Research on Whey in Egypt: An Overview

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ABSTRACT

In Egypt, in addition to "sweet whey" and acid whey, there is a third type of whey known as "salted whey" which resulted during the manufacturing of *Domiati* cheese. The present article describes some of the beneficial uses of whey and permeate as performed by the Egyptian research workers. Chemical composition, microbiological quality, microstructure and ultrafiltration of whey are discussed. Functional and rheological properties of whey proteins are also considered. The production of some useful products and foods from whey, (whey protein concentrates WPC) and permeate as, ethyl alcohol, biomass, enzymes, beverages, cheese, ice cream, probiotic dairy products, low fat yoghurt are also described. Finally, the nutritional characteristics of whey, WPC, permeate and their products are also cited.

Key words: acid whey, sweet whey, salted whey, WPC, Shersh, Masl, small milk, permeate.

INTRODUCTION

Whey is the liquid remaining after removal of the casein and fat from milk in the process of cheese making, it contains most of salts, lactose and water soluble vitamins and proteins of the milk. Whey from cottage cheese manufacture, called "Acid whey", has a lower pH, consequently longer storage life than "Sweet whey" from Cheddar and other kinds of cheese (Webb *et al.*, 1974).

During the past 30 years, membrane separation technology has been introduced in dairy industry for cheese making and whey processing. The by-product of cheese and whey processing is a clear greenish-yellow liquid permeable through ultrafiltration membrane is called "permeate". This permeate has been utilized using membrane bioreactors for the production of some useful biochemical products (Mehaia, 2007).

The whey is utilized in U.S.A., Canada, European countries, Australia and Nezealand to produce other dairy products. In France, the term "Petit lait" or "small milk" is commonly used by whey processors (Horton, 1997).

In Egypt, in addition to "Sweet whey" and "Acid whey", there are third type of whey known as "Salted whey", which results during manufacturing of *Domiati* cheese in which a high concentration of sodium chloride is added to milk prior to renneting to avoid the poor microbiological quality of the raw milk.

The whey is known in Egypt as "*Shersh*", while in Syria, Lebanon, Jordan and Palastein is known as "*Masl*". Unfortunately, in Egypt, the whey until now is considered as a dairy industry waste. The disposal of whey to a stream or lake leads to the consumption of great amount of oxygen, therefore the death of the aquatic plants and animals.

The strength of the whey components oxidation is expressed in terms of biological oxygen demand (BOD), which is the quantity of oxygen used by the aerobic microorganisms and reducing compounds in the stabilization of decomposable matter during a selected time at a certain temperature. The 5 days BOD of whey ranged from 500 to 2000 ppm. (Abou-Donia, 2000). The present article illustrates some of the successful attempts of the Egyptian research workers regarding the beneficial utilization of whey.

Chemical composition of salted whey

The salted whey from *Domiati* cheese manufacture had high total solid contents because of high NaCl content. The fat content of whey was relatively low, and it had an average protein content of 0.6%. The whey was characterized by high Ca and Mg contents. β-lactoglobulin was the major whey protein fraction present in salted whey followed by β-lactalbumin, proteosepeptone, immunoglobulin and serum albumin (Abd El-Salam *et al.* 1990a).

Microbiological quality of salted whey

The microflora of salted whey showed clear seasonal variations with tendency, for high counts in samples from November and December. The microflora of whey generally decreased on storage for 24 hr. Total bacterial count and aerobic spore-frmers counts in whey from large cheese factories tended to increase. Acidity slightly increased and pH and lactose content decreased in stored samples (Abd El-Salam *et al.* 1990b).

Microstructure of whey protein

Heat treatment of milk led to an extension in real distribution of small sized particles and an increasing of denaturated whey proteins. Whey protein particles in condensed milk are spherically shaped and varied from 12.5 to more than 312.5 nm in diameter. Fat globule appeared as an oval shape surrounded by the protein membrane (Omar, 1990, Abd El-Salam *et al.* 2000).

Ultrafiltration of whey

Salted whey from *Domiati* cheese was ultrafiltered at 40°C using T6B tublar module M.W. cut of 25.000. The flux of whey containing 6% NaCl was three times higher than sweet whey. Also, the permeability of whey proteins increased slightly as the salt levels increased. The total N, lactose, NaCl, Ca and pH of both permeates and retentates at concentration factors 5,10,15 and 20 from whey with different levels of salt were also determined (Mahfouz *et al.* 1990).

Calcium phosphate was separated from UF-permeate of milk by raising the pH to 9 using 0.065 molal $Ca(OH)_2/CaO$. The precipitate was separated by decantation and filtration. Residual lactose was removed from the precipitate by washing and precipitate was dried. After the removal of the calcium phosphate, the permeate was concentrated by reverse osmosis (RO) and permeation rate (flux) was compared to that of untreated permeate (Abd El-Salam *et al.* 2003).

Composition and functional properties of whey proteins

The modified milks by adding UF whey protein concentrates (WPC) were heat treated at 80°C for 1 min. The rennet coagulation time (RCT) was found to increase with both the addition of WPC and heat treatment. Proteolysis of milk from different treatments with pepsin and trypsin increased slightly by the heat treatment (Abd El-Salam *et al.* 1991). Buffalo whey proteins from normal, mastitic, subclinical mastitic milk and colostrums were analyzed using polyacrylamid gel electrophoresis and gel filtration techniques. Results indicated that α-lactalbumin and β-lactoglobulin were lower in abnormal samples than normal ones, but blood serum albumin, immunoglobulin and proteose peptone were higher than that of normal milk (Hamzawi *et al.*, 1991).

The whey protein fractions of 130 individual buffalo's milk samples were classified according to their migration rates in alkaline medium to β-lactoglobulin, α-lactalbumin, bovine serum albumin, immunoglobulin, proteose-peptone and minor fractions (Mohran, 1991).

The prepared WPC from fresh *Ras* cheese whey was fractionated to α-lactalbumin and β-lactoglobullin fractions, they varied in their TS, TP, NPN, Ca^{2+}, Mg^{2+}, lactose, and amino acid contents. They showed also varying functional properties (Abd Rabbo *et al.*, 1993).

Co-precipitates of whey and bean proteins were prepared from *Domiati* cheese whey protein (W), bean flour (F) and bean protein isolates (IS). The obtained results revealed that, cheese whey-bean isolate proteins coprecipitate (WI) had higher protein solubility, water absorption, oil absorption, emulsification capacity and foaming capacity than those of W and cheese whey-bean flour proteins coprecipitate (WF), but its functional properties were lower than the F and IS (Kebary, 1993).

The gelation (GT) increased with increasing in both protein content of WPC solutions and sodium chloride concentration and decrease with increasing in calcium chloride concentration (El-Etriby, 1996).

Anhydrous milk fat (AMF) was emulsified in reconstituted whey protein concentrate (WPC) solutions. The homogenization and cold storage (overnight at 8°C) of WPC decreased the average fat globule size (AFGS), while reducing the pH from 6.49-6.57 to 4.6 and slightly decreased the AFGS. The examination of powders by scanning electron microscopy revealed that the use of high protein WPC showed excessive indentation, while that prepared with low protein WPC and with skim milk showed almost spherical particles irrespective the fat content in the powder (Abd El-Salam *et al.*, 2000).

The addition of guar and xanthan gums decreased the strength of WPC gels, while the addition of small concentrations of mineral salts noticeably increased the gel strength. The effects of different cations on WPC gel strength were in desending order Ca>K>Na (El-Garawany *et al.*, 2002a).

Acetylation or succinylation of different WPC preparations increased protein solubility, fat and water absorption, emulsification and foam capacity, but decreased their foam stability. Functional properties of WPC's were more affected by acetylation as compared to succinylation (Kebary *et al.*, 2003).

Increasing whey protein concentration, free lactose decreased correlation with protein concentrate and they increased with increasing heat treatment. Monovalent cations content decreased with increasing heating. Modification high protein concentrate with phosphate buffer gave the best results for sweet whey as antioxidant (El-Din & Gad, 2004).

Whey from *Edam* cheese manufacture was concentrated by ultrafiltration, and whey protein concentrate (WPC) was fractionated into β-lactoglobulin (β-Lg) and α-lactalbumin (α-LA) rich fractions by two different methods. The results indicated that the yield and composition of the prepared fractions by two methods were different. However, the emulsifying capacity and stability and foam capacity and stability of WPC fractions prepared by the two methods were slightly different (El-Shibiny *et al.*, 2004).

A method was used to isolate immunoglobulins-rich fraction from whey protein concentrate (WPC) prepared from *Edam* cheese whey by ultrafiltration (UF), saturated ammonium sulphate (40%) was added to WPC to precipitate the immunoglobulins (Igs). Igs-rich fraction was dialysed and lyophilized. The total solids (TS), total protein (TP), fat, ash and lactose contents were determined in whey, WPC and lyophilized immunoglobulins-rich fraction (El-Loly & Farag, 2006).

Acid casein (AC) and whey proteins (WP) were prepared from cow's and goat's milk, whereas sodium caseinate (SC) and modified casein (MC) were prepared from acid casein.

All protein preparations were tested for sorption of water (SW), foaming capacity (FC) and oil absorption capacity (OAC). The SW of AC was not affected by type of milk whereas SC had higher values with the maximum figures in case of goat's milk. Modificaiton of casein significantly improved this property. The SW was significantly higher for goat's WP prepared from acid or salted whey and values greatly increased with increasing sorption time. The FC of all protein preparations was significantly affected by type of milk and the values were higher at pH7 than pH5.5. The OAC was higher in all protein preparations from goat's milk with exception of MC, whereas modification of cow's casein significantly improved OAC (Naeim *et al.*, 2007).

The composition and characteristics of whey proteins, their nutritional and functional properties and their uses with particular references of Egyptian studies were reviewed by Salem & Abd El-Salam (2007).

Rheological properties of whey proteins

Whey protein concentrate (15% protein) was prepared by UF. Emulsions were prepared from the WPC and milk fat, palm oil or corn oil with different protein/oil ratios by homogenization at pressures of 100/50, 200/50 or 300/50 kg/cm^2. The flow properties of the prepared emulsions were found to be affected variably by its composition and homogenization pressure. However, the viscosity of the heated emulsions decreased irreversibly with the increase in shearing (Abd-El-Salam *et al.*, 1994).

Desserts were prepared with the general formula of 4% WPC and 3% corn starch (CS) or 4% wheat flour (WF) or 2% waxy corn starch (WCS), 0.1 α-carrageenan, 10% sucrose, 3% milk fat and 3% cocoa powder. The desserts were prepared by heating at 100, 110 or 120°C for 30 min., packed hot and stored for 28 days at room temperature (20±5°C). Results indicated that the increase in heating temperature increased the log stress of desserts containing CS. In all desserts log G' was higher than lg G" indicating the predominance of the elastic response over the viscous flow. However the rheological parameters increased with the increase in log frequency, suggesting a weak gel structure (Abd-El-Salam *et al.*, 2001a).

The use of variable blends of skim milk powder (SMP) and WPC (100/0, 75/25, 50/50, 25/75) in desserts containing wheat flour (WF1), α-Carrageenan, sucrose, and cocoa powder was investigated. In all desserts, the elastic response (G') was higher than the viscous flow (G") at temperature from 90 to 100°C. Also the increase in log frequency linearly increased the log G', log G", log G* and loss angle of desserts from all treatments indicated weak gel structure (Abd-El-Salam *et al.*, 2001b).

The rheological properties of whey protein concentrate/wheat flour gels, corn starch, wax, modified starch and skim milk powder were intensively studied by El-Garawany *et al.*, (2001a, 2001b, 2001C, 2002b, 2003a, 2003b).

Addition of sodium chloride to UF whey from *Edam* cheese was found to decrease the viscosity of WPC solution. On the other hand, addition of $CaCl_2$ was found to increase the viscosity of WPC solution reaching a maximum when 60 mg/100 ml solution was added and then decreased on further increase in the added $CaCl_2$ (El-Shibiny *et al.*, 2004). Gels were prepared by heating different mixtures of whey protein concentrates (WPC) with potatoes and α-carrageenan. Analysis of variance showed a highly significant (P> 0.0001) relationship between the concentrations of different ingredients and gel strength (El-Garawany & Abd El-Salam, 2005).

Production of ethyl alcohol and biomass from whey

The lactose fermenting yeast could be utilized for the production of ethyl alcohol and biomass from whey, therefore, the whey could be utilized as promising source of the biofuel, *kluyveromyces lactis* NRRL-Y 1138, *K. fragilis* NRRL-Y 1137, *Torulopsis candida* NRRL-Y 211 and *Candida pseudotropicalis* NRRL-1165 gave the promising results with growing on salted whey (2-10% NaCl). (El-Nimr *et al.*, 1982a). The utilization of supplemented diluted whey medium would be comparable to the use of supplemented undiluted one for yeast cell biomass production (El-Nimr *et al.*, 1982b).

The growth of *Kluyveromyces lactis*, *K. fragilis*, *Candida pseudotropicalis* and *Torulopsis candida* in diluted salted whey was minimized (Badr El-Din *et al.*, 1983a). Also, the utilization of nitrogen by four tested yeasts was higher in diluted whey medium (Badr El-Din *et al.*, 1983b).

Saccharomyces fragilis NCYC 179 proved to be superior in fermenting deproteinized salted whey medium for the production of ethyl alcohol. The above yeast culture could be survive at 10% NaCl and 8% ethyl alcohol (Abou-Donia *et al.*, 1986a).

The supplementation of whey permeate with 40% (v/v) corn steep liquor stimulated *K. lactis* NRRL1137 growth and gave the highest protein yield (Murad *et al.*, 1992). Whey UF permeate supplemented with hydrolyzate of potatos starch waste was used as a medium for the growth of *K. fragilis* KHF-98. The highest production of ethanol and yeast biomass was achieved at 8% ($^v/_v$) inoculum. Under the aforementioned optimum culture conditions 13.2% (v/v) ethanol and 24.2g dry cell/L contained 47% crude protein were obtained after 24hr at 30°C (Fadel, 1998, Fadel & Degheidi, 1998).

Formation of lactulose from whey

The NaOH + boric acid (pH 11) gave the maximum formation of lactulose in the isomerized lactose solution. Heating at 70°C for 3hr under nitrogen gas gave the maximum yield of lactulose (about 60%). The formation of lactulose from permeate decreased with the increase in ionic strength (Mahran *et al.* 1995).

Enzymes production by some *Streptomyces* strains from whey

The maximum production of xylanase on UF permeate was 71.64 U/ml by *Streptomyces chromofuscus* 2, while α-amylase and glucanase at level of 258.32 and 158.44, respectively produced by *S. humidus*. Therefore, the optimum conditions for maximum production of α-amylase by *S. humidus* were studied. The α-amylase was purified by 22 fold using (60%) acetone precipitation by cooling and sephadex G100 gel filtration with yield 5.1% SDS-PAGE revealed two migrating protein bands with molecular masses of 64.8 and 47 KDa. Thermal and pH stability of α-amylase enzyme was found at range between 40-50°C and 6.0-8.0, respectively (Abd El-Nasser & Foda, 2002).

Preparation of whey beverages

Fifty four beer-like beverages were produced from mixtures (at 5:0 to 0:5) of malt wort and whey wort (from deproteinized whey) fermented under various conditions by 3 lactose utilizing yeasts (*Saccharsmyces fragilis*, *Brettanomyces dublinensis*, *B. clausenii*) (Abou-Donia *et al.*, 1986a).

The optimum conditions for preparation of powdered beverage based on carrot juice and UF permeate were: Mixing carrot juice and UF milk permeate at the rate of 1:3, addition of 0.2% stabilizer, homogenization at 200kg/cm^2 and concentration the mixture under vacuum to 25% total solid and dried (El-Shibiny *et al.*, 1994).

The best organoleptic properties and colour index obtained at the end of the storage period (15 days at 4-6°C) of banana sweet whey beverage were for beverages treated with 0.15% L-ascorbic acid +0.02% calcium chloride or 0.1% citric acid + 0.02% calcium chloride (Soliman *et al.*, 1995).

Beverages of accepted sensory properties were obtained by mixing tomato syrup and fermented whey (using *Bifidobacterium bifidum* 10^8 Cfu/g. Up to pH (4.6) 2:1 with 1% high fructose corn syrup (HFCS), and tomato syrup and fermented permeate

2:1 with 1% sucrose or HFCS or NaCl (Abd-El-Salam *et al.*, 2007).

Functional beverage can be successfully made using milk permeate fortified with black mulberry or sycamore, or cantaloupe as sources of natural antioxidants as well as improving the nutritive value (El-Sayed *et al.*, 2007).

The organoleptic properties showed that the nutraceutical milk permeate mixed drink has acceptable flavour. Drink fortified with 20% dried pulp of mandarine, 33.15% of papaya, or 33.15% pulp of pumpkin had more acceptable flavour and highest total overall acceptability than the other treatments (Hareedy *et al.*, 2007).

Manufacture of cheese from whey

Ricotta cheese was made from whey fortified with 0.5, 1.0, 1.5 of 2% skim milk powder (SMP) and acidified to pH 5.8-5.9 at 87-88°C using acetic acid, citric acid or lactic acid. The lactic acid cheese had higher protein and fat recovery. *Ricotta* made from whey/SMP blends (0.5 and 1.0%) attained higher scores similar to control cheese (100% whey) (Mahran *et al.*, 1999).

Ricotta cheese was made using either cheese whey, buffalo or cow milk. This study briefly outlined the chemical composition of the cheese (Salam *et al.*, 2001). *Ricotta* cheese made from WPC without SMP addition showed the best organoleptic quality, followed by that made from WPC fortified with 2% SMP. These ingredients can be successfully used in the manufacture of *Ricotta* cheese (El-Sheikh *et al.*, 2007).

Low-fat processed cheese spread was made using WPC at levels of 20, 30, and 40% to substitute cheese-base (Shazly *et al.*, 2008). The utilization of whey protein in manufacture of processed cheese was reviewed by Abou-Donia (2006a).

Utilization of whey protein in ice cream making

The utilization of whey protein in ice cream making was reviewed by Abou-Donia (2006b). Recently, the possibility of producing ice cream using some effective techniques mainly the UF and RO by incorporating the obtained concentrated milk as a substituting ingredient of MSNF with a level of 50, 75 and 100%. The results revealed that the levels of total protein, ash, specific gravity, freezing points, viscosity and weight per gallon increased (Shenana *et al.*, 2007b).

Manufacture of some probiotic dairy products using whey

The isolated glycomacropeptide (GMP) from UF sweet whey was found to promote the growth of bifidobacteria in media with and without other growth activators compared to control. The total cell count of *Bifidobacterium* Sp., and developed acidity increased by 100% and 25%, respectively when GMP was added alone and 150 and 34% when added with other activators (Metwally *et al.*, 2001).

Lactose hydrolyzed whey was inoculated with mixed culture of *L. acidophilus*, *Str. thermophilus* and *Bifidobacterium* spp., flavoured with anise, peppermint and carawy herb oils. The herbal oils enhanced the growth of *Bifidobacterium* spp. in the fermented whey product (El-Nemr *et al.*, 2004).

The growth behaviour and stability of the mixed probiotic culture of *B. bifidum*, *L. acidophilus* and *S. thermophilus* were used in the manufacture of UF milk retentate. The fermented product was very acceptable and flavour development was fast (El-Shibiny *et al.*, 2005).

Manufacture of low fat yoghurt using whey

Physico-chemical and organoleptic properties of low fat yoghurt made with microbial exopoly saccharides (EPS) produced from salted whey was studied by Ali *et al.*, (2007). Supplementation with EPS significantly affects curd tension, water holding capacity, susceptibility to synersis and apparent viscosity of low fat yoghurt.

Particulated whey protein/carrageenan concentrate (PWP) was prepared by heat denaturation of whey protein concentrate in the presence of carrageenan. The prepared particulate was added to the milk base during the preparation of low-fat yoghurt. The added particulate had no effect on the microbiological quality of yoghurt. There were differences in the chemical composition of the experimental yoghurt containing the different percentage of the particulate. Whereas, there was a slight increase in protein content with increasing of added whey protein particulate. However, there was no significant difference in fat content (Shenana *et al.*, 2007a).

Nutritional characteristics of whey products

The nutritional evaluation of *Ricotta* cheese made from whey buffalo or cow milk was studied. Results clarify that the essential amino acids beside the non essential amino acid content of the resultant cheese fruitful the commendations of the FAO/ WHO (Salem *et al.* 2001).

The effect of feeding half-fat processed cheese spreads containing different types of whey protein concentrations on plasma lipids of rats was studied. Results suggest that whey protein preparations had a lowering effect on blood serum lipids with particulated whey protein concentrate (PWPC) being more effective (Abd El-Aal *et al.*, 2007).

The functional beverage can be successfully made using milk permeate fortified with black mulberry or sycamore, or cantaloupe as sources of natural antioxidants as well as improving the nutritive value. Thus, these beverages are necessary for health protection, so they are introduced for patient in hospital or guest in clinical touristy venue (El-Sayed *et al.*, 2007).

Nutraceutical permeate drink juice was produced using peel and pulp from mandarin, pulp of pmpkin and papaya. All drinks can be considered as a good source of ascorbic acid, β-carotene, minerals, vitamin B_3 and B_6 for human nutrition (Hareedy *et al.*, 2007).

The composition and characteristics of whey proteins, their nutritional, functional properties and their uses with particular reference of Egyptian studies were reviewed by Salem & Abd El-Salam (2007).

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البحوث عن الشرش فى مصر: نظرة شاملة

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في مصر، بالإضافة إلى الشرش الحلو والشرش الحامض يوجد طراز ثالث هو الشرش المملح وهو الناتج عن صناعة الجبن الدمياطى. ويتضمن المقال الحالى بعض الاستخدامات النافعة للشرش والبرميات (الراشح)، وذلك كما وردت فى بحوث العلماء المصريين. ولقد تم مناقشة كل من التركيب الكيماوى ، الخواص الميكروبيولوجية ، التركيب الدقيق، والترشيح الفائق للشرش. كذلك تم توضيح التركيب والخواص الوظيفية والريولوجية لبروتينات الشرش ومركزاته.

وقد اشتمل المقال على مناقشة الطرق المختلفة لإنتاج مواد نافعه وأغذيه من الشرش والراشح (البرميات) مثل كحول الإيثايل، البيوماس، الإنزيمات، المشروبات، الجبن ، الأيس كريم، منتجات الألبان المحتوية على كائنات حية دقيقة داعمة للحيوية (البروبيوتيك)، اليوجورت منخفض الدهن وأخيرا تم استعراض البحوث الخاصة بالخواص التغذوية للشرش والراشح (البرميات).