

THE POSSIBILITY AND MODERN ACHIEVEMENTS IN UTILIZATION AND USE OF WHEY¹

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Abstract

Dairy industry keeps developing some new, enriched dairy products, which have proved themselves as very good. The dairy products, as we know from ancient times, have started to develop into a new generation of dairy products with different characteristics and better nutritive and health value. The whey beverages also belong to this group – a by-product which had been thrown away for a long time as waste or has been used as a fodder. Thus, down to the present day, there has been developed a whole range of whey beverages, whether they were produced by native sweet or acid whey, by deproteinized whey, of fresh whey diluted with water, fermented whey, or the powdered beverages with addition of different flavours. There are also alcoholic beverages, as the whey beer or wine, as well as the beverages of low alcohol (less than 1.5%). This paper tries to point out to some possibilities and modern achievements in exploitation and use of whey.

Key words: *composition of whey, alcoholic and non-alcoholic beverages, functional additives*

Introduction

One of the most important problems of a modern mankind is the lack of food problem. The problem appeared due to a large increase in population and insufficient food production in the countries with the largest increase in population. In this respect, besides the production increase, there is also

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put a question of more rational exploitation of food ingredients, which has already produced for the needs of man. If we observe the production and processing of milk from that point of view, whey is surely one of the most present by-products, with which most of milk nutrients are practically lost.

According to the average composition, whey contains around 93% of water, over 50% of dry matter turns into water, which depends on the basic composition of milk, as well as on the technological processes of cheese production, i.e. casein in which whey is produced. The composition of whey inputs are lactose as the most, less than 1% are the whey proteins, and in smaller quantities are present minerals and vitamins liquefiable in water and fat.

The possibilities of using whey in food industry are great, which is why have made efforts for a long time that whey uses regularly in human nutrition, not only as a fodder. The basic division of whey depends on a way of the casein coagulation, so it is divided on whey made by an acid activity (acid whey) and whey made by enzymes activity (sweet whey) (Tratnik, 1998). The acid whey is tastier and more stable, it contains less lactose and milk fat. There is also technical whey, which gets by precipitation of milk protein with different agents in regard to the ones which use in production of acid and sweet whey.

In food industry whey can be used in different ways, although it most often processes into the powder whey or there produce concentrates and isolates of some components as proteins and lactose. By dehydration of fresh whey, there gets the powder whey, which can be sweet (pH 5.6), acid (pH 5.1), demineralized powder whey and the powder whey without lactose. They often use as additives in food industry, while demineralised whey and lactose free whey often use in production of food for children.

The most valuable component of whey is the whey protein, which significantly differs, by its characteristics and activity, from the basic milk protein – casein. In fresh milk is around 80% of casein and approximately 20% of the whey protein which have different features. The most important components of the whey protein are beta-lacto globulin, alpha-lacto albumin, immunoglobulin, enzymes, free amino acids, lactoferrin, blood serum albumin and glycomacroteptides.

Considering that the whey proteins have the exquisite functional features (solubility, viscosity, emulsifying and gelling ability, water absorption), it provides them to fit into numerous dairy products, and primarily for the purpose of a biological value increase (Tratnik, 1998). The whey proteins stimulate the growth of some lactic acid bacteria, which is especially important in application of probiotic cultures, which adapt themselves and grow slower in milk, especially the bacteria *Bifidobacterium bifidum* (Krsev, 1989). They use as substitution for milk fat, too, which represents a big advantage for production of light milk and cheese spreads, fermented beverages and various desserts (Tratnik and Bozanic, 1996 b). Therefore, whey is mostly used for the production of the whey protein concentrate (WPC) and lactose which has the largest share in it.

For the purpose of obtaining the whey protein concentrate of wanted composition and depending on further use, today apply mostly a combination of different membrane processes as: ultra-filtration (UF), diafiltration (DF), micro-filtration (MF), reverse osmosis (RO), and often demineralization processes are included: ion exchange (IE) or electro-dialysis (ED) (Tratnik, 1998).

The application of micro-filtration (MF) in whey and milk processing has the specific significance for the micro-biological quality and durability of functional dairy products, especially in production of food for children (Borovic, 1993). Modernizing the membrane equipment and other processes of separation provides new and better opportunities for whey exploitation.

The largest part of the whey dry matter is lactose (approximately 70%), as very important source of the whey energy value, with multiple functions. Some of the beneficial effects of lactose are: stimulation of intestinal peristalsis, facilitation of calcium and phosphorus absorption, setting up a slightly acid reaction in the intestine, by which prevents the growth and multiplication of harmful bacteria.

It provides an optimal level of magnesium, and thereby enhances degradation of milk fat and other nutritive ingredients in the human organism. Technical processing of whey causes transformation of the specific lactose percentage into lactulose, which is considered as a promoter of the bifidobacteria growth (Tratnik, 2003).

Composition of whey

As we have already stated, whey is the main by-product of dairy industry. The biggest problem of dairy industry is that only 10-20% of milk uses for getting a specific product, while 80-90% of milk belongs to whey. About 6% of the total annual produced whey gets directly as a by-product during the casein production from skimmed milk, while a much greater amount of whey (94%) gets in the form of cheese whey, which is left after the production of various types of cheeses.

That is the reason why the whey problem mainly brings down to invention of such types and shapes of whey, which technology is simple and economically justified for our industry. One of the most economical ways of whey processing is the production of beverages, by which, within just one process all whey potentials as a raw material are used.

The composition and main features of whey depend on milk quality and production technology. According to the average composition, whey can consist around 93% of water, and around 50% of milk dry matter (solid) turns to water, and it can vary from 6% to 7%. Lactose makes the largest component of the whey, while approximately 1% is the whey proteins. In smaller quantities are present also minerals and fats.

The biggest differences are concerning the amounts of calcium, phosphate, lactic acid and lactate, which are more present in acid than in sweet whey (Table 1). The sweet whey, except the whey protein, contains also glycomacropeptide (GMP), which originates by enzymatic hydrolysis of *k*-casein.

Table 1. Typical composition (g/L) of sweet and acid whey

Component	Sweet whey	Acid whey
Total solids	63,0-70,0	63,0-70,0
Lactose	46,0-52,0	44,0-46,0
Proteins	6,0-10,0	6,0-8,0
Calcium	0,4-0,6	1,2-1,6
Phosphates	1,0-3,0	2,0-4,5
Lactates	2,0	6,4
Chlorides	1,1	1,1

Source: P. Jelen, *Whey Processing*, in: H. Rginski, J.F. Fuquau, P.F. Fox (Eds.), *Encyclopedia of Dairy Sciences*, Vol.4 Academic Press-An Imprint of Elsevier, Boston, London, 2003, pp. 2740.

As for the share of protein, it is slightly lower in whey got in the production of cheese from ultra-filtered milk. Anyhow, the share of protein in acid and sweet whey is almost equal and they exactly are the ingredients which put whey in the limelight concerning the dairy products market (Tratnik, 1998).

Different thermo-sensitive fractions as β -lactoglobulin, α -lactalbumin, blood serum albumin, immunoglobulin and thermostable fraction of proteases-peptone go to the whey proteins. Of the total share of protein in whey, beta-lacto globulin makes a half of it.

Next in line concerning the share is α -lactalbumin with 22%, then immunoglobulin, proteases-peptone, blood serum albumin and in smaller quantities are present lactoferrin, lactaline, glycoprotein and transferrin. In 1986, Kinsella had described in his research the milk proteins with special reference to their physical-chemical and functional features. In the table 2 was shown the total share of the proteins in whey.

Table 2. *Amount of proteins in whey*

Whey proteins	% of total
β -laktoglobulin	50
α -laktalbumin	22
Imunoglobulins	12
Protease peptons	10
Blood serum albumin	5
Others	1

Source: *Kinsella, J.E.(1986.): Milk proteins: physicochemical and functional properties. Critical Reviews in Food Science and Nutrition, 21, 197-262.*

Thanks to a high share of essential amino acids, first of all lysine, cysteine and methionine, the whey proteins belong to the most valuable proteins in nutritive sense, and they have much bigger biological value in comparison to casein, as well as other proteins of animal origin. Utilization of the whey protein in organism is closely connected to the relation cysteine/methionine, which is in the whey protein almost ten times higher than in casein.

It is necessary to mention also free amino acids, which share in whey can differ and it depends mostly from the level of casein hydrolysis in the production of various types of cheeses (acid or sweet). Owing to that fact,

the share of free amino acids in sweet whey is approximately four times higher, while in acid whey even up to ten times higher than in milk, which is shown in the table 3 (Tratnik,1998).

Table 3. *Content of aminoacids (mg/l) in whey*

Whey	Free aminoacids		Aminoacids in proteins	
	Total	Essential	Total	Essential
Sweet whey	132,7	51,0	6,490	3,326
Acid whey	450,0	356,0	5,590	2,849

Source: *Tratnik, LJ. (1998): Mlijeko-tehnologija, biokemija I mikrobiologija, Hrvatska Udruga, Zagreb*

Daily needs for most of the essential amino acids can be satisfied by consuming about 1.5 l of whey or 0.5 l of milk (Popovic-Vranjes and Vujcic, 1997).

There should also mention that the whey proteins have excellent functional features, as: good solubility, ability of gelling and emulsification, and that is why their concentrates often use in food industry. Immunoglobulins and other glycoproteins as lactoferrin and transferrin, enzymes lysozyme and lactoperoxidase, as very significant components of the whey immuno active composition are necessary to mention, too. They have antimicrobial characteristics, and they can reduce or inhibit allergic reactions (Tratnik, 2003).

Lactose makes the largest part of the whey dry matter -solid (around 70%) and it is very important source of the whey energy value, and has a multiple function. Lactose has the beneficial effect on stimulation of the intestine peristalsis, makes easier the absorption of calcium and phosphorus, as well as setting up slightly acid reaction in the intestine, by which prevents the growth and reproduction of harmful bacteria. Likewise lactose provides an optimal relation of magnesium, by which influences to degradation of milk fat and other nutrients in human body. During the thermal treatment of whey comes to transformation of certain percentage of lactose into lactulose, which is among the promoters of bifidobacteria growth.

Vitamins soluble in water transfuse from milk to whey, but their share is very changeable depending on the method of the whey storing. The whey in its composition can have larger amounts of vitamin B2 (riboflavin), as

well as cobalamin and folic acid from milk, which pass in whey during the production of cheese.

In the dry matter (solids) of whey, the composition of minerals is very changeable and it ranges from 7% to 12%, which depends on the technological procedure of cheese production (Popovic-Vranjes, Vujicic, 1997). From milk to whey pass also all dissolved salts and micro-elements, but also salts added during the cheese production. Related to it, the share of calcium and phosphorus is much higher in acid whey, considering that at the higher acidity of environment, the solubility of these minerals is also higher.

Production

Over 100 million tons annually amounts the world production of whey, and approximately 50% of this amount is produced in the European Union (EU). Approximately 6% of the total annually produced amount of whey gets directly as a by-product during the production of casein from skimmed milk, while around 94% gets in the form of cheese whey which is left after the production of various types of cheeses.

The amount of whey got by cheese production is almost equal to the amount of milk which is necessary for its production. Which means that, during the production of 1 kg of cheese is made in average 9 kg, i.e. 8-12 l of whey depending on the type of cheese which is produced. According to the data on cheese production projected until the year 2019, the scientists consider that the world production of whey until the end of 2019 will record a permanent growth of around 2% per a year.

The situation in the Serbian market at the moment is such that the production and export of whey are negligible (minimal). Annually from Serbia exports whey in the amount of a tens of thousands of US dollars, while import is higher and it ranges from 1.9 to 4.7 million US dollars.

Mostly imports from Croatia, Belgium, the Netherlands and Hungary. On other continents also trades with whey. The most important exporters are Germany, France, USA, New Zealand and the Netherlands, and the most important importers are the Netherlands, China and USA (Obućina B., Bardić D., Dulić Marković, Bernardoni P. , 2010.).

The world processing of whey is mainly based on its utilization in production of the products which do not require the expensive technological processes. In consideration to the permanent production growth and the fact that whey has been recognized as a raw material with great potential, there is more and more researches directed to its maximum utilization.

The structure of milk production in Serbia is such that almost 90% of the products produced every year belong to the group of fermented products and liquid milk (Jelinić, J., Đurović, S., 2009.). In regard to the fermented products, the amount of the whey products is negligible, which leads to the conclusion that, by the whey fermentation, could get the products, which would take more significant place in the range of dairy products meant for general consumption. Considering that the current absence of plants for whey processing, encouraging the processing of whey in Serbia would save a lot of money, which currently uses for import of whey. Regarding the perspective of utilization of whey as the raw material and according to the existing condition of equipment in Serbia, the basic goal should be encouraging the whey exploitation in food industry.

In most of industrially developed countries in Europe and United States of America, whey has found a significant place in food industry, so in those countries' market can find a wide range of the whey products or in which it has been significantly represented. In our country also make efforts in using this important by-product of dairy industry in order to reduce losses of the whey nutrients. Whey has found wide application in food industry, in bread and rolls industry, confectionery products industry, in meat industry and the production of various creams, soups, sauces and toppings in which it is mostly used as the concentrated whey or the powder whey. Its application in dairy industry is very significant.

Dried whey is a good substitute for skimmed milk powder in the production of ice-creams, and various desserts and beverages are made of whey. It adds to whipped cream in order to get stable foam, and it uses in the production of yoghurt and other fermented beverages for enrichment and increase of biological value of the products. Some types of cheeses are produced of the whey albumens, as the albumin cheese – curd, hard cheese – manur, etc. Due to a great content of lactose and biologically valuable proteins, there makes also a wide range of food for children and various kinds of dietary products based on whey.

Whey is very important for the pharmaceutical industry, too – through the lactose which uses for the production of tablets, usually as an inert carrier for the medicinal substances.

Bakovic and Tratnik (1979a; 1980) have shown numerous possibilities of using whey and its products in many branches of food industry, by pasteurization, thickening and fermentation. Today the tendency of lactic-acid fermented beverages production is especially represented in food industry, for example fruit- or vegetable-based juices, milk and whey beverages, which are extremely healthy so called “functional’ food products.

Processing whey into beverages

The production of the liquid whey beverages makes certain difficulties. First of all, a large share of water in the content of liquid whey makes it a very suitable environment for the growth and the reproduction of microorganisms, due to which it is necessary to apply the heat treatment. On the other hand, the whey proteins are thermo-labile and they start to denature at the temperature of 60 °C, so at the usual heat treatment (72°C/15-20s), a part of the existing proteins are deposited, which substantially complicates the process of its heat treatment. That is why the heat treatment at high temperatures replaces with the membrane processes, e.g. micro-filtration, application of ultra-sound or some other procedures. Solubility of the whey proteins can increase by using the ultra-sound (Rezek-Jambrak and associates, 2008), by which decreases a sediment, which is formed during the beverage storing. Besides, by acidification of whey to pH<3.9, the whey proteins become thermostable, and thus their coagulation can be prevented, even when using the UHT sterilization (Jelen, 2003).

The next problem in the production of whey-based beverages is relatively high share of minerals in the whey solids, because they exactly are responsible for undesirable salty taste of whey. The problem is particularly pronounced in acid whey, in which the amount of dissolved minerals is greater due to an increased share of lactic acid, which results in the production of the whey-based beverages with lumping and increased acidity of an end product. In order to avoid these problems, there enriches whey with various additives of fruit concentrates, which would neutralize the unfavourable sensory features of the whey-based beverages, especially of tastes (Koffi and associates 2005).

Whey non-alcoholic beverages

Processing whey into beverages has started in seventies, and up to date has developed a whole range of the whey beverages. Non-alcoholic whey beverages mean a diversified group of products derived exclusively by mixing the native sweet, rarely acid whey with various additives, as the ones from tropical fruits (but also other fruits, as for example apples, pears, berries), cereals and their products (the most often bran), protein isolates of vegetable origin, CO₂, chocolate, cocoa powder, vanilla and other aromatized additives. Special attention in this group was paid to development of the fermented beverages production using robotic strains, and it is the most important to choose an adequate bacterial cultures in order to get a highly-valuable functional product of acceptable sensory features. Dietary beverages, the beverages with hydrolyzed lactose, the beverages similar to milk and the powder beverages also belong to the group of the non-alcoholic whey beverages.

Numerous patents have been registered in the last twenty years and they contain the recipes of various beverages of whey, with addition of a certain quantity of fruit concentrates, whereby the share of dry matter (solids) of the fruit component varied from 5% to 12%. Aromas that are usually suggested as the best, which manage the best to mask the undesirable smell of whey after cooking, as well as the sour-salty taste as: citruses and tropical fruits additives, like mango, banana or papaya. There were also tested the additives of various other fruits, such as apples, pears, peaches, apricots and sour cherries. As the most successful has shown an additive of berries concentrate, owing to the significant presence of iron and antioxidants as very important in the production of the nutritionally enriched beverages of whey.

Some scientists have developed, except fruits, the recipes for the whey beverages with additives of chocolate, cocoa powder, vanilla, cereals, honey and other favourable aromatized components. The addition of cereals, i.e. their bran is very important procedure, because in that procedure gets the beverage enriched by dietary fibres, essential acids, as well as the hypoallergenic proteins, which are favourable for consumption in allergic people and children.

There have appeared recently the beverages with addition of CO₂, in combination with fruit additives, where refreshing taste masks undesirable smell and taste after cooking milk.

In order to obtain the products of desirable sensory characteristics, the production of the fermented beverages of whey has shown as the best option. In the range of beverages which produce based on whey as a raw material, a special place take the fermented beverages based on whey, which can be divided into two groups: functional and probiotic. Both groups have a beneficial effect on the host organism, but in two different ways.

The probiotic beverages are characterized by a direct action of live microorganisms (probiotics), while the functional beverages are characterized by an indirect action through metabolites, produced by the micro-organisms during the fermentation, and which are also called biogenes.

During the fermentation, the components of whey degrade into different functional substances, such as lactic acid, butyric acid, bioactive peptides, β -galactosidase and exopolysaccharides, which point out to a significant impact to the human organism (A. Y. Tamime, R. Božanić, I. Rogelj, 2003.).

Studies confirm that fermented products based on whey have the beneficial effects in the following cases: in case of lactose intolerance, infections of gastro-intestinal tract, viral diarrhoea, diarrhoea caused by antibiotics, as well as gastritis caused by the bacteria *Helicobacter pylori*. On the other hand, probiotics as an integral part of the fermented beverages affect favourably on human health by stimulating the growth and micro flora activities, which is naturally present in human gastro-intestinal tract. Besides these beneficial effects, the functional food and thereby also the beverages do not consider as a medicine, because they have an effect only on improvement of essential bio-chemical functions in the human body.

In the group of non-alcoholic whey beverages belong also the dietary beverages, the beverages with hydrolysed lactose, the beverages similar to milk and the powder beverages.

Thanks to its composition, whey is very suitable raw material for the production of dietary beverages in simple way, which includes the addition of some sweeteners, usually saccharin and cyclamate, then the addition of apple or tropic fruits fruit base, as well as the addition of some stabilizer. These beverages have a very low energy value, which ranges from 104 kJ/100 mL to 113 kJ/100 mL, therefore they are suitable for a wide group of consumers.

The liquid or the powder whey mixes with skimmed or rich milk, selected vegetable oils, hydrocolloids and emulsifying agents, during the production of beverages similar to milk. During the production of these types of beverages adds milk for the purpose of firmness and density improvement.

In this group of beverages, the most significant is "Way-Mil", very similar to cow's milk by its appearance; it has a specific taste and can mix with additives like chocolate and fruits. This beverage includes around 2-4% of fats, 1-1.5% of proteins, 4-5% of lactose, around 0.7% of minerals, as well as vitamins soluble in water (Popović-Vranješ, A., Vujičić, I., 1997.).

The powder beverages make a wide group of beverages, which must distinguish by good instant features, and they can be enriched with vitamins and minerals. These beverages should have a long best-before date and good solubility. Owing to easier transport and storing, they have an advantage in regard to the liquid whey beverages, which is very important for nutrition of population in difficult life conditions and are poor in proteins. In the production of these beverages, whey usually mixes with soy, powder fruits, concentrated fruit juices, and there adds the concentrates of whey proteins, too.

Alcoholic whey beverages

Whey is a very good raw material for the production of alcoholic beverages, considering that a major part of dry matter is lactose (around 70%). The alcoholic whey beverages can be divided into the beverages which contain small amount of alcohol (1.5%), such as a whey beer or a whey wine. The production of these alcoholic beverages of whey comprises whey deproteinization, concentration, fermentation of lactose or the addition of saccharose up to a desirable share of alcohol (0.5% – 1%), and then follows flavouring, sweetening and bottling. During the

production, a part of lactose turns to lactic acid, and it gives a refreshing sourish taste to the final beverage, and it ferments the rest to alcohol. From this group of beverages, some of the most famous are “Milone”, which gets by fermentation of a kefir culture and the whey wine “Serwovit”, produced in Poland.

The whey beer, which produces with or without malt, considers being a very nutritious beer enriched with minerals or as the beverages which contains starch hydrolyzates and vitamins. The only problem concerning the production is a fact that there is the presence of fat that might affect a loss of beer foam, a bad smell and a smell caused by poor solubility of the whey proteins, as well as the impossibility of lactose fermentation by beer yeast.

The whey wine has a small amount of alcohol 10% - 11%, it is flavoured by fruit aromas and is intended for younger population. Technological procedure of the whey wine production comprises clarification, deproteinization, hydrolysis of lactose with β -galactosidase, cooling, adding yeast and fermentation, aging, filtrating and bottling. In the preparation of this beverage, there was put a lot of effort, but the scientists still search for an ideal recipe and they meet many difficulties. Considering that whey is very worthy source of nutrients, they do not give up lightly from the invention of an optimal technological procedure of the production. (Popović-Vranješ, A., Vujičić, I., 1997.).

Thanks to lactoferrin, the whey beverages can use as the functional food for the purpose of iron absorption increase. However, they can also decrease iron necessary for the growth and reproduction of pathogens in the intestines and in that way they strengthen the immune system, which is extremely important in nutrition of small children. These beverages can improve the absorption of calcium, which is very important when it comes to older persons, who increasingly suffer from osteoporosis. With the addition of rye and oat bran in the beverages, as well as the isolates of soy and potato proteins, they are ideal for persons who suffer from allergies to milk proteins or persons suffering from celiac disease. Many clinical studies have proved that the whey beverages, especially fermented, act antihypertensive (lower blood pressure). They also use as a meal substitution for people with overweight, elder people and sportsmen. Market research point out to a fact that fermented/or fruit whey beverages are consumed by women who take care of a healthy and balanced diet,

then children, as well as the other consumers who use these products for breakfast or a healthy snack (Huth and associates, 2006).

These are just some of the possible ways of the whey beverages consumption, and depending on the production method and used additives they can use in much wider scope.

As far back as 460 B.C. the father of medicine Hippocrates had noticed the value of whey as a therapeutic beverage, so he had recommended the use of whey as a cure for the therapy in the treatment of various types of diseases, such as skin diseases, tuberculosis, jaundice and alimentary canal diseases. In developed European countries in 18th and 19th Century (Switzerland, Germany and Austria) had considered that whey had diuretic characteristics and that it can help while recovering after illness or hard physical work.

It seems that the time is coming when the modern man is just discovering its importance in the daily diet.

Conclusion

Every year the whey production is increasing and in modern dairy industry it is a growing problem, considering its exploitation and possibility of using the whey products. On the other hand, whey is a significant polluter of the environment when thrown, and also the destruction of whey is as expensive as the costs of its further processing. That is the reason why, nowadays, the whey problem brings down to discovering of such types and forms of the whey product, which might find as much as possible usability at a reasonable economy. By further research in this field, in close cooperation with the dairy industry, would provide the possibility of increasing utilization of whey through products interesting as from the standpoint of nutrition, as well as sale.

In the paper was introduced a wider possibility for utilization of whey, where a special emphasis was put on its attractiveness. One of the ways to include whey in daily diet of people, i.e. to activate its common processing in food industry, is the production of fermented functional beverages based on whey. With this was made another effort to preserve large quantities of whey for human nutrition, by producing the products with simple technology and economically justified for our industry.

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