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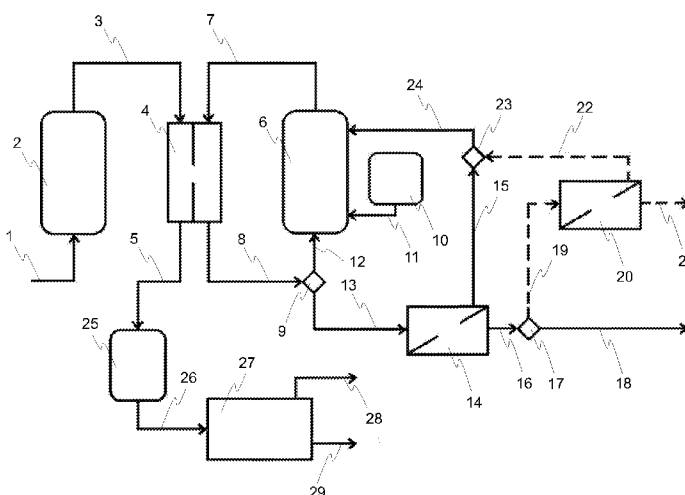
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(54) Title: A METHOD FOR HIGH VOLUME RECOVERY OF PROCESS- WATER AND ECONOMIC PRODUCT ACQUISITION FROM WHEY

FIGURE 1



(57) Abstract: This invention is related to a method based on the use of innovative membrane systems with different combinations, which deals with whey as cheese production wastewater that should be significantly taken into account in relation to environmental pollution from the dairy industry; in comparison to pressure-driven membrane process combinations in common use (32-40% water recovery and production of concentrated whey in 15-20% solid content), whose main purpose is to both recover water from whey at higher water recovery percentages (65-80%) having reusable quality in the production process and to technically and commercially enable increased economic production of whey powder by means of concentrated whey obtainment having higher solid percentages (25-35%).



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DESCRIPTION

A METHOD FOR HIGH VOLUME RECOVERY OF PROCESS- WATER AND ECONOMIC PRODUCT ACQUISITION FROM WHEY

5 **Technical Field**

This invention is related to a method based on the use of innovative membrane systems with different combinations, which deals with whey as cheese production wastewater that should be significantly taken into account in relation to
10 environmental pollution from the dairy industry; in comparison to pressure-driven membrane process combinations in common use (32-40% water recovery and production of concentrated whey in 15-20% solid content), whose main purpose is to both recover water from whey at higher water recovery percentages (65-80%) having reusable quality in the production process and to technically and commercially
15 enable increased economic production of whey powder by means of concentrated whey obtainment having higher solid percentages (25-35%).

Prior Art

20 In our country, since the 1980s until today, depending on population growth, development of animal husbandry and the increase integrated milk and milk products production, also increased both the quantity of wastewater originated from dairy industry and hence the potential of pollution creation of the sector. Milk and milk products industry includes plants in which milk is processed and converted into milk
25 products such as raw milk, drinking milk, yoghurt and buttermilk, butter, cheese, ice cream, condensed milk, milk powder, baby food, and concentrated and dried whey. Milk processing plants which are available in our country have various sizes and have complex structure as technologies and other characteristics. The main source of pollutant of wastewaters originating from the dairy industry is the whey which is

formed as a result of cheese production and has a lot of pollutant effects because of high nutrient content (C, N, P). Approximately 90 kg of the 100 kg milk which is processed for cheese emerges as whey. In this regard, in our country in 2002 considering that 564,000 ton milk is consumed to produce cheese, it is estimated that
5 approximately 508,000 ton cheese whey is produced across the country.

Cheese whey contains 93-94% water, 4.5-6.0% lactose, 2.0-5.0% casein, 0.6-1.1% dissolved protein, 0.8-1.0% mineral, 0.05-0.9% lactic acid, 0.06-0.5% fat as essential compounds. Two types of whey exist, which are sweet (pH=6.5) and sour (pH<5.0).
10 Average water quality has characteristics of 7.0-10.0 mS/cm conductivity, 800-1500 mg chloride/L, 60,000-90,000 mg COD/L, 900-1200 mg total nitrogen/L, 200-900 mg total phosphorus/L. Because the treatment of these wastewaters is difficult and expensive, said waste water may be discharged to receiving environment without being treated, or without being sufficiently refined; thus, on the one hand significant
15 amount of nutrient wastage, on the other hand serious environmental pollution issues can be encountered. Though a lot of small enterprises obtain curd by boiling this water for the purpose of whey reuse, economic value of the application is relatively limited because of the high cost of the energy. By means of this processing, approximately 1.5% of whey solid matter is retrieving as curd while high solid
20 content of 5.0-6.6% in whey is released to wastewater without recovering most of solid matter in whey.

When whey is powdered, recovery of all of the solid matter it contains can be carried out. Because the water is totally evaporated during the powdering process by means
25 of direct thermal evaporation, there is no generation of wastewater; however there is a need of high energy consumption. Although discharge pollution of receiving environments can be prevented due to zero liquid discharge of any liquid waste, releasing organic emissions to the environment -included water vapours in drying exhaust gases if they have not been treated and this may lead to air pollution.

30

In comparison to whey powder recovery mentioned above, because of being economically more applicable, nowadays more commonly preferred application is by; raw wastewater is concentrated by membrane processes in the first step, recovery

of filtered effluent wastewater as demineralized water or process water and thereafter evaporating the water in concentrated whey stream so as to whey powder production. Although whey powder can be concentrated conventionally by industrial methods such as direct or vacuum evaporation and spray drying, pre-concentration by
5 membrane filtration prior to the main concentration process is especially preferred in the sense that whey powder in higher quality is gained from membrane concentrate streams; not only for decreasing energy cost and total plant operating cost in whey powder production, but also minimal protein decay effect at lower process temperatures ($< 60^{\circ}\text{C}$).

10

In water recovery from whey, single step membrane process or combined membrane systems are applied depending on quality and quantity of the targeted product. Water recovery from whey is performed commonly by pressure-driven membrane processes (microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis
15 (RO)); combined membrane treatment system applications are more preferred in practice based on the purpose of utilization of the membrane concentrate streams (content and quality of various product or products (butter, cream, protein liquids, etc.) to be produced later from these streams).

20 MF and UF processes are utilized in separating relative large molecular weighted whey proteins (caseins) and fats from smaller molecular weighted whey proteins (α -lactalbumin, β -lactoglobulin, etc.), lactose and minerals. Production of whey protein concentrates by UF process is carried out in concentrations around 35% to 85%. However, for obtaining 70-85% production levels, utilizing of MF prior to UF
25 process is necessary for removing fat in raw whey. By means of the UF process, proteins can be concentrated as well as for production of whey protein concentrates and isolates; lactose and salt can be removed simultaneously. Besides, in contrast to removal of monovalent salts present in whey powder that can have negative health effects, inclusion of divalent salts that have positive contribution to health is
30 preferred for whey powder of good quality; for this purpose, production of whey powder having the targeted quality, can be carried out over NF concentrate stream by applying NF after UF.

Recovering water and producing concentrate whey stream by treating raw whey by means of pressure-driven processes, MF/NF, UF/NF, UF/RO, NF/NF and NF/RO combinations in the forms of industrial applications are effectively used; the UF/RO membrane system among these applications is mostly preferred because of easy operability in worldwide applications and economic viability. When production of whey powder which includes all the content of whey, is targeted, a main concentrate stream is formed by collecting together concentrate streams of membrane processes in the whole system. In the combination of UF/RO, 5% initial solid content of whey is increased to levels of 15-20% by means of UF process in the first step and thereafter recovered water is produced from UF permeate stream by single step or sequential two steps processing in RO process in the next step. By the application of UF following RO, joint concentrate stream is produced by combining RO concentrate streams produced up to high concentrate ratios of $\geq 75\%$ per process with UF concentrate stream; afterwards whey powder is produced by using the joint concentrate stream in which the concentrate is subjected to water removal using one of the processes such as direct evaporation, vacuum evaporation or spray drying. However, in the water recovery effectiveness of the system, the UF process which is applied in the first step is limited factor. For providing long term safe operating by means of obtaining adequate amount of permeate flux in the process, application pressure in UF has to be higher than the osmotic pressure of whey. This leads to a concentrate ratio in the UF process which is not as high as the ratio in RO. In the UF/RO system where recovered water is produced by a single step RO process at water recovery ratios of 50 and 80% for UF and RO, respectively, water recovery ratio of the system is 40% in total for the whole system. However, the requested quality of process water cannot be provided mostly in this situation. In the UF/RO process including two steps RO, respectively 50% (UF), 80% (RO-I. step) and 80% (RO-II. step) process water separation ratios, only 32% of the raw whey is recovered as process water. Although this percentage can be increased by diafiltration (by diluting whey which is concentrated in UF in advance of RO, diluted UF whey stream is again filtrated in sequential two or more step UF processing prior to RO); increases in both the UF process step and membrane module number, not only makes it difficult for the simple operation of the system to be carried out, but it also causes the investment and operation costs to increase and therefore it reduces the

preferability of the application in practice. On the other hand, diafiltration is mostly applied in UF/NF system integrity for the purpose of separation of protein and lactose; at this point, protein liquid is utilized generally in commercial beverage production. In conclusion, at dual combinations of pressure-driven membrane system, osmotic pressure of raw whey which limits high water recovery in the first
5 step process, on the one hand decreases water recovery ratio of treated water in process water quality obtained from RO effluent which on the other hand causes obtaining concentrate streams for whey powder production at relative higher investment and operating costs.

10

Forward osmosis (FO) and membrane distillation (MD) processes nowadays have become more prominent with increasing importance in various industrial applications in terms of the fact that they can provide flexible operability, high filtration efficiency and relatively low operation costs. The reason for usage of said novel
15 membrane processes subject to the invention which targets to recover water from whey is that concentrated whey stream production can be provided by said processes without degradation of the food content as they comprise high dissolved pollutant separation efficiency, and by means of being able to produce pure water efficiently from whey and by means of treating (below 60°C at which protein denaturation
20 occurs) whey at ambient temperatures and under conditions close to ambient pressures.

Forward osmosis process, is a membrane process depending on osmosis (movement of water from the low pressure side to the high pressure side through a semi
25 permeable membrane due to osmotic pressure difference). A semi-permeable membrane, permits water while it prevents dissolved molecules or ions to pass through. Because osmotic pressure of a liquid is proportional to dissolved matter concentration in definite volume solvent, effectiveness of water passage in an osmotic process depends on osmotic pressure difference between solutions at each
30 side of the membrane without necessitating hydraulic or hydrostatic pressure. By utilizing FO process, water transport can be provided even from wastewaters with high pollutant levels to the solution, having high osmotic pressure (draw solution) and whereby volume stream of wastewater feed can be decreased. Fundamental

advantages of the FO process are known as the low fouling tendency and the rejection (filtration) of pollutant matters at very high proportions and having much lower energy requirement and design costs compared to pressure-driven membrane processes. As external pressure or heat application is not necessary in the process, utilization of FO becomes rather valuable especially in the food industry. The main disadvantage of the process is the need of reconcentration of draw solution having high osmotic pressure. This disadvantage can be removed by water recovery based on combining FO draw solution with an external process (such as RO or MD). Nowadays, the process can be utilized in various applications such as sea water desalination, wastewater treatment, drinking water production, clean water production from brackish water, food beverages or liquid food concentration (fruit juice and protein liquids) and alcohol dehydration.

MD process is a process in which the driving force of the process is temperature, micro porous membrane material is utilized and good quality of treated water is gained by high filtration performance (except for volatile organics, dissolved organics and inorganics 99% and above). In the process, the passing of water through the membrane is provided during the vapour phase under heat difference without applying pressure, while the penetration of water stream in liquid feed stream into membrane pores is prevented. Treated water is obtained by condensing water vapour passing through the membrane to the cold stream side. Ultimately, by preventing non-volatile components from sweeping or going through water vapour, permeation of high purity is obtained during the process contrary to conventional distillation.

Technologically, the process can be applied having four different contents including direct contact, air gap, sweeping gas and vacuum. While industrial wastewater treatment efficiency of the process is well known, the field scale applications of the process have been focused on in different industries in the last few years. The most important disadvantages which prevent the process from being used commonly are the need for membranes that are resistant to long term operations and especially high energy expenditures of necessary heating/cooling processes for providing the required heat difference between feed and permeate streams during operation. The

process has effective utilization potential in water and wastewater treatment, fruit juice concentration, the pharmaceutical industry and sea water desalination.

5 The afore mentioned Combined RO applications of innovative membrane processes have effective field applicability potential in various areas ranging from clean water production to industrial wastewater treatment and industrial water recovery. The RO process is a membrane process which possesses the lowest molecular size of separation among the pressure-driven membrane processes, and its process dynamics and field effectiveness are very well known nowadays. During the process, where
10 operations are performed at high pressures (10-130 bar, mostly 20-60 bar), very low molecular weighted dissolved organics (100 Da) as well as monovalent dissolved inorganics can be rejected at high filtration performance (99% and above) from the water environment. The process can be used commonly in order to recover water from wastewater received from different industries and to produce process water and
15 clean water with good quality for industrial usage primarily to produce drinking water from seawater.

A method where whey is ultrafiltrated from a 2 staged membrane ultrafiltration in order to obtain protein products has been described in the Canadian patent document
20 numbered CA966361 of the known state of the art.

In the United States patent document numbered US5679780 of the known state of the art, a method is described wherein the whey is subjected to cross stream filtration and microfiltration in order to obtain high quality products from whey.
25

In the European Patent document numbered EP1046344 of the known state of the art, a method which uses membrane filtration and membrane ultrafiltration in order to obtain protein concentrate from whey is described.

30 However the applications mentioned in these documents may sometimes be insufficient to reach the desired results.

The Objects and Brief Description of the Invention

The invention intends to carry out a method comprising basically two steps in terms of technology and three different steps in terms of membrane process content such as whey concentration, water recovery for reuse and obtaining whey powder, which
5 aims to produce concentrated whey stream having high solid content by dehydration of whey which is obtained as a by-product following cheese production activities, during the first step membrane process using technological configurations having novel membrane processes possessing different dual combinations and following this, to obtain reuse water during the process at relatively high rates in comparison to
10 the feed volume for industrial operations via other complementary membrane process applications that are carried out in the second step.

Another aim of the invention is to carry out a method where concentrated whey stream production is provided having higher solid content (%25-35) and where
15 industrial reuse water is produced at high volumes (%65-80) by increasing the whey that is a by product of the cheese production industry, focusing on achieving treatable concentrated whey production having lower drying costs during whey powder production, together with lower whey concentration costs using novel integrated industrial membrane systems.

20

Proposed innovative membrane systems, is designed for three different combinations consisting of FO/RO, FO/MD and MD/RO with regard to membrane process content. The systems are technologically classified into two different bases which are related to the characteristic of innovative membrane process which is applied in the first
25 step. In the first membrane operating step of the system which is aimed to achieve concentration of raw whey, dehydration and producing a concentrate whey stream, two distinctive technological configurations are constituted for situations of utilization of FO and MD processes; membrane systems designed for "*First step with FO and with MD*" different membrane application technologies are illustrated in
30 Figure 1 and Figure 2, respectively, in order of process flow diagram including whey powder production from concentrated whey.

Main superiority of the proposed innovative membrane systems in comparison to pressure-driven membrane systems known in common use arises from innovative membrane processes in the first operating step which can be operated without being much affected by high osmotic pressure content of whey. In order to describe more clearly, the unique aspect of the patent is that it enables to produce a concentrated whey stream having higher solid content (at average interval 25-35% while at UF/RO 15-20%) by filtration of higher amounts of water from raw whey in first step membrane process operations of innovative membrane systems. Other unique aspect is that the process enables to produce treated water of reusable quality in the production process by using second step membrane filtration, by means of combining water withdrawn from whey at the first step with another membrane process having high filtration efficiency performance. As a result, an integrated industrial waste water management approach is achieved, by recovering water directly from whey, whose purification on the one hand is difficult and expensive, and following this producing whey powder from concentrated whey on the other hand. Based on the increase in the solid content of the concentrated whey depending on relatively higher water recovery by innovative systems, whey powder production in undenaturated quality from the concentrated whey by means of membrane process operations without protein denaturation below 60 °C is provided at more economic costs with less energy consumption during the powder production by the methods such as direct evaporation, vacuum evaporation or spray drying.

Detailed Description of the Invention

The combined membrane systems that have been provided to achieve the method used in order to reach the aims of the invention have been illustrated in the attached figures.

According to the Figures;

30

Figure 1 – Is the schematic representation of FO/RO or FO/MD innovative combined membrane systems including whey concentration, water recovery and whey powder production by industrial whey treatment and,

Figure 2 – Is the schematic representation of MD/RO innovative combined membrane system including whey concentration, water recovery and whey powder production by industrial whey treatment.

5

The parts in the figures have each been numbered and their references have been listed below.

- 1) Raw whey filling line from production process,
- 10 2) Raw whey storage tank,
- 3) Feed line of raw whey to FO process,
- 4) FO process module
- 5) Concentrated whey stream line from FO process in FO/RO and FO/MD systems, or from MD process in MD/RO system,
- 15 6) FO draw solution storage tank,
- 7) FO draw solution feeding line,
- 8) Diluted FO draw solution return line,
- 9) Stream distribution structure of diluted FO draw solution,
- 10) Draw solution/dissolved matter/mixture storage tank,
- 20 11) Draw solution/dissolved matter/mixture addition line,
- 12) Return line of diluted FO draw solution to storage tank,
- 13) Feeding line of diluted FO draw solution to RO in FO/RO or MD in FO/MD system,
- 14) I. stage RO for FO/RO or MD process for FO/MD,
- 25 15) Membrane concentrate stream line for I. stage RO in FO/RO or MD process in FO/MD,
- 16) Filtered water effluent line by I. stage RO in FO/RO or MD process in FO/MD,
- 17) Stream collection and distribution structure of water filtered by I. stage RO in FO/RO or MD process in FO/MD,
- 30 18) Effluent line of process recovered water produced by I. stage RO in FO/RO or MD process in FO/MD,
- 19) II. stage (optional) RO process feed line for FO/RO,

- 20) II. stage (optional) RO process for FO/RO,
- 21) Recovered water effluent line of II. stage (optional) RO process for FO/RO,
- 22) Membrane concentrate line of II. stage (optional) RO process for FO/RO,
- 23) Membrane concentrates collection and distribution structure of I. and II.
- 5 stages (optional) RO processes for FO/RO,
- 24) Return line of membrane concentrate to FO draw solution storage tank for RO processes in FO/RO or MD process in FO/MD,
- 25) Concentrated whey storage tank,
- 26) Transfer line of concentrated whey to evaporation or drying unit,
- 10 27) Concentrated whey evaporation or drying unit,
- 28) Emission or liquid waste effluent line,
- 29) Whey powder effluent line,
- 30) Whey collection and distribution structure,
- 31) Feed line of whey to MD process,
- 15 32) MD process,
- 33) Filtered water effluent line of MD process,
- 34) RO process,
- 35) Effluent line of process recovery water produced by RO process,
- 36) Membrane concentrate return line of RO process.

20

In the innovative membrane system configuration of “*First step including FO process*” for which general operating lines are shown in Figure 1, FO/RO and FO/MD integrated membrane system configurations are applied. During operation of

25 the system, the raw whey which first of all is received from cheese production process is delivered to the raw whey storage tank (2) via the filling line (1). Afterwards, the raw whey is fed to the FO module feed flow channel of the FO process module (4) via the FO process feed line (3). And to the other flow channel of the FO process module containing two separate flow channels separated by

30 membrane, the FO draw solution is fed from the FO draw solution storage tank (6) via the feed line (7), and as a result the passage of an amount of water in raw whey into the draw solution is provided. By this means, the concentrated whey using the FO process in FO/RO and FO/MD systems and the MD process of the MD/RO

system, that is delivered through the concentrate whey effluent line (5), is submitted to the concentrate whey storage tank (25) in order to produce whey powder. On the other hand, FO draw solution which is diluted by water withdrawn from whey, is recycled to the FO draw solution storage tank (6) through the diluted FO draw solution return line (12) by sending it to the diluted FO draw solution stream distribution line (9) through the diluted FO draw solution return line (8); thus, closed loop operation of FO draw solution line can be enabled. Whether mass transport to whey stream from draw solution by diffusion in the reverse direction to the water stream, or whether depending on filtration efficiency for dissolved matter of the second step membrane process; some amount of dissolved matter content in draw solution is decreased by time despite closed loop operation. In this regard, in order to maintain the desired osmotic pressure difference in the FO process (4) operation, draw solution/dissolved matter/mixture is added to the FO draw solution storage tank (6) through the addition line (11) from the storage tank (10) which contains dissolved matter or mixture, constituting osmotic pressure effect. The amount of FO draw solution arriving to the stream distribution structure (9) through the return line (8) that is required to maintain the desired osmotic pressure difference in the FO process; is fed to the I. step RO (14) for FO/RO system or MD process (14) for FO/MD system through the feed line (13) in order to be concentrated and obtaining clean water by second step membrane filtration. Membrane process at the second step for the FO/RO system is optionally applied in sequential two stages; while application of MD process in FO/MD system is carried out in a single stage. Whether or not the two-stage application of RO process in the FO/RO system depends on the osmotic pressure level of diluted FO draw solution; while relative low osmotic pressure content is to be mentioned, process water of good quality can be obtained under high filtration efficiency; when relative high osmotic pressure content is to be mentioned, because of the decreased filtration efficiency performance, II. stage RO application becomes mandatory to obtain clean water. The membrane concentrate, is delivered to the membrane concentrates collection and distribution structure (23) (optional RO application is not provided for FO/MD) of the I. II stage (optional) RO process for FO/RO via the I. stage RO for FO/RO and the MD process membrane concentrate line (15) for FO/MD, the filtered water is then delivered to the filtered water stream collection and distribution structure (17) processed with MD for FO/MD or I. Stage

RO for FO/RO, via the filtered water effluent line (16) processed with MD for FO/MD or I. stage RO for FO/RO, and is obtained as process water over the reuse water effluent line (18) during the production process of MD for FO/MD or I. Stage RO for FO/RO, if optional II stage RO application is not necessary. In case of its necessity; a portion of or all of the filtered effluent water of I. stage RO or MD process (14) for FO/MD, is fed to II. stage (optional) RO process (20) for FO/RO with the connection of II. stage (optional) RO process feed line (19) for FO/RO, via the I. stage RO for FO/RO or MD process for FO/MD filtered water stream collection and distribution structure (17). As a result of the second filtration operation carried out therein, process water is obtained through the II. stage (optional) RO process for FO/RO recovery water effluent line (21). Membrane concentrate stream belonging to II. stage RO process is first submitted to I. and II. stage (optional) RO process membrane concentrates collection and distribution structure (23) for FO/RO via the II. stage (optional) RO process membrane concentrate transfer line (22) for FO/RO. In case of optional II. stage RO is not applied, membrane concentrate belonging to I. stage RO for FO/RO or MD process for FO/MD is recycled back to the FO draw solution storage tank (6) under a closed loop via the I. stage for FO/RO and MD process membrane concentrate transfer line (15) for RO or FO/MD, and to the I. and II. stage (optional) RO flow collection and distribution structure (23) for FO/RO and to the FO draw solution return line (24) of the MD process membrane concentration for FO/MD or RO processes for FO/RO. In the case of optional II. Stage RO application, the II stage RO membrane concentrate, is included into a loop via the II. Stage (optional) RO process membrane concentrate line (22) for FO/RO and, is sent to the I. and II stage (optional) RO process membrane concentrates collection and distribution structure (23) for FO/RO and is combined with the I. stage RO concentrate stream received from the membrane concentrate line (15) of I. stage RO process or from the MD process for FO/MD.

30 In the innovative membrane system configuration of “*First step including MD process*” for which general operating lines are shown in Figure 2, MD/RO integrated membrane system combination is applied. During operation of the system, the raw whey which first of all is received from cheese production process is delivered to the

raw whey storage tank (2) via the filling line (1). Afterwards, the whey directed to the collection and distribution structure (30) via the feed line (3); from this line, the whey is fed to MD process (32) which is the first step membrane process of the system via the feed line (31). Filtered water in the MD process is sent to the RO process (34) which is the second step membrane process via the MD process filtered water effluent line (33). Whey which is concentrated during the MD process is delivered to the concentrated whey storage tank (25) for the purpose of whey powder production via the concentrated whey effluent line (5) from the FO process in FO/RO and FO/MD systems and from the MD process in MD/RO systems. Re-filtration of the MD filter effluent water during the RO process, the water production of recovered water quality for the production process is provided via the RO process filter water effluent line (35). Additionally, cyclical operation of the MD/RO system under closed loop is carried out by sending the RO process concentrate stream to the whey collection and distribution structure (30) via the return line (36).

In the technological system configurations shown in Figure 1 and 2, whey powder production from whey streams (5) concentrated at the first step membrane processes is carried out in common production processes such as the FO process in FO/RO and FO/MF systems and the MD process in MD/RO systems. In this context, both two innovative membrane systems classified technologically, upon the first step membrane process become integrated by combining them with whey powder production. As follows, on the one hand a concentrated whey stream in relative high solid content is obtained by recovery of process water in high volume in the systems; on the other hand because of increased solid content of concentrated whey, production of whey powder is carried out economically by removing water of concentrated whey under relatively lower energy consumption. In order to achieve this, whey concentrated by both technological configurations, such as from the FO process in FO/RO and FO/MF systems and from the MD process in the MD/RO processes is submitted to the storage tank (25) via effluent line (5), and is then transferred to unit where water removal processes such as concentrated whey evaporation or drying (27) are carried out with the transfer line (26). Whey dewatered in this unit, is produced as powder via whey powder the effluent line (29). In the emissions during drying, organic vapour emissions originating from volatile

organics in whey, are present besides presence of water vapour. At this point, using condensation process by means of liquidization of water vapour, organic pollutants which are in the vapour phase are taken to liquid phase. Even though a wastewater obliged to be treated emerges in such a situation, along with high proportion of water recovery from whey and more economic whey powder production, contaminant content of wastewater that is obtained, is decreased to the levels lower than whey pollutant content (approximately one 15th-one 20th of raw whey organic content). Thus, notably effective application of water and valuable product recovery and waste reduction in terms of sustainable environmental protection characteristics is constituted. This wastewater is discharged from the liquid waste effluent line (28).

Primarily the quality content of whey and the input flow rate of whey is taken into account during industrial application designs of FO, MD and RO processes which are the subject of the invention and which involve innovative membrane systems. Processing of membrane modules can be carried out by utilizing different structured membrane modules (tubular, hollow fibre, spiral wound or flat sheet) independent of their geometry. Every individual membrane system, by also taking into account process specific technical necessities; is provided as comprising technical equipment such as pumps, pressure gauges, flow control valves, temperature control (heating/cooling) units, gas control and release valves. Operating of membrane systems can be designed to be intermittent, semi-continuous or continuous depending on the purpose of use, quality content of whey and influent flow rate of system. Prior to the first step membrane process, by equipping the system with processes such as centrifuge, MF or UF, the fat content of raw whey can be eliminated and afterwards all operations on water recovery, whey concentration and whey powder production from fat free whey can be carried out as mentioned in this patent. By this means, besides whey powder production, commercial product gain such as cream and butter can be provided using fat separated from raw whey. In the FO process, various organic, inorganic or organic/inorganic included mixture draw solutions can be utilized to render high osmotic pressure difference during the process, but without causing any deterioration in quality of whey powder. In case of NH_4HCO_3 salt is used as draw solution during the FO process in the FO/RO system, by constituting a gasification unit (operating temperature $\geq 58^\circ\text{C}$) prior to concentration of draw

solution in RO, recycling of NH_4HCO_3 as NH_3 and CO_2 to the FO draw solution line is provided. By this means, during the RO process which is the next step, a more effective clean water production is achieved. In order to decrease the heating costs in the MD process, renewable energy sources (solar, wind, etc.) can be utilized. Besides
5 this, applications wherein waste heat originating from industrial activities is recovered and utilized, can be preferred.

CLAIMS

- 1) The invention relates to a method which utilizes novel membrane systems (FO/RO, FO/MD and MD/RO) having dual combinations which provides recovery of process water by processing whey by-produced from the cheese production industry and which enables to obtain concentrated whey and commercial whey powder production; **characterized in that** during the 1st step of the membrane process whey is concentrated and the water from whey is separated from raw whey; during the second step of membrane process the filtered whey obtained from the first step is treated and recycled water which can be reused is obtained during the production process and the whey that has been concentrated in the first step membrane process is treated in the whey powder production line and commercial whey powder is produced.
- 2) A method according to claim 1, characterized in that it comprises the steps of;
- Feeding the raw whey via the FO process feeding line (3) to the FO module feeding effluent line of the FO process module (4) in order to ensure that the raw whey is passed into the draw solution of whey water, and feeding the FO draw solution via the FO draw solution feed line (7) from the FO draw solution storage tank (6) to the other flow channel of the FO process module (4) having two separate flow channels that have been separated by a membrane.
- 3) A method according to claim 1, characterized in that it comprises the steps of;
- a method according to claim 1 or 2, characterized in that it comprises the step of; adding the draw solution via the draw solution/dissolved matter/mixture addition line (11) to the FO draw solution storage tank (6) from the draw solution/dissolved matter/mixture storage tank (10) which contains dissolved matter or mixtures thereof, which create osmotic pressure effect; in order to produce concentrated whey stream having higher solid matter content (%25-35) in comparison to the concentrated whey streams (%15-20 solid matter content) produced by means of pressure driven membrane process combinations and in order to obtain concentrated whey stream having lower

water content and to enable treatment with high recovery rates without being affected from the high osmotic pressure content of whey following FO and MD processes.

- 5 4) A method according to claim 1, 2 or 3, characterized in that it comprises the steps of;
carrying out treatment with high recovery rates without being affected from the high
osmotic pressure content of whey following FO and MD processes in the first step and
to refiltering the whey water obtained from the first step during the second membrane
process with high filtration efficiency in order to obtain water having such quality that
10 can be re-used during drying production processes at higher recovery rates (%65-80) in
comparison to water recovery rates (%32-40) that have been obtained using pressure
driven membrane process combinations.

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FIGURE 1

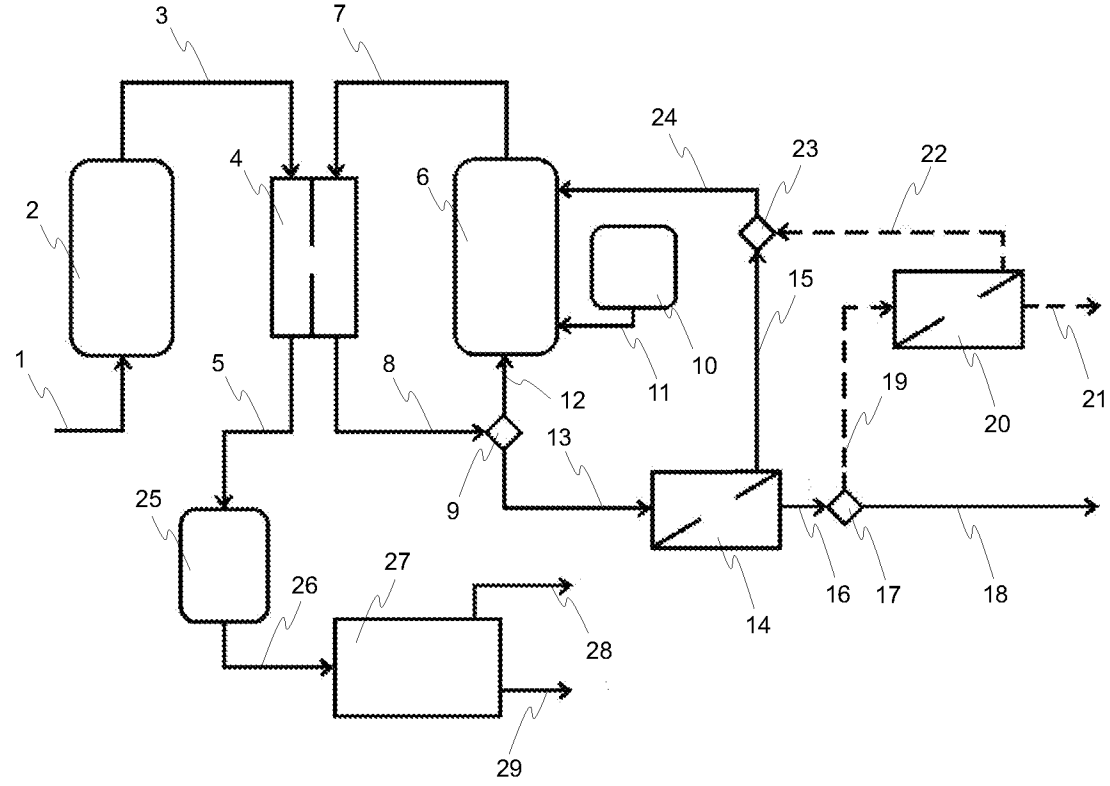
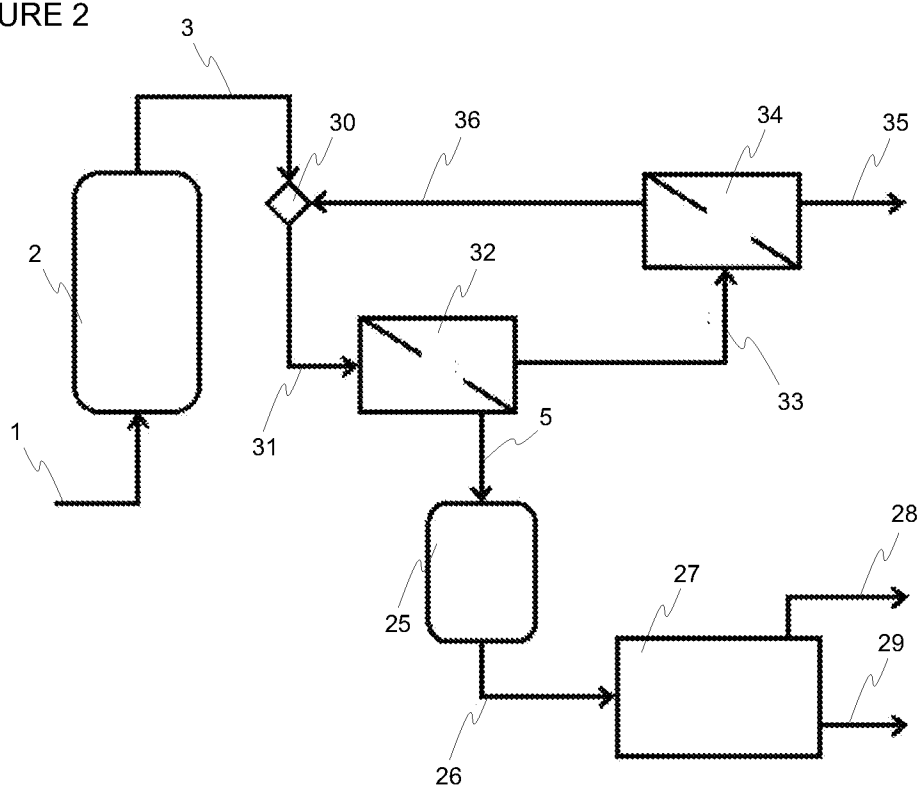


FIGURE 2



INTERNATIONAL SEARCH REPORT

International application No
PCT/TR2016/050573

A. CLASSIFICATION OF SUBJECT MATTER

INV. A23C1/12 A23C21/00 A23J1/08 A23J1/20 B01D61/00
B01D61/36 B01D61/58 C02F1/44 B01D61/02
ADD. C02F103/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A23C A23J B01D C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	COSKUN AYDINER ET AL: "Techno-economic viability of innovative membrane systems in water and mass recovery from dairy wastewater", JOURNAL OF MEMBRANE SCIENCE, vol. 458, 1 May 2014 (2014-05-01), pages 66-75, XP055363329, NL ISSN: 0376-7388, DOI: 10.1016/j.memsci.2014.01.058 the whole document figures 1a, 1b, 5, 6; tables 2,3,5	1-4
A	US 2013/220927 A1 (MOODY CHARLES D [US] ET AL) 29 August 2013 (2013-08-29) paragraph [0005] - paragraph [0006] figures 1-2 claims 1-6	1-4

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No

PCT/TR2016/050573

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No

PCT/TR2016/050573

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