

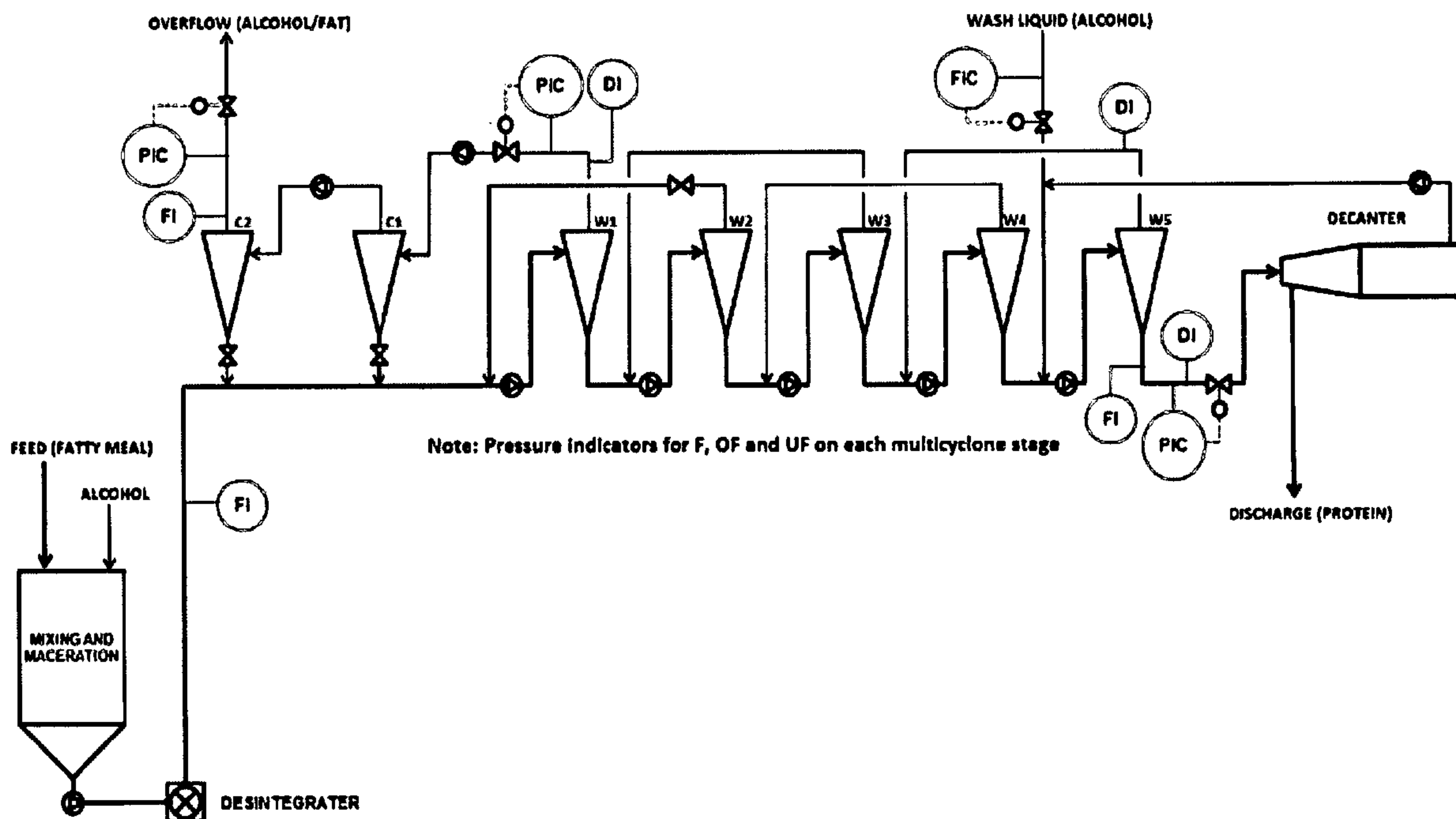


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(54) Titre : EXTRACTION DE LIPIDES DANS DE L'ETHANOL A CHAUD A PARTIR DE MATIERES VEGETALES OU ANIMALES

(54) Title: HOT ETHANOL EXTRACTION OF LIPIDS FROM PLANT OR ANIMAL MATERIALS



(57) Abrégé/Abstract:

The present invention relates to a process for the production of a fat rich and a fat lean product from a plant or animal starting material, comprising the steps of: i) providing a particulate fat containing starting material, ii) mixing the particulate fat containing starting material with ethanol of at least 90 %w/w concentration, iii) heating the mixture, iv) subjecting the heated mixture to a hydrocyclone treatment to provide a fat reduced underflow stream and an overflow stream, v) recovering the fat lean product from the fat reduced underflow stream, vi) recovering the fat rich product from the overflow stream. The fat rich and the fat lean products are suited for use in human food or for animal feed products.

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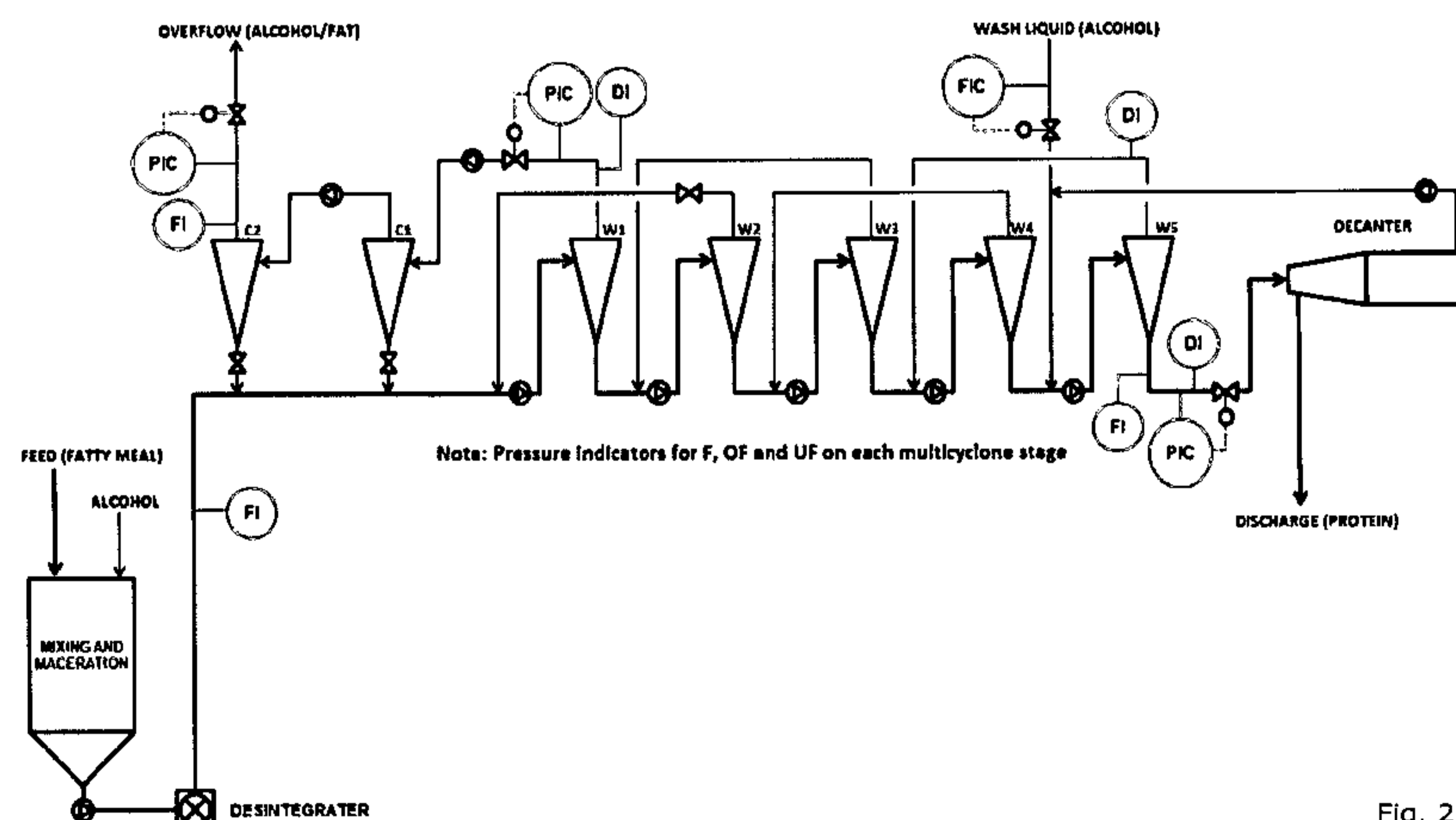


Fig. 2

(57) Abstract: The present invention relates to a process for the production of a fat rich and a fat lean product from a plant or animal starting material, comprising the steps of: i) providing a particulate fat containing starting material, ii) mixing the particulate fat containing starting material with ethanol of at least 90 %w/w concentration, iii) heating the mixture, iv) subjecting the heated mixture to a hydrocyclone treatment to provide a fat reduced underflow stream and an overflow stream, v) recovering the fat lean product from the fat reduced underflow stream, vi) recovering the fat rich product from the overflow stream. The fat rich and the fat lean products are suited for use in human food or for animal feed products.

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Hot ethanol extraction of lipids from plant or animal materials

Field of the invention

The present invention relates to a process for the production of a fat rich and
5 a fat lean product from a plant or animal starting material. The fat rich product may for example be an oil, and relevant starting materials may be derived from, slaughterhouse by-products, marine materials, such as fish or fish by-products, or oil seeds. The fat rich and the fat lean product may be of food grade and may thus be employed in human food or for animal feed products.

10

Background

In general several industrial scale techniques for the production of food grade oils or fats exist. Certain starting materials may be treated simply by pressing in order to provide an oil product from the material. However, other starting
15 materials, e.g. oil seeds, typically require solvent based extraction to separate fats and oils from the material. Due to the hydrophobic nature of fats and oils these are commonly efficiently extracted with non-polar solvents, such as hexane. Non-polar solvents are generally incompatible with products for human or animal consumption and must carefully be removed from the
20 extracted product to avoid the presence of potentially toxic or carcinogenic residues in the product. Furthermore, the use of such solvents represents a potential environmental hazard and may also be hazardous due to the risk of fire or explosions. Certain starting materials may furthermore be dehydrated prior to extraction of oil or fat. Several dehydration techniques are known in
25 the art and typically comprise application of heat to remove water from the starting material. Another approach to dehydrate a fat containing starting material is the so-called Carver-Greenfield process described in US 3,323,575.

US 4,486,353 provides a method for extracting vegetable oil and fat
30 from a flaked oleaginous material. The method of US 4,486,353 may involve an initial step of drying the oleaginous material, which is in the form of flakes. Subsequently the flakes of the oleaginous material are contacted with ethanol of at least 90% purity and at a temperature between 70°C and the

boiling point to obtain miscella. The miscella are cooled to form an oil and defatted miscella. The ethanol may be removed from the defatted miscella to be recycled in the extraction. The method of US 4,486,353 is limited to be operated at a temperature up to the boiling point of the ethanol solution,
5 since the evaporation of ethanol will otherwise be too violent.

US 4,211,695 provides a process for the treatment of comminuted oats so as to effect separation of the comminuted oats into fractions differing in composition, which comprise an oil fraction. The process of US 4,211,695 involves admixing with and forming a slurry of comminuted oats in an organic
10 solvent, which solvent is capable of extracting oat oil from the oats. The slurry is then subjected to the influence of centrifugal force to separate the comminuted oats in the slurry into at fractions. A preferred solvent is hexane, and when the slurry has been centrifuged the oil may be recovered by removal of the hexane. Preferred centrifugal separation are hydrocyclones and
15 continuous centrifuges, such as a solid bowl centrifuge equipped with a screw conveyor. Heat treatment of the oats is avoided in US 4,211,695 to facilitate separation of products of differing protein content. The process of US 4,211,695 relies on hexane as a solvent and the choice of centrifugal separation appears to be based on characteristics of the particulate matter to
20 be separated from the slurry, so that no specific advantages for the specified centrifugal separation principles employed are indicated.

There is thus a need to provide an improved process for the production of oil and other products from animal and plant starting materials. In particular, there is a need to provide a robust scaleable technology capable of efficiently producing food grade products at a reduced environmental risk. The
25 present invention addresses one or more of these aims.

Summary of the invention

A first aspect the present invention relates to a process for the production of
30 a fat rich and a fat lean product from a plant or animal starting material. The process comprises the steps of:

- i) providing a particulate fat containing starting material,
- ii) mixing the particulate fat containing starting material with ethanol of at least 90 %w/w concentration,

- iii) heating the mixture,
- iv) subjecting the heated mixture to a hydrocyclone treatment to provide a fat reduced underflow stream and an overflow stream,
- v) recovering the fat lean product from the fat reduced underflow stream,
- 5 vi) recovering the fat rich product from the overflow stream.

The present inventors have surprisingly found that fat and oil may be efficiently extracted from a fat containing material in a hydrocyclone using ethanol as the extractant.

10 The solubility of oil/fat in ethanol is depicted in Figure 1, which shows the solubility as a function of temperature for different concentrations of ethanol in water. As is clear from Figure 1 the solubility is dependent on temperature and water content, and as the temperature increases the solubility of fat increases exponentially. Thus, for example for absolute ethanol (i.e. 15 99.9 %w/w) the exponential increase in solubility sets in at a temperature of about 60°C, whereas for lower concentrations of ethanol the exponential increase sets in at a temperature above the boiling point.

Conventional solvent extractors as used in the commercial bulk extraction of oil seeds are not suited for the extraction of meals using hot ethanol, 20 as the meal compacts and clogs the perforated product cells and as it is a relatively open construction not ideally suited for operating with solvents at, near or above the boiling point.

The present invention utilises the finding, that hydrocyclones may be employed with hot ethanol, e.g. near or at or even above the boiling point. A 25 hydrocyclone is designed to separate particles from a liquid, but the design and operation also allows the liquid phase in the hydrocyclone to extract matter from a solid, particulate material. Thus, the hydrocyclone allows processing of a mixture of a particulate fat containing starting material and ethanol, which is heated close to or above its boiling point to efficiently extract fat and 30 oil into the ethanol while separating the fat reduced particulates from the ethanol/fat phase. The fat reduced particulates are present in the underflow from which the fat lean product can be recovered, while the fat rich product can be recovered from the ethanolic overflow stream. In summary, hydrocyclones are particularly suited, since one or more of the following advantages 35 may be obtained:

- they are totally enclosed and can be operated at elevated pressure;
- they are suitable for handling product milled into very fine particles, which also facilitates fast extraction rates;
- they can operate in counter-current configuration;
- 5 -they allow a high throughput and exhibit fast start-up and close down;
- small solvent volumes reduce explosion and fire hazards.

In general, the higher the temperature the more efficient the extraction, and the temperature should be at least 60°C, although it is preferred
 10 that the temperature is at least 65°C, at least 70°C, such as at least 80°C, at least 90°C, or at least 100°C. A generally preferred range of temperatures is from 70°C to 95°C, regardless of the ethanol concentration. Likewise, the higher the ethanol concentration the more efficient the extraction of fat. It is preferred that the ethanol concentration is at least 95 %w/w, such as at least
 15 98 %w/w, at least 99 %w/w, or at least 99.5 %w/w. In general, there is no upper limit for the temperature, although the temperature may be controlled to be lower than 130°C in order to secure safe operation of the hydrocyclone. Particularly preferred combinations of ethanol concentrations and temperatures are summarised in Table 1.

20

Table 1 Exemplary combinations of ethanol concentration and temperature

Ethanol concentration	Temperature
95.6 %w/w (azeotropic)	90°C to 100°C
98 %w/w	75°C to 85°C
99 %w/w	70°C to 80°C
99.9 %w/w (absolute)	65°C to 70°C

The feed pressure of the mixture applied to the hydrocyclone may be
 25 any value appropriate for the hydrocyclone type and size employed. The feed pressure will typically be in the range of from about 1 bar to about 10 bar, e.g. from about 4 bar to about 8 bar. The pressure drop between the feed and the overflow will typically be from about 1 bar to about 8 bar, e.g. from about 3 bar to about 6 bar, such as about 4 bar.

Any fat containing starting material of plant or animal origin may be processed according to the invention. Appropriate plant materials are plants conventionally used as raw materials for oil extraction, such as oil seeds. Materials of animal origin may be from any land or marine animal, and the starting material
5 may be dehydrated meat or meat by-product, fish or fish material, such as by-product from industrially processed fish or whole fish or parts of fish.

The solids content of the mixture of the fat containing starting material and the ethanol will typically be between 10 %w/w and 30 %w/w, such as about 20 %w/w.

10 It is advantageous for the process of the invention that the fat containing starting material has a low water content, such as 3 %w/w or less. When the starting material has a water content below 3 %w/w it is possible to avoid dehydrating side streams in the process of the invention so that the side streams may be recycling directly in the process. In an embodiment of the invention the
15 process thus further comprises reducing the water content of the particulate fat containing starting material to below 3 %w/w in the steps of:

a) mixing the particulate fat containing starting material with 1 to 20 parts fat or oil to obtain a slurry,

20 b) heating the slurry to evaporate water and to obtain a water reduced slurry,

c) subjecting the water reduced slurry to a solid-liquid separation to provide the particulate fat containing material having a water content below 3 %w/w and an oil or fat fraction. The solid-liquid separation may be decanter technology.

In particular, step b) may be performed as a multi-step process comprising
25 subjecting the water reduced slurry to sequential heat treatments, where each subsequent heat treatment is performed at a lower temperature than the preceding heat treatment. The dehydration process, also known as the "Carver-Greenfield process", is described in more detail in US 3,323,575, in particular from column 6, line 35 to column 8, line 49. This dehydration processing is advantageously
30 compatible with the hydrocyclone extraction process. Despite it that the Carver Greenfield process has been known for more than 45 years it has not

gained very widespread use, probably due to the fact that high levels of fat/oil may be absorbed in the dehydrated solids during the dehydration processing. However, in the present invention absorption of fat/oil is not considered problematic since the fats/oils are efficiently extracted in the following hydrocyclone processing. In a preferred embodiment the fat or oil mixed with the particulate fat containing starting material is derived from the fat rich product produced according to the process of the invention. This allows that an integrated process is set up where a stream of the fat rich product produced in the process of the invention is diverted to the dehydration process so that no external source of fat or oil is required in the dehydration step. The fat rich product may readily be recovered again from the oil phase after the dehydration processing.

In a specific embodiment of the invention the dehydration process is performed as a multi-step process comprising subjecting the water reduced slurry to sequential heat treatments, where each subsequent heat treatment is performed at a lower temperature than the preceding heat treatment. Adding several volumes of fat to a fine particulate solid makes a suspension, which will remain liquid even after removal of water. Hereby it is possible to utilise multi-effect evaporation equipment as dehydrating systems, thereby benefiting that energy consumption is reduced to 50% in a two effect system and down to only 33% in a 3 effect system. Thus, the dehydration process allows efficient control of the water content of the particulate fat containing starting material without requiring excessive heating. Since absolute ethanol has dehydration properties and readily absorbs water, it is advantageous that the starting material to be extracted has low water content. The Carver Greenfield oil drying process is very efficient in reaching near zero water levels in dehydrated products, e.g. reducing the water content to 3 %w/w or less, such as 1 %w/w. The combination of Carver Greenfield with hot-ethanol extraction is therefore optimal.

The fat rich product may be separated from the overflow of the hydrocyclone using any appropriate technology. The overflow stream will generally comprise a hot solution of fat / oil in ethanol, which can form a two-phase system simply upon cooling. This unique property is utilised in this invention, where the mere lowering the temperature of the ethanol-fat solution results in the formation of two layers, the lower heavier layer consisting mainly of

fat/oil with 4-5% ethanol content only. In general, a temperature below 40°C will be sufficient to create the two phases, although a temperature in the range of 10°C to 30°C, e.g. about 25°C is preferred. There is generally no lower limit to the temperature, although for practical reasons it should be
5 above 0°C. Thus, in a specific embodiment of the invention the process further comprises the steps of:

- cooling the overflow stream of the first hydrocyclone to a temperature of 40°C or below to form an ethanolic upper phase and a lower phase,
- recovering the fat rich product from the lower phase, and
- 10 -optionally recycling the ethanolic upper phase in step ii).

When the process employs ethanol of high concentration, e.g. azeotropic ethanol, and the starting material has a water content below 3 %w/w the lighter upper phase will remain undiluted and can be recycled to the extractor without further dehydration. However, if required the ethanolic
15 upper phase may also be dehydrated before recycling the ethanol in step ii). Any method of dehydration of the ethanolic phase may be employed, such as molecular sieving using a zeolite. Other technologies for ethanol dehydration are well-known to the skilled person.

The fat reduced product may be recovered from the underflow of the
20 hydrocyclone using any technology as appropriate. For example, the underflow may be subjected to centrifugal separation, e.g. in a decanter centrifuge, to provide the fat reduced product. The composition of the fat reduced product will depend on the fat containing starting material. Thus, for example, when the starting material is a slaughterhouse by-product the fat reduced
25 product may be a protein product. A protein product may also be provided when the fat reduced product is an oil seed. Regardless of the nature of the fat containing starting material the fat reduced product may be subjected to any further processing as desired.

The process of the invention may employ a single hydrocyclone. How-
30 ever, in another embodiment the heated mixture is subjected to a sequential counter current processing in a series of hydrocyclone stages. In this embodiment, the fat reduced underflow stream of a hydrocyclone stage is fed to a down-stream hydrocyclone stage of the series, and the overflow stream of a hydrocyclone stage is fed to an up-stream hydrocyclone stage in the series,
35 and the fat lean product is recovered from the fat reduced underflow stream

of the last hydrocyclone stage of the series, and the fat rich product is recovered from the overflow stream of the first hydrocyclone stage of the series. In general, the feed stream to a hydrocyclone in the series will thus comprise the underflow stream from its up-stream hydrocyclone, which has been
5 pooled with the overflow stream of its down-stream hydrocyclone. For example, when the process comprises N serially connected hydrocyclone stages the heated mixture is fed to a first hydrocyclone stage to provide a first fat reduced underflow stream and a first overflow stream, the first fat reduced underflow stream is then fed to a second hydrocyclone stage to provide a
10 second fat reduced underflow stream and a second overflow stream, and subsequently for hydrocyclone stage n , where $n=2$ to $N-1$ the process comprises

-feeding the fat reduced underflow stream of hydrocyclone stage n together with the overflow of hydrocyclone stage $n+2$ to hydrocyclone stage
15 $n+1$, to provide a fat reduced underflow stream $n+1$ and an overflow stream $n+1$,

-feeding the overflow stream $n+1$ to hydrocyclone stage n together with the underflow from hydrocyclone stage $n-1$,

-recovering the fat lean product from the fat reduced underflow stream
20 of hydrocyclone stage N ,

-recovering the fat rich product from the first overflow stream.

The feed to hydrocyclone N , where there is no down-stream hydrocyclone, comprises the underflow stream of hydrocyclone stage $N-1$ optionally together with a washing liquid. Hydrocyclone stage N provides the underflow
25 stream from which the fat lean product may be recovered.

When the method comprises only a single stage this may be referred to as the first stage, and thus the overflow stream of this stage may be referred to as the overflow of the first stage, and the underflow stream of this stage may be referred to as the underflow stream of the first stage.

30 In general, the more hydrocyclone stages in a series the more efficient the extraction of fat from the starting material. The number of hydrocyclone stages, N , will typically be 3 or more or 4 or more. A preferred number of hydrocyclone stages in series is from 4 to 6. In further embodiments the heated mixture is subjected to hydrocyclone treatment in two or more hydro-
35 cyclones arranged in parallel, or each stage in a series of hydrocyclones com-

prises two or more hydrocyclones. Parallel hydrocyclone operation, e.g. that each stage comprises two or more hydrocyclones, allows easy scalability of the process. The process may for example comprise 50, 100, 250 or more hydrocyclones operated in parallel, e.g. each stage comprises 50, 100, 250 or
5 more hydrocyclones. Each stage of hydrocyclones in the process need not comprise the same number of hydrocyclones. In a certain embodiment the respective overflow and underflow streams from a specific stage of hydrocyclones are pooled before subjecting to an up-stream or down-stream stage, respectively, of hydrocyclone treatment. For example, when a stage com-
10 prises 100 hydrocyclones, the underflow streams may be pooled to represent the underflow stream of the stage and the overflow streams may be pooled to represent the underflow stream of the stage. This embodiment allows that each stage is scaled appropriately according to the mass of the stream to be treated. The pooled streams may be distributed, e.g. evenly, to the corre-
15 sponding next stage of hydrocyclone treatment according to the throughput provided by each hydrocyclone.

Any hydrocyclone may be employed in the invention. However, it is preferred that the hydrocyclone is of small scale. Thus, in an embodiment of the invention the diameter of the cylindrical upper part of the hydrocyclone is
20 25 mm or less, such as about 20 mm or about 15 mm or about 10 mm. Hydrocyclones in this scale may also be referred to as "cyclonettes", and in the following a 10 mm cyclonette may be referred to with the abbreviation "D10". The small diameter of the cyclonettes generates high g-force – and efficient separation of very fine particles. The cyclonettes still provide a high through-
25 put, e.g. about 250-350 l/h per cyclonette when the feed contains about 14 %w/w dry solids. When several cyclonettes are set up in parallel it can handle any flow rate. Furthermore, the cyclonettes, due to their small size, reduce the hazards from potential fires or explosions caused to the presence of ethanol at high concentration near its boiling point.

30 The size of the particles of the particulate fat containing starting material will be as is appropriate for the hydrocyclone, and the particle sizes may be reduced as desired using any appropriate technology. It is however preferred, that the mean diameter of the particles of the particulate fat contain-
ing starting material is from about 20 μm to about 300 μm , such as from
35 about 30 μm to about 100 μm , such as about 50 μm . It is further preferred

that the particles are monodisperse. In a specific embodiment of the invention the standard deviation, Dv_{95} , of the mean diameter of the particles of the particulate fat containing starting material is therefore 50% or less from the mean diameter of the particles.

5 The preferred embodiment for the invention is a hydrocyclone arrangement in which the overflow stream from the first stage, e.g. of serially connected hydrocyclone stages, is fed to a clarifying separation, e.g. in a clarifying hydrocyclone stage or a series of clarifying hydrocyclones stages, in which suspended solids in the overflow stream of the first hydrocyclone stage
10 are separated. The clarifying separation may also be accomplished using a centrifuge. The clarifying separation provides a clarified stream and a concentrated stream. The concentrated stream may be added to the feed of the 1st hydrocyclone stage. The fat rich product is recovered from the clarified stream from the clarifying separation. When the clarifying separation is a hydrocyclone separation the clarified stream may be referred to as the overflow
15 of the clarifying hydrocyclone from which fat is to be recovered in the further process steps. The clarifying separation with hydrocyclones will, dependent on the quality of the oil rich feed material, preferably comprise 1 to 3 serially connected hydrocyclone stages.

20 Employment of a clarifying hydrocyclone advantageously minimises the suspended solids content in the fat rich product. In another aspect the invention relates to a fat rich product obtainable in the process of the invention, and in yet another aspect the invention relates to a fat lean product obtainable in the process of the invention. The products provided in the process
25 of the invention can readily be employed for human or animal consumption due to the lack of noxious extractants, since ethanol as an extractant is considered compatible with food products and may additionally easily be removed to levels of no concern. Further uses of the fat rich product of the invention are for biofuel applications, e.g. as a material for producing biodiesel.

30

Brief description of the figures

The invention will be readily understood from the following detailed description in conjunction with the accompanying figures, in which

Figure 1 shows the solubility of oil/fat in ethanol.

Figure 2 shows a schematic process diagram of an embodiment of the invention.

Detailed description of the invention

5 In order to more fully explain the invention it is disclosed in more detail below, and definitions of the terms used throughout the document are given.

The present invention relates to a process for the production of a fat rich and a fat lean product from a plant or animal starting material. In the context of the invention the term "fat" refers to a triglyceride of biological
10 origin. The fat may also be referred to as "oil" and the two terms may be used interchangeably in the context of the invention.

The starting material is of plant or animal origin. Any plant commonly cultured to provide a plant oil may be used in the invention, and any part of such plant may be subjected to the process. Typical plant materials are de-
15 rived from rapeseed, canola, soybean, sunflower seed, peanut, cottonseed, palm, palm kernel, coconut, olive, corn, grape seed, hazelnut and other nut, linseed, rice bran, safflower, sesame, etc. The plant material may for example be the press cake remains after extraction, e.g. expeller extraction, of the oilseeds. In general, any oilseed may be processed according to the inven-
20 tion. The animal may be any land animal, such as livestock, poultry etc. or marine animal, such as fish. In particular, the starting material may be derived from slaughterhouse by-product or dehydrated slaughterhouse by-products, or from by-product from industrial processing of fish.

The process of the invention employs ethanol. In the context of the in-
25 vention "ethanol" is referred to in terms of concentration where the ethanol concentration is provided as a percentage by mass, i.e. %w/w. The balance will normally be water unless otherwise indicated. The ethanol may be referred to as "azeotropic" meaning that it contains 95.6 %w/w ethanol and 4.4 %w/w water. The term "absolute" ethanol refers to ethanol of at least
30 99.9 %w/w concentration.

The enclosed nature, and also the small volume of the preferred hydrocyclone size, allows that the feed stream fed to the hydrocyclone is heated above its boiling point without evaporating when processed in the hydrocyclone. This effect of retaining a liquid state is referred to as "superheated" in

the context of the invention. This is particularly advantageous since it allows that the mixture of the particulate fat containing starting material and the ethanol is heated to a temperature where the fat and oil of the particulate fat containing starting material are dissolved in the ethanol and thus may be extracted from particulate fat containing starting material.

The following abbreviations may be used to describe the present invention:

Abbreviation	Term
SSP (in kg/h or in %)	Suspended Solid (protein)
L (in kg/h)	Liquid (alcohol)
T (in kg/h)	Mass flow (SSP + L)
FLOW (in m ³ /h)	Volume flow
S.G (in kg/m ³)	Specific gravity
SLS (in kg/h)	Soluble Solids (fat)
TS (in kg/h)	Total Solids (SSP + SLS)
TS (in %)	Total Solids (SSP + SLS)
TOT (in kg/h)	Total mass flow (SSP + L + SSL)
F.L.	Fresh Liquid
W.L.	Washing Liquid
UF	Underflow
OF	Overflow
F	Feed flow
delta P	Pressure drop
D10	Cyclonette with 10 mm upper diameter

In a specific embodiment of the invention the fat containing starting material is a slaughterhouse by-product. This starting material typically contains about 2/3 water. In order to provide a shelf stable protein meal the water content needs to be reduced. Besides protein slaughterhouse by-products contain minerals and a varied quantity of fat depending on the specific by-product fraction. Slaughterhouse by-products can therefore appropriately be treated according to the invention. Conventional dehydration processes are very costly both in terms of energy usage, but also as large and expensive equipment is needed to transfer evaporation heat into wet products. Since

products containing high fat levels have better heat conductivity, less drying surface is needed in indirect heaters, and the slaughterhouse by-product can be initially dehydrated according to the Carver-Greenfield process as outlined above.

5 Existing carver Greenfield installations typically use falling film tubular heat exchangers. However, the present inventors have now found that surprisingly it is possible to use conventional plate heat exchangers of the wide-gap type. Raising film flash plate cassette evaporators of flash or conventional type provide a compact though flexible and cost efficient design for
10 making dehydration units. Obviously, solid particle size needs to be calibrated to at least less the clearance of the plate heat exchanger – and ideally less. For example, a cassette with an 8 mm clearance, will face significantly less risk of clogging if particle sizes are not more than 2-3 mm. Furthermore, the solid particles should ideally be spherical rather than fibrous. Fibres can be
15 caught at supporting points between plates and also in the distribution channel. Consequently, the particle size reduction mill needs to be of a certain quality. We have found that high speed colloid pin mill in combination with a slotted safety filter provides stable particle size output. It has further proven advantageous, that proteinaceous material of animal origin is pre-minced in a
20 conventional hole-plate grinder and thoroughly pre-coagulated before the final milling. Coagulated, even thoroughly milled raw materials tends to re-adhere into fibrous structures.

Smaller particle size further significantly shortens dehydration time as both heat penetration increases and also water/steam diffusion towards the
25 surface is reduced. In conventional Carver Greenfield operations there is however a general reluctance to reduce particle size too much, as this will negatively affect the ability of expeller presses to build up high pressure thus extracting maximum amount of fat from final product. In this invention, however, we will not use expeller presses, but centrifuges, e.g. decanter centri-
30 fuges, as the fat left within the solids will be recovered in the following extraction phase. Decanters are not sensitive to product particle size, and will readily recover fine solids particles having a higher density than the carrying fat. Thus, following dehydration in the Carver Greenfield process the slurry may be subjected to solid-liquid separation in a decanter centrifuge to pro-

vide the particulate fat containing starting material and a liquid fat phase from which the fat rich product may be recovered.

The slaughterhouse by-product can for example be pre-milled in a hole-plate grinder followed by re-milling, e.g. by a pre-emulsifier, to provide
5 a wet fatty product of a fineness that allows stable operation of the plate heat exchangers in the CG dehydration. Pre-milling may be done directly to the slaughterhouse by-product, whereas re-milling is typically done after suspending the pre-milled slaughterhouse by-product in ethanol.

Pending the milling system, the dehydrated product may still contain
10 pieces (e.g. 2 – 3 mm) of bones and the like. To ensure that the particulate starting material is within the size range optimal for the operation of the hydrocyclones, the particulate material could undergo a re-milling after dispensing in ethanol, e.g. by a colloid wet-milling in combination with a classifying hydrocyclone treatment, where the underflow is recycled for re-milling, and
15 the overflow containing appropriate sized product is subjected to the extraction process of the invention. The particle sizes of the materials may be monitored throughout the process.

The particulate fat containing starting material to be extracted is mixed with ethanol, milled to appropriate particle size in a colloid mill, pre-
20 heated in an economiser system before final heating and feeding into the hydrocyclone extraction system. Extraction ethanol is fed into the hydrocyclone system counter-current to the product flow. The underflow of the last hydrocyclone station or stage containing defatted material, may be subjected to heat reduction before being fed to a decanter centrifuge for maximum etha-
25 nol removal prior to desolventising.

The overflow from the hydrocyclone treatment containing the fat/oil may be clarified using e.g. hydrocyclones in clarifying configuration and/or a high-speed disk stack centrifuge, before being chilled to separate the fat from the ethanol. After chilling down to e.g. 25°C or less the optionally clarified
30 overflow may be transferred to a column or cone shaped phase separator, or a disk stack centrifuge.

The recovered fat/oil contains minor amounts of ethanol which can be removed by conventional vacuum stripping technology. If required, phospholipids can be removed using conventional degumming technology, comprising
35 addition of water and lye, mixing and separation.

Solid desolventising can be achieved with any known technology, being indirect heated vacuum driers or by superheated ethanol flash drying.

Processing of a slaughterhouse by-product according to the process of the invention provides a fat rich product comprising triglyceride fats from the material, and a fat lean product which may be referred to as a protein meal. Both the fat rich and the fat lean product can be used for human or animal consumption, e.g. as a component of an animal feed. The fat rich product may also be used as a starting material for the production of biodiesel or the like.

10

Examples

Example 1 - Tests of hydrocyclone operating conditions

A slaughterhouse by-product was treated according to the invention. The separation tests were done with a single 10 mm cyclonette fed with a suspension of fatty meal and alcohol. The fatty bone meal was prepared from the material, which had been dehydrated in a carver Greenfield process, pre-milled in a hammermill and was re-milled to a fineness that allowed a stable operation of the cyclonette and a proper recovery of solids.

The re-milling was done with a suspension, at TS concentration 32%, in a mill with double cone (both with ribbons) of which the clearance could be adjusted to a finer or courser milling.

The first separation test was made with a suspension, at TS concentration approximately 27%, that was re-circulated over the mill for 8 minutes at a clearance of 8/18 (indication on mill).

The test rig operated well for approximately half an hour and then plugged. To assure a consistent stable operation of the test rig it was decided to re-mill the starting material to a finer grade.

The additional re-milling was done during 10 minutes at the finest clearance 0/10 (0.1 mm clearance between the cones). The separation tests were done with this suspension.

Additional separation tests were done with a suspension, at a TS concentration of approximately 7%, from which the coarse fraction had been removed (by discharging the underflow from the cyclonette for a while). These

tests were done to get an impression of the operation of clarifier stages that would be installed to clarify the overflow of "the washing station".

The test runs are summarised in Table 2 and Table 3. Table 2 shows the test of the hydrocyclone operating parameters without dry solids in the feed. The feed temperature was 22°C, and the feed specific weight was 800 kg/m³. Table 3 shows the test of the hydrocyclone operating parameters with dry solids in the feed. Table 4 shows the results of hydrocyclone tests with dry solids. The feed temperature was 88°C, except in test 7, and the specific weight of the feed was 824 kg/m³, except in test 12.

10

Table 2 Test of hydrocyclone operating parameters without dry solids.

Test	Feed P (Bar)	OF P (Bar)	UF P (Bar)	Feed Flow (l/h)	delta P (Bar)	OF Flow (l/h)	UF Flow (l/h)	UF/F Flow
1	3	0.4	0.4	294	2.6	105	189	0.64
2	4.1	0.8	0.8	338	3.3	136	202	0.60
3	5.3	1	0.8	363	4.3	140	223	0.61
4	6	1.1	1	405	4.9	150	255	0.63
5	6.9	1.2	1	425	5.7	159	266	0.63
6	7.6	1.4	1	431	6.2	167	264	0.61

Table 3 Test of hydrocyclone operating parameters with dry solids.

Test	Feed P (Bar)	OF P (Bar)	UF P (Bar)	Feed Flow (l/h)	delta P (Bar)	OF Flow (l/h)	UF Flow (l/h)	UF/F Flow
7*	4.6	2	1.4	340	2.6	112	228	0.67
8	5.1	1.9	1.7	376	3.2	87	289	0.77
9	6.1	2.1	2	431	4	91	340	0.79
10	6.2	2.2	2.6	425	4	99	326	0.77
11	7.3	3.2	3.8	419	4.1	124	295	0.70
12**	6	2	2.3	440	4	87	353	0.80
13**								

*Feed temperature was 86°C

15 **Feed TS content was 25% and Feed specific weight was 840 kg/m³.

Table 4 Results of hydrocyclone tests with dry solids

Test	OF solids		UF solids		TS recovery %
	TS %	ml	TS %	ml	
7*	3.5	0.8	26	3.2	80
8	4	0.5	33	3.7	88
9		0.7	32	4	85
10		0.6	32	4	87
11			33		
12**			32		
13**			34		

*Feed temperature was 86°C

**Feed TS content was 25% and Feed specific weight was 840 kg/m³.

- 5 From the initial experiments presented in Table 2 to Table 4 it is evident that
- The cyclonette operates stably with consistent results at the tested concentrations and pressures
 - The cyclonette has a capacity at a delta P of 4 Bar of :
 - 10 at 0 % TS, 380 l/h
 - at 14 % TS, 430 l/h
 - at 25 % TS, 440 l/h;
 - The maximum dry solids concentration in the underflow was 32-33%;
 - 15 - The dry solids concentration in the overflow was 3.5 – 4%;
 - The recovery of solids in the underflow was 85 – 88% of the dry solids;
 - Fat recovery was calculated to be 94% with 4 multi-cyclone washing stages;
 - 20 - Fat recovery was calculated to be 97% with 6 multi-cyclone washing stages.

Example 2 - Simulations of processes

25 Figure 2 shows a schematic process diagram of a five stage process of the invention. In the process of Figure 2 the particulate fat containing starting material ("Feed (fatty meal)") is mixed with ethanol ("alcohol") in a mixing

tank ("Mixing and maceration") and led to a colloid mill ("Disintegrater") for further comminution. The mixture is fed to the hydrocyclone of the first stage ("W1"). The underflow of the first hydrocyclone is fed to the hydrocyclone of the second stage ("W2"), and the underflow and overflow streams of the second stage hydrocyclone are processed as described above in the subsequent stages of hydrocyclones, W3 to W5, respectively. The overflow of the first hydrocyclone W1 is clarified in a two-step hydrocyclone separation process where the overflow stream of the first clarification hydrocyclone C1 is fed to the second clarification hydrocyclone C2. The underflow streams from clarification hydrocyclones C1 and C2 are combined with the feed stream fed to the first stage hydrocyclone W1. The overflow stream of clarification hydrocyclone C2 is processed further by cooling to separate a fat phase from an ethanolic phase in a phase separator (not shown). The lower phase of the separator may optionally be further processed to provide the fat rich product, and the ethanolic upper phase may be recycled, optionally after dehydrating, to be mixed with the particulate fat containing starting material. The underflow stream from hydrocyclone W5 is subjected to a decanter centrifuge ("Decanter") to further concentrate the fat lean product ("Discharge (protein)") from the W5 underflow. The overflow of the decanter is combined with the feed stream to hydrocyclone W5. The set-up also comprises a line for applying a washing liquid ("Wash liquid (alcohol)") to the final stage hydrocyclone and/or to the W5 underflow. This washing liquid may be combined with the clarified stream from the decanter centrifuge. It is to be understood that while Figure 2 only shows a single hydrocyclone for each stage, any number of hydrocyclones may operate in parallel at a single stage.

The results obtained in Example 1 were employed to simulate multi-stage processes having 4, 5 or 6 stages using an empiric mathematical model used and verified in the starch washing industry. The multistage set-ups for the simulations were as illustrated in Figure 2 except that the numbers of stages were as indicated below. Table 5 shows the default parameters that were used in all three simulations.

Table 5 Defaults for process simulations

F.L. rate	4	kg/kg TS
Protein recovery in hydrocyclone	85	% of SSP in F

Fat concentration OF	70	% of fat concentration UF
Rest fat in protein	1	% of SSP
Specific weight alcohol	800	kg/m ³
Specific weight fat	900	kg/m ³
Specific weight protein	1050	kg/m ³

4 stage process

The simulations of the 4-stage process are summarised in the tables below.

5 Table 6-1 Feed stream to W1

	NEW FEED	UF C2	UF C1
SSP in kg/h	700*	22	127
L in kg/h	3967	258	1146
T in kg/h	4667	281	1274
FLOW in m ³ /h	5.6	0.3	1.5
SSP in %	15*	8*	10*
S.G in kg/m ³	834	842	833
SLS in kg/h	300*	140	280
TS in kg/h	1000	162	408
TS in %	20.1	38.6	26.2
TOT in kg/h	4967	421	1554

* indicates a default value for the calculations

Table 6-2 Feed streams streams of W1 to W4

	F W1	F W2	F W3	F W4
SSP in kg/h	999	995	969	824
L in kg/h	11064	7813	7015	6382
T in kg/h	12063	8807	7984	7205
FLOW in m ³ /h	14.7	10.7	9.7	8.8
SSP in %	8.3	11.3	12.1	11.4
S.G in kg/m ³	822	825	825	823
SLS in kg/h	1015	399	140	45
TS in kg/h	2015	1393	1108	868
TS in %	15.4	15.1	13.6	12.0
TOT in kg/h	13078	9206	8124	7250

Table 6-3 Underflow streams of W1 to W4

	UF W1	UF W2	UF W3	UF W4
SSP in kg/h	849	845	824	700
L in kg/h	2548	2121	1750	1488
T in kg/h	3397	2966	2574	2188
FLOW in m ³ /h	4.0	3.5	3.0	2.5
SSP in %	25*	28.5	32	32*
S.G in kg/m ³	854	860	867	866
SLS in kg/h	304	108	45	13.60
TS in kg/h	1153	954	868	714
TS in %	31.2	31.0	33.2	32.4
TOT in kg/h	3701	3074	2618	2201

*indicates a default value for the calculations

Table 6-4 Overflow streams of W1 to W4 and C1 to C2

	OF C2	OF C1	OF W1	OF W2	OF W3	OF W4
SSP in kg/h	0	22	150	149	145	124
L in kg/h	7111	7370	8516	5692	5265	4894
T in kg/h	7111	7392	8666	5841	5411	5018
FLOW in m ³ /h	8,9	9,2	10,7	7.2	6.7	6.2
SSP in %	0	0,3	1,7	2.6	2.7	2.5
S.G in kg/m ³	800	805	810	809	807	805
SLS in kg/h	291	431	711	290	95	31
TS in kg/h	291	453	861	440	240	155
TS in %	3,9	5,8	9,2	7.2	4.4	3.1
TOT in kg/h	7402	7823	9377	6132	5505	5049

5

Table 6-5 Fresh feeds and decanter centrifuge streams

	F.L.	W.L.	OF DEC	UF DEC
SSP in kg/h	0	0	0	700
L in kg/h	4000	4632	632	856
T in kg/h	4000	4632	632	1556
FLOW in m ³ /h	5	5.8	0.79	1.7
SSP in %	0	0	0	45*
S.G in kg/m ³	800	800	800	896

	F.L.	W.L.	OF DEC	UF DEC
SLS in kg/h	0	0	0	8
TS in kg/h	0	0	0	708
TS in %	0	0	0	45.3
TOT in kg/h	4000	4632	632	1563

*indicates a default value for the calculations

Table 6-6 Pump settings and number of cyclones per stage

	Feed pumps				Cyclonettes
	Flow	S.G.	Delta P	Power	D10
	m ³ /h	kg/m ³	Bar	kW	Pieces
C1	10.7	805	4*	0.7	28
C2	9.2	810	4*	0.6	24
W1	14.7	822	4*	0.9	34
W2	10.7	825	4*	0.7	25
W3	9.7	825	4*	0.6	23
W4	8.8	823	4*	0.6	20

*indicates a default value for the calculations

5

5 stage process

The simulations of the 5-stage process are summarised in the tables below.

Table 7-1 Feed stream to W1

	NEW FEED	UF C2	UF C1
SSP in kg/h	700*	22	127
L in kg/h	3967	259	1147
T in kg/h	4667	281	1275
FLOW in m ³ /h	5.6	0.3	1.5
SSP in %	15*	8*	10*
S.G in kg/m ³	838	844	836
SLS in kg/h	300*	143	294
TS in kg/h	1000	166	422
TS in %	20.1	39.0	26.9
TOT in kg/h	4967	424	1569

10 *indicates a default value for the calculations

Table 7-2 Feed streams of W1 to W5

	F W1	F W2	F W3	F W4	F W5
SSP in kg/h	1000	999	995	969	824
L in kg/h	10435	7192	6439	6059	5750
T in kg/h	11435	8191	7434	7028	6574
FLOW in m ³ /h	13.8	9.9	8.9	8.4	7.9
SSP in %	8.7	12.2	13.4	13.8	12.5
S.G in kg/m ³	826	831	832	832	829
SLS in kg/h	1071	465	196	93	34
TS in kg/h	2071	1464	1191	1061	857
TS in %	16.6	16.9	15.6	14.9	13.0
TOT in kg/h	12506	8656	7630	7120	6607

Table 7-3 Underflow streams of W1 to W5

	UF W1	UF W2	UF W3	UF W4	UF W5
SSP in kg/h	850	849	845	824	700
L in kg/h	2550	2130	1796	1750	1488
T in kg/h	3399	2980	2642	2574	2188
FLOW in m ³ /h	3.9	3.4	3.0	2.9	2.5
SSP in %	25*	28.5	32	32	32*
S.G in kg/m ³	862	869	877	877	877
SLS in kg/h	338	138	70	34	11.30
TS in kg/h	1188	987	915	857	711
TS in %	31.8	31.7	33.8	32.9	32.3
TOT in kg/h	3738	3117	2711	2607	2199

*indicates a default value for the calculations

5

Table 7-4 Overflow streams of W1 to W5 and C1 to C2

	OF C2	OF C1	OF W1	OF W2	OF W3	OF W4	OF W5
SSP in kg/h	0	22	150	150	149	145	124
L in kg/h	6479	6738	7885	5062	4643	4309	4263
T in kg/h	6479	6760	8035	5212	4792	4454	4386
FLOW in m ³ /h	8.1	8.4	9.9	6.4	5.9	5.5	5.4
SSP in %	0	0.3	1.9	2.9	3.1	3.3	2.8

	OF C2	OF C1	OF W1	OF W2	OF W3	OF W4	OF W5
S.G in kg/m ³	800	806	811	811	809	808	807
SLS in kg/h	295	438	733	327	126	59	23
TS in kg/h	295	461	883	477	276	204	146
TS in %	4.4	6.4	10.1	8.6	5.6	4.5	3.3
TOT in kg/h	6774	7199	8768	5539	4918	4513	4409

Table 7-5 Fresh feeds and decanter centrifuge streams

	F.L.	W.L.	OF DEC	UF DEC
SSP in kg/h	0	0	0	700
L in kg/h	4000	4632	632	856
T in kg/h	4000	4632	632	1556
FLOW in m ³ /h	5	5.8	0.79	1.7
SSP in %	0	0	0	45*
S.G in kg/m ³	800	800	800	912
SLS in kg/h	0	0	0	6
TS in kg/h	0	0	0	706
TS in %	0	0	0	45.2
TOT in kg/h	4000	4632	632	1562

*indicates a default value for the calculations

5 Table 7-6 Pump settings and number of cyclones per stage

	Feed pumps				Cyclonettes
	Flow	S.G.	Delta P	Power	D10
	m ³ /h	kg/m ³	Bar	kW	Pieces
C1	9.9	806	4*	0.6	26
C2	8.4	811	4*	0.5	22
W1	13.8	826	4*	0.9	32
W2	9.9	831	4*	0.6	23
W3	8.9	832	4*	0.6	21
W4	8.4	832	4*	0.5	20
W5	7.9	829	4*	0.5	18

*indicates a default value for the calculations

6 stage process

The simulations of the 6-stage process are summarised in the tables below.

5 Table 8-1 Feed stream to W1

	NEW FEED	UF C2	UF C1
SSP in kg/h	700*	22	127
L in kg/h	3967	259	1147
T in kg/h	4667	281	1275
FLOW in m ³ /h	5.6	0.3	1.5
SSP in %	15*	8*	10*
S.G in kg/m ³	838	844	836
SLS in kg/h	300*	142	286
TS in kg/h	1000	165	413
TS in %	20.1	38.9	26.5
TOT in kg/h	4967	424	1561

*indicates a default value for the calculations

Table 8-2 Feed streams of W1 to W6

	F W1	F W2	F W3	F W4	F W5	F W6
SSP in kg/h	1000	1000	999	995	969	824
L in kg/h	11067	7826	7081	6745	6691	6382
T in kg/h	12067	8826	8080	7740	7660	7205
FLOW in m ³ /h	14.6	10.7	9.7	9.3	9.2	8.7
SSP in %	8.3	11.3	12.4	12.8	12.6	11.4
S.G in kg/m ³	824	829	829	830	829	826
SLS in kg/h	1034	421	165	77	34	12
TS in kg/h	2034	1421	1165	1072	1003	835
TS in %	15.5	15.4	14.1	13.7	13.0	11.6
TOT in kg/h	13101	9247	8246	7817	7694	7217

10 Table 8-3 Underflow streams of W1 to W6

	UF W1	UF W2	UF W3	UF W4	UF W5	UF W6
SSP in kg/h	850	850	849	845	824	700
L in kg/h	2550	2132	1804	1796	1750	1488

	UF W1	UF W2	UF W3	UF W4	UF W5	UF W6
T in kg/h	3400	2982	2654	2642	2574	2188
FLOW in m ³ /h	3.9	3.4	3.0	3.0	2.9	2.5
SSP in %	25*	28.5	32	32	32	32*
S.G in kg/m ³	862	869	877	877	877	877
SLS in kg/h	310	115	54	26	12	3.50
TS in kg/h	1160	965	903	872	835	704
TS in %	31.3	31.1	33.4	32.7	32.3	32.1
TOT in kg/h	3710	3097	2708	2668	2585	2191

* indicates a default value for the calculations

Table 8-4 Overflow streams of W1 to W6 and C1 to C2

	OF C2	OF C1	OF W1	OF W2	OF W3	OF W4	OF W5	OF W6
SSP in kg/h	0	22	150	150	150	149	145	124
L in kg/h	7111	7370	8517	5694	5277	4949	4941	4894
T in kg/h	7111	7392	8667	5844	5426	5098	5086	5018
FLOW in m ³ /h	8.9	9.2	10.7	7.2	6.7	6.3	6.3	6.2
SSP in %	0	0.3	1.7	2.6	2.8	2.9	2.9	2.5
S.G in kg/m ³	800	806	810	810	808	807	807	806
SLS in kg/h	296	439	724	306	111	51	23	8
TS in kg/h	296	461	874	456	261	200	168	132
TS in %	4.0	5.9	9.3	7.4	4.7	3.9	3.3	2.6
TOT in kg/h	7407	7831	9392	6151	5538	5149	5109	5026

5 Table 8-5 Fresh feeds and decanter centrifuge streams

	F.L.	W.L.	OF DEC	UF DEC
SSP in kg/h	0	0	0	700
L in kg/h	4000	4632	632	856
T in kg/h	4000	4632	632	1556
FLOW in m ³ /h	5	5.8	0.79	1.7

	F.L.	W.L.	OF DEC	UF DEC
SSP in %	0	0	0	45*
S.G in kg/m ³	800	800	800	912
SLS in kg/h	0	0	0	2
TS in kg/h	0	0	0	702
TS in %	0	0	0	45.1
TOT in kg/h	4000	4632	632	1558

*indicates a default value for the calculations

Table 8-6 Pump settings and number of cyclones per stage

	Feed pumps				Cyclonettes
	Flow	S.G.	Delta P	Power	D10
	m ³ /h	kg/m ³	Bar	kW	Pieces
C1	10.7	806	4*	0.7	28
C2	9.2	810	4*	0.6	24
W1	14.6	824	4*	0.9	34
W2	10.7	829	4*	0.7	25
W3	9.7	829	4*	0.6	23
W4	9.3	830	4*	0.6	22
W5	9.2	829	4*	0.6	21
W6	8.7	826	4*	0.6	20

*indicates a default value for the calculations

5

Summary of multi-stage simulations

The results with respect to recovery of fat relative to the particulate fat containing starting material are indicated in Table 9.

10 Table 9 Fat recovery in multistage separation

Number of stages	Fat recovery (%)
4	95.1
5	95.5
6	97.0

It is clear from the simulations that the process affords a high capacity. For example, with a volumetric flow of 5.6 m³/h each stage of hydrocyclone treatment requires from 18 to 35 cyclonettes depending on the number

of the stage in the process. This number of cyclonettes can be easily implemented in a process using standardised equipment readily available.

CLAIMS:

1. A process for the production of a fat rich and a fat lean product from a plant or animal starting material, comprising the steps of:
 - i) providing a particulate fat containing starting material,
 - ii) mixing the particulate fat containing starting material with ethanol of at least 90 %w/w concentration,
 - iii) heating the mixture,
 - iv) subjecting the heated mixture to a hydrocyclone treatment to provide a fat reduced underflow stream and an overflow stream,
 - v) recovering the fat lean product from the fat reduced underflow stream,
 - vi) recovering the fat rich product from the overflow stream.

2. The process according claim 1, wherein the heated mixture is subjected to a sequential counter current processing in a series of hydrocyclone stages, wherein the fat reduced underflow stream of a hydrocyclone stage is fed to a down-stream hydrocyclone stage of the series, and the overflow stream of a hydrocyclone stage is fed to an up-stream hydrocyclone stage in the series, and the fat lean product is recovered from the fat reduced underflow stream of the last hydrocyclone stage of the series, and the fat rich product is recovered from the overflow stream of the first hydrocyclone stage of the series.

3. The process according to claim 1 or 2, wherein the overflow stream of the first hydrocyclone stage is subjected to a clarifying separation to provide a clarified stream and a concentrated stream.

4. The process according to claim 3, wherein clarifying separation comprises a series of from 1 to 3 hydrocyclone stages, or the clarifying separation is accomplished using a centrifuge.

5. The process according to any one of claims 1 to 4 further comprising the steps of:

cooling the overflow stream of the first hydrocyclone to a temperature of 40°C or below to form an ethanolic upper phase and a lower phase, recovering the fat rich product from the lower phase, and optionally recycling the ethanolic upper phase in step ii).

6. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in two or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises two or more hydrocyclones.

7. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in two or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 50 or more hydrocyclones.

8. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in two or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 100 or more hydrocyclones.

9. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in two or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 250 or more hydrocyclones.

10. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 50 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises two or more hydrocyclones.

11. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 50 or more hydrocyclones arranged in

parallel or wherein each stage in a series of hydrocyclones comprises 50 or more hydrocyclones.

12. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 50 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 100 or more hydrocyclones.

13. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 50 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 250 or more hydrocyclones.

14. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 100 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises two or more hydrocyclones.

15. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 100 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 50 or more hydrocyclones.

16. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 100 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 100 or more hydrocyclones.

17. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 100 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 250 or more hydrocyclones.

18. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 250 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises two or more hydrocyclones.

19. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 250 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 50 or more hydrocyclones.

20. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 250 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 100 or more hydrocyclones.

21. The process according to any one of claims 1 to 5, wherein the heated mixture is subjected to hydrocyclone treatment in 250 or more hydrocyclones arranged in parallel or wherein each stage in a series of hydrocyclones comprises 250 or more hydrocyclones.

22. The process according to any one of claims 2 to 21, wherein the number of hydrocyclone stages in the series is 3 or more.

23. The process according to any one of claims 2 to 21, wherein the number of hydrocyclone stages in the series is 4 or more.

24. The process according to any one of claims 2 to 21, wherein the number of hydrocyclone stages in the series is from 4 to 6.

25. The process according to any one of claims 1 to 24, wherein the diameter of the upper part of the hydrocyclone is 25 mm or less.

26. The process according to any one of claims 1 to 24, wherein the diameter of the upper part of the hydrocyclone is about 20 mm.
27. The process according to any one of claims 1 to 24, wherein the diameter of the upper part of the hydrocyclone is about 15 mm.
28. The process according to any one of claims 1 to 24, wherein the diameter of the upper part of the hydrocyclone is about 10 mm.
29. The process according to any one of claims 1 to 28, wherein the mean diameter of the particles of the particulate fat containing starting material is from about 20 μm to about 300 μm .
30. The process according to any one of claims 1 to 28, wherein the mean diameter of the particles of the particulate fat containing starting material is from about 30 μm to about 100 μm .
31. The process according to any one of claims 1 to 28, wherein the mean diameter of the particles of the particulate fat containing starting material is about 50 μm .
32. The process according to any one of claims 1 to 31, wherein the standard deviation Dv_{95} of the mean diameter of the particles of the particulate fat containing starting material is 50% or less from the mean diameter of the particles.
33. The process according to any one of claims 1 to 32, wherein the particulate fat containing starting material has a water content below 3% w/w.
34. The process according to any one of claims 1 to 33, wherein the temperature is at least 65°C.
35. The process according to any one of claims 1 to 33, wherein the temperature is at least 70°C.

36. The process according to any one of claims 1 to 33, wherein the temperature is at least 80°C.
37. The process according to any one of claims 1 to 33, wherein the temperature is at least 90°C.
38. The process according to any one of claims 1 to 33, wherein the temperature is at least 100°C.
39. The process according to any one of claims 1 to 38, wherein the heated mixture of the particulate fat containing starting material and ethanol is superheated above the boiling point of the mixture.
40. The process according to any one of claims 1 to 39, wherein the ethanol concentration is at least 95% w/w.
41. The process according to any one of claims 1 to 39, wherein the ethanol concentration is at least 98% w/w.
42. The process according to any one of claims 1 to 39, wherein the ethanol concentration is at least 99% w/w.
43. The process according to any one of claims 1 to 39, wherein the ethanol concentration is at least 99.5% w/w.
44. The process according to any one of claims 5 to 43, wherein the ethanolic upper phase is dehydrated before recycling the ethanol in step ii).
45. The process according to any one of claims 1 to 44 further comprising reducing the water content of the particulate fat containing starting material to below 3% w/w in the steps of:

- a) mixing the particulate fat containing starting material with 1 to 20 parts fat or oil to obtain a slurry,
- b) heating the slurry to evaporate water and to obtain a water reduced slurry,
- c) subjecting the water reduced slurry to a solid-liquid separation to provide the particulate fat containing material having a water content below 3% w/w and an oil or fat fraction.

46. The process according to claim 45, wherein step b) is performed as a multi-step process comprising subjecting the water reduced slurry to sequential heat treatments, where each subsequent heat treatment is performed at a lower temperature than the preceding heat treatment.

47. The process according to claim 45 or 46, wherein the fat or oil is derived from the fat rich product produced according to the process of any one of claims 1 to 44.

48. The process according to any one of claims 45 to 47, wherein the fat rich product is recovered from the fat or oil fraction.

49. The process according to any one of claims 1 to 48, wherein the fat reduced underflow stream is subjected to centrifugation to produce the fat lean product.

50. The process according to any one of claims 1 to 49, wherein the starting material is slaughterhouse by-products, dehydrated slaughterhouse by-products, fish by-products, or oil seeds.

51. The process of claim 50, wherein the oil seeds are rape seeds, soy, sunflower, linseed, sesame, or the press cake remains after extraction of oilseeds.

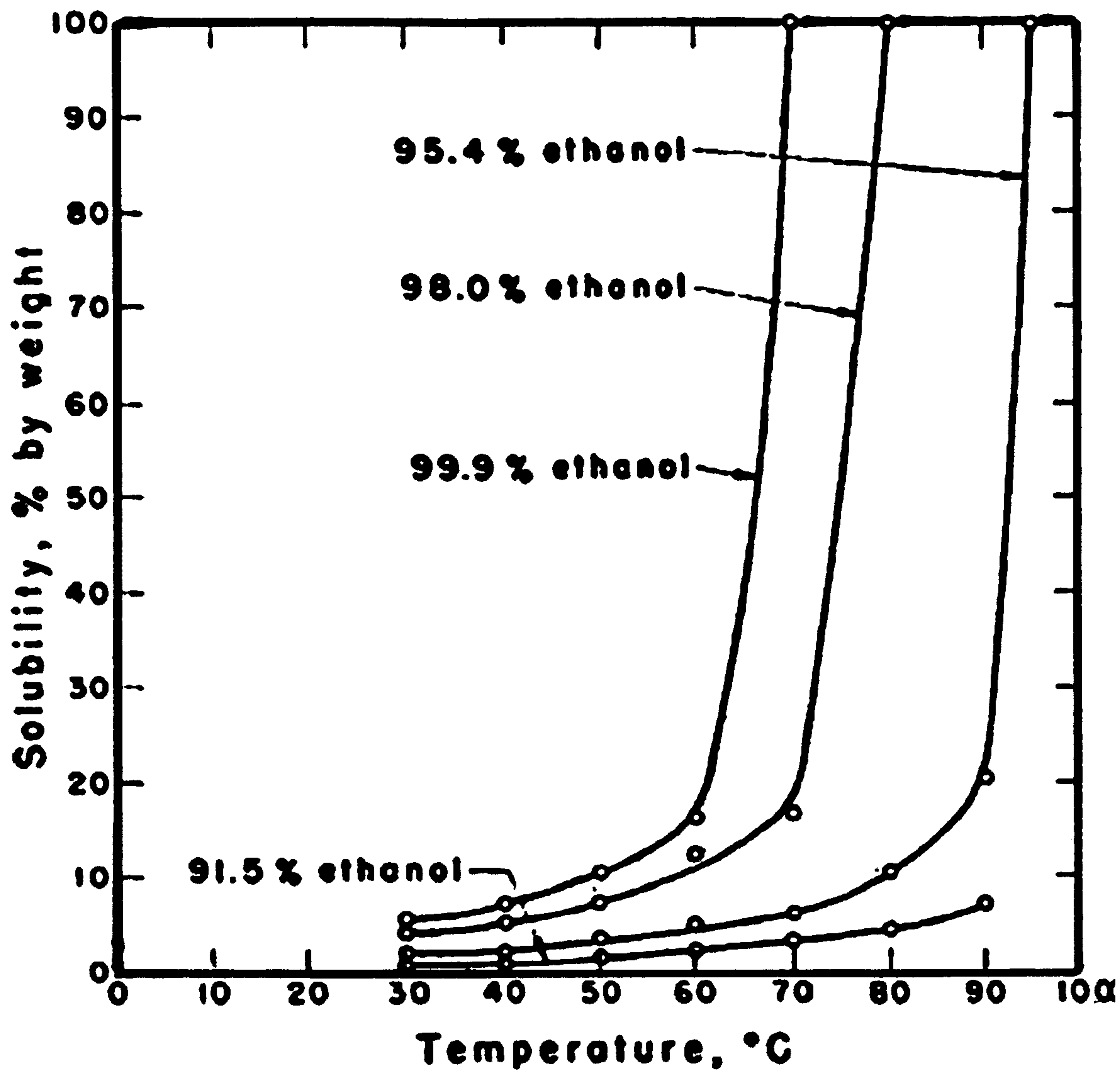


Fig. 1

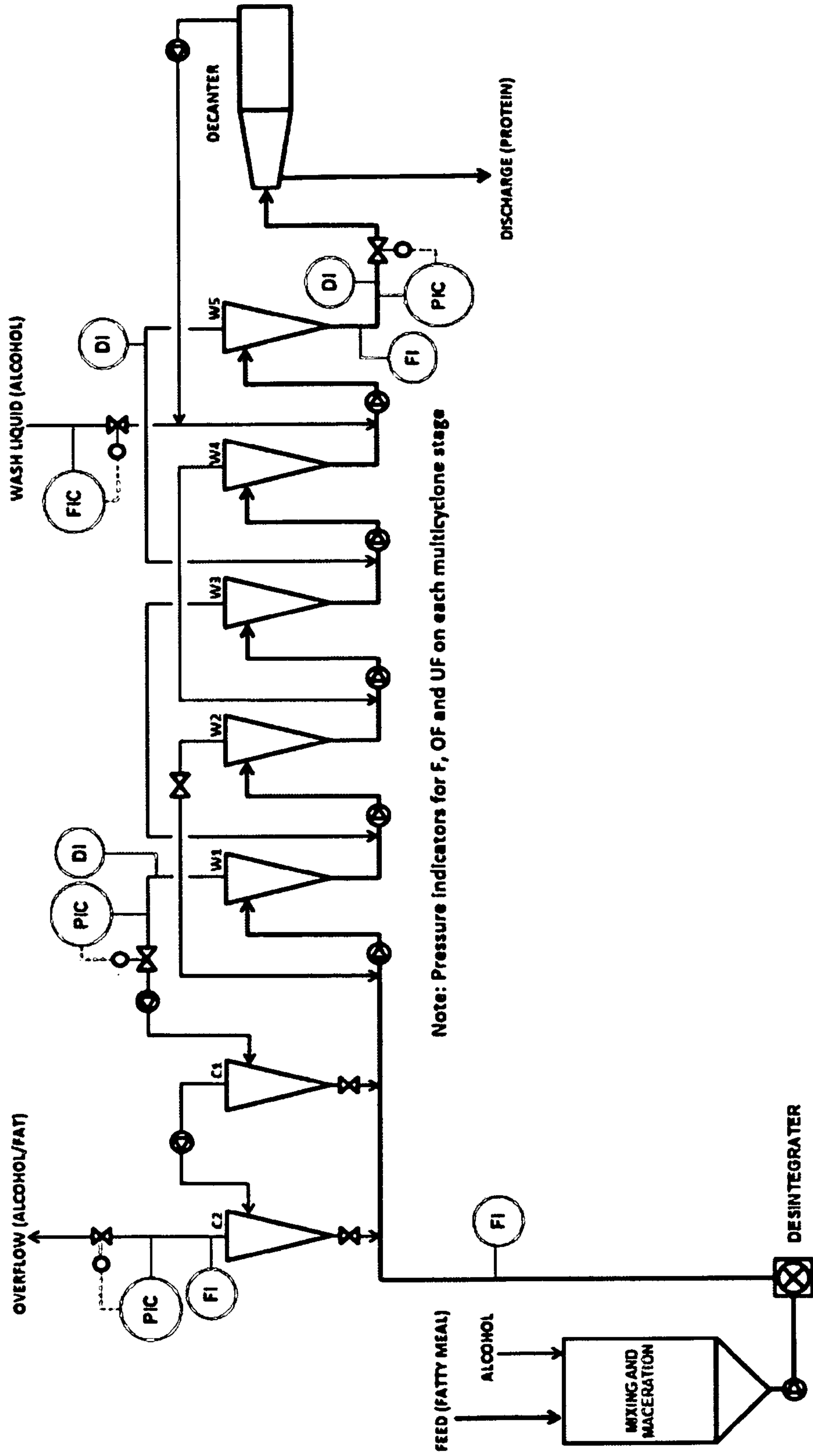


Fig. 2

