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INFLUENCE OF PARTICULATED WHEY PROTEIN CONCENTRATE ON THE RHEOLOGICAL AND SENSORY PROPERTIES OF LOW FAT YOGHURT.

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ABSTRACT

The present work is concerned with the manufacture of low fat yoghurt using particulated whey protein concentrates (PWPC) as fat replacer. Experimental yoghurts milk contained 3.0% fat (control), 2% fat +10% PWPC, 1% fat + 20% PWPC and skim milk + 30% PWPC, were prepared and their rheological and sensory attributes were followed.

The results indicated that increasing shear rate significantly reduced the apparent viscosity of low fat yoghurt. Increasing rate of fat replacement with PWPC reduced viscosity values of yoghurt compared with control. Viscosities of all yoghurt samples increased during storage. Low fat yoghurt made with 10 and 20% PWPC showed similar firmness and syneresis of the control, and had good flavour when fresh and after 2 weeks of storage while, yoghurt with 30% PWPC resulted in too firm body and gave an undesirable flavour. Substituting milk fat with PWPC up to 20% in milk can produce good quality low fat yoghurt.

Keywords: Low fat yoghurt, Particulated Whey Protein Concentrate (PWPC), Viscosity, Firmness, Syneresis.

INTRODUCTION

The association between the type and level of dietary fat and the risk of arteriosclerosis and related health problems, has led to a greater consumer awareness of dietary fat and a dramatic increase in the supply of, and demand for, low fat foods, including yoghurt. Also, in the recent years growing interest in dairy products with a reduced fat content is attributed, mainly due to dietary concern to reduce overall fat intake. Dietary guidelines (USDA and UDDHHS, 1995) recommended limiting total fat intake, with saturated fat no more than 10% and monounsaturated and polysaturated fat accounting for at least one third of daily energy intake. On the other hand, milk fat plays crucial roles in developing the texture, colour, flavour, perception, flavour stability, flavour generation and the overall sensation of dairy products (Giese, 1996; Huyghebaert *et al.,* 1996 and de Roos, 1997).

Many commercial fat replacers are available for use in foods and they are classified as fat-based fat replacers, carbohydrate-based fat replacers and protein-based fat replacers, (Giese, 1996 and Huyghebaert *et al*., 1996).

Chawala and Balachandran (1993) and Khalafalla and Roushdy (1996) manufactured low fat yoghurt from buffalo milk. Rheological properties of non fat yoghurt using *lactobacillus delbruekii ssp. bulgaricus* producing exopolysaccharide was carried out by Hess *et al.* (1997). Tamime *et al.* (1996) manufactured low caloric yoghurt containing sugar esters. Good quality fat-free yoghurt produced by supplementing skim milk with a high milk protein powder up to 5.6% protein, Mistry and Hassan (1992). Keating and White (1990) using alternative sweetening to produced Swiss low fat yoghurt.

The use of ultrafilteration techniques in the production of good quality of yoghurt was carried out by Mehanna *et al.* (1988); Haggag and Fayed, (1988); El-Etriby *et al.* (1997); Lankes *et al.* (1998).

Sweet whey was used successfully to replace up to 50% of the water added for reconstituted milk Zabadi (El-Safty and El-Zayat, 1984). Modler and Kalab (1983); Modler *et al.* (1983); Abd El-Salam *et al.* (1991) and Hofi *et al* (1994), followed by incorporation of whey protein concentrate with milk in yoghurt manufacture.

Whey technologies have grown exponentially during last years with the perfection of membranes as well as an increased understanding of whey itself. Whey containing more than half of the solids presented in the original milk including about 20% of the protein and most of lactose (Sienkiewicz and Riedel 1990, Zall 1992). Whey proteins can provide functional, nutritional and economic benefits. Potential functional benefits include emulsification and stabilization, increased viscosity, improved appearance, taste, texture, and binding of fat or water (Jost 1993). Moreover, Paquin *et al.* (1992) demonstrated that whey protein particles are excellent as fat substitutes.

The present research was carried out to evaluate low fat yoghurt manufactured with the use of particulated whey protein concentrate (PWPC) as fat replacer.

MATERIALS AND METHODS

- **Fresh cow's milk:** was obtained from the herd of Faculty of Agriculture, Cairo University. A part of milk was preheated to 40-45°C and separated in a centrifugal separator (α-Laval, Sweden). Obtained fresh cow skim milk was used with whole cow milk to adjust the fat level in milks.

-**Spray dried skim milk** (low heat) was obtained from USA.

- **Particulated whey protein concentrate which was prepared as follows**:

Sweet whey from Edam cheese manufacture was obtained from Arab Dairy Co. Ultrafiltration of whey was carried out at 45-50°C using DDS-Lab 20 ultrafiltration unit (Pasilac, Silkburg-Denmark). Ultrafiltration was continued to a concentration factor of 20. The retentate was diluted with an equal volume of water and diafiltered four time to remove lactose and minerals from whey retentate. Preparation of particulated whey proteins was prepared according to Paquin *et al* (1992). The pH of WPC was adjusted to 3.0 and heated at 80°C/10 min., then cooled to 60°C and adjusted pH to 7.0, homogenized first stage at 300 Kp/cm^2 and second stage 200 Kp/cm^2 using Rannie homogenizer (Copenhagen, Denmark).

- **Fat level was adjusted by blending cow milk with fresh cow skim milk.**

2**%** skim milk powder was added to increase SNF in milks of the different fat content. Particulated whey protein concentrate was added as fat substitute as follows:

1- Cow milk 3% fat (Control)
2- 900 ml cow milk 2% fat + 100 ml PWPC (10%)
3- 800 ml cow milk 1% fat + 200 ml PWPC (20%)
4- 700 ml cow milk 0% fat + 300 ml PWPC (30%)

All treatments were carried out in three replicates.

- Starter MY 87 was obtained from Texel-France containing *Lactobacillus delbruki subsp bulgaricus* and *Sterptococcus salivarius subsp. thermophilus.* The starter was propagated in sterilized skim milk (121°C/15 min.). Flasks were incubated at 42°C for 8 hrs for uniform coagulation.
- The procedure of Kosikowski (1982) was adopted for making yoghurt with slight modification. Milk samples of different treatments were heated initially to 60°C and homogenized first stage at 200 Kp/cm2 and second stage at 50 Kp/cm^2 using Rannie homogenizer, (Copenhagen – Denmark). Homogenized milk was heated to 90°C for 1 min in water bath, cooled to 42°C and incubated with 2% culture (*L. bulgaricus* and *S. thermophilus,* 1:1 ratio). The cultured milk samples were poured in 100 ml plastic cups, covered with lids and incubated at 42 ±1°C in an incubator. The cups with yoghurt samples were transferred to refrigerator when their pH was between 4.8-4.9. The fresh samples and after 3,7,15 days of storage in refrigerator were analysed.

Yoghurt samples were analysed for total solids by dry oven at 120°C for 3 hr, fat, titratable acidity and pH as described in AOAC (1990), protein by micro Kjeldahl method according to IDF (1986), lactose content by the phenol-sulphuric method of Barrnet and Tawab (1957).

Curd tension of yoghurt was measured by the method of Chandrasekhare *et al.* (1957). The apparatus used consists of knives of constant weight (5 g) H-shaped with needle in the middle ending with a hook, and a wire crossing a freely rotating wheel attached to the knife at one end, and a pan (5 g) at other. The knife was placed in a 100 ml cup yoghurt mixture inoculated with the yoghurt starter and incubated at 42 ± 1°C until set. The curd tension was measured as weight in grams to remove the knife from the yoghurt.

Syneresis was evaluated by measuring the volume of separated whey (ml/100 ml) yoghurt as described by Hassan *et al.* (1999). The amount of free whey collected after 30 min at room temperature (23± 1°C) was taken as the index of syneresis.

A coaxial cylinder viscometer (Bohlin V88, Sweden) attached to a workstation loaded with software V88 viscometery program was used for measuring viscosity. The samples were first gently stirred for 1 min and the viscometer probe (system C30) was placed in the samples. Measurement of viscosity was carried out at room temperature 22 ± 1°C at shear rates ranging from 125 to 1050, 1/s in the up and down mode allowing 60 sec intervals between successive measurements.

For sensory evaluation ten panelists from the Department of Dairy & Food technology, NRC scored the resultant yoghurts according to El-Shibiny *et al*., (1979).

RESULTS AND DISCUSSION

Chemical composition of milk and particulated whey protein concentrate (PWPC):

Table (1) shows the composition of milk and PWPC used in the preparation of yoghurt milk. The PWPC contained 12.85% whey protein, 18.4% TS and 1.2% lactose.

Table (1): Composition of milk and particulated whey protein concentrates (PWPC) used in preparation of yoghurt milk.

Test	Milk	PWPC
TS %	11.70	18.4
Total protein %	3.0	12.85
Fat %	3.1	3.7
Lactose %	4.8	1.2
PH	6.66	6.4

Composition of fresh yoghurt

The analytical verifications of fresh low fat yoghurt composition are shown in table (2). The slight variations in total solids of yoghurt made ranges from 13.08 to 13.54%. Fat level content was 3.0% for control and 2.1, 1.3 and 0.8% for treatments 1,2 and 3, respectively. Addition of particulated whey protein concentrates (PWPC) as fat replacer led to increase protein content in yoghurt to 4.51, 5.48 and 6.39% for treatments 1,2 and 3, respectively. Lactose content decreased with increased particulated whey protein concentrates added.

Table (2): Chemical composition of yoghurt manufactured from different fat level using PWPC as fat substitution.

Treatment / Tests	Control	1	2	3
Total solids %	13.54	13.36	13.21	13.08
Fat %	3.0	2.1	1.3	0.8
Fat/DM	22.16	15.72	9.84	6.11
Protein %	3.72	4.51	5.48	6.39
Protein/DM	27.47	33.76	41.48	48.85
Lactose	4.87	4.72	4.49	4.10
Lactose/DM	35.96	35.32	33.98	31.34

Table (3): shows the changes in titratable acidity and pH values during storage of manufactured yoghurt. There were a slight differences in pH and acidity of the various yoghurt samples overall fat content and storage. The pH of fresh low fat yoghurt ranged from 4.78 for 2.1% fat to 4.70 for 0.8% fat decreased to 4.15 to 4.07 after 15 days of storage respectively. In fresh samples no differences were found in acidity of yoghurt of different fat level. The rate of acidity development slightly increased during storage with increasing the added of particulated whey protein concentrate (PWPC) as fat replacer. These finding are in agreement with Mehanna and Gonc (1988) and Chawala and Balachandran (1993).

Table (3): Effect of added PWPC as fat replacer to yoghurt on the development of acidity and pH during storage.

Treatment / Storage (Days)	Control		1		2		3	
	pH	Acidity	pH	Acidity	pH	Acidity	pH	Acidity
Fresh	4.78	0.78	4.78	0.78	4.72	0.78	4.70	0.76
3	4.59	0.84	4.58	0.84	4.54	0.86	4.50	0.88
7	4.39	0.94	4.36	0.94	4.36	0.96	4.34	0.98
15	4.15	1.16	4.14	1.18	4.11	1.22	4.07	1.24

Control = 3.0% fat
1 = 2.1% fat + 10% PWPC .
2 = 1.3% fat + 20% PWPC .
3 = 0.8% fat + 30% PWPC .

Rheological properties

1- Curd Tension:

The curd tension (firmness) of low fat yoghurt is shown in Table (4). Fresh yoghurt sample containing 2.1% and 1.3% fat had similar curd tension compared with control, while treatment containing 0.8% had slightly higher firmness. Higher curd tension was noticed in case 0.8% fat of 75.72 g, while lowest curd tension was in case 2.1% fat of 62.24 g after 15 days of storage. Generally increasing portion of particulated whey protein concentrate (PWPC) as fat replacer increased the curd tension. The presence of fat globules probably resulted in the formation of week point in gel structure, which lead to reduction in curd tension. These results agreement with that reported by Modler *et al.* (1983) who mentioned that increasing protein concentration increased gel strength of yoghurt.

Table (4): Changes in curd tension (g/100g) of different low fat yoghurt as affected by addition of PWPC as fat replacer.

Treatment / Storage period (Days)	Control*	1*	2*	3*
Fresh	36.77	36.10	36.80	40.98
3	44.42	44.00	44.65	47.16
7	51.40	50.65	52.44	53.93
15	64.91	62.24	67.19	75.72

- **See legend Table 3**

1- Syneresis:

Syneresis (whey separation) in yoghurt is an important parameter, on which the quality of yoghurt is evaluated. The results (table 5) reveal that there is an inverse relationship between the amount of PWPC replacement of fat and susceptibility of yoghurt to syneresis. The greatest syneresis was found in treatment containing 0.8% fat of 5.2 ml/100 ml, while other treatment containing 2.1% and 1.3% fat had similar syneresis of 4.2 and 4.3 ml/100 ml respectively compared with control of 4.2 ml/100ml in fresh samples. The lowest syneresis was found in yoghurt after 15 days storage of 2.20, 2.20 and 2.50 ml/100ml for sample containing 3.0% (control), 2.1 and 1.3% fat respectively. The treatment containing 0.8% fat, higher portion of PWPC had syneresis of 3.4 ml/100 ml after 15 days of storage. However, the results generally clear that the PWPC addition produced fresh low fat yoghurt of similar syneresis to control. This finding agreed with that reported by El-Etriby *et al*. (1997); Abd El-Salam *et al* (1991), Dannenberg and Kessler, (1988) and Modler *et al.* (1983). Also, Huffman (1996) mentioned that a strong gel net work helps hold water and prevents syneresis which improve appearance in yoghurt.

Table (5): Syneresis ratio (ml/100ml) of low fat yoghurt as affected by addition of particulated whey protein concentrate as fat replacer.

Treatment / Storage period (Days)	Control *	1*	2*	3*
Fresh	4.20	4.20	4.3	5.2
3	4.10	4.00	4.3	5.1
7	3.50	3.40	3.60	4.00
15	2.20	2.20	2.50	3.40

*** See legend Table 3**

1- Viscosity

Fig. 1-4 shows the effect of added particulated whey protein concentrate (PWPC) as fat replacer on the viscosity (mPas) of fresh, 3, 7 and 15 days stored yoghurt at shear rate ranging from 125 to 1050 1/s, respectively. It can be seen that increasing shear rate significantly reduced the apparent viscosity. This might be explained by the deformation of curd, due to shearing. Also, this results in deformation of the protein hydration sphere, rupture of week ponds (such as ionic and hydration bonds) and dissociation of protein aggregates. However, all treatment showed non-Newtonian behaviour, and hestersis loop was apparent. These results confirm that there was a thixotropic hestersis effect. The thixotropic behaviour yoghurt could be caused by the aggregates breaking. According to Cheng, (1987), thixotropic arises from structure deformation due to interparticle repulsion forces greater than interparticle attraction forces.

Increasing rate of PWPC replacment reduced viscosity values compared with control. This attributed to PWPC enhanced the water binding capacity of the yoghurt coagulum, decreased fat content and may be to decrease total solids content, thereby influencing viscosity.

Fig1

fig2

fig3

fig4

Moreover, apparent viscosity was increased during storage period. Fig. (5) summarized the effect of PWPC added as fat replacer of fresh and stored low fat yoghurt on the viscosity at shear rate 125 1/s. It can be seen that increasing of portion PWPC added reduce the viscosity of low fat yoghurt. The apparent viscosity were 584, 476, 380 and 380 mPas in fresh samples which increased after 15 days storage to 994, 780, 654 and 660 mPas for control (3.0% fat), 2.1%, 1.3% and 0.8% fat respectively. The development of acidity may be contribute to this increase.

Sensory properties

Organoleptic and sensory evaluation of low fat yoghurt as affected by added PWPC as fat replacer are presented in Table (6). Flavour and consistency scores of low fat yoghurt containing PWPC, 2.1 and 1.3% fat were not different than control sample, while that containing 0.8% fat had the lowest scores by the panel judges. During storage, scores of low fat yoghurt slightly decreased but retained acceptable properties except in case of the lowest fat content of 0.8% fat, which ranked the lowest scores after 15 days of storage.

Finally, the most acceptable low fat yoghurt were yoghurt made from 2.1 and 1.3% fat while, that contained 0.8% fat obtained lowest scores especially at the end of storage period.

Table (6): Organoleptic scoring of low fat yoghurt manufactured from different fat content using PWPC as fat replacer.

Storage Days	Treatment *	Flavour (60)	Consistency (30)	Appearance (10)	Total (100)
Fresh	Control	58	29	10	97.0
	1	58	29	10	97.0
	2	57	29	10	96.0
	3	53	29	10	92.0
3	Control	56	27.5	9.5	93.0
	1	56	27.5	9.5	93.0
	2	55.5	27.0	9.5	92.0
	3	54	27	9.0	90.0
7	Control	54	27.0	9.0	90.0
	1	54	27.0	9.0	90.0
	2	52.4	25.5	8.6	86.5
	3	49.5	24.0	8.0	81.5
15	Control	49.2	26.2	8.6	84.0
	1	48.4	26.2	8.5	83.10
	2	47.5	24.6	8.0	80.10
	3	44.0	23.2	7.2	74.4

*** See legend Table 3.**

CONCLUSION

The major objective of this works was to develop a high quality, low calorie yogurt product and utilization of whey protein concentrates as fat replacer. It could be concluded that replacement of milk fat by particulated whey protein concentrates (PWPC) as fat replacer decreased fat, caloric values while, increased protein and nutrition values of yoghurt. Samples contain 2.1% and 1.3% fat, which containing 10 and 20% PWPC had similar firmness, syneresis and lowest viscosity compared with control. Low fat yoghurt containing 10 and 20% PWPC had similar scores judging compared with control.

From the foregoing results, it is recommend using PWPC as fat replacer at the level of 2.1 and 1.3% fat to gave acceptable flavour and good quality of yoghurt.

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تأثير استخدام مركزات بروتينات الشرش المحببة PWPC على الخواص الريولوجية والحسية لليوغورت منخفض الدهن

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في هذا البحث تم تحضير مركزات بروتينات الشرش المحببة
Particulated whey protein concentrates (PWPC).
واستخدامها كبديل للدهن في إنتاج اليوغورت (الزبادي) منخفض الدهن من اللبن البقري.
وقد تم تحضير اللبن المعد لصناعة اليوغورت كالتالي :

1- المعاملة الأولى لبن بقري ٣% دهن (المقارنة).
2- المعاملة الثانية لبن بقري ٢,١% دهن + ١٠% PWPC
3- المعاملة الثالثة لبن بقري ١,٣% دهن + ٢٠% PWPC
4- المعاملة الرابعة لبن بقري ٠,٨% دهن + ٣٠% PWPC

وقد خلصت النتائج إلى:

- انخفاض لزوجة اليوغورت المنخفض الدهن مع زيادة نسبة ال PWPC المضافة كبديل للدهن مقارنة باليوغورت المقارنة.
- انخفاض لزوجة اليوغورت المنخفض الدهن مع زيادة ال Shear rate المستخدم .
- زيادة لزوجة اليوغورت المنخفض الدهن مع تقدم فترة التخزين .
- كان اليوغورت المنخفض الدهن والمضاف إليه ال PWPC بنسبة ١٠ ، ٢٠% مشابها تقريبا في درجة الصلابة Firmness وكذلك في معدل طرد الشرش Syneresis وذلك سواء في العينات الطازجة أو أثناء التخزين وذلك مقارنة باليوغورت المقارنة.
- حصل اليوغورت المنخفض الدهن والمضاف إليه ال PWPC بنسبة ١٠، ٢٠% على نفس درجات التحكيم تقريبا وذلك مقارنة باليوغورت المقارنة.
- يمكن إنتاج اليوغورت المنخفض الدهن باستخدام ال PWPC كبديل للدهن وذلك حتى نسبة ٢٠% مع إنتاج يوجهورت جيد الصفات وذو جودة عالية.