and/or a flash processing system 1416, the present disclosure is not limited in this regard. For example, with reference now to FIG. 14B, the jet cooker 1414, the injection of steam or vapor 1412 and/or the flash processing system 1416 can be eliminated by selecting each of the one or more enzymes 1210 and selecting a temperature
10 for heating the liquefaction tank 1408 such that each of the one or more enzymes 1210 naturally dies (or is naturally deactivated) prior to the liquid stream 1429 (e.g., a fiber liquid stream) being re-introduced to the one or more slurry tanks 104 (e.g., via a slurry mixer). For example, in various embodiments, each of the one or more enzymes 1210 comprises a life cycle that is less than or equal to the time period that the fiber slurry 1407 is disposed
15 in the liquefaction tank 1408. In this regard, the temperature that the fiber slurry 1407 is heated to in the liquefaction tank 1408 and each of the one or more enzymes can be selected to ensure that each of the one or more enzymes naturally dies (e.g., is naturally deactivated), prior to a treated fiber slurry (e.g., fiber slurry stream 1409) being output from the liquefaction tank 1408, in accordance with various embodiments. Accordingly, the liquid
20 stream 1429 (and/or the liquid stream 1429) that is output from the rotary press 1410 no longer includes the one or more enzymes 1210 that were added into the mix tank 1406.

[00185] In various embodiments, if the one or more enzymes 1210 disclosed herein remain active and are re-slurried in the one or more slurry tanks 104, downstream effects could be significant. For example, a significant benefit of separating fiber via the
25 fiber separation system 108 prior to fermentation and distillation is that increased protein content can be achieved in downstream animal products (e.g., Hi-Pro 140 can include protein contents ranging from approximately 47% to approximately 64% dry basis). However, if the one or more enzymes 1210 remain active, and participate in the fermentation and distillation process (e.g., the one or more fermentation tanks 110 and/or
30 the one or more distillation devices 112 from FIG. 1), the one or more enzymes can degrade protein, which could greatly reduce a value of the one or more animal feed products created

by the process 100 from FIG. 1.

[00186] A life cycle for each of the one or more enzymes 1210 disclosed herein is temperature dependent. Typically, protease enzymes (and/or pectinase enzymes) have long life cycles. However, by heating the protease enzyme (and/or the pectinase enzymes) to a specific temperature range (e.g., between 165 °F (74 °C) to 210 °F (99 °C), or from 170 °F (77 °C) to 205 °F (96 °C), or from 175 °F (79 °C) to 200 °F (93° C), or from 180 °F (82 °C) to 195 °F (91° C)), and by selecting a specific protease enzyme (and/or pectinase enzyme) to be mixed in the mix tank 1406 prior to heating in the liquefaction tank 1408, the respective enzyme can naturally die prior to the liquid stream 1429 being routed back to the one or more slurry tanks 104. Accordingly, the fiber concentration system 113 can reduce the protein content and fat content of the fiber process stream to create a more valuable fiber based product from the fiber cake stream 1426 via the fiber concentration system 113 without having potentially significant downstream consequences by preventing the one or more enzymes 1210 from remaining active when sending the liquid stream 1429 back into the process 100, 200, 300 from FIGs. 1-3.

[00187] In various embodiments, each of the one or more enzymes 1210 is a protease enzyme that is produced from bacterial fermentation. For example, protease enzymes can comprise enzymes that are produced from bacterial fermentation or by fungal fermentation. However, protease enzymes produced from fungal fermentation have long life cycles and are not thermally stable above 130 °F (54 °C). In contrast, protease enzymes that are produced from bacterial fermentation can remain thermally stable at higher temperatures (e.g., between 165 °F (74 °C) to 210 °F (99 °C)), and a life cycle of the protease enzyme that is produced from bacterial fermentation can be controlled (e.g., as temperature increases, a life cycle of the protease enzyme can be reduced). For example, a protease enzyme can have a life cycle between 1 and 2.5 hours at 203 °F (95 °C), in accordance with various embodiments. International flavor and fragrances (IFF). In various embodiments, the each of the one or more enzymes 1210 can comprise an alkaline protease enzyme. In this regard, the alkaline protease enzyme can be active in an acidic environment to reduce the protein content and fat content in the liquefaction tank 1408 as described previously herein.

[00188] In various embodiments, the fiber slurry stream 1409 that is output from

the liquefaction tank 1408 can have a significant mass reduction relative to an untreated fiber slurry stream (i.e., one without the one or more enzymes 1210) that traverses the separation device 1404, the mix tank 1406, and the liquefaction tank 1408. For example, due to hydrolysis that occurs in the liquefaction tank 1408, as described further herein, a mass of the fiber slurry stream 1409 can be reduced by between 10% and 50%, or between 20% and 50%, or between 30% and 50% relative to an untreated fiber slurry stream (i.e., one without the one or more enzymes 1210). Accordingly, a speed of the rotor for the rotary press 1410 can be reduced (e.g., by approximately 25%) and maintain similar inlet pressure, which indicates a more efficient dewatering of the fiber slurry stream 1409, in accordance with various embodiments. In various embodiments, the one or more dryers 138 utilized for drying the fiber cake stream 1426 can have reduced natural gas consumption relative to a process 100, 200, 300, 400, 500 without the fiber concentration system 113 described herein. In various embodiments, the one or more dryers 138 can operate at a lower temperature relative to a process 100, 200, 300, 400, 500 from FIGs. 1-5B without the fiber concentration system 113, which can be indicative of less water and substrate mass entering the one or more dryer 138.

[00189] Referring now to FIG. 15, a flow chart for a process 1500 performed by the fiber concentration system 113 from FIGs. 1-6 and 12 is illustrated with like numerals depicting like elements, in accordance with various embodiments. The process 1500 is similar to the process 1400, 1401 from FIGs. 14A, 14B with the exception that the fiber slurry stream 1409 that is output from the liquefaction tank 1408 is sent through a second pass (e.g., through a second separation device (e.g., separation device 1504), a second mixing tank (e.g., mix tank 1506), where one or enzymes 1210 can again be added or where no further enzymes may be added, then through a second liquefaction tank (e.g., liquefaction tank 1508), which outputs the second pass stream to the rotary press 1410). In various embodiments, the process 1500 can include any number of passes prior to outputting a fiber slurry stream to the rotary press 1410 (e.g., three passes, four passes, or the like). In various embodiments, by having a second pass in the process 1500, the fiber slurry process stream can be further enriched at each respective pass. For example, a fiber content output from a respective pass can be enriched relative to a fiber content input into the respective pass, in accordance with various embodiments.

[00190] In various embodiments, the second pass separation device (e.g., separation device 1504) includes a slower rotary speed relative to the first pass separation device (e.g., separation device 1404). For example, the second pass separation device can be at least 10% less, or between 10% and 30% less, relative to the first pass separation device, in accordance with various embodiments.

[00191] In various embodiments, the second pass separation device (e.g., separation device 1504) includes larger screens relative to the first pass separation device (e.g., separation device 1404). For example, an open area of the screen of the second pass separation device can be at least 5% greater, or at least 10% greater, or at least 15% greater than the first pass separation device. In this regard, by having a greater open area for a screen of the second pass separation device relative to the first pass separation device, larger solids can pass therethrough relative to the prior separation device, in accordance with various embodiments.

[00192] In various embodiments, the separation device 1504 can be a same type of device or a different type of device relative to the separation device 1404. Similarly, the mix tank 1506 can be a same type of mixing tank or a different type of mixing tank as the mix tank 1406. In various embodiments, the separation device 1504 and the separation device 1404 can each be a multi-zone separation apparatus.

[00193] In various embodiments, at the first separation device (e.g., separation device 1404), the fiber is concentrated (e.g., a fiber content output is enriched relative to a fiber content input). Then, at the first mix tank (e.g., mix tank 1406), enzymes and liquids are added as described previously herein. The stream can be sent to the first liquefaction tank (e.g., the liquefaction tank 1408).

[00194] After liquefaction and enzymes treatment, the fiber slurry stream 1409 is sent to a second separation device (e.g., separation device 1504) to re-concentrate (or further concentrate) the fiber into a cake, and separate the liquids, prior to the rotary press 1410. A second mix tank (e.g., mix tank 1506) is used. The second mix tank can output to a liquefaction tank 1508, which can then output an enriched fiber slurry stream 1509 to the rotary press 1410.

[00195] In various embodiments, the separation device 1504 can route backset (e.g., backset 1530), which can be combined with the backset from the separation device

1404 (e.g., backset 1430) and sent to the one or more slurry tanks 104 described previously herein.

[00196] In various embodiments, the liquid stream 1424 output from the rotary press can be cycled back to the first mix tank (e.g., mix tank 1406), and/or to the second mix tank (e.g., mix tank 1506), and/or the liquid stream 1422 output from the rotary press 1410 can be treated and returned for use as cook water in the one or more slurry tanks 104.

[00197] Although the process 1500 is illustrated with the steam or vapor 1412, the jet cooker 1414, and the flash processing system 1416 corresponding to the process 1400 from FIG. 14A, the present disclosure is not limited in this regard. For example, the process 1500 could directly route the liquid stream 1429 that is output from the rotary press 1410 to the one or more slurry tanks 104 without further processing in accordance with the embodiment from FIG. 14B.

[00198] Referring now to Fig. 16, a method 1600 for creating feed products (e.g., via system 101, 201, 301, 401, 501 from FIGs 1-5B) is illustrated, in accordance with various embodiments. The method 1600 comprises imparting shear on suspended solids of a process stream (step 1602). In various embodiments, the shear can be imparted on the suspended solids of the process stream 602 in the process 600 from FIG. 6 via the separation device 604. Although illustrated in method 1600 from FIG. 16 as starting with imparting shear on suspended solids of a process stream in step 1602, the present disclosure is not limited in this regard. For example, the method 1600 can start with the feedstock 102 in process 100, 200, 300, 400, 500, 501 from FIGs. 1-5B, in accordance with various embodiments. Accordingly, the method 1600 can further comprise grinding or milling a feedstock into at least one of a meal, a powder or a flour and sending at least one of the meal, the powder, the flour to the one or more slurry tanks (e.g., the one or more slurry tanks 104 from FIGs. 1-5B); and forming the process stream in the one or more slurry tanks (e.g., prior to step 1602).

[00199] In various embodiments, the method 1600 further comprises separating the process stream into a fiber process stream (e.g., the fiber process stream 109 and/or the fiber process stream 309, 409, 509 from FIGs. 1-5B) and a defiber process stream (e.g., defiber process stream 111, 306, 406, 506 from FIGs. 1-5B) (step 1604).

[00200] In various embodiments, the method 1600 further comprises fermenting

and distilling the defiber process stream prior to the separating the solids of the defiber process stream from the liquids of the defiber process stream (e.g., as shown in process 100, 200, 300 from FIGs. 1-3). In various embodiments, the fiber process stream bypasses the fermenting and the distilling in a dry grind process. In various embodiments, the method 1600 further comprises fermenting and distilling the process stream prior to the separating the process stream into the fiber process stream and the defiber process stream (e.g., process 400 from FIG. 4 or process 500, 501 from FIGs. 5A, 5B).

[00201] In various embodiments, the method 1600 further comprises mixing one or more enzymes (e.g., the one or more enzymes 1210 from FIGs. 12, 14, and 15) with the fiber process stream to form a fiber slurry in a fiber slurry mixing tank (e.g., mix tank 1406) (step 1606). In various embodiments, the fiber process stream can also be mixed with a liquids stream (e.g., liquid stream 1424 routed from the rotary press 1410 and/or clean water) in the mix tank 1406.

[00202] In various embodiments, prior to the mixing step (e.g., step 1606), the method 1600 can comprise separating a backset (e.g., backset 1430 from FIGs. 14 and 15 and/or backset 1530 from FIG. 15 from the defiber process stream) and sending the backset to one or more slurry tanks (e.g., one or more slurry tanks 104 from FIGs. 1-5B).

[00203] In various embodiments, the method 1600 further comprises imparting shear on the fiber slurry (step 1608). In this regard, the mix tank 1406 can generate impart the shear on the fiber slurry. For example, the mix tank 1406 can comprise a high shear mixer (e.g., an agitator, a recirculatory centrifugal pump, an ultrasonic transducer in a recirculatory flow, or any other high shear mixer that may be readily apparent to one skilled in the art). In various embodiments, a high shear mixer can be defined relative to its counterpart, a low shear mixer. In this regard, high shear mixers utilize high shear, or forceful mixing, to homogenize a mixture, whereas low shear mixing utilizes flow, turbulence, and rotational force to combine miscible good.

[00204] In various embodiments, the method 1600 further comprises separating the fiber slurry (e.g., fiber slurry stream 1409 from FIGs. 14A, 14B or the enriched fiber slurry stream 1509 from FIG. 15) into a fiber cake stream (e.g., fiber cake stream 1426 from FIGs. 14A, 14B) and one or more fiber liquid streams (e.g., liquid stream 1422 and/or liquid stream 1424), the fiber cake stream enriched in fiber relative to the fiber process

stream (e.g., fiber process stream 1402 from FIGs. 14 or 15) (step 1610). In various embodiments, the method 1600 further comprises sending one of the one or more fiber liquid streams (e.g., liquid stream 1424 from FIGs. 14A, FIG. 14B, or FIG. 15) to the fiber slurry mixing tank (e.g., the mix tank 1406 from FIGs. 14 and 15 and/or the mix tank 1506 from FIG. 15).

[00205] In various embodiments, the method 1600 further comprises heating the fiber slurry (e.g., prior to the separating step 1610) to a temperature between 170 °F (77 °C) and 205 °F (96 °C). In this regard, the heating the fiber slurry, in combination with the added enzymes can greatly reduce a fat content, a protein content, and/or a starch content in the fiber slurry, in accordance with various embodiments. In various embodiments, the heating the fiber slurry, in combination with the added enzymes, can greatly enrich a fiber content in the fiber slurry. In various embodiments, the imparting shear on the fiber slurry is performed for between one hour and eight hours. In various embodiments, the method 1600 further comprises re-slurrying the fiber slurry after the imparting shear on the fiber slurry (e.g., in the mix tank 1406 from FIGs. 14A, 14B and/or the mix tank 1506 from FIG. 15) and prior to the separating the fiber slurry into the fiber cake stream and the one or more fiber liquid streams (e.g., via the rotary press 1410 from FIGs. 14 and 15).

[00206] In various embodiments, the method 1600 further comprises heating a second of the one or more fiber liquid streams (e.g., liquid stream 1422 via jet cooker 1414, steam or vapor 1412, and/or the flash processing system 1416) to denature the one or more enzymes and form a denatured liquid stream (e.g., liquid stream 1428). In various embodiments, the second to the one or more fiber liquid streams is heated between 250 °F (121 °C) and 300 °F (149 °C) (e.g., via the jet cooker 1414 with or without the steam or vapor 1412). In various embodiments, the method 1600 further comprises separating a backset (e.g., backset 1430 from FIGs. 14A, 14B and/or backset 1530 from FIG. 15) from the defiber process stream prior to the mixing the fiber process stream (e.g., in the mix tank 1406). In various embodiments, the method 1600 further comprises combining the denatured liquid stream (e.g., liquid stream 1428 from FIGs. 14 and 15) with the backset (e.g., backset 1430 and/or backset 1530 from FIGs. 14 and 15) to form a combined backset stream, and sending the backset to one or more slurry tanks (e.g., the one or more slurry tanks 104 from FIGs. 14 and 15).

[00207] In various embodiments, the method 1600 further comprises sending the fiber cake stream (e.g., fiber cake stream 1426 from FIGs. 14A, 14B or fiber cake stream 1526 from FIG. 15) through one or more dryers (e.g., the one or more dryers 138) to form a dried fiber cake (step 1612).

5 [00208] In various embodiments, the method 1600 further comprises separating, by a solids separation system (e.g., solids separation systems from FIGs. 7-9), solids of the defiber process stream from liquids of the defiber process stream to form a defiber cake stream (e.g., wet cake 722 from FIGs. 7-9) and a defiber liquids stream (e.g., liquids stream 716A, 718A from FIGs. 7-9) (step 1614). In various embodiments, the separating the solids
10 of the defiber process stream from the liquids of the defiber process stream further comprises sending the defiber process stream through a first separation device (e.g., separation device 704 or separation device 706) to create the defiber liquids stream and a first wet cake material (e.g., wet cake 710 from FIG. 7), diluting the first wet cake material in a mixing tank (e.g., mix tank 712 from FIG. 7) to create a diluted wet cake stream (e.g.,
15 combined stream 714 from FIG. 7), and sending the diluted wet cake stream through a second separation device (e.g., the separation device 716 and/or the separation device 718) to create the defiber cake stream.

[00209] In various embodiments, the method 1600 further comprises separating suspended solids from the defiber liquid stream to form a separated defiber solids stream
20 (e.g., separated solids stream 1008 from FIGs. 10 and 11) and a separated defiber liquids stream (e.g., separated liquids stream 1010 from FIGs. 10 and 11) (step 1616). In various embodiments, the separated defiber solids stream can be mixed with the defiber cake stream (e.g., wet cake 722) in a mixer (e.g., mixer 808) prior to sending a mixed stream to the one or more dryers.

25 [00210] In various embodiments, the method 1600 further comprises sending the separated defiber liquids stream through one or more evaporators to form a condensed distillers solubles (CDS) (e.g., CDS 130 as shown in FIGs. 1-5B, 10, and 11) (step 1618). In this regard, the CDS can be formed by sending the separated defiber liquids stream through one or more evaporators (e.g., as shown in FIGs. 10 and 11).

30 [00211] In various embodiments, the method 1600 combining at least a first portion of the CDS with at least a portion of the dried fiber cake to form a fiber & syrup

product (e.g., fiber & CDS 132 as shown in FIGs. 1-6) (step 1620). In various embodiments, the method 1600 further comprises recovering a recovered oil (e.g., oil 136 via oil recovery 134 from FIGs. 10 and 11) from the separated defiber liquids stream. In various embodiments, the method 1600 further comprises combining at least a first portion of the defiber cake stream with at least a first portion of the separated defiber solids stream to create an animal feed product (e.g., Hi-Pro 140 from Fig. 10, DDG 142, DDGS 146, and/or enrich yeast hi-pro 144 from FIG. 1).

[00212] In various embodiments, the separated defiber solids stream undergoes hydrolysis (e.g., hydrolysis 1104 from FIGs. 11A and 11B) prior to being combined with the defiber cake stream to form the animal feed product (e.g., hydrolyzed yeast hi-pro 1110 from FIGs. 11A and 11B).

[00213] In various embodiments, the method 1600 further comprising drying a combined stream that is formed from the defiber cake stream and the separated defiber solids stream to create the animal feed product (e.g., Hi-Pro 140 from FIG. 10), wherein optionally the animal feed product comprising feed product formed from the drying includes a protein content ranging from approximately 47% to approximately 62% on a dry matter basis.

[00214] In various embodiments, the method 1600 further comprising combining the defiber cake stream with a first portion of the separated defiber solids stream to create a yeast enriched feed product (e.g., enrich yeast hi-pro 144 from FIGs. 1, 3-5, and/or hydrolyzed yeast hi-pro 1110 from FIGs. 11A and 11B). In various embodiments, a second portion of the separated defiber solids stream undergoes hydrolysis (e.g., to form the hydrolyzed yeast hi-pro 1110 from FIGs. 11A and 11B).

[00215] In various embodiments, the method 1600 further comprises distilling the defiber process stream to separate an alcohol (e.g., in the one or more distillation devices 112 from FIGs. 1-5B) from the defiber process stream, forming an alcohol-based product from the alcohol (e.g., ethanol 118 from FIGs. 1-5B). In various embodiments, the method 1600 further comprises removing moisture from the alcohol (e.g., post distillation, i.e., downstream from the one or more distillation devices 112) via dehydration (e.g., by the one or more dehydration apparatuses 114 as shown in FIGs. 1-5B) prior to form the alcohol-based product. In various embodiments, the alcohol-based product is product an

ethanol product (e.g., ethanol 118 from FIGs. 1-5B). In various embodiments, the method 1600 further comprises adding a denaturant to the alcohol to form the ethanol product for use as a fuel or a fuel additive.

5 **[00216]** Referring now to FIG. 17, a method 1700 for enriching fiber in a dry grind process is illustrated, in accordance with various embodiments. In various embodiments, the method 1700 is a sub-process in the method 1600 from FIG. 16. For example, the method 1700 can replace steps 1606, 1608, 1610, 1612 of method 1600 from FIG. 16, in accordance with various embodiments.

10 **[00217]** With combined reference to FIGs. 14A, 14B, 15, and 17, the method 1700 comprises mixing, by a fiber mix tank (e.g., mix tank 1406), a first enzyme cocktail (e.g., at least one of the one or more enzymes 1210) with a fiber process stream to form a first fiber slurry (e.g., fiber slurry 1407) (step 1702). In various embodiments, the fiber process stream includes a solids stream output from a separation device 1404 (e.g., separated fiber stream 1405).

15 **[00218]** In various embodiments, an enzyme composition of the enzyme cocktail from step 1702 consists of one or more protease enzymes and optionally one or more pectinase enzymes, one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes, and the one or more protease enzymes includes the protease enzyme. An
20 “enzyme composition” as referred to herein is the enzyme specific elements of a respective enzyme cocktail. Stated another way, an enzyme cocktail can include enzyme elements and non-enzyme elements, such as water or any other non-enzyme element that is typically included in an enzyme cocktail. Accordingly, an enzyme composition of an enzyme cocktail only includes enzyme elements (e.g., one or more different types of enzymes).

25 **[00219]** In various embodiments, an enzyme composition of the enzyme cocktail from step 1702 consists of one or more pectinase enzymes and optionally one or more protease enzymes, one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes, and the one or more pectinase enzymes includes the pectinase enzyme.

30 **[00220]** In various embodiments, the first enzyme comprises one of a protease enzyme or a pectinase enzyme. In various embodiments, the fiber slurry sent to the

liquefaction tank only includes one type of enzyme, the one type of enzyme is the first enzyme, and the first enzyme comprises the protease enzyme. In various embodiments, the protease enzyme comprises an alkaline protease enzyme.

5 **[00221]** In various embodiments, the method 1700 further comprises sending the first fiber slurry to a liquefaction tank (e.g., liquefaction tank 1408) for a first time period (step 1704). In various embodiments, the first time period is between 1 hour and 8 hours.

10 **[00222]** In various embodiments, the method 1700 further comprises heating the first fiber slurry in the liquefaction tank to a first temperature for the first time period to form a treated fiber slurry (step 1706). In various embodiments, the first enzyme comprises a life cycle that is less than or equal to the first time period at the first temperature in the liquefaction tank. In this regard, downstream processing to denature the first enzyme (e.g., steam or vapor 1412, jet cooker 1414 and/or flash processing system 1416 as shown in FIGs. 14A and 15) can be eliminated reducing cost and energy consumption (e.g., as shown in Fig. 14B) during the method 1700, in accordance with various embodiments.

15 **[00223]** However, the present disclosure is not limited in this regard. For example, the first enzyme can include a longer life cycle than the first time period, and the method 1700 can include steps to denature the first enzyme prior to reintroducing the first enzyme into the one or more slurry tanks 104. In this regard, the method 1700 can further comprise heating the fiber liquid stream (e.g., liquid stream 1422 that is output from the rotary press 1410) to denature the first enzyme and form a denatured liquid stream, the fiber liquid stream heated between 250 °F (121 °C) and 300 °F (149 °C). In various
20 embodiments, the heating the fiber liquid stream comprises heating the fiber liquid stream to a second temperature between 65 °C (149 °F) and 100 °C (212 °F), or between 90 °C (194 °F) and 100 °C (212 °F) for between 1 minute and 30 minutes.

25 **[00224]** In various embodiments, the first temperature is at least 170 °F (77 °C). In various embodiments, the first temperature is between 170 °F (77 °C) and 205 °F (96 °C). In various embodiments, responsive to the heating the first fiber slurry to the first temperature for the first time period, an oleosome disposed in corn germ of the first fiber slurry is degraded to release oil therefrom. In this regard, the oil released from the oleosome
30 can be recovered downstream in the process 100, 200, 300, 400, 500 described previously herein, which can result in increased oil yields relative to processes without the method

1700, in accordance with various embodiments. For example, in various embodiments, the recovered oil (e.g., oil 136 via oil recovery 134 from process 100, 200, 300, 400, 500 from FIGs. 1-5B) includes oil that was released from an oleosome disposed in corn germ of the first fiber slurry previously in the dry grind process. In this regard, in various embodiments, an oil yield from a process with the method 1700 can increase oil yields by at least 3%, or at least 4%, or at least 5%, relative to a method 1600 from FIG. 16 that does not include the method 1700 (or similar method), in accordance with various embodiments.

[00225] In various embodiments, relative to the fiber process stream 1402 the treated fiber slurry (e.g., fiber slurry stream 1409 or enriched fiber slurry stream 1509) that is output from the liquefaction tank 1408, 1508 is enriched in fiber and reduced in protein, fat, and starches. In various embodiments, the treated fiber slurry reduces a protein content between 20% and 60% relative to the fiber process stream 1402. In various embodiments, the treated fiber slurry reduces a starch content between 70% and 99% relative to the fiber process stream 1402. In various embodiments, relative to the fiber process stream 1402, the treated fiber slurry that is output from the liquefaction tank is reduced in mass, and wherein optionally, a solids content of the treated fiber slurry that is output from the liquefaction tank is reduced in mass by at least 20%, or more preferably by at least 30%.

[00226] In various embodiments, the method 1700 further comprises sending at least a first portion of the fiber liquid stream to a slurry mixer (e.g., one of the one or more slurry tanks 104) (step 1708). In various embodiments, the slurry mixer is configured to mix at least one of a meal, a powder, or a flour formed from a feedstock with the fiber liquid stream and output a process stream (e.g., process stream sent to the one or more liquefaction tanks 106 in process 100, 200, 300, 400, 500, 501 from FIGs. 1-5B) to be sent through fermentation and distillation.

[00227] In various embodiments, the method 1700 further comprises mixing the first fiber cake stream (e.g., the first fiber cake stream output from the separation device 1504 to the mix tank 1506 of FIG. 15) with a second enzyme cocktail (e.g., a second of one or more enzymes 1210 added to mix tank 1506) comprising a second enzyme to form a second fiber slurry (step 1708). In various embodiments, the enzyme cocktail comprises one or more enzymes without the protease enzyme or the pectinase enzyme. In various embodiments, the second enzyme comprises a second life cycle that allows the second

enzyme to survive through a majority of the dry grind process. In this regard, and in contrast with the first enzyme from the first enzyme cocktail in step 1702, the second enzyme can be an enzyme that is selected and configured to be used to increase protein content by solubilizing undesirable or targeted fractions found within the substrate composition may be employed. Accordingly, the second enzyme can be added after the life cycle of the first enzyme has ended, preventing contradictory activities from occurring simultaneously, and/or facilitating additional protein content in one or more downstream animal feed products in the process 100, 200, 300, 400, 500, 501 from FIGs. 1-5B described previously herein. In various embodiments, the second life cycle is configured to allow the second enzyme to survive at least 70% of the dry grind process, or at least 80% of the dry grind process, or at least 90% of the dry grind process, or an entirety of the dry grind process.

[00228] Although the second pass of mix tank and liquefaction tanks in the process 1500 from FIG. 15 is described herein as having a different enzyme cocktail relative to the first pass (e.g., mix tank 1406 and the liquefaction tank 1408), the present disclosure is not limited in this regard. For example, the enzyme cocktail (e.g., the one or more enzymes 1210 from FIG. 15) that is added to the mix tank 1506 can be the same as the enzyme cocktail that is added to mix tank 1406 in the process 1500 from FIG. 15, and would still be within the scope of this disclosure. In this regard, the second pass could further reduce a fat content, a starch content, and a protein content in a slurry that is output therefrom (e.g., the enriched fiber slurry stream 1509), and further increase the fiber content relative to the input stream received from the mix tank 1506, in accordance with various embodiments.

[00229] In various embodiments, a first enzyme composition of the first enzyme cocktail from step 1702 consists of one of: one or more protease enzymes or one or more pectinase enzymes, and optionally one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes, the second enzyme cocktail from step 1708 consists of another of: the one or more protease enzymes or the one or more pectinase enzymes, and optionally one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes, the one or more protease enzymes includes the protease enzyme, and the one or more pectinase

enzymes includes the pectinase enzyme. In various embodiments, step 1708 can further comprise sending the second fiber slurry to a second liquefaction tank for a second time period, and heating the second fiber slurry in the second liquefaction tank to a second temperature for the second time period to form a second treated fiber slurry, each of the
5 one or more protease enzymes or the one or more pectinase enzymes from the second enzyme cocktail comprising a second life cycle that is less than or equal to the second time period at the second temperature.

[00230] In various embodiments, an enzyme composition of the first enzyme cocktail from step 1702 and the second enzyme cocktail from step 1708 each consist of
10 one or more protease enzymes and/or one or more pectinase enzymes, and optionally one or more xylanase enzymes, one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes, the one or more protease enzymes includes the protease enzyme, and the one or more pectinase enzymes includes the pectinase enzyme. In various embodiments,
15 step 1708 can further comprise sending the second fiber slurry to a second liquefaction tank for a second time period, and heating the second fiber slurry in the second liquefaction tank to a second temperature for the second time period to form a second treated fiber slurry, each of the one or more protease enzymes or the one or more pectinase enzymes from the second enzyme cocktail comprising a second life cycle that is less than or equal
20 to the second time period at the second temperature.

[00231] In various embodiments, the method 1700 further comprises separating the treated fiber slurry (e.g., fiber slurry stream 1409 from FIGs. 14A, 14B or fiber slurry stream 1509 from FIG. 15) into a first fiber cake stream (e.g., fiber cake stream 1426, 1526) and a fiber liquid stream (e.g., liquid stream 1422, 1429 and/or liquid stream 1424, 1425)
25 (step 1710). In various embodiments, fiber liquid stream (or a portion thereof) no longer includes the first enzyme because the life cycle of the first enzyme has ended.

[00232] In various embodiments, the method 1700 further comprising forming a fiber-based product (e.g., fiber-based product 1450, 1550) (step 1712). In various embodiments, the fiber-based product comprises cellulosic biofuel feedstock from the first
30 fiber cake stream. In various embodiments, the cellulosic biofuel feedstock is configured as an input feedstock for use in a process to form renewable diesel fuel or sustainable

aviation fuel. In various embodiments, the fiber-based product is formed in response to drying the fiber cake stream that is output from the separating step (e.g., step 1710). However, the present disclosure is not limited in this regard. For example, the fiber-based product can comprise the cake stream that is output from the separating step (e.g., step 5 1710) and would still be within the scope of this disclosure.

[00233] In various embodiments, the fiber-based product comprises an animal feed product with a protein content ranging from 8% to 17% on a dry matter basis, or ranging from 8% to 15% on a dry matter basis, or ranging from 9% to 13% on a dry matter basis. In various embodiments, such a protein content in a fiber-based feed product could 10 be more desirable, such as a feed product for cattle where the production of milk fat is inversely proportional to protein content of the feed. Without the method 1700 disclosed herein, the process 100, 200, 300, 400, 500 would typically result in a protein content ranging from 17% to 28% on a dry matter basis. Such a protein content would be too much for cattle. Accordingly, by reducing the percentage of protein in the fiber-based product to 15 the compositions disclosed herein, a more valuable end feed product may be generated, in accordance with various embodiments.

[00234] In various embodiments, the method 1700 can further comprise sending at least a second portion of the fiber liquid stream (e.g., liquid stream 1424, 1425, 1524) to the fiber mix tank for mixing with the first enzyme and the fiber process stream 1402 to 20 form the first fiber slurry.

[00235] In various embodiments, the fiber process stream 1402 is pre-fermentation and pre-distillation (e.g., received from fiber separation system 108 from process 100, 200, 300 from FIGs. 1-3) in the dry grind process. However, the present disclosure is not limited in this regard, and the fiber process stream 1402 could also be 25 received post-fermentation and post-distillation and would still be within the scope of this disclosure.

[00236] In various embodiments, the method 1700 further comprises separating a backset (e.g., backset 1430 and/or backset 1530) from a defiber process stream prior to the mixing the fiber process stream (e.g., in the mix tank 1406). In various embodiments, 30 the method 1700 further comprises combining the first portion of the fiber liquid stream with the backset to form a combined liquid stream, and sending the combined liquid stream

to the slurry mixer.

Processed Fiber Cakes

[00237] The methods and systems discussed herein can be used to produce beneficial feedstock, with good composition properties such as desired fat, protein, and starch. The methods and systems herein can also be used to produce fiber, protein, and syrup as separate products. The fiber cakes (e.g., fiber cake stream 1526 from FIG. 15 or fiber cake stream 1426 from FIGS. 14A, 14B) can have at least 39%, or at least 40%, or at least 45% solids.

[00238] In various embodiments, the fiber cakes produced by the methods herein (e.g., fiber cake stream 1526 from FIG. 15 or fiber cake stream 1426 from FIGS. 14A, 14B) can have a fat content of between 6% and 10%, or between 6.3% and 9.9 %, or between 6.4% and 9.8%, or between 6.5% and 9.7%, or between 6.6% and 9.6%, or between 6.7% and 9.5%, or between 6.8% and 9.4%, or between 6.9% and 9.3%, or between 7.0% and 9.2%, or between 7.1% and 9.1%, or between 7.2% and 9.0%, or between 7.3% and 8.9%, or between 7.4% and 8.8%, or between 7.5% and 8.7%, or between 7.6% and 8.6%, or between 7.7% and 8.5%, or between 7.8% and 8.4%, or between 7.9% 8.3%, or between 8.0% and 8.2%.

[00239] In various embodiments, fiber cakes produced by the methods herein (e.g., fiber cake stream 1526 from FIG. 15 or fiber cake stream 1426 from FIGS. 14A, 14B) can have a protein content of between 9.0% and 21.0%, or between 10.0% and 20.0%, or between 10.0% and 15.0%.

[00240] In various embodiments, fiber cakes produced by the methods herein (e.g., fiber cake stream 1526 from FIG. 15 or fiber cake stream 1426 from FIG. 14) can have a starch content of between 5.0% and 18.0%, or between 6.0% and 17.0%, or between 7.0% and 16.0%, or between 8.0% and 15.0%, or between 9.0% and 14.0%, or between 10.0% and 13.0%.

[00241] Methods discussed herein can produce fiber cakes (e.g., fiber cake stream 1526 from FIG. 15 or fiber cake stream 1426 from FIGS. 14A, 14B) with a solids output of between 39.0% and 50.0%, or between 41.0% and 49.0%, or between 42.0% and 48.0%, or between 43.0% and 47.0%, or between 44.0% 46.0%. The fiber cakes produced by the methods discussed herein (e.g., fiber cake stream 1526 from FIG. 15 or fiber cake

stream 1426 from FIG. 14A, 14B) can have, for example, a 50% reduction of fat content to other production methods.

Examples

5 **[00242]** Various examples of the present disclosure can be better understood by reference to the following Examples which are offered by way of illustration. The present disclosure is not limited to the Examples given herein.

Example 1. Feedstock Samples

10 **[00243]** Samples were produced by the methods discussed herein. Specifically, a series of samples were produced starting with a milled corn slurry. The slurry was concentrated with a multi-zone separation apparatus and then sent to a tank where it was re-slurried with clean water and an enzyme cocktail was added.

15 **[00244]** The enzyme cocktail included Optimas AX, Optimash DCO+, Spezyme HT, Optimash F200, Laminex 750, Spezyme LPL, and Optimash Phytase from IFF (enzymes from International Flavors and Fragrances). The enzyme cocktail was provided at 10% total solids and 0.06 wt% enzyme dose. The enzymes were added in two stages of hydrolysis in the tank. First, 1/3 of the enzyme cocktail was added and the tank was kept at 140 °F (60 °C) and pH 5.5 for 120 minutes. Next, the remaining 2/3 of the enzyme cocktail was added and the tank was kept at 190 °F (88 °C) and pH 5.5 for 120 minutes.

20 **[00245]** After treating with the enzymes, the fiber was re-concentrated with another multi-zone separation apparatus, and the resultant water was collected. The fiber was treated in a rotary press having 1000 µm round holes, 27% open area, and a 0.5 inches (1.26 cm) inlet and outlet. The fiber was fed at a rate of +25gpm (95 liters per minute) wash water flow at 50 psig (345 KPa). The produced fiber cakes, in addition to the other products, such as syrup and protein, were reviewed.

25 **[00246]** The losses seen in a Sample product made by this method is compared to a standard fiber cake that did not separately process fiber prior to fermentation. Original feedstock samples, as received, are summarized below in Table 1:

Table 1: Feedstock Sample Results

No.	Fat	Protein	Starch
1	9.9%	18.1%	9.4%
2	9.9%	18.1%	9.4%
3	7.9%	15.3%	6.0%
4	8.1%	18.1%	11.2%
5	6.4%	17.7%	6.5%
6	8.2%	17.6%	10.8%
8	6.3%	20.1%	5.3%
9	8.3%	17.9%	17.4%
10	8.4%	19.2%	6.1%
11	8.5%	20.3%	5.5%

[00247] The samples were treated as outlined above, resulting in the losses summarized in Table 2 below:

5

Table 2: Feedstock Sample Losses

Batch	Reduction			Fiber Separation Method
	Fat	Protein	Starch	
1	-13%	-6%	-74%	enzymes and rotary press plus thermal
2	-23%	-59%	-80%	enzymes
3	-1%	-44%	-94%	enzymes
4	-19%	-57%	-95%	enzymes
5	-28%	-23%	-95%	enzymes
6	-24%	-27%	-98%	enzymes
8	-55%	-42%	-97%	enzymes and rotary press
9	-53%	-52%	-96%	enzymes and rotary press

[00248] Overall, the sample treated with both enzymes and rotary press (e.g., biological and mechanical treatments, such as batch 8 and batch 9) performed best for low fat corn fiber compositions. The samples in Table 2 had a total mass reduction of more than about 30%. Sample batches 5 to 9 had a starch removal of about 95-98%, and a reduction of the amount of protein left on fiber of about 30% to 50%.

10

[00249] The samples were additionally tested for type of fat content, with average fatty acid and glyceride contents (out of total fat content) as follows in Table 3:

Table 3: Fatty Acid and Glyceride Contents

Monoglycerides	2.5%
Diglycerides	10.6%
Triglycerides	82.8%
Glycerol	1.3%
Fatty acid methyl esters	< 1.0%

[00250] The samples made by the methods discussed herein had an overall lower total fat content composition in resulting fiber cakes. The greater reduction in fat content when treated with enzymes and rotary press allows for lower fat composition corn fiber.

Example 2. Sample Porosimetry Data

[00251] The samples were additionally tested for porosimetry data, which is summarized below in Table 4:

Table 4: Porosimetry Data for Samples

	Processing Methods	Total intrusion volume (mL/g)	Total pore area (m ² /g)	Volumc median pore diameter (μm)	Bulk density (g/mL)	Apparent density (g/mL)	% porosity
Comparative Sample	N/A	0.37	12.54	34.14	0.92	1.41	34.5
Sample 1	Enzyme Cocktail & Rotary Press	0.39	14.09	25.80	0.94	1.49	36.7

[00252] The Sample 1 had a larger pore volume, total pore area, and percent porosity, but smaller median pore density than the Comparative Sample. The Sample 1 had a larger density, both when measured as bulk and apparent density. These results show that the use of enzymes in fiber processing did not degrade the fiber itself. That is, the pore structure of the fiber was maintained, and did not collapse.

Example 3. Sample Composition of Fiber Cake

[00253] The fiber concentration system 113 from FIG. 14B was tested with a commercial scale testing version of the process 100 from FIG. 1 with the fiber

concentration system 113 from FIG. 14B and the results are shown below in Table 5. The resulting fiber cake stream 1426 that was produced therefrom can be compared with a fiber cake stream that was generated with a production scale version of the process 100 from FIG. 1 without the fiber concentration system 113 (baseline A), which was averaged over seven samples, and baseline B, which corresponds to a test version of the process 100 with the fiber concentration system 113 without treatment with the one or more enzymes 1210 (Baseline B). In various embodiments, the trial runs for the Test experiments were with short residence time in the liquefaction tank 1408 from FIG. 14B. In this regard, longer residence time with the one or more enzymes 1210 would further reduce the amount of protein in the fiber cake stream 1426, further reduce the amount of crude fat in the fiber cake stream 1426, further reduce the total starch, and increase the crude fiber in the fiber cake stream 1426.

Table 5: Composition of Fiber Cake Stream 1426

Experiment	Type	Dry Matter (%)	Crude Protein (%)	Crude Fiber (%)	Crude Fat (%)	Total Starch (Megazyme) (%)
Baseline A	Process 100 w/o Fiber concentration system 113	39.8	18.1	17.0	7.7	3.4
Baseline B	Process 100 w/ Fiber concentration system 113 w/o Enzyme(s) 1210	40	19.8	15.2	9.5	3.2
Test	Fiber Cake Stream 1426 from Process 100 w/ Fiber concentration system 113 from FIG. 14B	40	17.9	16.7	7.6	2.5

[00254] As shown in Table 5, the percentage of crude protein from the test relative to Baseline B was decreased by about 10%, the crude fat was reduced by about 20%, and the total starch was reduced by about 22%, and the fiber content was increased by about 10%. In comparison to the Baseline A, which was a production level operation, crude protein was reduced slightly, crude fiber was relatively comparable, but reduced slightly, crude fat was reduced slightly, and total starch was reduced significantly by about 26%. In various embodiments the reduction in total starch is indicative of the corn starch

converting to sugar, which can be beneficial for higher yields in response to routing the liquid stream 1429 from the rotary press 1410 back to the one or more slurry tanks 104 (e.g., via a slurry mixer). In this regard, as described previously herein, the liquid stream 1429 can carry with it liberated fat, liberated starch, and solubilized proteins.

5 **[00255]** In various embodiments, the mass of the fiber cake stream 1426 from the fiber concentration system 113 from FIG. 14B can be greatly reduced relative to a fiber cake stream 1426 that is produced without the enzyme treatment (e.g., adding the one or more enzymes 1210 to the mix tank 1406 as described previously herein). Comparisons between a baseline untreated batch vs a treated test batch at a test version scale, a treated
10 test composite at a test version scale, and a treated test batch at a pilot scale are shown below in Tables 6, 7, and 8 respectively.

Table 5: Mass % Reduction by w/w

			Total	Fat	Protein	Starch
Baseline B (Untreated Batch)	Process 100 w/ Fiber concentration system 113 w/o Enzyme(s) 1210	Percent	100%	9.5%	19.8%	3.2%
		Mass (g)	1000.0	95.0	198.0	32.0
Test (Treated Batch)	Process 100 w/ Fiber concentration system 113 from FIG. 14B	Percent	100.00%	7.60%	17.90%	2.50%
		Mass (g)	937.5	71.2	167.8	23.4
		Change		-25.0%	-15.2%	-26.8%

Table 6: Mass % Reduction by w/w

			Total	Fat	Protein	Starch
Baseline B (Untreated Batch)	Process 100 w/ Fiber concentration system 113 w/o Enzyme(s) 1210	Percent	100%	9.5%	19.8%	3.2%
		Mass (g)	1000.0	95.0	198.0	32.0
Test (Treated Composite)	Process 100 w/ Fiber concentration system 113 from FIG. 14B	Percent	99.50%	7.40%	17.50%	1.30%
		Mass (g)	920.6	69.4	164.1	12.2
		Change		-27.0%	-17.1%	-61.9%

Table 8: Mass % Reduction by w/w

Experiment 3			Total	Fat	Protein	Starch
Baseline B	Process 100 w/ Fiber concentration system 113 w/o Enzyme(s) 1210	Percent	100%	8.3%	17.9%	17.4%
		Mass (g)	1000.0	83.0	179.0	174.0
Test	Process 100 w/ Fiber concentration system 113 from FIG. 14B	Percent	100.00%	5.60%	12.30%	1.00%
		Mass (g)	695.4	38.9	85.5	7.0
		Change		-53.1%	-52.2%	-96.0%

[00256] As shown above on a weight by weight basis, the fat composition, the protein composition, and the starch composition that is output from the fiber concentration system 113 can be significantly reduced when treated with the one or more enzymes 1210 described previously herein relative to without being treated with the one or more enzymes 1210 as shown in FIGs. 14A, 14B, and 15. In various embodiments, the significant mass reduction can result in reduced natural gas consumption, lower dryer operation temperatures and/or a more flowable feed product that is produced from the fiber cake stream 1426, 1526.

[00257] The following exemplary examples are provided, the numbering of which is not to be construed as designating levels of importance.

[00258] In some aspects, the techniques described herein relate to a method of processing fiber including: receiving a process stream; concentrating fiber from the process stream with a separation device to produce a first fiber cake and a first liquid stream; suspending the first fiber cake to produce a fiber slurry; treating the fiber slurry with an enzyme; and concentrating the fiber slurry with a mechanical separation device to produce a second fiber cake and a second liquid stream.

[00259] In various embodiments, the techniques described herein relate to a method, wherein treating includes heating the fiber slurry with an enzyme that has been previously added therein at a temperature of at least 170 °F (77 °C) for a first time period(e.g., between 1 hour and 8 hours).

[00260] In various embodiment, responsive to heating the fiber slurry with the enzyme, the enzyme is configured to naturally die (or naturally deactivate) within the first time period.

[00261] In various embodiments, the enzyme comprises one of a protease enzyme or a pectinase enzyme.

[00262] In various embodiments, the enzyme includes a life cycle that is less than or equal to the first time period at the temperature.

5 [00263] In various embodiments, the techniques described herein relate to a method, wherein treating includes heating the fiber slurry an enzyme at a temperature of about 170 °F (77 °C) to about 205 °F (96 °C).

[00264] In various embodiments, the techniques described herein relate to a method, wherein treating the fiber slurry an enzyme is done via a high shear mixer.

10 [00265] In various embodiments, the techniques described herein relate to a method, wherein high shear includes shear that causes the enzyme to not be immobilized.

[00266] In various embodiments, the techniques described herein relate to a method, wherein treating the fiber slurry with an enzyme includes treating the first fiber cake with the enzymes for a first time period.

15 [00267] In various embodiments, the techniques described herein relate to a method, wherein the enzyme includes xylanases, proteases, SYMBOL-amylases, cellulases, xylanases, lipases, phytases, pectinases, or combinations thereof.

[00268] In various embodiments, the techniques described herein relate to a method, further including denaturing the enzyme in the second liquid stream.

20 [00269] In various embodiments, the techniques described herein relate to a method, wherein denaturing the enzyme includes heating the enzyme in a cook tube.

[00270] In various embodiments, the techniques described herein relate to a method, wherein the mechanical separation device includes a rotary press.

25 [00271] In various embodiments, the techniques described herein relate to a method, wherein the separation apparatus includes a multi-zone screening apparatus or a centrifuge.

[00272] In various embodiments, the techniques described herein relate to a method, wherein the process stream includes a milled grain slurry.

30 [00273] In various embodiments, the techniques described herein relate to a method, wherein the process stream includes a preliminary fiber slurry that was produced by concentrating fiber from a milled grain slurry to produce preliminary concentrated fiber

and mixing the preliminary concentrated fiber with liquid to produce the preliminary fiber slurry.

[00274] In various embodiments, the techniques described herein relate to a method, further including suspending the second fiber cake to produce a secondary fiber
5 slurry and concentrating fiber from the secondary fiber slurry to produce a third fiber cake and a third liquid stream.

[00275] In various embodiments, the techniques described herein relate to a method, further including fermenting the first liquid stream.

[00276] In various embodiments, the techniques described herein relate to a
10 system for processing fiber, the system including: a separation apparatus for receiving a process stream and concentrating fiber from the process stream to produce concentrated fiber; a solids mix tank for receiving the concentrated fiber; a liquefaction tank for liquefying the concentrated fiber with one or more enzymes and liquid to produce a fiber slurry; and a mechanical separation device for receiving the fiber slurry and producing a
15 liquid stream and a fiber cake.

[00277] In various embodiments, the techniques described herein relate to a system, wherein the mechanical separation device is a rotary press or a centrifuge.

[00278] In various embodiments, the techniques described herein relate to a
20 system, further including: a secondary screening apparatus for concentrating fiber from the fiber slurry; and a secondary solids mix tank for receiving the concentrated fiber.

[00279] In various embodiments, the techniques described herein relate to a system, further including a jet cooker for receiving and treating the liquid stream.

[00280] In various embodiments, the techniques described herein relate to a fiber cake made by the method having a solids content of at least 39% on a dry matter basis.

[00281] Benefits, other advantages, and solutions to problems have been
25 described herein regarding specific embodiments. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be
30 present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become

more pronounced are not to be construed as critical, required, or essential features or elements of the disclosure. The scope of the disclosure is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean “one and only one” unless explicitly so stated, but rather “one or
5 more.” Moreover, where a phrase similar to “at least one of A, B, or C” is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B and C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C. Different cross-
10 hatching is used throughout the figures to denote different parts but not necessarily to denote the same or different materials.

[00282] Systems, methods, and apparatus are provided herein. In the detailed description herein, references to “one embodiment,” “an embodiment,” “various embodiments,” etc., indicate that the embodiment described may include a particular
15 feature, structure, or characteristic, but every embodiment may not necessarily include the feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with
20 other embodiments whether explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

[00283] Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element,
25 component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112(f) unless the element is expressly recited using the phrase “means for.” As used herein, the terms “comprises,” “comprising,” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include
30 only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

[00284] Finally, any of the above-described concepts can be used alone or in combination with any or all the other above-described concepts. Although various embodiments have been disclosed and described, one of ordinary skill in this art would recognize that certain modifications would come within the scope of this disclosure.

5 Accordingly, the description is not intended to be exhaustive or to limit the principles described or illustrated herein to any precise form. Many modifications and variations are possible considering the above teaching.

CLAIMS

What is claimed is:

1. A method for enriching fiber in a dry grind process, the method comprising:
mixing, by a fiber mix tank, a first enzyme cocktail with a fiber process stream to
5 form a first fiber slurry, the first enzyme cocktail comprising a first enzyme that includes
at least one of a protease enzyme or a pectinase enzyme;
sending the first fiber slurry to a first liquefaction tank;
heating the first fiber slurry in the first liquefaction tank to a first temperature for
a first time period in the first liquefaction tank to form a treated fiber slurry, the first
10 enzyme comprising a first life cycle that is less than or equal to the first time period at the
first temperature;
separating the treated fiber slurry into a first fiber cake stream and a fiber liquid
stream; and
sending at least a first portion of the fiber liquid stream to a slurry mixer, the
15 slurry mixer configured to mix at least one of a meal, a powder, or a flour formed from a
feedstock with the fiber liquid stream and output a process stream to be sent through
fermentation and distillation.
2. The method of claim 1, wherein the first temperature is at least 170° F (77 °C).
- 20 3. The method of claim 2, wherein the first temperature is between 170 °F (77 °C)
and 210 °F (99 °C).
4. The method of claim 1, further comprising mixing the first fiber cake stream with
25 a second enzyme cocktail to form a second fiber slurry, the second enzyme cocktail
comprising a second enzyme composition comprising one or more enzymes without the
protease enzyme or the pectinase enzyme.
5. The method of claim 4, wherein each enzyme in the second enzyme composition
30 comprises a second life cycle that allows each enzyme in the second enzyme composition
to survive through a majority of the dry grind process.

6. The method of claim 5, wherein the second life cycle and a temperature range throughout the dry grind process is configured to allow each enzyme in the second enzyme composition to survive at least 70% of the dry grind process.

5

7. The method of claim 1, wherein responsive to the heating the first fiber slurry to the first temperature for the first time period, an oleosome disposed in corn germ of the first fiber slurry is degraded to release oil therefrom.

10 8. The method of claim 7, further comprising forming a cellulosic biofuel feedstock from the first fiber cake stream.

9. The method of claim 8, wherein the cellulosic biofuel feedstock is configured as an input feedstock for use in a process to form renewable diesel fuel or sustainable
15 aviation fuel.

10. The method of claim 1, wherein relative to the fiber process stream, the treated fiber slurry that is output from the first liquefaction tank is enriched in fiber and reduced in protein and fat, and wherein optionally the treated fiber slurry:

20 reduces a protein content between 20% and 60% relative to the fiber process stream, and
reduces a starch content between 70% and 99% relative to the fiber process stream.

25 11. The method of claim 1, wherein relative to the fiber process stream, the treated fiber slurry that is output from the first liquefaction tank is reduced in mass, and wherein optionally, a solids content of the treated fiber slurry that is output from the first liquefaction tank is reduced in mass by at least 20%, or more preferably by at least 30%.

30 12. The method of claim 1, wherein the first time period is between 1 hour and 8 hours.

13. The method of claim 1, further comprising sending at least a second portion of the fiber liquid stream to the fiber mix tank for mixing with the first enzyme and the fiber process stream to form the first fiber slurry.

5

14. The method of claim 1, wherein the fiber process stream is pre-fermentation and pre-distillation in the dry grind process.

15. The method of claim 1, further comprising:

10 separating a backset from a defiber process stream prior to the mixing the fiber process stream,

combining the first portion of the fiber liquid stream with the backset to form a combined liquid stream, and

sending the combined liquid stream to the slurry mixer.

15

16. The method of claim 1, wherein the first portion of the fiber liquid stream no longer includes the first enzyme.

17. The dry grind process of claim 1, the dry grind process comprising a method for forming one or more animal feed products, the method for forming one or more animal feed products comprising:

20

grinding or milling the feedstock into the at least one of the meal, the powder or the flour;

mixing the at least one of the meal, the powder, or the flour in the slurry mixer to form a mixed slurry;

25

imparting shear on suspended solids of the process stream that is output from the slurry mixer to separate the process stream into the fiber process stream and a defiber process stream;

fermenting and distilling the defiber process stream to form a distilled defiber process stream; and

30

forming one or more animal feed products from the distilled defiber process stream.

18. The dry grind process of claim 17, wherein the method for forming the one or
5 more animal feed products further comprises:

separating, by a solids separation system, solids of the distilled defiber process stream from liquids of the distilled defiber process stream to form a defiber cake stream and a defiber liquids stream;

10 separating suspended solids from the defiber liquids stream to form a separated defiber solids stream and a separated defiber liquids stream;

sending the separated defiber liquids stream through one or more evaporators to form a condensed distillers solubles (CDS); and

sending the first fiber cake stream through one or more dryers to form a dried fiber cake;

15 combining at least a first portion of the CDS with at least a portion of the dried fiber cake to form a fiber & syrup product.

19. The dry grind process of claim 18, wherein the method for forming the one or more animal feed products further comprises:

20 separating a backset from the defiber process stream prior to the mixing the fiber process stream, and

sending the backset to the slurry mixer.

20. The dry grind process of claim 18, wherein the method for forming the one or
25 more animal feed products further comprises:

recovering a recovered oil from the separated defiber liquids stream, the recovered oil including oil that was released from an oleosome disposed in corn germ of the first fiber slurry previously in the dry grind process; and

30 combining at least a first portion of the defiber cake stream with at least a first portion of the separated defiber solids stream to create one of the one or more animal feed products.

21. The dry grind process of claim 18, wherein the separated defiber solids stream is output to undergo hydrolysis prior to being combined with the defiber cake stream to form one of the one or more animal feed products.

5

22. The dry grind process of claim 18, wherein the forming the one or more animal feed products further comprises drying a combined stream that is formed from the defiber cake stream and the separated defiber solids stream to create one of the one or more animal feed products, wherein optionally the one of the one or more animal feed products
10 comprises a feed product formed from the drying that includes a protein content ranging from approximately 47% to approximately 62% on a dry matter basis.

23. The dry grind process of claim 18, wherein the separating the solids of the defiber process stream from the liquids of the defiber process stream further comprises:

15

sending the defiber process stream through a first separation device to create the defiber liquids stream and a first wet cake material,
diluting the first wet cake material in a mixing tank to create a diluted wet cake stream,
and

sending the diluted wet cake stream through a second separation device to create
20 the defiber cake stream.

24. The dry grind process of claim 18, wherein the method for forming the one or more animal feed products further comprises: combining the defiber cake stream with a first portion of the separated defiber solids stream to create a yeast enriched feed product,
25 wherein optionally a second portion of the separated defiber solids stream is output to undergo hydrolysis.

25. The dry grind process of claim 18, wherein the method for forming the one or more animal feed products further comprises:

30

distilling the defiber process stream to separate an alcohol from the defiber process stream;

forming an alcohol-based product from the alcohol; and
removing moisture from the alcohol via dehydration prior to form the alcohol-based product, wherein the alcohol-based product is product an ethanol product; and optionally

5 adding a denaturant to the alcohol to form the ethanol product for use as a fuel or a fuel additive.

26. The method of claim 1, wherein:

the first fiber slurry sent to the first liquefaction tank only includes one type of
10 enzyme,

the one type of enzyme is the first enzyme, and
the first enzyme comprises the protease enzyme.

27. The method of claim 26, wherein the protease enzyme comprises an alkaline
15 protease enzyme.

28. The method of claim 1, wherein:

an enzyme composition of the first enzyme cocktail consists of one or more
protease enzymes and optionally one or more pectinase enzymes, one or more α -amylase
20 enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more
lipase enzymes, and/or one or more phytase enzymes, and
the one or more protease enzymes includes the protease enzyme.

29. The method of claim 1, wherein:

an enzyme composition of the first enzyme cocktail consists of one or more
pectinase enzymes and optionally one or more protease enzymes, one or more α -amylase
25 enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more
lipase enzymes, and/or one or more phytase enzymes, and
the one or more pectinase enzymes includes the pectinase enzyme.

30

30. The method of claim 1, further comprising:

mixing the first fiber cake stream with a second enzyme cocktail to form a second fiber slurry, wherein:

a first enzyme composition of the first enzyme cocktail consists of one of: one or more protease enzymes or one or more pectinase enzymes, and optionally one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes,

the second enzyme cocktail consists of another of: the one or more protease enzymes or the one or more pectinase enzymes, and optionally one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes,

the one or more protease enzymes includes the protease enzyme, and

the one or more pectinase enzymes includes the pectinase enzyme;

sending the second fiber slurry to a second liquefaction tank for a second time

period; and

heating the second fiber slurry in the second liquefaction tank to a second temperature for the second time period to form a second treated fiber slurry, each of the one or more protease enzymes or the one or more pectinase enzymes from the second enzyme cocktail comprising a second life cycle that is less than or equal to the second time period at the second temperature.

31. The method of claim 1, further comprising:

mixing the first fiber cake stream with a second enzyme cocktail to form a second fiber slurry, wherein:

an enzyme composition of the first enzyme cocktail and the second enzyme cocktail each consist of one or more protease enzymes and/or one or more pectinase enzymes, and optionally one or more xylanase enzymes, one or more α -amylase enzymes, one or more cellulase enzymes, one or more xylanase enzymes, one or more lipase enzymes, and/or one or more phytase enzymes,

the one or more protease enzymes includes the protease enzyme, and

the one or more pectinase enzymes includes the pectinase enzyme;

sending the second fiber slurry to a second liquefaction tank for a second time period; and

heating the second fiber slurry in the second liquefaction tank to a second temperature for the second time period to form a second treated fiber slurry, each of the one or more protease enzymes or the one or more pectinase enzymes from the second enzyme cocktail comprising a second life cycle that is less than or equal to the second time period at the second temperature.

32. A method for enriching fiber in a dry grind process, the method comprising:

10 mixing, by a fiber mix tank, a first enzyme cocktail with a fiber process stream to form a first fiber slurry, the first enzyme cocktail comprising a first enzyme, the first enzyme comprising one of a protease enzyme or a pectinase enzyme;

sending the first fiber slurry to a liquefaction tank for a first time period;

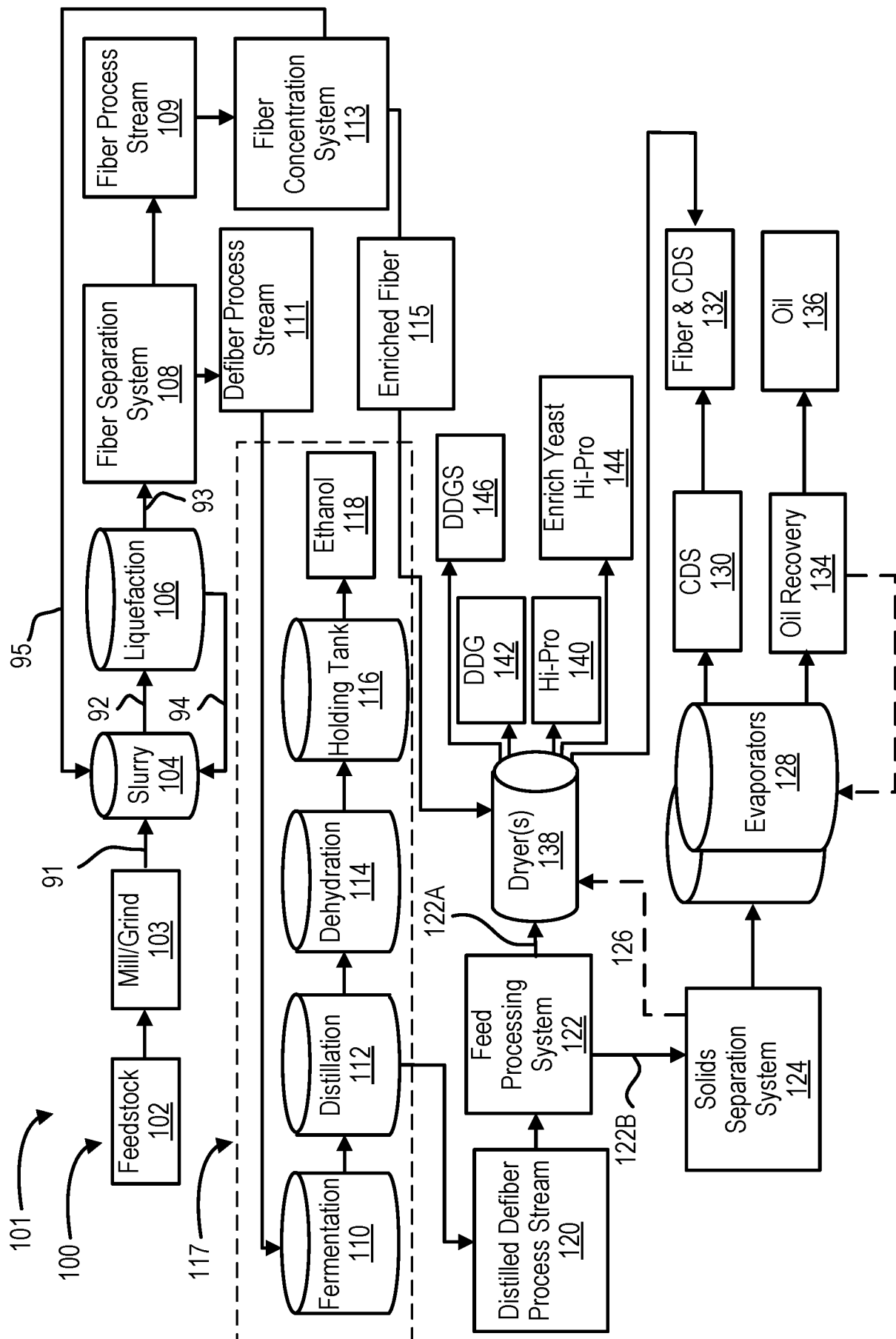
15 heating the first fiber slurry in the liquefaction tank to a first temperature for the first time period to form a treated fiber slurry;

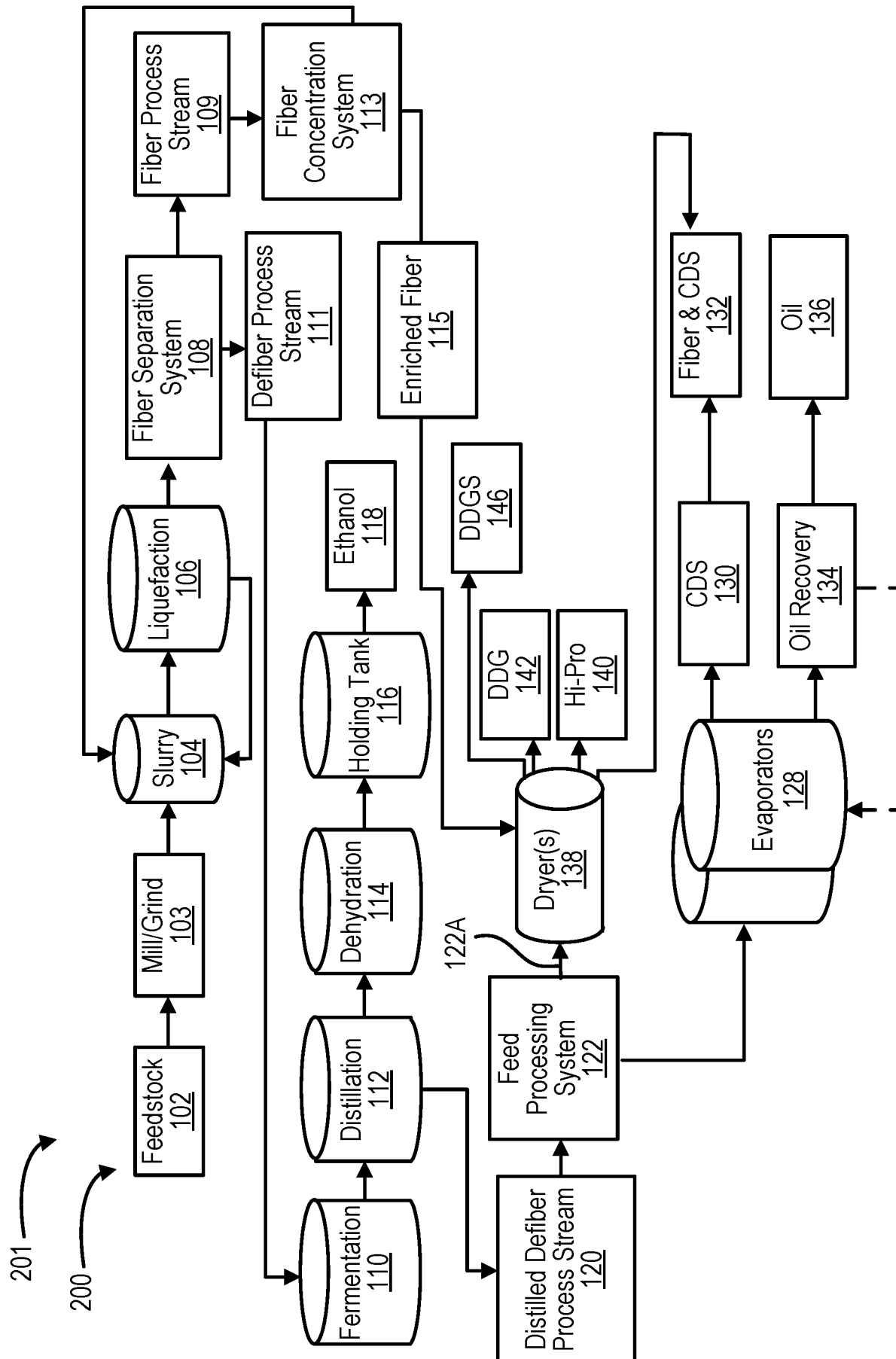
separating the treated fiber slurry into a first fiber cake stream and a fiber liquid stream;

20 heating the fiber liquid stream to denature the first enzyme and form a denatured liquid stream, the fiber liquid stream heated between 250 °F (121 °C) and 300 °F (149 °C); and

sending at least a first portion of the denatured fiber liquid stream to a slurry mixer, the slurry mixer configured to mix at least one of a meal, a powder, or a flour formed from a feedstock with the fiber liquid stream and output a process stream to be sent through fermentation and distillation.

25 33. The method of claim 32, wherein the heating the fiber liquid stream comprises heating the fiber liquid stream to a second temperature between 65 °C and 100 °C for between 1 minute and 30 minutes.





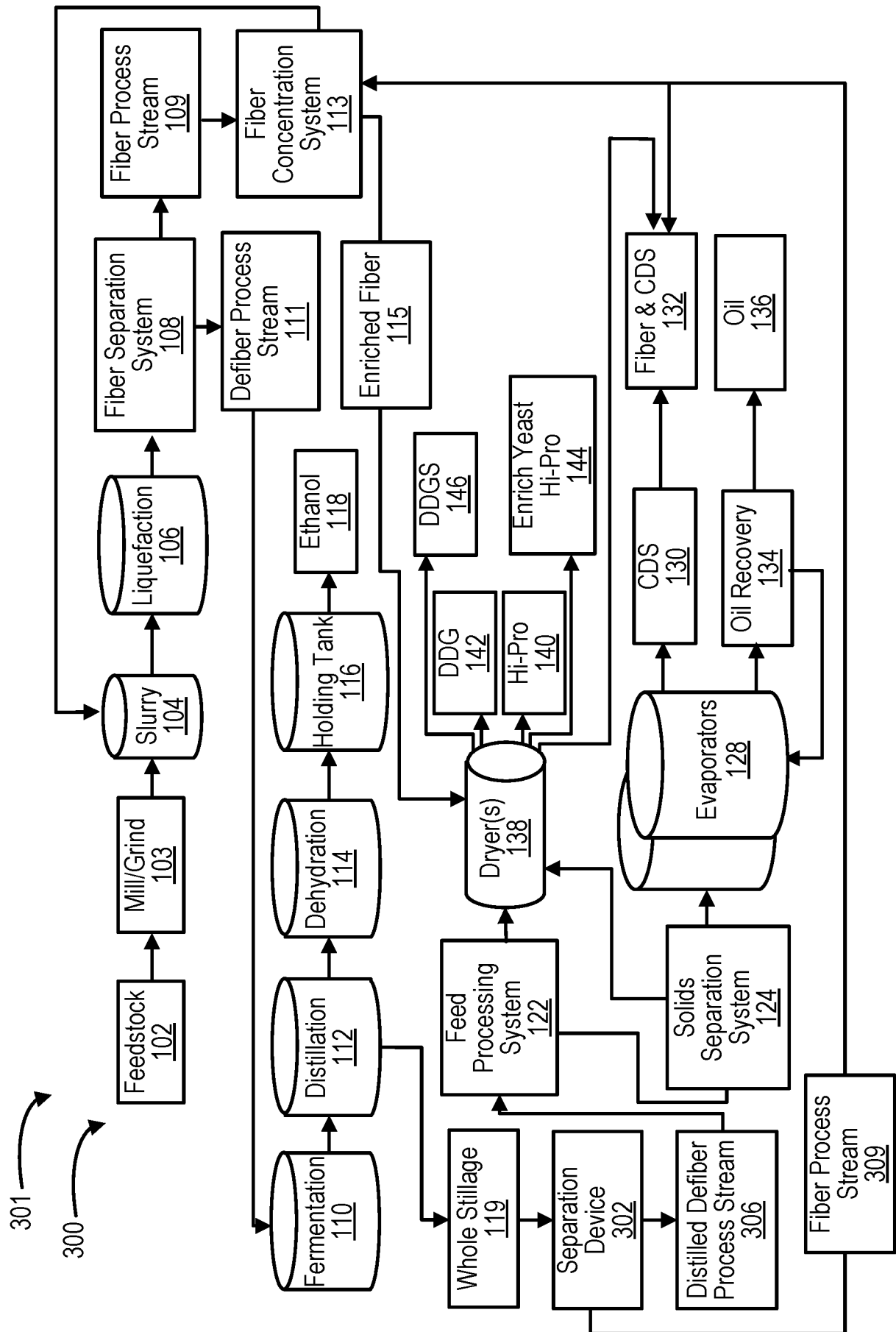


Fig. 3

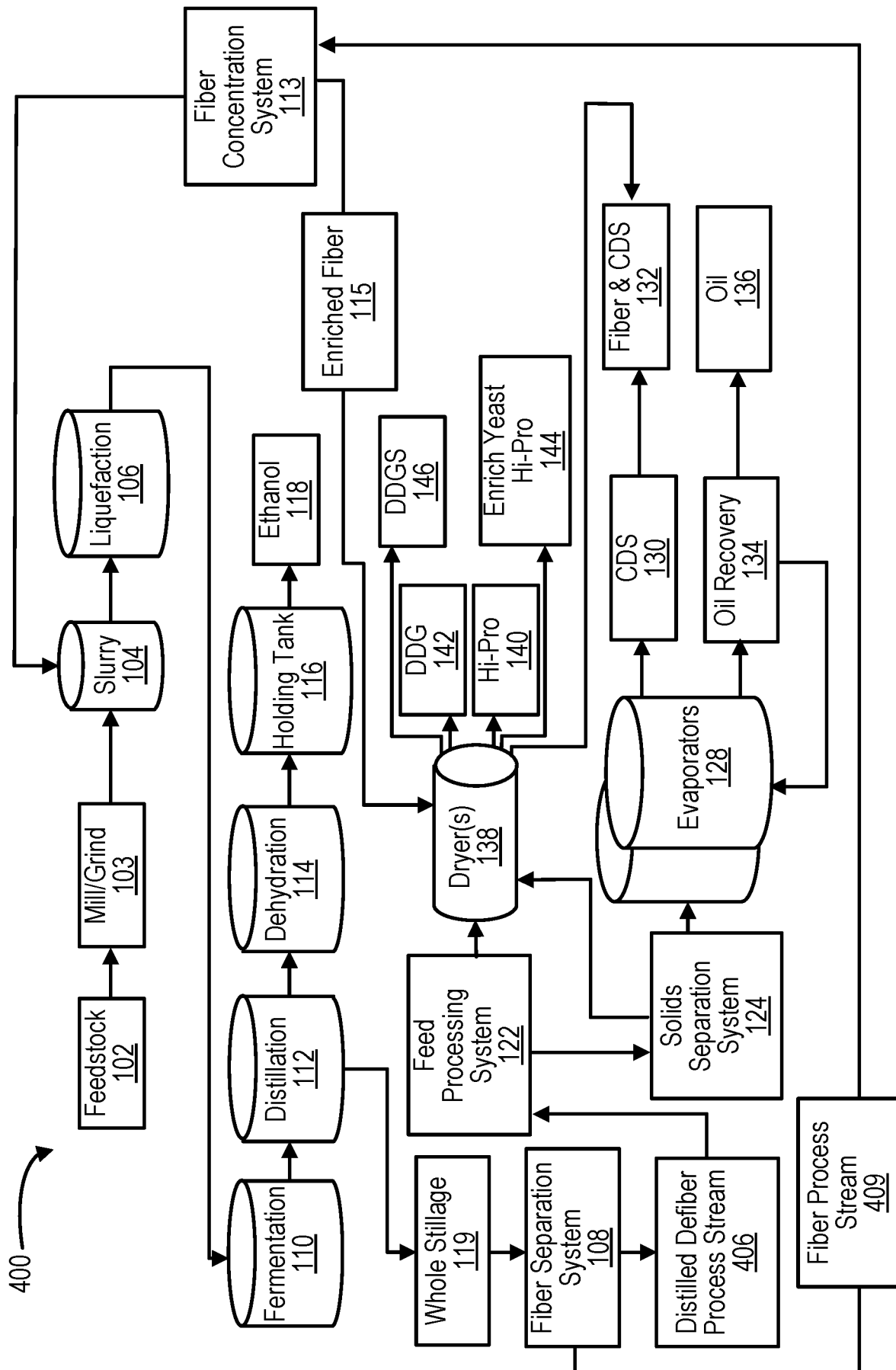


FIG. 4

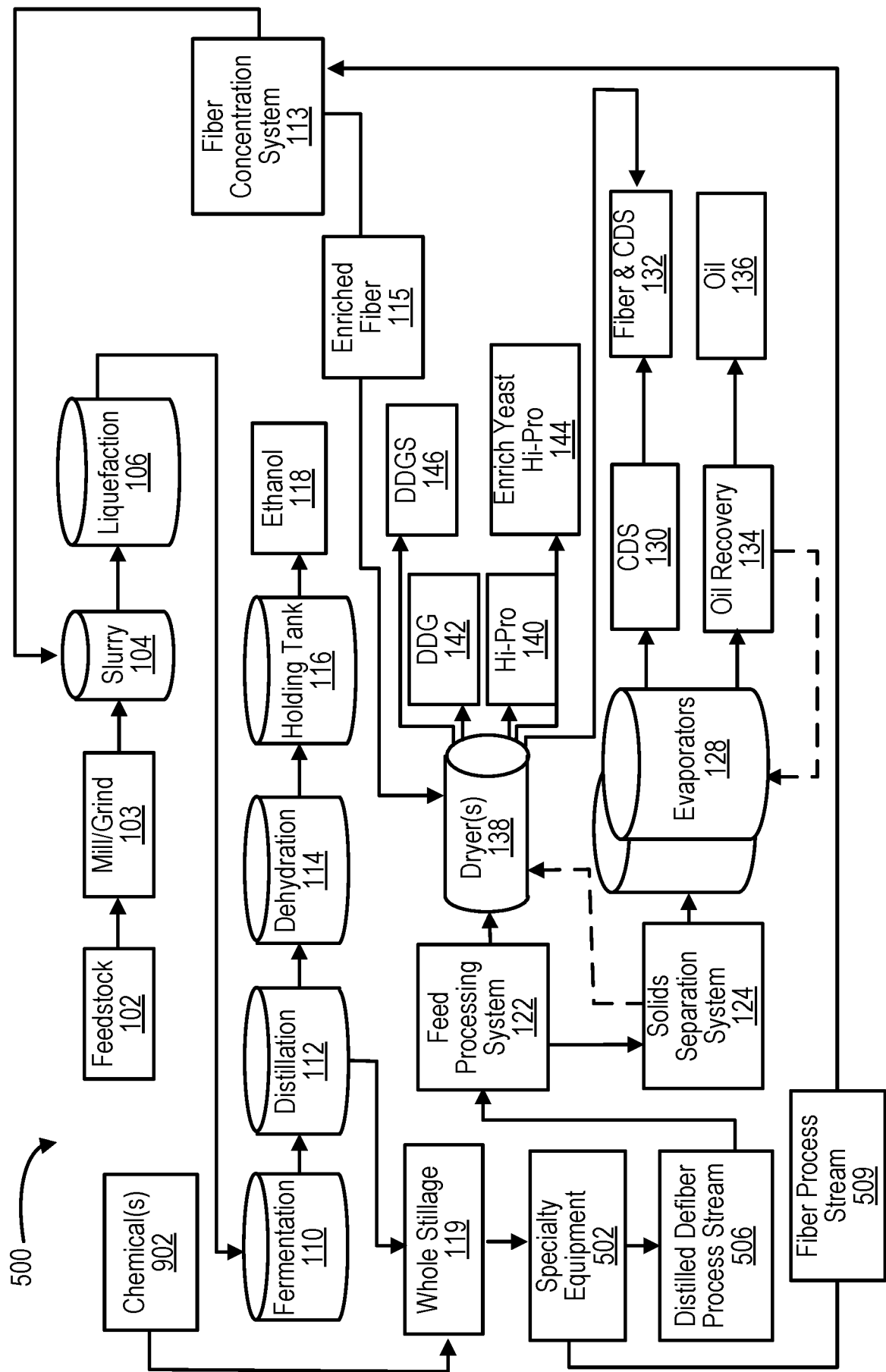


FIG. 5A

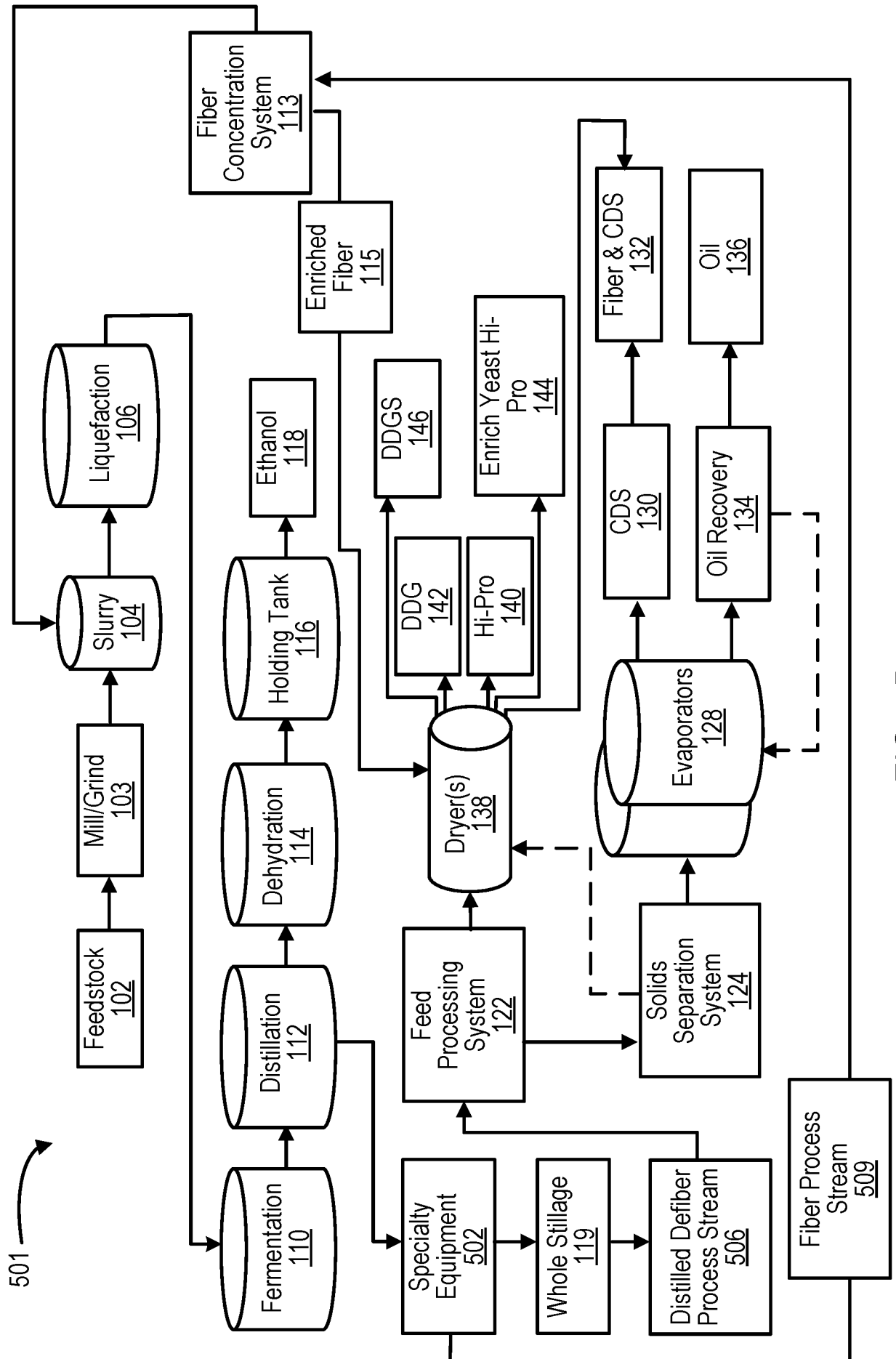


FIG. 5B

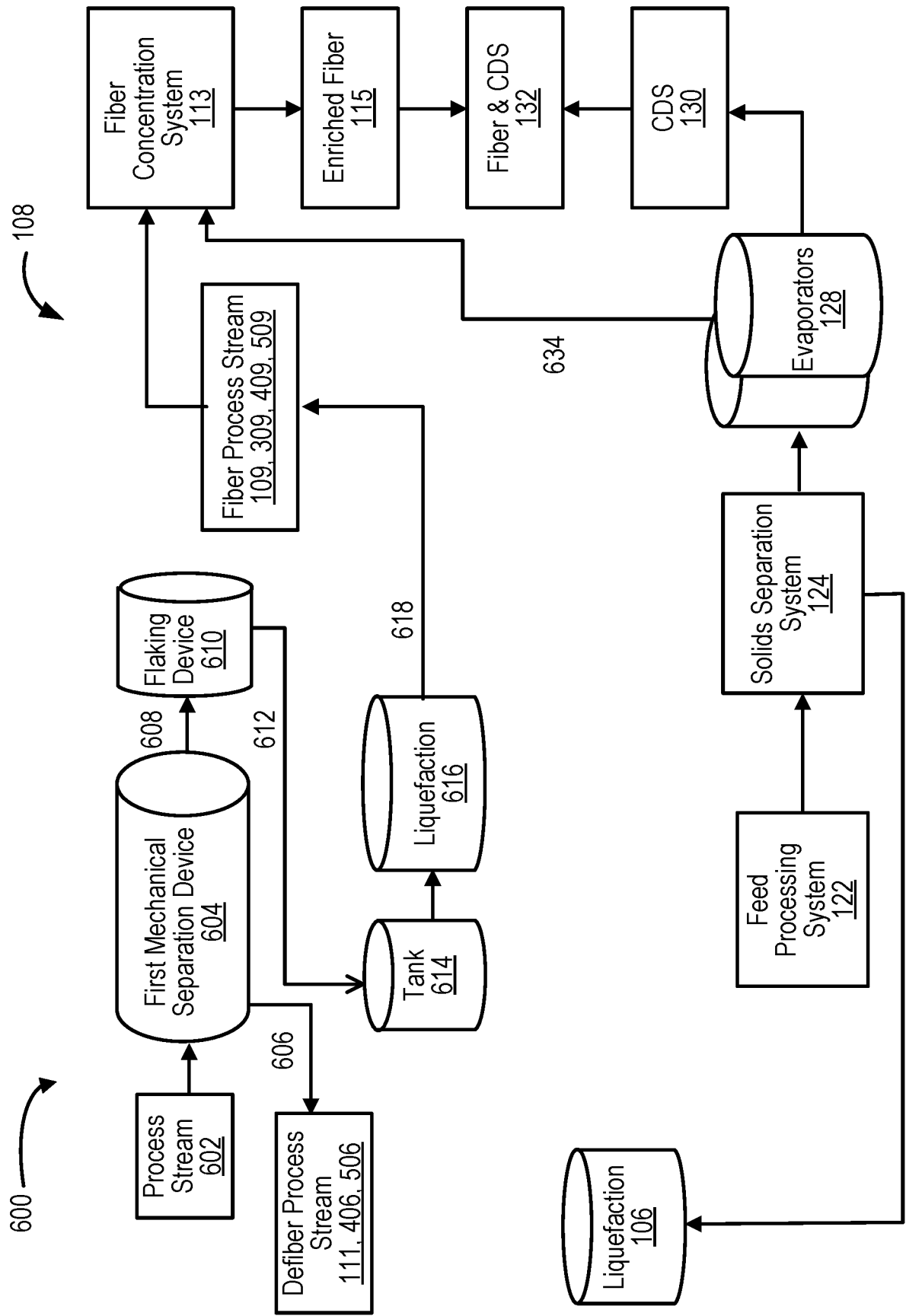


FIG. 6

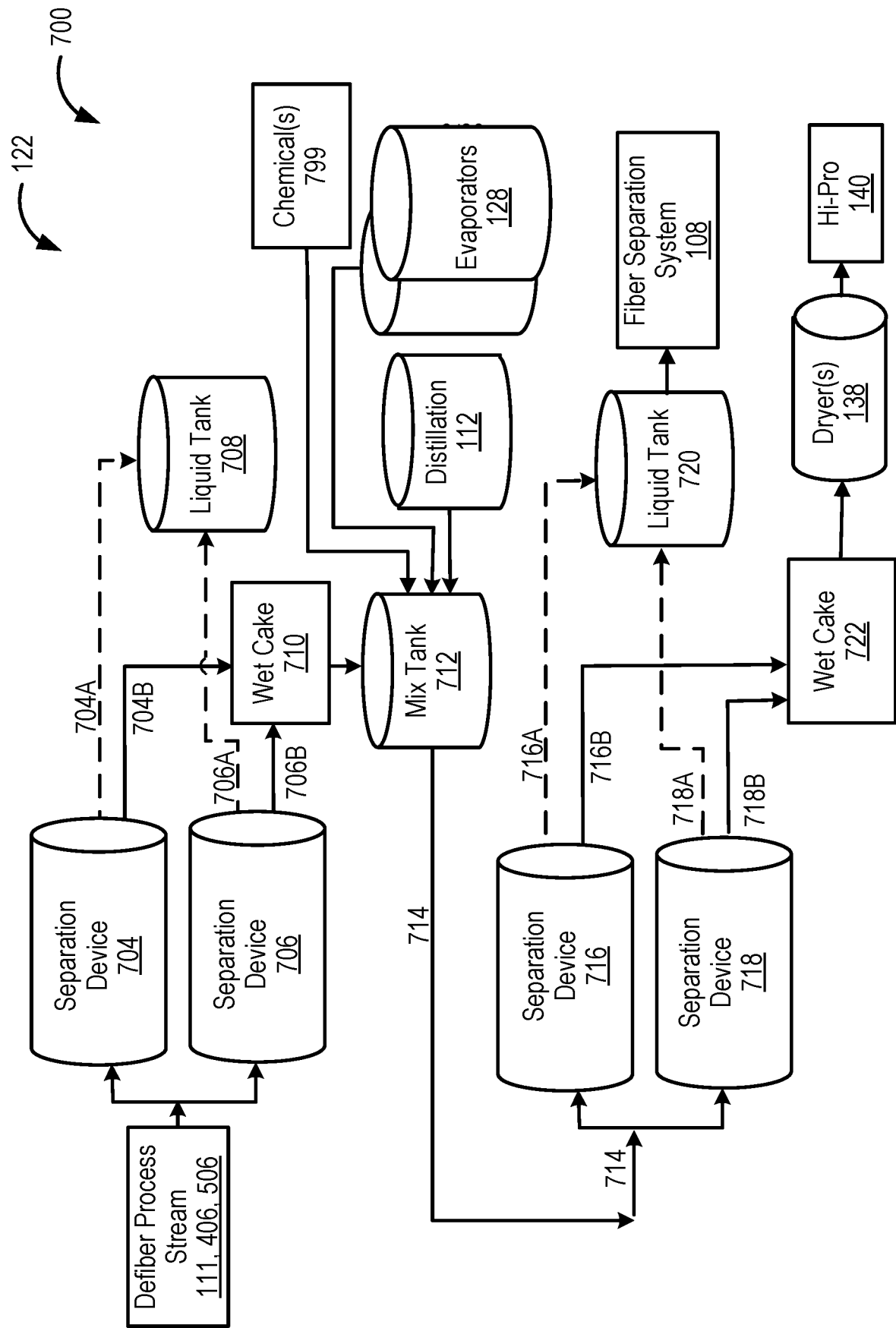


FIG. 7

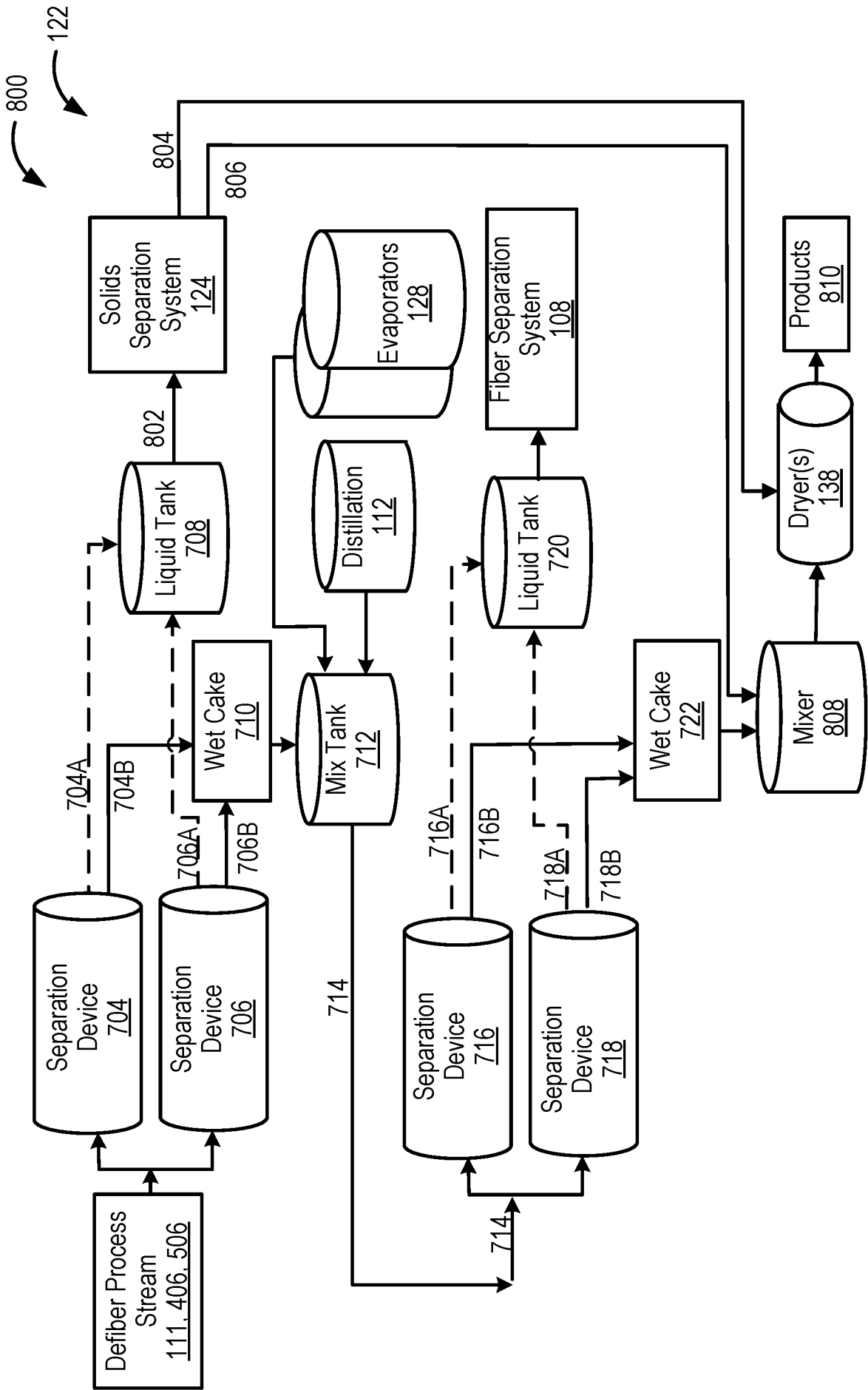


FIG. 8

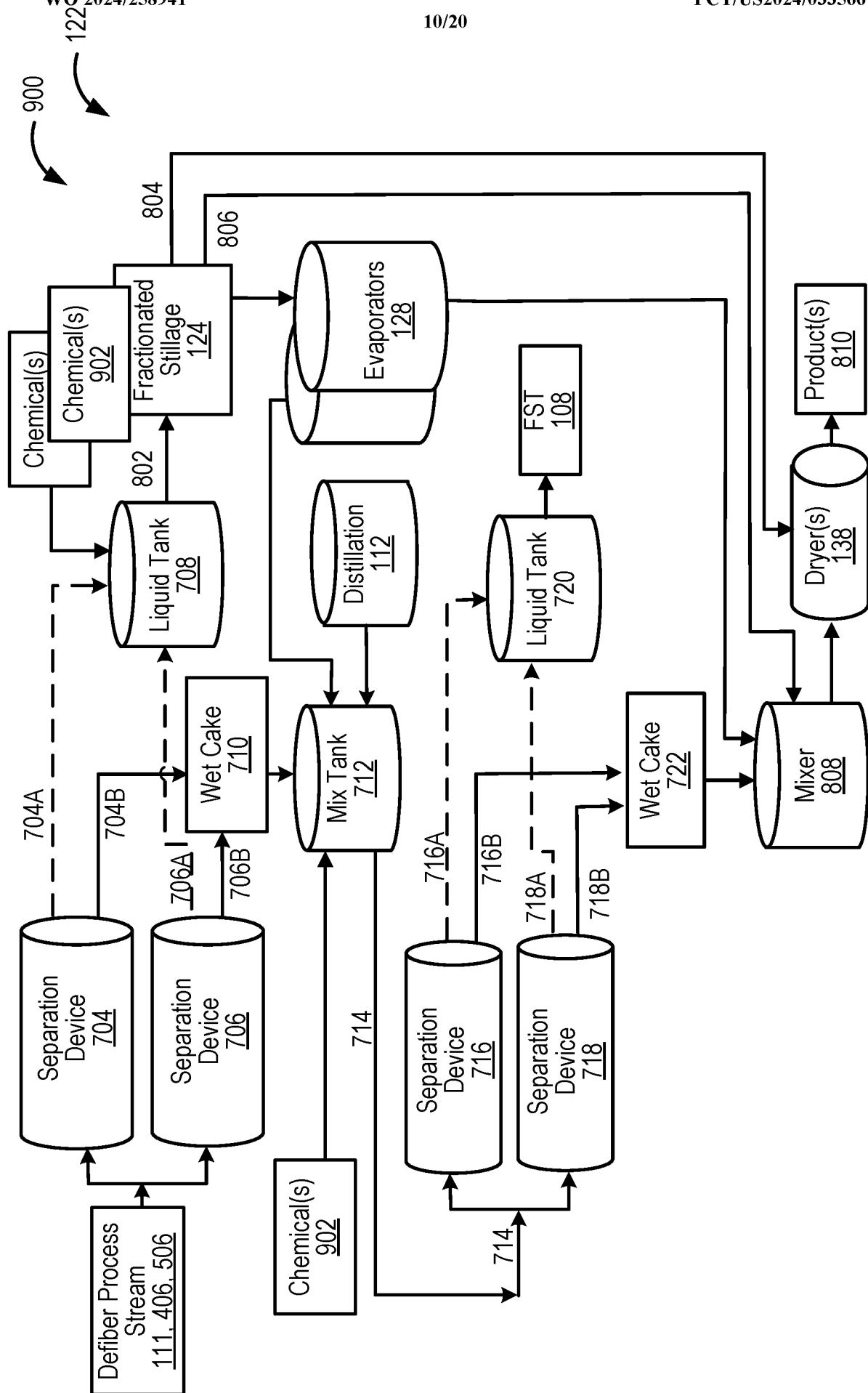


FIG. 9

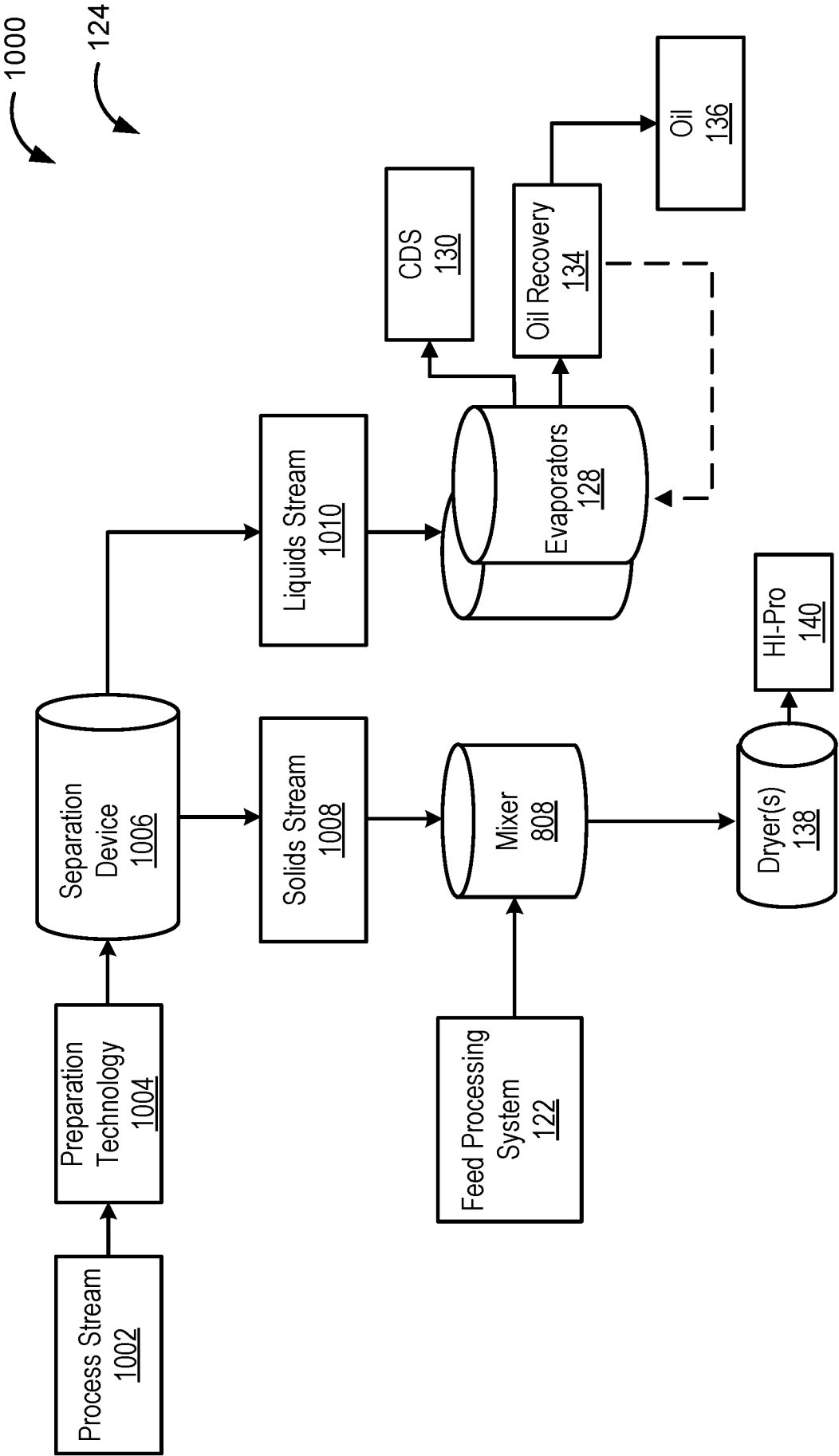


FIG. 10

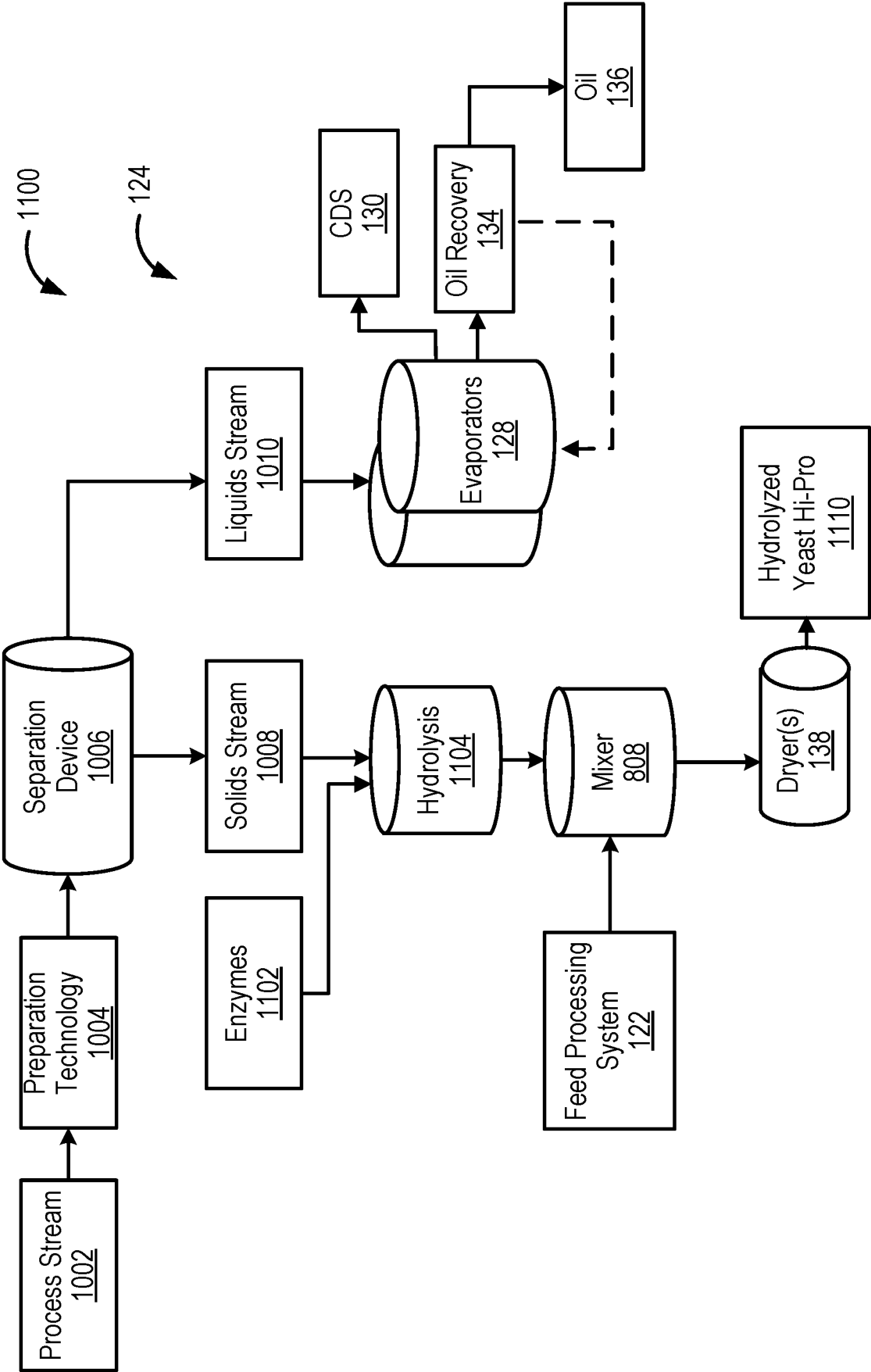


FIG. 11A

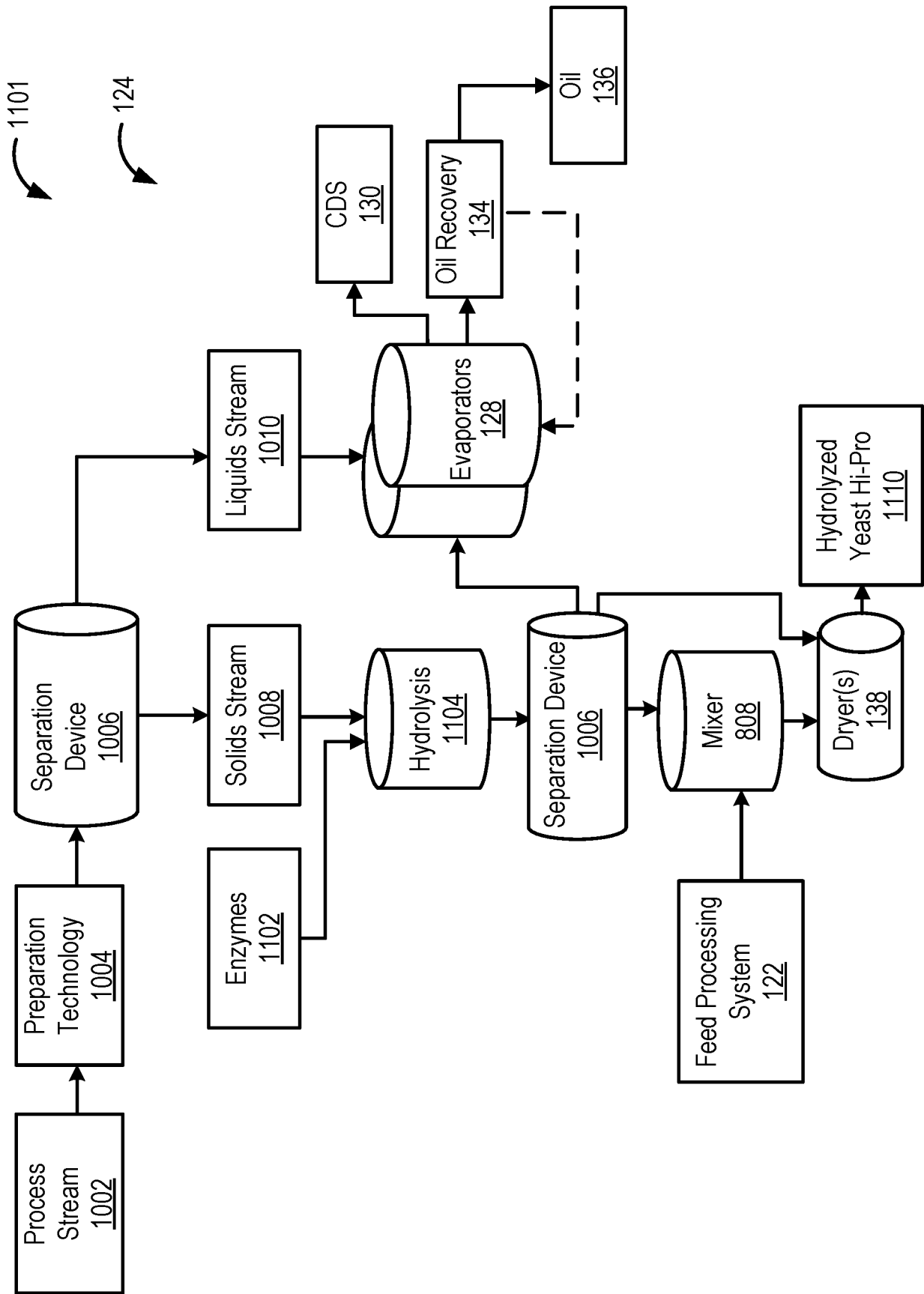


FIG. 11B

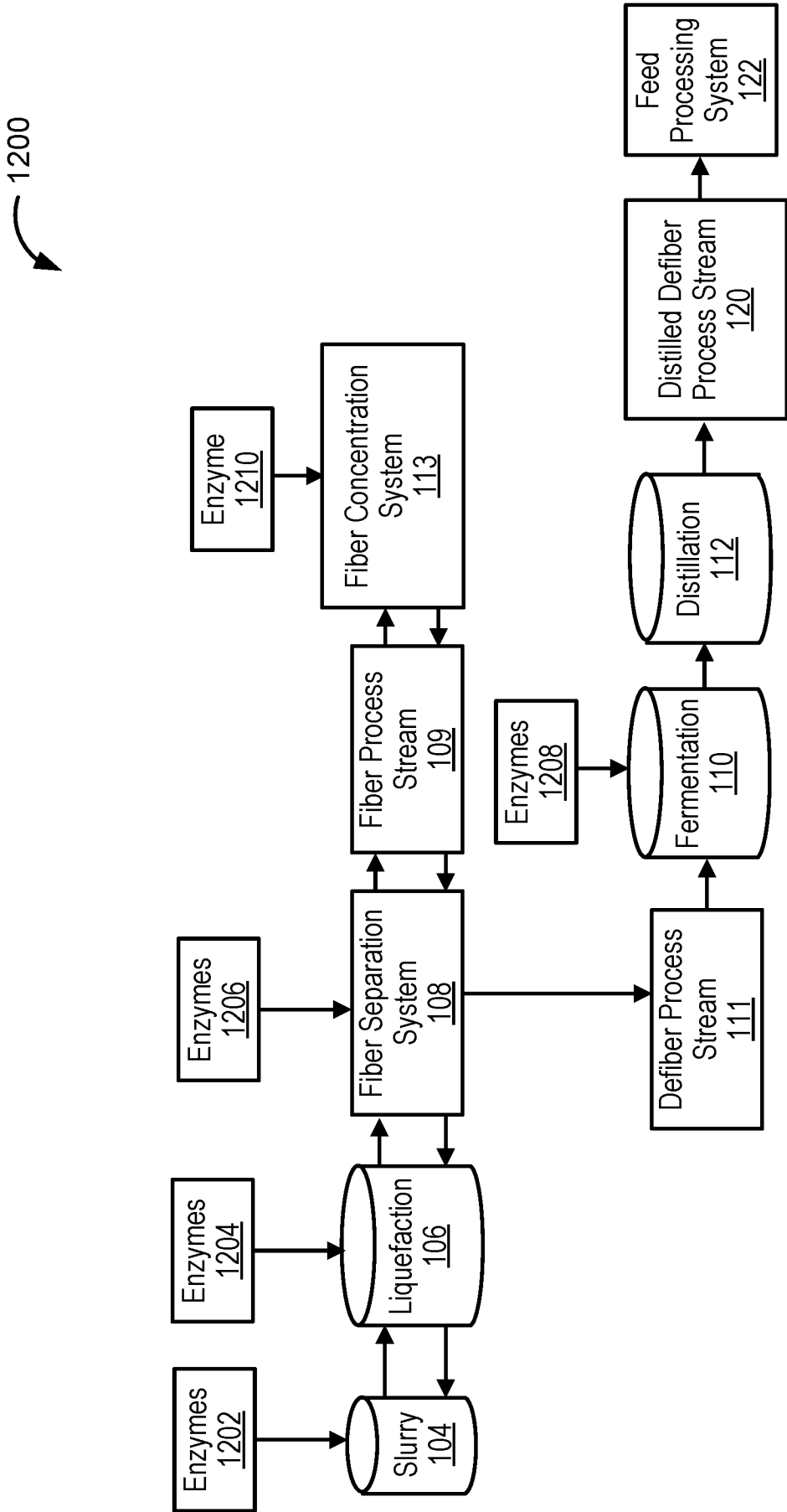


FIG. 12

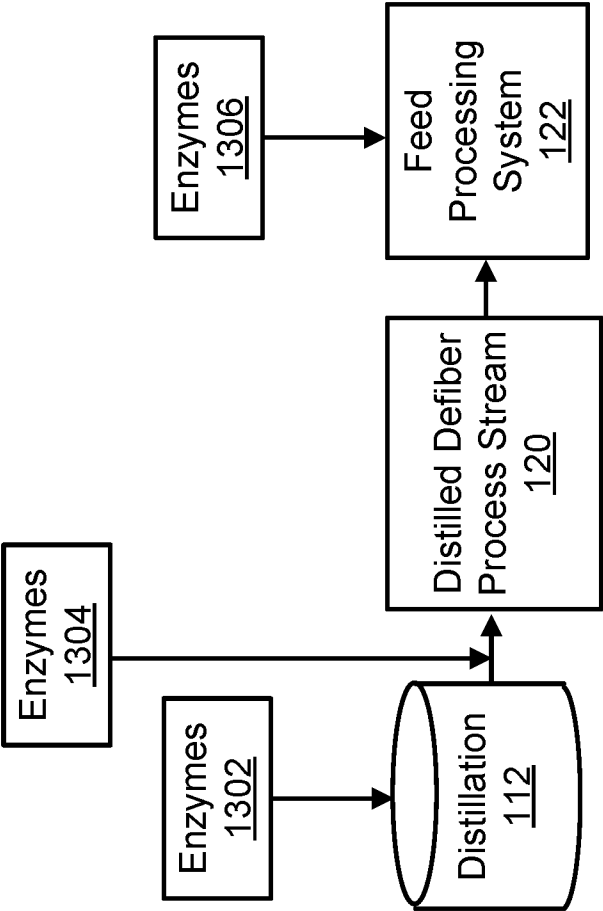


FIG. 13

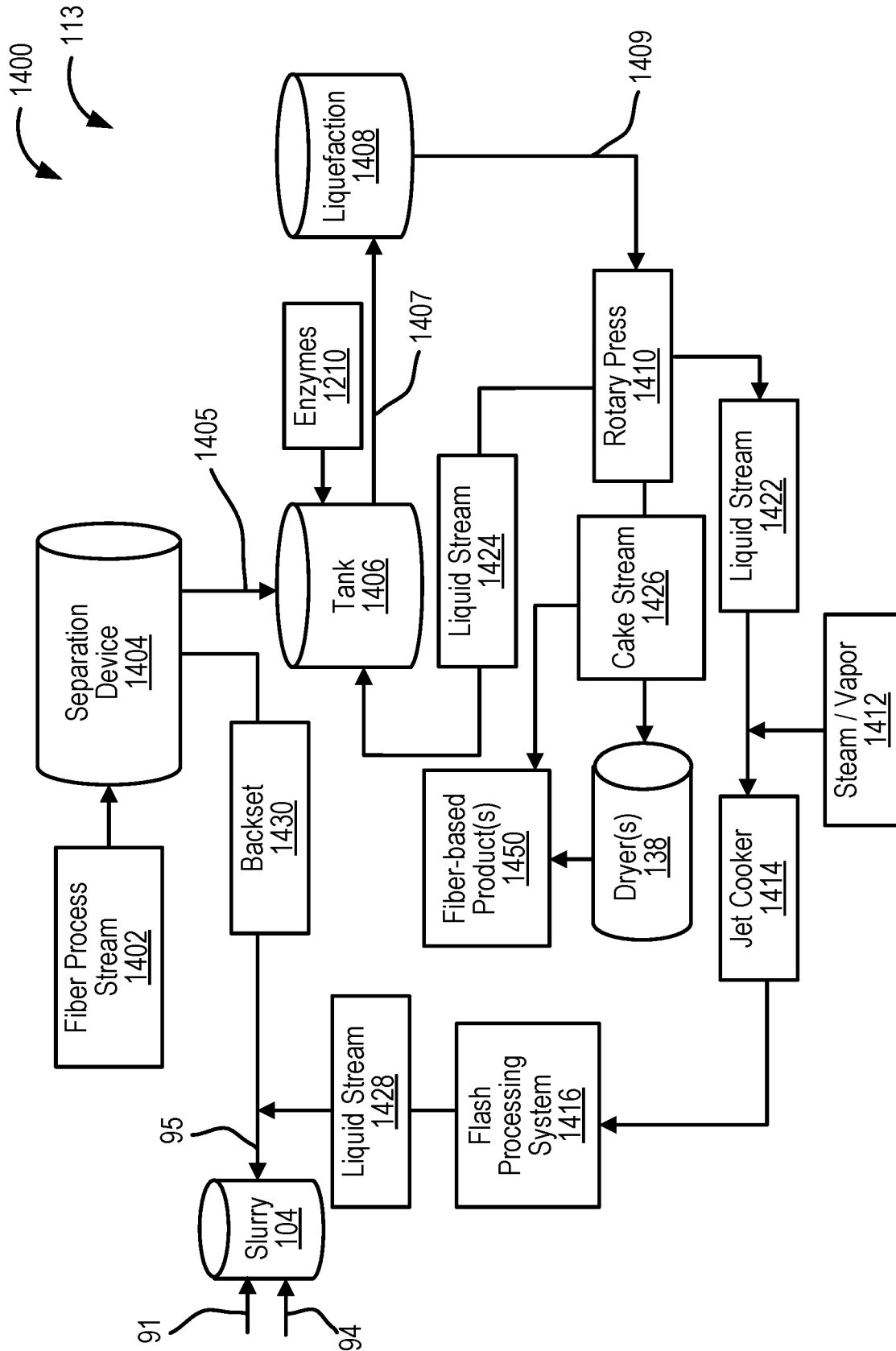


FIG. 14A

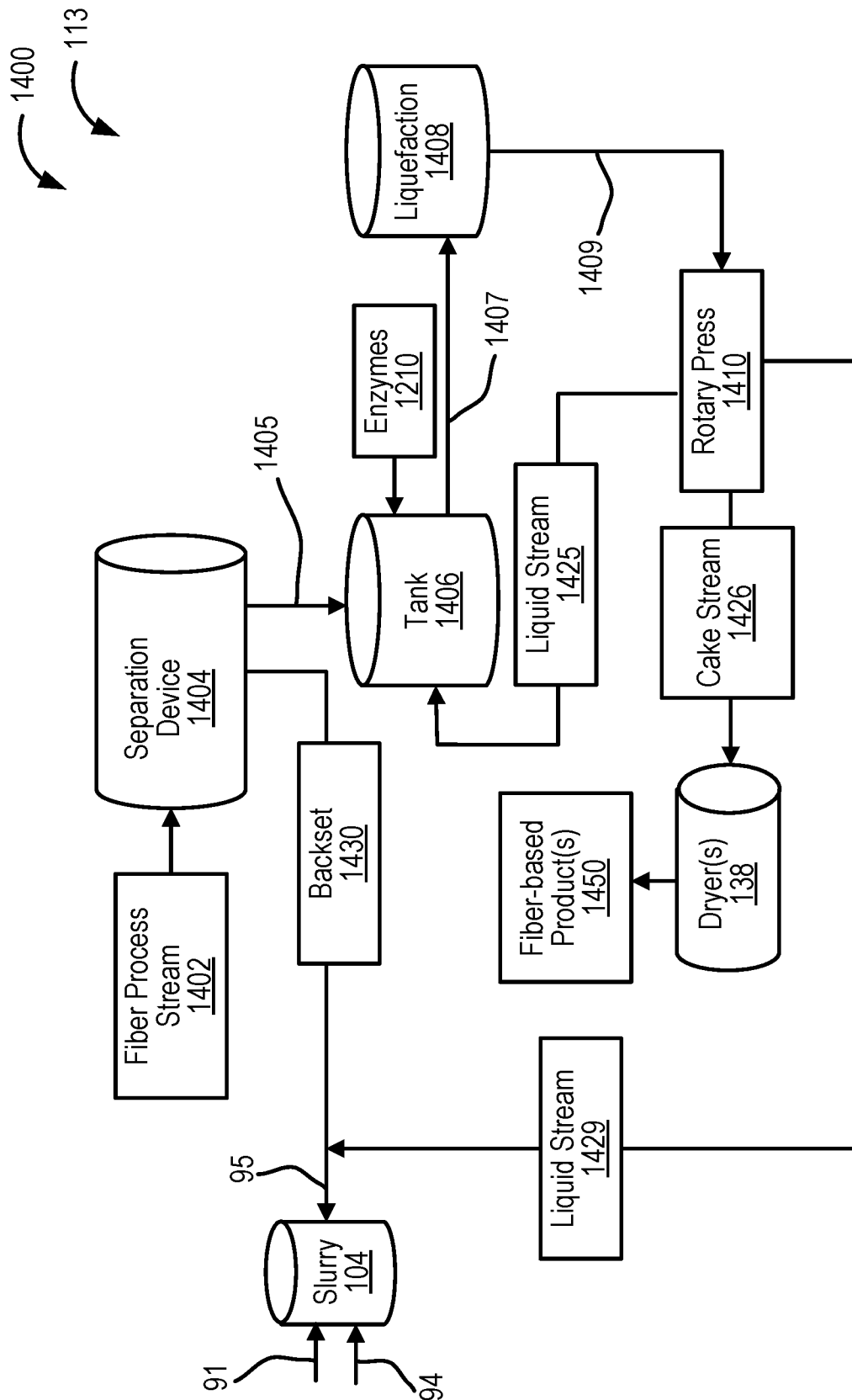
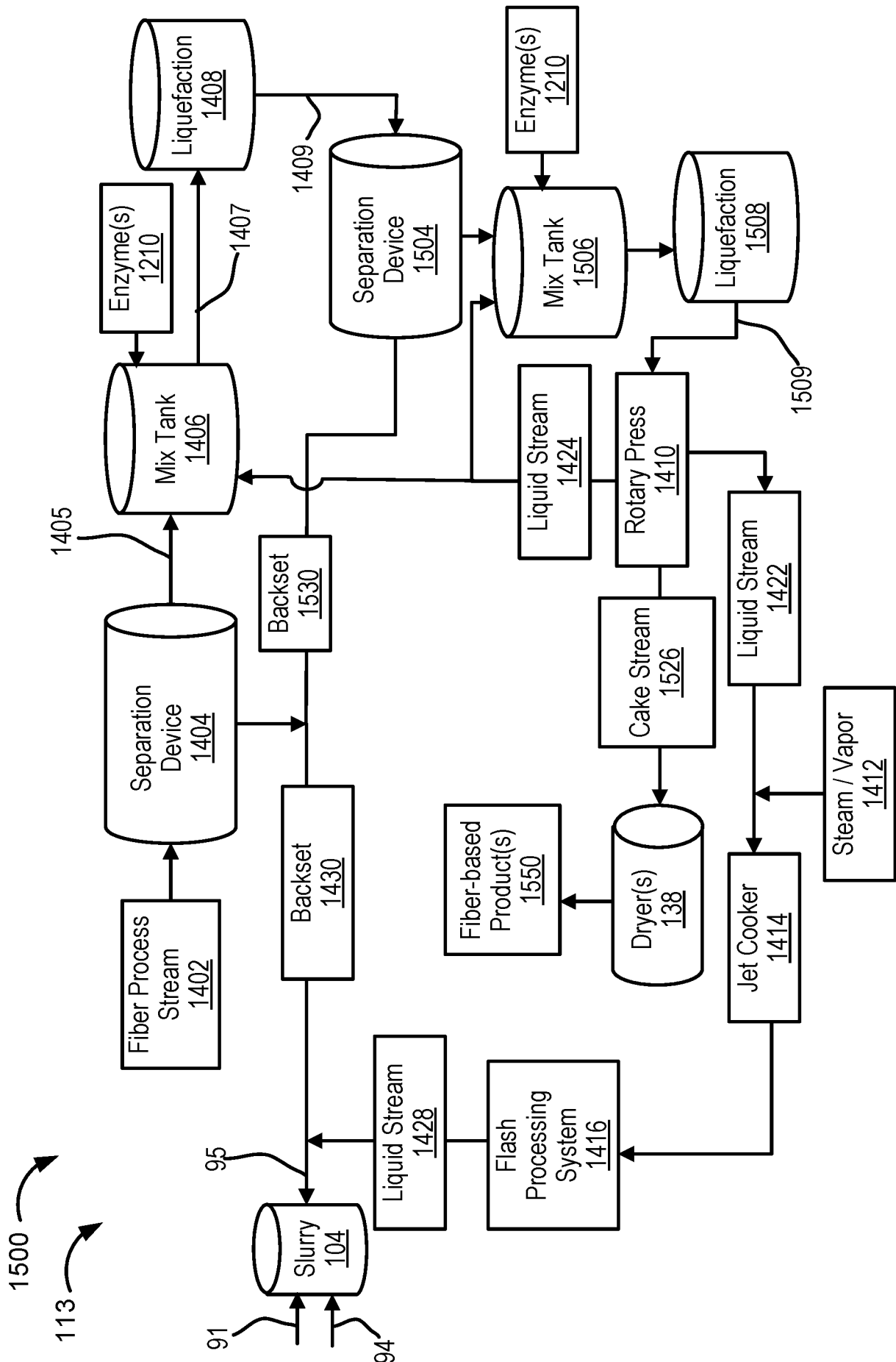


FIG. 14B



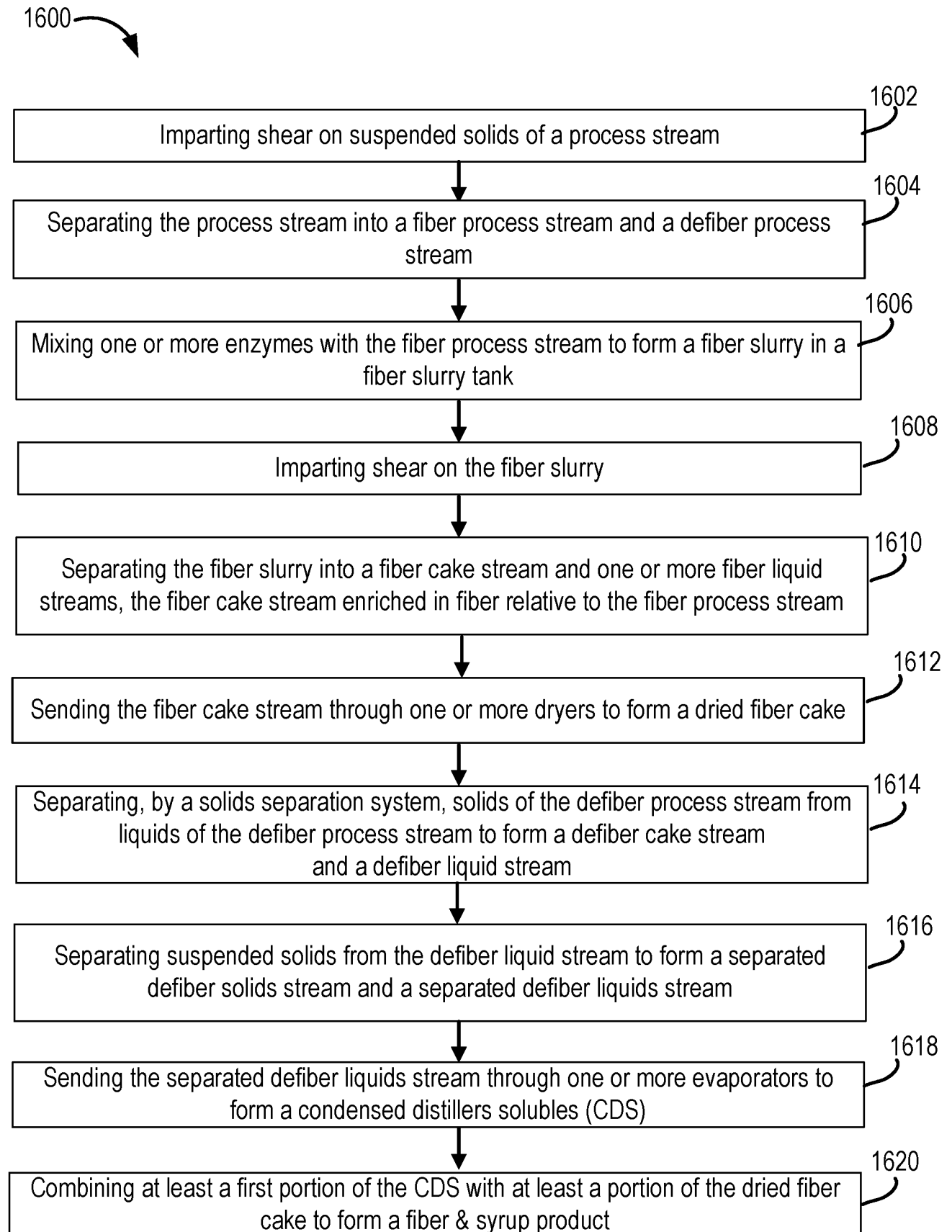


FIG. 16

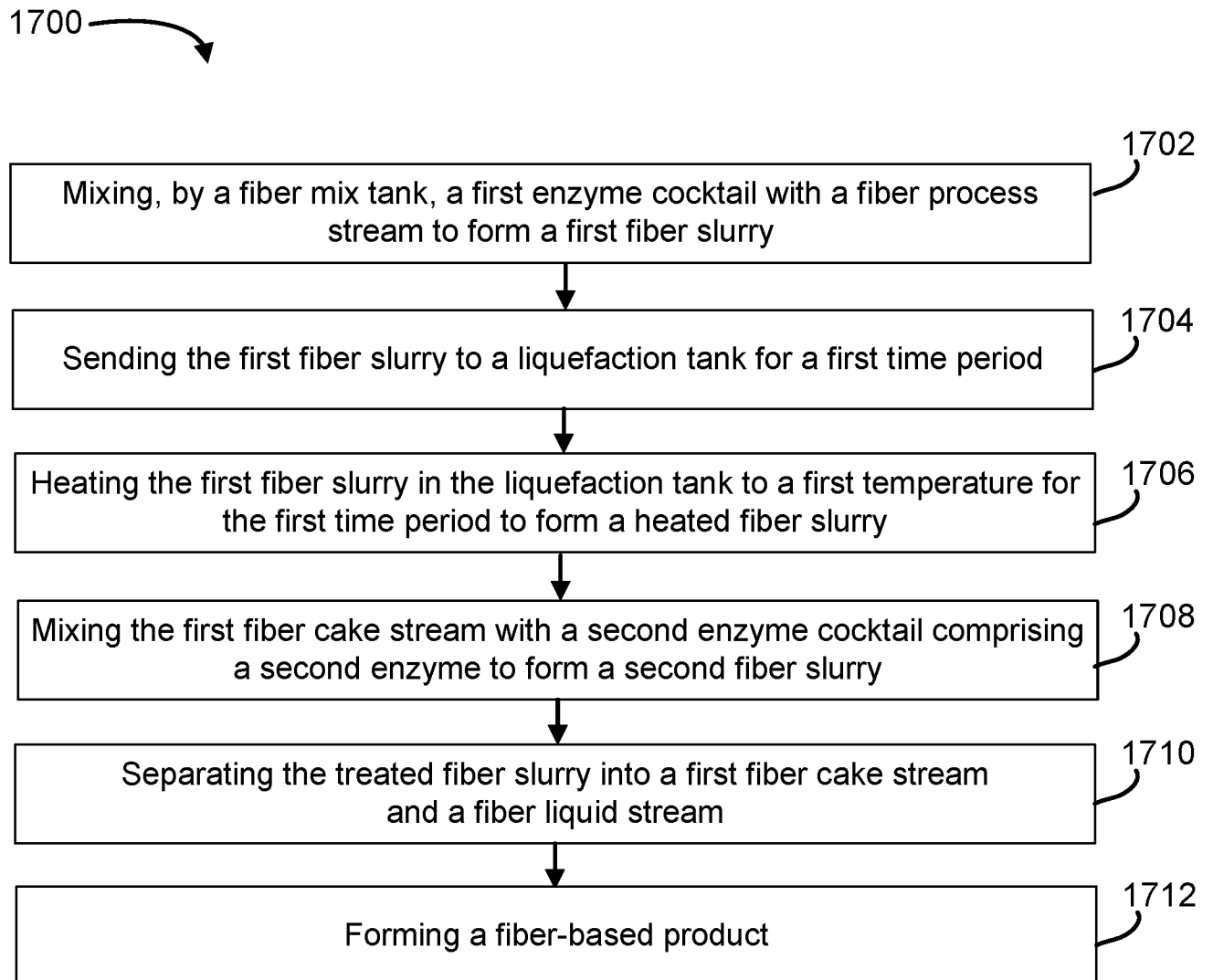


FIG. 17