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ENVIRONMENTAL PROTECTION: FROM SORBENTS TO MEMBRANES

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ENVIRONMENTAL PROTECTION: FROM SORBENTS TO MEMBRANES

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Колективна монографія «Environmental Protection: from Sorbents to Membranes» - під ред. проф. Н. Кабай, докт. хім. наук Ю. С. Дзязько, проф. М. Арда, докт. хім. наук К.О. Каздобіна - 108 с.

Колективна монографія включає статті за матеріалами українсько-турецького семінару, який було проведено 11 листопада 2016 р. на базі Інституту загальної та неорганічної хімії ім. В. І. Вернадського НАН України за участю фахівців Егейського університету (Турецька республіка) та за підтримки Відділення хімії НАН України, Відділу міжнародних зв'язків НАН України, а також Наукової та Технічної дослідної Ради Турецької республіки TÜBİTAK. У монографії наведено результати досліджень, які направлені на вилучення токсичних і цінних компонентів із розчинів техногенного та природного походження, зокрема з біологічних рідин, із застосуванням сорбційних та мембранних методів. Результати робіт можуть бути застосовані у водопідготовці, хімічній, фармацевтичній, харчовій промисловості. Особливу увагу приділено синтезу нових матеріалів для процесів розділення та впливу структури цих матеріалів на їх функціональні властивості: проникну здатність, електропровідність, каталітичну спроможність тощо.

Монографія є корисною для фахівців в області мембранних та сорбційних технологій, а також для студентів вищих навчальних закладів.

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WHEY AND WHEY PROCESSING

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Abstract. *Whey is a liquid by-product of the dairy industry produced during the manufacture of cheese and it contains more than half of the solids present in the original whole milk, including whey proteins (20% of the total protein) and most of the lactose, minerals, water-soluble vitamins and minerals. In recent years, whey has been recognized as a major source of nutritional and functional ingredients for the food industry. Commercial whey products include various powders, whey protein concentrates and isolates, and fractionated proteins, such as a-lactalbumin and b-lactoglobulin. The increased interest in separation and fractionation of whey proteins arises from the differences in their functional, biological and nutritional properties. For this reason, the aim of this work is first to put together all the necessary information about whey, its composition, properties, potential usages and describe the common methods of whey processing.*

Keywords: *whey, type of whey, whey composition, whey valorization, whey processing.*

Introduction. Whey is the liquid substance obtained by separating the coagulum from milk, cream, or skim milk in cheese making. Whey could be also obtained from curd formation by the direct acidification of milk. The whey stream contains approximately 6% of solids, mainly lactose, minerals, whey proteins, fat, and by-products of cheese (or casein) manufacture. The quality and compositions of the whey vary depending on the type of cheese (or casein) being produced and manufacturing practices [1-3].

Whey is used mainly as animal feed or discharged into the wastewater treatment plants, although it is rich in valuable components. It contains lactose, minerals (e.g., calcium, magnesium, phosphorus), vitamins, non-casein protein (except glycomacropeptide), and traces of milk fat. Because of its content of organic compounds, whey cannot be discharged to receiving environments. Therefore, it is necessary to process the whey even it may not be economic. Also, when its considered that on cheese making about half of the total milk finds its way into the whey, it is more understandable that the processing of whey and in particular its organic constituents are considered very important. Thus, recovery of valuable compounds such as protein and lactose from whey has received intense attention recently.

Worldwide whey production is estimated at around 180 to 190×10^6 ton/year; of this amount only 50% is processed. The whey can be considered as a valuable by-product with several applications in the food and pharmaceutical industries; however, it is often treated as a dairy wastewater. The treatment of whey represents a serious problem due to its high organic load, which can reach a chemical oxygen demand (COD) of 100,000 mg O_2 L^{-1} [4].

In Turkey, 5 major dairy companies that process 19% of Turkish raw milk are present, whereas there are hundreds of so called "mandras" possessing small traditional dairy processors which generate huge amounts of whey. Whey treatment processes include traditional techniques such as evaporating and drying which are widely employed in Turkish companies. These processes do not contribute to recovery of valuable products in whey. These methods are used to remove some part of the water in whey to diminish the volume and to enhance the keeping quality. Anaerobic treatment is another process employed for organics removal from whey. This process is preferred instead of conventional aerobic wastewater treatment since cheese whey has a very high organics content (60–80 g COD/L) and may impair biomass granulation during biological treatment. This would in turn result in biomass wash-out [5]. Further purification of whey can be achieved via ion exchange, affinity chromatography and selective precipitation. Recent developments in membrane filtration have provided exciting new opportunities for large-scale whey treatment to produce cleaner discharge as well as protein and lactose fractionation [6,7].

Type and Forms of Whey. The traditional whey is produced as a result of processes aimed at recovering casein, the principal protein of milk. Separation of casein from the rest of the milk (as in cheese making or production of industrial casein and caseinates) is usually accomplished by acidification to pH 4.5-4.8 or through the action of rennet, a casein-coagulating enzyme preparation. In acid coagulation, the pH is lowered either by microbial fermentation of the milk sugar lactose into lactic acid or by direct addition of a mineral (phosphoric, hydrochloric, sulfuric, etc.) or an organic (lactic, citric) acids. The fermentation route is most often used in the production of fresh cheeses, while the direct acidification is typical for production of industrial casein and caseinate products; in both cases, the resulting why is referred to as *acid whey*. In contrast, *sweet wheys* are obtained in manufacture of most hard and semihard cheeses for which the rennet coagulation principle is employed, as well as in production of industrial rennet casein. Since enzymatic clotting of milk by rennet occurs at pH 6.0 or higher, the lactic acid content of freshly obtained sweet whey is very low but may increase quickly if subsequent bacterial fermentation is not controlled by rapid pasteurization and/or by deep cooling [8,9].

*Whey Composition***.** Whey is a fairly dilute product with a total solids of about 6.5%. As mentioned before the solids are basically lactose, whey protein, ash, lactic acid and fat (Table 1).

Table 1. Whey Composition

Constituent	Sweet Whey (%)	Acid Whey (%)
Water	93-94	94-95
Dry matter	6-6.5	5-6
Lactose	4.5-5	3.8-4.3
Lactic acid	Traces	Up to 0.8
Total protein	0.8-1	0.8-1
Whey protein	0.6-0.65	0.6-0.65
Citric acid	0.1	0.1
Minerals	0.5-0,7	0.5-0.7
pH	6.4-6.2	5-4.6

***Source:** *www.dairyforall.com*

Possibilities of Whey Utilization. The whey can be considered a valuable by-product with several applications in the food and pharmaceutical industries.

From a valorization point of view, two different options in cheese whey (CW) management can be considered: the first one is based on the application of technologies to recover valuable compounds such as proteins and lactose. Currently, valorization processes applied to CW constitute the preferential option to treat this by-product, only exceeded by the production of powdered CW. The second option relies on the application of fermentation processes to obtain value added products such as: organic acids (e.g. lactic, succinic and propionic), single cell proteins and oils, biopolymers (enzymes, polyhydroxyalkanoates, exopolysaccharides) and bacteriocins. Sometimes whey permeate, obtained from ultrafiltration (UF) step, has been used as fermentation medium; in this case, both management options are applied.

The UF process produces a whey permeate rich in lactose (about 80% of the original lactose in milk) and nanofiltration (NF) or reverse osmosis (RO) processes can be applied for concentration of the lactose which can be applied in the sweet industry or in pharmaceutical fermentation procedures.

In addition to lactose, whey permeate containing other nutrients essential for microbial growth; so the possibility to use it as a fermentation medium to obtain high value products represents an interesting opportunity which must not be neglected. Moreover, whey permeate is an attractive source of oligosaccharides for potential application in human nutrition [10].

Among the different possibility of whey valorization, reported in Figure 1, individual whey protein purification and application of fermentation technology on whey permeate could be also considered [11].

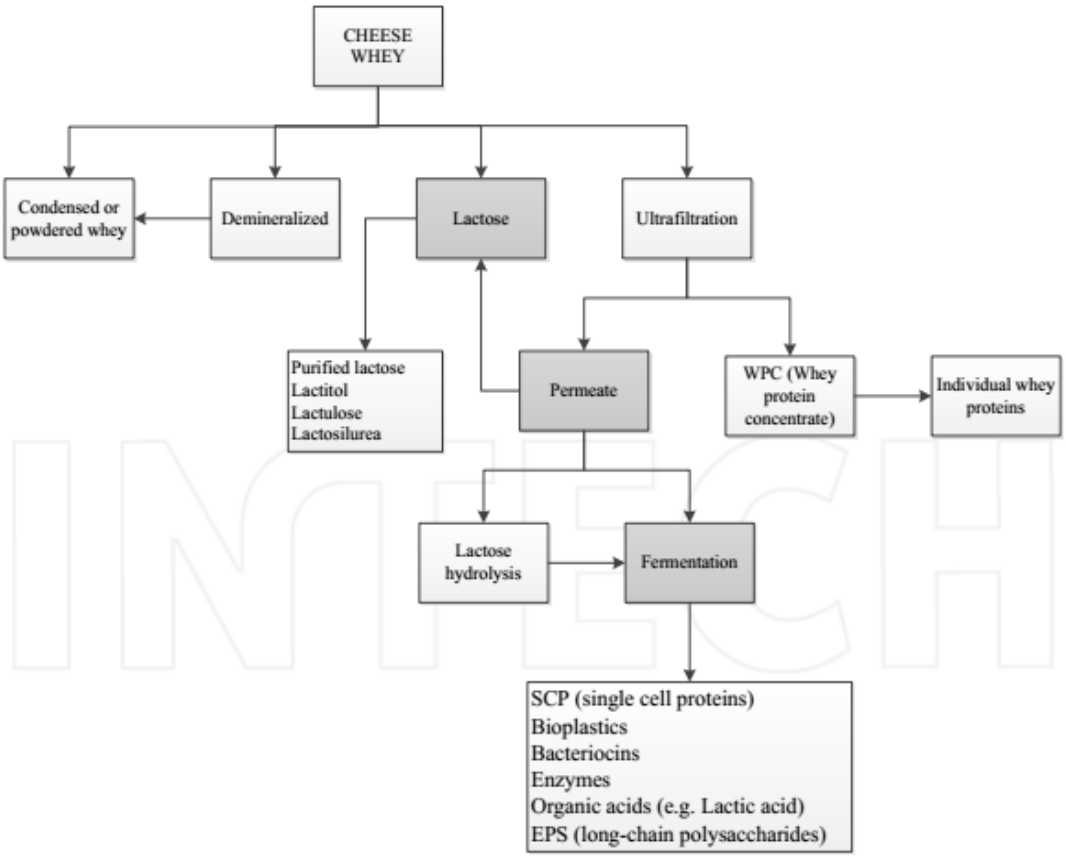

Fig. 1. *Scheme of Current Possibility of Whey Valorization [11].*

Industrial Processing of Whey. Processing of cheese whey was the first successful commercial application with several research initiatives underway to find uses of whey-waste. Since whey disposal is costly and problematic for cheese manufacturers; the focus is on techniques to convert this waste product into valuable functional components [12].

Whey processing is one of the most successful industrial membrane applications. For reasons of simplicity, urgency and the economics of disposal problem solution, UF of whey was the first application of membrane fractionation to reach a full commercial scale. The membranes used should be high yielding, resistant to physical, chemical and microbiological agents, unaffected by cleaning and disinfection materials [4,12]. Figure 2 shows a general scheme of possible membrane applications in whey treatment [13].

Applications of membranes in whey processing include **a)** concentration of whey 3 folds (24%) with RO and NF prior to evaporation and drying, **b)** manufacture of whey protein isolate (WPI) (90%), **c)** production of whey protein concentrate (WPC) (35-80% protein), **d)** converting the lactose to higher-value products by fermentation (e.g., ethanol or lactic acid) or by enzyme hydrolysis in continuous membrane reactors, **e)** fractionation of whey to value-added nutraceuticals, **f)** Microfiltration (MF) of whey as a pre-treatment for UF, and **g)** concentration and demineralization of whey and UF permeate with NF [10,13].

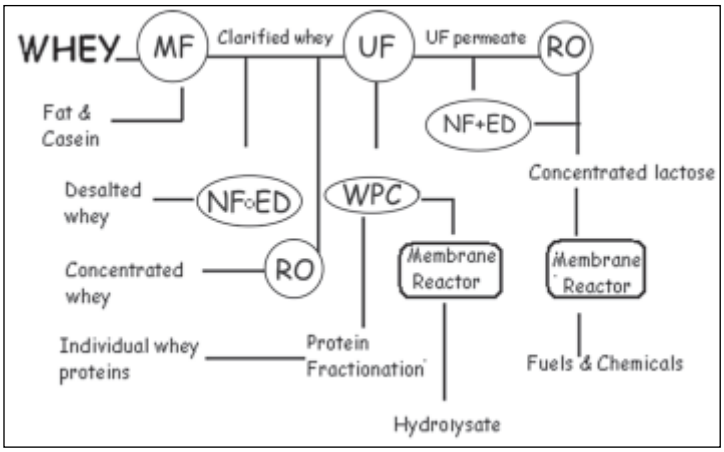

Fig.2. *Membrane Applications Used in Whey Processing [13]*

Conclusions. Whey is a very interesting by-product due to its components. Their properties, functions and chemistry structure make whey a great base for the creation of a series of new products or an ideal alternative compound to more traditional ones.

Membrane technologies have been commercially integrated in dairy industry and recently the new applications exist for extending their uses. Challenging developments in membrane processes should focus on efficient fractionation of minor whey components with desired biological and nutraceutical properties.

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СИРОВАТКА ТА ЇЇ ПЕРЕРОБКА

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Резюме. Сироватка являє собою рідкий побічний продукт, який утворюється при виробництві сиру. У сироватці міститься більше половини твердих речовин, які є наявними у вихідному незбираному молоці, зокрема білки молочної сироватки (20% від загального білка), більша частина лактози, мінеральні речовини, водорозчинні вітаміни та мінерали. В останні роки, сироватка була визнана основним джерелом поживних речовин та функціональних інгредієнтів серед відходів харчової промисловості. Комерційні продукти, які виробляють із сироватки, – концентрати та ізоляти білків, а також фракціоновані білки, такі як α-лактальбумін і β-лактоглобулін. Підвищений інтерес до поділу і фракціонування сироваткових білків зумовлений відмінностями їх функціональних, біологічних та поживних властивостей. З цієї причини, метою даної роботи є, передусім, систематизація всієї необхідної інформації щодо сироватки, її складу, властивостей та потенціальних можливостей використання, а також огляд загальних методів переробки сироватки.

***Ключові слова**: сироватка, тип сироватки, склад сироватки, ревалоризація, переробка молочної сироватки.*