PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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Pakistan Journal of Nutrition 12 (2): 172-177, 2013
ISSN 1680-5194

Characterization, Concentration and Utilization of Sweet and Acid Whey

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Abstract: Normal acid and sweet whey samples were collected from six national dairy plants located in Amman city. They were characterized physico-chemically. The whey was concentrated using vacuum scraper concentrator; the concentration process was optimized with regard to several variables. The concentrated whey either acid or sweet were obtained and evaluated organoleptically with regard to color, flavor and consistency. Accordingly, the optimum concentration treatment was chosen, characterized physico-chemically and used for further research work. The obtained results revealed that the Concentrated Acid Whey (CAW) had more dry matter (68.98%), acidity (4.95%) and salt (14.56%) compared with the Concentrated Sweet Whey (CSW). On the other side, CSW had more lactose (36.40%) and protein (8.25%) compared to CAW. CAW had a better stability or shelf life than that of CSW due to its lower water activity (0.35). The concentrated whey was relatively rich in many minerals and trace elements i.e Na, K, Ca and Mg. Consumption of 50 g of CAW when used as a sugar replacer in bakery and confectionery items will contribute 114, 34, 25, 22, 20 and 18% of the recommended daily intakes of Na, Zn, Cu, Ca, Mg and K respectively. The mineral composition data as well as the sensory evaluation results reflected the unlimited benefits that can be achieved by concentrating acid and sweet whey and there incorporating in formulating some bakery and confectionery items. The addition of acid whey solids to the three studied items i.e cookies, spongy cake and bread improved their quality parameters specially flavor, color and texture.

Key words: Sweet whey, acid whey, whey characterization, whey concentration, French type bread, cookies and biscuit

INTRODUCTION

Whey is a by- product resulting from dairy industry especially cheese production. Both traditional and modern methods of cheese manufacture produce a huge amount of cheese whey (about 83% of the entire volume of milk used). Whey is classified to two types, sweet whey with a pH of about 6.02 to 6.58 and acid whey with a pH of 3.57 to 4.34 (Yousif *et al*., 1998). The annual estimated amount of whey produced by the Jordanian dairy industry is about 40000 tons. More than three quarters of this quantity is acid whey and is produced from labeneh, whereas the other is sweet whey that is produced from white cheese. The total solid of whey was recently used in the food production in different forms, as whey powder, concentrated whey and totally and partially hydrolyzed lactose. There is a huge increase in the use of whey products in the food industry due to the best understanding of the nutritional value of whey component (Mathur and Shahani, 1979). Cha *et al*. (2006), made an invention that provides an economical way to profitably utilize the disposed acid whey in the manufacture of sour cream, other cheese products with a creamy texture, enhancers, spreads, sauces, dressing, desserts and dairy beverages without the disposal or recycling costs common in the industry. Recently, Hydrolyzed labneh whey lactose syrup was obtained by the action of immobilized B-galactosidase enzyme using fluidized bed reactor system (Alomary *et al*., 2012). The obtained sweet syrup was used as sugar replacement in three products (French-type bread, Cherry cake and Kunafeh syrup). The sensory evaluation results showed that bread made with 25% sugar replacement level was better than the control one. For Cherry cake and Kunafeh there were no significant differences between the products made with 25% sugar replacement level and the control samples. The nutritional value of the newly developed product was improved compared to control products. Johnson (2000) used whey products in seasonings and extruded snack whey products mainly in crackers due to their several properties such as flavor carrier, volume agent, flavor enhancer, texture modification and increased nutritional value. Many studies concentrated on the application of whey and whey powders in food industry. Ostojic *et al*. (2005) reused the whey that was disposed from factories and added them again to the dairy products mainly in cheeses after concentrating of whey and they considered the resulted products as "functional foods".

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This study aimed at concentrating of whey using the vacuum concentrator technique and utilization of the produced concentrated whey efficiently as a sugar replacer in the local food industry like bakery and confectionery.

MATERIALS AND METHODS

Sample collection: Normal acid and sweet whey samples were collected from six national dairy plants located in Amman city. The collected whey samples were characterized physico-chemically i.e., smell, color, pH, titratable acidity, protein, fat, ash, dry matter, sodium chloride and lactose.

Whey concentration: The normal whey samples either sweet or acid were concentrated using vacuum scraper concentrator (Fig. 1); manufactured by Zhejiang Wenxiong Machine Valve Co., China; its model is ZN50 with an evaporating ability of 20 kg/h, heat area of 0.4 m^2 condensation area 1.2 m^2 and cooling area 0.25 m^2. The concentration process was optimized with regard to several variables including heating temperature (75, 80 and 90°C), vacuum and pressure (0.03, 0.06 and 0.08 mpa), time or duration needed for concentration (35, 40 and 45 minutes), the quantity of normal whey charged to the concentrator (20, 30 and 60 L) and total solids achieved (50, 60 and 70%). Many samples of the concentrated whey either acid or sweet were obtained and evaluated organoleptically with regard to color, flavor and consistency. Accordingly, the optimum concentration treatment was chosen and used in producing large quantities of concentrated whey (10 kg of each of concentrated sweet and acid whey) for further research work (to be used for characterization of the concentrated whey and to be added as a sugar replacer in some bakery and confectionery items).

Analysis of normal and concentrated whey: Moisture, total solids, ash, titratable acidity and protein were determined following AOAC (1995) standard methods. Fat, NaCl and pH were measured following ISO procedures (1990). Lactose was determined as described by Pearson (1991). Water activity was determined as described by Alsaed *et al.* (2012).

Test baking: The experiments regarding the replacing of sugars by Concentrated Acid Whey (CAW) in three bakery items (French-type bread, spongy cake and cookies) was carried out in the University of Jordan (UJ) restaurant. The methods and recipe for preparation the 3 mentioned items by the UJ restaurant were followed with little modifications.

French-type bread: The control dough was prepared using the straight dough bulk fermentation process. All ingredients i.e., flour (1.5 kg), water (about 375 ml), salt (30 g), yeast (50 g), improver (30 g) and sugar (60 g) were mixed. Three experimental bread doughs were prepared having 25, 50 and 75% sugar replacement by CAW. The dough's were mixed until they had achieved

Fig. 1: Vacuum scraper concentrator of the model ZN50

proper development. The dough's were first proofed for 5-10 minutes at 35°C, then divided into 80g pieces, moulded, panned and finally proofed at 45°C and 85% relative humidity until a suitable height had been attained. The loaves were baked at 230°C for 15 minutes using a rotating oven and then allowed to cool in the pans for 10 minutes before depanning.

Spongy cake: The control spongy cake mixture was prepared using 1.25 kg flour, 1 kg sugar, 0.5 kg eggs, 250 ml water, 250 g improver and 75 g starch. All ingredients were added together and mixed until a homogenous mix is obtained. Another 3 experimental spongy cake mixes were prepared where 25, 50 and 75% of the sugar was replaced by CAW. The spongy cake mixes were baked in a rotary oven at 350°C for 5 minutes and then allowed to cool in the pans for 10 minutes before depanning.

Cookies: The control cookies dough was prepared using 1.50 kg flour, 1 kg butter, 0.5 kg sugar, 5 eggs. All ingredients were added together and mixed until a homogenous mix is obtained (10-15 minutes). Another 3 experimental cookies mixes were prepared where 25, 50 and 75% of the sugar was replaced by CAW. The cookies mixes were cut into small pieces, shaped and baked in a rotary oven at 200°C for 25 minutes and then allowed to cool for 1 hour before evaluation.

Sensory evaluation of the developed bakery items: The produced products, bread, cookies and cake samples were evaluated by a panel of assessors (12 semi-trained subjects) from the Department of Nutrition and Food Technology at the Faculty of Agriculture of the University of Jordan. The panel tested each product samples twice on two different days using the preference multiple comparison sensory test (Yousif *et al*. 1991).

Statistical analysis: Data were analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS Institute, 1997). A complete randomized design was used for the analysis of variance of the physical and chemical properties of liquid and concentrated whey as well as the sensory properties of the developed bakery products. Means were compared at 0.0 5 level of significance using Least Significant Test.

RESULTS AND DISCUSSION

Chemical and physical characteristics of normal acid and sweet whey: It is clear from data in Table 1 that there are large and significant differences (p = 0.05) between the dry matter content of the normal acid whey collected from the 6 national dairy plants; it ranged from 5.0 to 7.0%. Such large variation was not observed in normal sweet whey (6-7%) collected from the same dairy plants

Table 1 those differences might be attributed to the variation in salt level added by the different dairy plants during "Labeneh" processing. Such results, however, agree with those reported by Yousif *et al*. (1997) Regarding the pH values, they have little variations and ranged between 3.57 to 4.34 for acid whey and from 6.02 to 6.58 for sweet whey. Almost similar pH results for normal acid and sweet whey (4.70 and 6.10, respectively) were reported by Gernigon *et al*. (2010).

Relatively, large variations could also be observed in the ash content of acid whey (from 0.57 to 1.88) with small one for sweet whey (from 0.37 to 0.58).

It is apparent from data in Table 1 that acid whey had a lower figures from fat, lactose and protein compared with sweet whey. Such results are in agreement with those reported by Gernigon *et al*. (2010). However, significant differences (p = 0.05) could be noticed in most of the chemical and physical characteristics of both acid and sweet whey samples collected from the six national dairy plants (Table 1). Such differences could be attributed to the variation in milk composition and or processing and handling techniques practiced by the different dairy plants.

Optimization of the concentration process: As mentioned earlier in the materials and methods section, the concentration process was optimized with regard to several variables such as temperature, vacuum and pressure and others. Many samples of the concentrated whey either acid or sweet were obtained and evaluated organoleptically with regard to color, flavor and consistency. Accordingly, the concentration treatment using 75°C, 0.08 mpa vacuum and pressure, 35 minute concentration duration and the 20 L as the quantity of normal whey charged to the concentrator were chosen and used in producing relatively large quantities of concentrated whey.

Chemical and physical properties of concentrated acid and sweet whey: Data in Table 2 reveal that the Concentrated Acid Whey (CAW) had more dry matter (68.98%), acidity (4.95%) and salt (14.56%) compared with the Concentrated Sweet Whey (CSW). On the other side, CSW had more lactose (36.40%) and protein (8.25%) compared to CAW. Furthermore, CAW had a better stability or shelf life than that of CSW due to its lower water activity (0.35). However, the water activity of both CAW and CSW was less than o.6 indicating good stability or storability and shelf life for the two products (Yousif and Alghzawi, 2000). However, marked variations could be observed in the composition of the concentrated whey obtained in this study and those obtained by other researchers (Yousif *et al*., Al. 1997; Geringon *et al*., 2010).

Table 1: Chemical and physical properties of normal sweet (A) and acid whey (S) samples collected from six national dairy plants

National dairy plant code	Dry matter%	pH	Ash %	NaCL %	Lactose %	Protein %	Fat %
1	S 6.57b	S 4.07c	S 1.88a	S 1.30c	S 3.13b	S 0.42c	S 0.40b
	A 7.22a	A 6.29b	A 0.48b	A 0.29a	A 4.64a	A 0.96a	A 0.93a
2	S 6.72b	S 4.34a	S 1.35c	S 0.87c	S 3.56a	S 0.61ab	S 0.18cd
	A 6.13bc	A 6.58a	A 0.38	A 0.20c	A 2.99d	A 0.88ab	A 0.78b
3	S 5.54c	S 4.01d	S 0.63d	S 0.18d	S 2.71c	S 0.38cd	S 0.27c
	A 7.21a	A 6.10d	A 0.43bc	A 0.20c	A 4.39b	A 0.69b	A 0.55c
4	S 7.48a	S 3.57f	S 1.64b	S 0.94b	S 2.77c	S 0.60b	S 0.38b
	A 5.80c	A 6.54a	A 0.37c	A 0.18d	A 3.52c	A 0.65b	A 0.52c
5	S 6.79b	S 3.93e	S 0.73d	S 0.19d	S 3.60a	S 0.65a	S 0.67a
	A 6.38b	A 6.02e	A 0.45bc	A 0.22b	A 4.34b	A 0.90ab	A 0.57c
6	S 4.59d	S 4.19b	S 0.57d	S 0.21d	S 2.80c	S 0.37d	S 0.13d
	A 6.44b	A 6.19c	A 0.58a	A 0.28a	A 4.76a	A 0.88ab	A 0.25d

*Means of triplicate; **Means in each row followed by the same letter are not significantly different at 95% confidence

Table 2: Chemical and physical properties of some concentrated whey samples

	Concentrated whey samples code*			
Whey properties**	A	B	LSD	CV
Moisture %	29.84a***	27.21b	2.49	5.05
Dry matter %	68.98a	64.35b	0.52	0.45
Water activity (a_w)	0.35b	0.55a	0.07	9.60
Acidity %	4.95a	2.07b	0.08	1.28
NaCl %	14.56a	2.59b	0.68	4.58
Lactose %	30.13b	36.40a	0.76	1.33
Protein %	4.06b	8.25a	0.26	2.44

*A: Acidic whey concentrated at 75 C; B: Sweet whey concentrated at 75 C; **Means of triplicate; ***Means in each row followed by the same letter are not significantly different at 95 % confidence

Table 3: Mineral and trace element composition of normal and concentrated whey samples

	whey samples code*			
Minerals/trace element**	A	B	C	CV
K (%)	0.14b	1.23a	1.20a	12.42
Ca (%)	0.11c	0.43a	0.27b	9.95
Na (%)	0.33c	3.43a	0.43b	2.85
Mg (%)	0.023c***	0.09a	0.07b	12.42
Al (ppm)	1.7c	4.23a	3.13b	6.24
Zn (ppm)	2.17c	13.97a	12.20b	6.01
Cu (ppm)	0.30c	2.23a	0.45b	7.32
Mn, Cr, Ni, Cd, Pb, Hg, AS (ppm)	< 0.10	< 0.10	< 0.10	

* A: Normal acid whey; B: Concentrated acid whey; C: Concentrated sweet whey, **Means of triplicate, ***Means in each row followed by the same letter are not significantly different at 95% confidence

Normal and concentrated whey mineral composition: Data in Table 3 show that the concentrated whey (acid or sweet type) are relatively rich in many minerals and trace elements i.e., they contain appreciable amounts of Na, K, Ca and Mg. However, some attention should be paid to the high sodium level and efforts should be taken to reduce excessive additions of salt to acid whey as a step to minimize any limitations for its utilization in bakery and confectionery items. On the other hand, such negative effect is not present in the mineral composition of CSW where daily consumption of 50 g will provide 31, 18, 15, 14, 13 and 5% of the recommended daily intakes (Skrbic and Filipcer, 2008) of Zn, K, Mg, Na, Ca and Cu respectively. Taking the contaminant minerals (Cr, Cd, Hg, Pb, Ni, As) into consideration, data in Table 3 reveal that the concentration of these contaminants were below the permitted levels (Alsaed, 2007) and do not have any limitations on the utilization of concentrated whey.

Addition of concentrated acid whey as a sugar replacer in cookies, spongy cake and French-type bread: As mentioned earlier, 75% of the produced whey in the country is acid type whey. Accordingly, CAW were incorporated in 3 confectionery and bakery items i.e., cookies, spongy cake and French-type bread as a sugar replacer at three levels, 25, 50 and 75% (Fig. 2). The CAW added items were sensory evaluated using the multiple comparison preference test where a 9 point

Table 4" Sensory evaluation results of French bread, spongy cake and cookies having concentrated acid whey as a sugar replacer

	Sugar replacement by concentrated acid whey (%)		
Bakery items	25%	50%	75%
French-type bread	4.80a*	3.80ab	3.40b
Spongy cake	5.90b	5.30a	4.60a
Cookies	4.80a	3.80ab	3.40b

*Means of duplicate; **Means in each row followed by the same letter are not significantly different at 95 % confidence

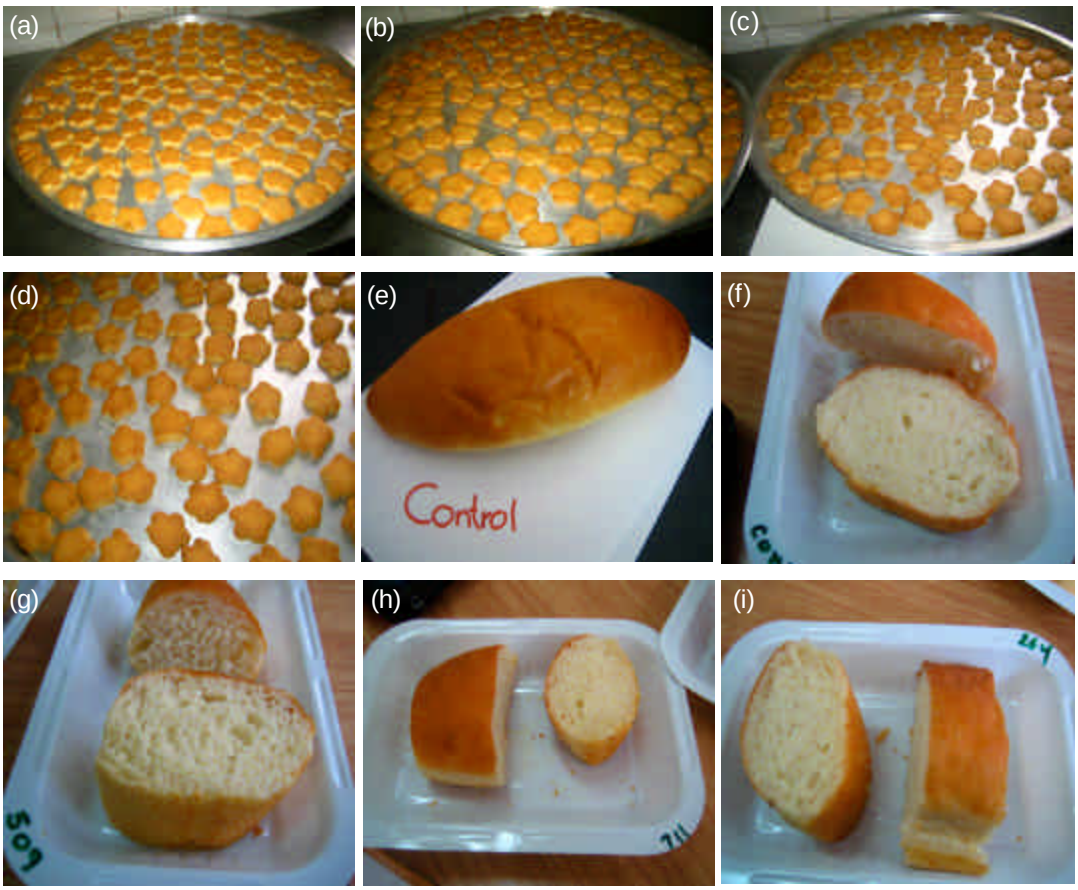

Fig. 2(a-i): (a) 25 % whey (cookies), (b) 0% whey (control cookies), (c) 50 % whey (cookies), (d) 75 % whey (cookies), (e) and (f) 0% whey (control bread), (g) 75 % whey (bread), (h) 50% whey (bread), (i) 25% whey bread

scale is used i.e., 1 for extremely better than control, 5 is equal to control and 9 is extremely inferior than the control.

The sensory evaluation results (Table 4) of the French-type bread showed that the bread prepared at 25, 50 and 75% sugar replacement level were better than the control bread and the 75% treatment achieved the best scores (3.4) and differed significantly (p = o.o5) from the 25% replacement treatment. The same trend can also be noticed for the sensory results of cookies. With regard to the spongy cake, it was observed that the 75 and 50% replacement treatments were better or almost equal (4.6 and 5.3 respectively) to the control cake.

Conclusion: The mineral composition data as well as the sensory evaluation results reflected the unlimited benefits that can be achieved by concentrating acid and sweet normal whey and their incorporating in formulating some bakery and confectionery items. The addition of whey solids to the three studied items i.e., cookies, spongy cake and bread improved their quality parameters specially flavor, color and texture.

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