Menoufia J. Food & Dairy Sci., Vol. 2 April (2017): 23 - 35

QUALITY OF LOW FAT PREBIOTIC FROZEN YOGHURT

K.M. Kamaly, K.M.K. Kebary, A.H. El-Sonbaty and Khadega R. Badawi
Department of Dairy Sci. and Technol., Faculty of Agriculture, Menoufia University,
Shibin El-Kom, Egypt.

Received: Feb. 25 , 2017 Accepted: Feb. 27 , 2017

ABSTRACT: *Frozen yoghurt is a complex fermented frozen dairy desert that combines the physical characteristics of ice cream with sensory and nutritional properties of fermented milk products.Six batches of frozen yoghurt were made to study the effect of replacing milk fat with inulin (Frutafit HD®) on the quality of frozen yoghurt. Control vanilla frozen yoghurt mix containing 4% fat, 13% milk solid not fat, 15% sucrose and 0.5% stabilizer was prepared. The other 5 batches were made by replacing 20, 40, 60, 80 and 100% of milk fat with inulin. The obtained results indicated that replacement of milk fat with inulin increased the acidity, the specific gravity, weight per gallon and viscosity of all mixes and specific gravity, weight per gallon, melting resistance and carbohydrate content of frozen yoghurt and this increase was proportional to the rate of replacement, and decreased pH values of frozen yoghurt mixes, fat and caloric value of frozen yoghurt, while replacement of milk fat inulin did not affect the ash, total protein and total solids content of frozen yoghurt. Increasing the rate of replacing milk fat with Frutafit HD® up to 60% increased the overrun and improved the acceptability of the resultant frozen yoghurt, while increasing the rate of the replacement above that decreased the overrun and the scores of organoleptic properties of frozen yoghurt.*

Key words: *Low fat, frozen yoghurt, prebiotic, inulin, fat replacers.*

INTRODUCTION

Frozen yoghurt is a complex fermented frozen dairy desert that combines the physical characteristics of ice cream with sensory and nutritional properties of fermented milk products. This elaboration results in a nutritious product with a refreshing taste and storage stability significantly longer than of yoghurt (Guven and Karaca, 2002). Consumers often choose to eat frozen yoghurt because they expect that it contains less lactose than ice cream and provides health benefits from the viable bacteria contained in it (Marshall, 2001).

Inulin is a unique fat replacer in this regard and can have an important role in improving ice cream texture due to its ability to bind water molecules and form aged network (Franck, 2002; Srisuvor *et al.,* 2013 and Akbari *et al.,* 2016). Inulin is a linear polymer of fructose molecules that usually contains a glucose molecule at its terminal (Khuenpet *et al.*, 2017). Akalin and Erisir (2008) and Rezaei *et al*. (2014) reported that prebiotics are non-digestible carbohydrates that resist hydrolysis and absorption in the upper parts of gastrointestinal tract and are metabolized selectively by at least one type of probiotic in the colon (Mattila-Sandholm*et al.,* 2002). Inulin considered as a prebiotic which can cause a specific shift in the composition of the colonic microbiota that has beneficial effects for the human host (Oliveira *et al.,* 2011 and Krasaekoopt and Watcharapoka, 2014). These beneficial effects such as increasing calcium absorption with positive effects for bone health (Meyer and Stass-Wolthuis, 2009), lowering of serum lipids with relevance for heart health (Brighenti, 2007), enhancing resistance to infections (Cummings *et al.,* 2001) and stimulating the immune system (Lomax and Calder, 2009). Inulin has been used as fat replacer, a low caloric bulking agent and as texturizing and water binding agents (Tungland and Meyer, 2002; Kip *et al.,* 2006; Buriti *et al.,* 2010; Meyer *et al.,* 2011; Oliveira *et al.,* 2011 and Kebary *et al.,* 2015).

In view of the aforementioned the objectives of this study were to evaluate the possibility of making good quality prebiotic low fat frozen yoghurt by replacing milk fat with inulin, which is a prebiotic and to monitor the chemical, physical and sensory changes during storage of frozen yoghurt.

MATERIALS AND METHODS

Ingredients:

Fresh bulk buffalo's milk andcream was obtained by separating fresh buffalo's milk in the pilot plant of Department of Dairy Science and Technology, Faculty of Agriculture, Menoufia University, Shibin El-Kom, Egypt. Inulin (Frutafit HD®) as fat and sugar replacer (Average Chain Length 8-13 monomers) was gratefully provided by Sensus, Borchwerf, The Netherlands. Sucrose and Vanilla were obtained from local market, Stabilizer (Mercol IC) was obtained from Meer Corporation, North Bergen, NJ, USA, Active *Streptococcus thermophiles* EMCC 1043, *Lactobacillus delbrueckii* subsp. *Bulgaricus* EMCC 1102, were obtained from Cairo Mercin, Ain Shams University, Egypt.

Manufacture of frozen yoghurt:

Frozen yoghurt batches were made according to Goda *et al.* (1993). Control frozen yoghurt mix was standardized to contain 4.0% milk fat, 15.0% sucrose, 13.0% milk solids not-fat, 0.5% emulsifier stabilizer (Mercol) and 0.01% vanilla. The required amount of skim buffalo's milk for each batch was divided into two portions. The first portion was heat treated in a water bath at 85°C for 10 min and then was cooled to 42°C, inoculated with 1.5% *Streptococcus thermophiles* and 1.5% *Lactobacillus delbrueckii* subsp. *bulgaricus* and was incubated at 42°C until coagulated then kept in cooler overnight. The required amount of sucrose, cream, emulsifier, non-fat dry milk to adjust the frozen yoghurt base mix were added to the second portion of fluid skim buffalo's milk with continuous agitation. This mix was heat treated at 85°C for 10 min then cooled to 6°C ± 2 and kept at same temperature overnight for aging. Frozen yoghurt was manufactured by mixing the first and second portions and vanilla was added to each mix before freezing in an experimental ice cream batch freezer (Cattabriga, Bolongia, Italy). The other five frozen yoghurt treatments were made as described above except 20, 40, 60, 80 and 100% of milk fat was replaced with inulin (Frutafit HD®). Inulin (Frutafit HD®) was added to the first portion of skim buffalo's milk before heat treatment. The resultant frozen yoghurt was packaged in plastic cups and kept in deep freezer at -18°C for 24 hrs. for hardening. Frozen yoghurt was stored at -20° ± 2 for 10 weeks. Samples from each frozen yoghurt treatment were taken at fresh and every two weeks for chemical and sensory evaluation. The whole experiment was done in triplicate.

Physical and chemical analysis:

Overrun of the frozen yoghurt was determined according to the method of Arbuckle (1986). The specific gravity of frozen yoghurt mixes and frozen yoghurt samples was determined according to Winton (1958). Weight per gallon of frozen yoghurt mixes in kilogram (kg) was directly calculated according to Burke (1947) and Arbuckle (1986). The melting resistance of frozen yoghurt was determined according to Reid and Painter (1933). The viscosity of frozen yoghurt mixes were measured using coaxial cylinder viscometer (Bohin V88, Sweden). Fat content, titratable acidity and pH values were determined according to Ling (1963). The pH value was measured using pH meter (Jenway LTD, Felsted Dunmow, Essex, UK). Total solids, ash and total protein were determined according to the Official Method (A.O.A.C., 2007). Carbohydrate was calculated by difference. Total energy of frozen yoghurt was calculated based on conversion factors as follows; protein 4, carbohydrate 4, inulin 2 and fat 9 and expressed as kcal / 100 g frozen yoghurt.

Sensory evaluation:

Ten panelists from the Staff members and graduated students at the Department of Dairy Science and Technology, Department of Food Science and Technology, Faculty of Agriculture, Menoufia University evaluated the organoleptic properties of each batch of vanilla frozen yoghurt at fresh and at the2nd, 4th, 8th and 10th week of storage period according to score sheets described by Kebary and Hussein (1997).

Statistical analysis:

Data were analyzed using the completely randomized block design and 2 × 3 factorial design. Newman-Keuls Test was used to made the multiple comparisons (Steel and Torrie, 1980) using Costat program. Significant differences were determined at p < 0.05.

RESULTS AND DISCUSSION

Frozen yoghurt mix properties:

Table (1) shows that the titratable acidity of frozen yoghurt mixes increased significantly ($p \leq 0.05$) by increasing the rate of replacing milk fat with inulin (Frutafit HD®).

Changes in pH values of low fat frozen yoghurt mixes were shown in (Table 1). pH values decreased significantly ($p \leq 0.05$) by increasing the rate of replacement. This decrease might be due to the stimulating effect of inulin on the growth and activity of yoghurt starter (Akin *et al.,* 2007 and Rezaei *et al.,* 2014).

Replacement of milk fat with inulin caused a marked ($p \leq 0.05$) increase in viscosity (Table 1). This increase was proportional to the rate of the replacement of milk fat with inulin. The increase of viscosity by adding inulin could be attributed to the capacity of inulin to retain water (Soukoulis *et al.,* 2009 and Rezaei *et al.,* 2014), the interaction of inulin with milk protein that can lead to an increase in the molar mass (Scaller-Povolny and Smith, 2001) and the formation of small aggregates of microcrystals that are able to retain water (Gonzalez-Tomas *et al.,* 2008). These results are in accordance with those reported by Arcia *et al.* (2010) and Cruz *et al.* (2013).

Table (1). Effect of replacing milk fat with inulin (Frutafit HD®) on some properties of frozen yoghurt mixes.

Treatments¤	Titratable acidity	pH value	Specific gravity	Weight per gallon (kg)	Viscosity (m pas)
C*	0.680^{F}	4.92^{A}	1.2528^{F}	4.743^{F}	263.9^{F}
T_1	0.726^{E}	4.84^{B}	1.2531^{E}	4.744^{E}	276.4^{E}
T_2	0.741^{D}	4.80^{B}	1.2533^{D}	4.745^{D}	293.8^{D}
T_3	0.749^{C}	4.75^{C}	1.2538^{C}	4.747^{C}	344.5^{C}
T_4	0.761^{B}	4.67^{D}	1.2540^{B}	4.748^{B}	389.1^{B}
T_5	0.782^{A}	4.56^{E}	1.2546^{A}	4.750^{A}	429.7^{A}

¤ Each value in the table was the mean of three replicates.

● For each effect the different letters in the same column means the multiple comparisons are different from each other, letter A is the highest mean followed by B, C,..etc.Significant at 0.05 level ($p \leq 0.05$).

C* = Control frozen yoghurt mix made with 4% milk fat.

T_1, T_2, T_3, T_4 and T_5 are frozen yoghurt mixes prepared by replacing 20, 40, 60, 80 and 100% of milk fat with inulin (Frutafit HD®), respectively.

Replacing milk fat with inulin caused a marked increase ($p \leq 0.05$) in specific gravity and weight per gallon, this increase was proportional to the rate of replacing milk fat with inulin. These results could be attributed to the higher specific gravity of inulin (Frutafit HD®) than that of milk fat (Tarrega and Costell, 2006; Naskar *et al.,* 2010 and Cruz *et al.,* 2013).

Frozen yoghurt properties:

There were significant ($p \leq 0.05$) differences among samples in overrun (Table 2). Overrun depends on the amount of air trapped in frozen yoghurt. Replacement of milk fat with inulin (Frutafit HD®) caused a significant ($p \leq 0.05$) increase in overrun of the resultant frozen yoghurt (Table 2). It has been reported that adding inulin during the manufacture of frozen desserts improved the whip ability (Arbuckle, 1986, Rajasckaran and Rajor, 1989 and Hamed *et al.,* 2014). Addition of inulin (Frutafit HD®) up to 60% (T_3) increased the overrun significantly ($p \leq 0.05$) (Rezeai *et al.,* 2014), while increasing the rate of replacing milk fat with inulin (Frutafit HD®) above 60% caused a significant ($p \leq 0.05$) decrease of overrun of the resultant frozen yoghurt (Table 2). This decrease in overrun might be due to the increase of viscosity which consequently suppress the ability of frozen yoghurt to retain air (Chang and Hartel, 2002; Sofjan and Hartel, 2004 and Meyer *et al.,* 2011).

Table (2) shows the effect of replacing milk fat with inulin on specific gravity and weight per gallon of fresh frozen yoghurt treatments. Both specific gravity and weight per gallon followed similar trends. Replacing milk fat with inulin caused a slight increase in specific gravity and weight per gallon. Control frozen yoghurt and treatment T_3 exhibited the lowest values of specific gravity and weight per gallon, while treatment T_5 which contained the highest inulin content exhibited the highest values of weight per gallon and specific gravity, while there were no significant differences ($p > 0.05$) between treatments T_1 and T_2 and T_3. These results could be attributed to the higher specific gravity of inulin (Frutafit HD®) than that of milk fat (Terrega and Costell, 2006; Cruz *et al.,* 2013 and Hamed *et al.,* 2014), and the negative correlation between overrun and specific gravity and weight per gallon (Kebary, 1996; Badawi*et al.,* 2010 and Kebary *et al.,* 2015).

Table (2). Effect of replacing milk fat with inulin (Frutafit HD®) on some properties of frozen yoghurt.

Treatments¤	Overrun	Specific gravity	Weight per gallon (kg)	Melting Resistance		
				First 60 min	Next 30 min	Last 30 min
C*	59.34^{D}	0.7290^{DE}	2.760^{DE}	37.00^{A}	45.70^{A}	17.30^{F}
T_1	64.91^{BC}	0.7308^{CD}	2.767^{CD}	35.60^{B}	44.90^{B}	19.50^{E}
T_2	69.75^{B}	0.7311^{C}	2.768^{C}	34.70^{C}	43.50^{C}	21.80^{D}
T_3	75.18^{A}	0.7305^{CD}	2.765^{CD}	33.60^{D}	42.40^{D}	24.00^{C}
T_4	55.83^{DE}	0.7841^{B}	2.969^{B}	32.40^{E}	41.80^{E}	25.80^{B}
T_5	50.42^{E}	0.7953^{A}	3.011^{A}	31.60^{F}	40.90^{F}	27.50^{A}

¤ , * See Table (1).

Melting resistance of resultant frozen yoghurt is expressed in Table (2) as the loss in weight percent of the initial weight. Replacement of milk fat with inulin (Frutafit HD®) caused on obvious decrease of the rate of melting resistance at 60 min and next 30 min which means that increasing the melting resistance of the resultant frozen yoghurt. The increase of melting resistance was proportional to the rate of replacing milk fat with inulin. This might be due to the increase of viscosity and the higher water holding capacity of inulin which binds higher amount of water and left lowest amount of free water that can be melted faster than bound water which consequently increases the melting resistance (Villegas and Costell, 2007; Torres *et al.,* 2010 and Akbari *et al.,* 2016). The melting resistance of all treatments after the last 30 min had contradictory trend of these of the first 60 min. These results are in agreement with those reported by Kebary and Hussein (1997) and Hamed *et al.,* (2014).

Frozen yoghurt treatments were significantly ($p \leq 0.05$) different from each other in titratable acidity (Tables 3, 7).

Treatment T_5 which contained the highest inulin percent had the highest value of titratable acidity that might be due to the stimulating effect of inulin on lactic acid bacteria (Gibson and Roberfroid, 1995 and Ahmadi *et al.,* 2014) on the other hand titratable acidity of all frozen yoghurt treatments did not change significantly ($p > 0.05$) during ten weeks of storage period ($p > 0.05$) (Kebary, *et al.,* 2015).

Changes in pH value of frozen yoghurt treatments are presented in Tables (3, 7). pH values of frozen yoghurt treatments followed on apposite trend of titratable acidity. Replacing milk fat with inulin (Frutafit HD®) caused a significant ($p \leq 0.05$) decrease in pH values. The lowest pH value was for treatment T_5 which contained the highest percent of inulin. This decrease could be due to the stimulating effect of inulin on the growth of lactic acid bacteria (Akin *et al.,* 2007 and Rezeai *et al.,* 2014). On the other hand, there were no significant changes ($p > 0.05$) in pH values during the storage period (Kebary, 1996).

Table (3). The effect of replacing milk fat with inulin (Frutafit HD®) on titratable acidity and pH values.

Treatments ▫	Titratable acidity						pH values					
	Storage period (weeks)						Storage period (weeks)					
	0	2	4	6	8	10	0	2	4	6	8	10
C*	0.680	0.683	0.686	0.687	0.687	0.689	4.92	4.89	4.87	4.87	4.85	4.85
T_1	0.726	0.728	0.731	0.731	0.732	0.734	4.84	4.81	4.80	4.79	4.79	4.78
T_2	0.741	0.745	0.746	0.748	0.747	0.748	4.80	4.79	4.80	4.78	4.77	4.77
T_3	0.749	0.751	0.753	0.752	0.753	0.755	4.75	4.73	4.73	4.71	4.72	4.69
T_4	0.761	0.763	0.765	0.767	0.767	0.769	4.67	4.66	4.64	4.63	4.63	4.62
T_5	0.782	0.784	0.786	0.785	0.786	0.788	4.56	4.56	4.54	4.53	4.51	4.52

▫ , * See Table (1).

Total solids, total protein and ash contents of frozen yoghurt treatments made with the addition of inulin were not significantly different ($p > 0.05$) from that of control frozen yoghurt which means that replacement of milk fat, total nitrogen and ash of inulin did not affect significantly ($p > 0.05$) the total solids content of the resultant frozen yoghurt. Total solids, total protein and ash contents of all frozen yoghurt treatments did not change significantly ($p > 0.05$) during storage period (Tables 4, 7). These results are in accordance with those reported by Kebary and Hussein (1999), Badawi *et al.* (2008) and Kebary *et al.* (2009).

Fat content of all frozen yoghurt treatments did not change significantly ($p > 0.05$) as the storage period progressed (Tables 5, 7). These results are in accordance with those of Kebary and Hussein (1999), Badawi *et al.* (2008) and Kebary *et al.* (2015). On the other hand, there was negative correlation between the fat content and the rate of replacing milk fat with inulin (Frutafit HD®), which means that fat content of frozen yoghurt treatments decreased significantly ($p \leq 0.05$) as the rate of replacing milk fat with inulin (Frutafit HD®) increased. Similar results were reported by Hussein *et al.* (2004) and Hamed *et al.* (2014).

Carbohydrate content of all frozen yoghurt treatments did not change significantly ($p > 0.05$) during the storage period (Salama and Hassan, 1994; Kebary and Hussein, 1999 and Hamed *et al.,* 2014). Carbohydrate content of all frozen yoghurt treatments increased by substituting milk fat with inulin (Frutafit HD®) (Tables 5, 7). Treatment T_5 which made by replacing 100% of milk fat with inulin contained the highest carbohydrate content, these results are in agreement with that reported by Hamed *et al.* (2014).

Total calories of all frozen yoghurt treatments did not change significantly ($p > 0.05$) as storage period progressed (Hamed *et al.,* 2014 and Kebary *et al.,* 2015). Replacement of milk fat with inulin caused a reduction of total calories of frozen yoghurt treatments. This reduction was proportional to the rate of replacement (Tables 5, 7). Treatment T_5 which made by adding the highest percent of inulin had the lowest caloric value (Kebary and Hussein, 1999 and Hamed *et al.,* 2014).

Table (4). The effect of replacing milk fat with inulin (Frutafit HD®) on total solids, ash content, protein content.

Treatments¤	Total solids(%)			Ash content(%)			Protein content(%)		
	Storage period (weeks)			Storage period (weeks)			Storage period (weeks)		
	0	5	10	0	5	10	0	5	10
C*	35.02	34.93	34.71	1.18	1.14	1.14	5.80	5.80	5.76
T_1	35.13	35.11	34.84	1.14	1.12	1.11	5.78	5.76	5.70
T_2	35.11	34.85	34.56	1.17	1.15	1.12	5.85	5.86	5.83
T_3	34.94	34.63	34.31	1.17	1.14	1.13	5.82	5.80	5.80
T_4	35.08	34.69	34.38	1.13	1.10	1.11	5.79	5.77	5.77
T_5	34.87	34.36	34.32	1.15	1.14	1.14	5.88	5.86	5.89

¤ , * See Table (1).

Table (5). The effect of replacing milk fat with inulin (Frutafit HD®) on fat content, carbohydrate content, and the caloric value.

Treatments ◘	Fat content(%)			Carbohydrate content(%)			Caloric value(K.cal./gm)		
	Storage period (weeks)			Storage period (weeks)			Storage period (weeks)		
	0	5	10	0	5	10	0	5	10
C*	4.1	4.1	4.0	23.94	23.89	23.81	155.86	155.66	154.28
T_1	3.3	3.2	3.3	24.91	25.03	24.73	150.86	150.36	149.82
T_2	2.5	2.5	2.5	25.59	25.34	25.11	145.06	144.10	143.04
T_3	1.6	1.6	1.7	26.26	25.91	25.68	137.92	136.44	136.42
T_4	0.8	0.7	0.7	27.42	27.12	26.80	133.40	131.46	130.18
T_5	0.2	0.1	0.1	27.64	27.26	27.19	127.88	125.38	125.22

◘ , * See Table (1).

Scores of organoleptic properties are presented in Table (6). The results indicated that there were a positive correlation between organoleptic scores and the rate of replacement of milk fat with inulin up to 60% then the total scores decreased significantly ($p \leq 0.05$). Treatment T_3 exhibited more creaminess property than other treatments. Although many frozen yoghurt treatments were accepted by the panelists, the most accepted treatment was T_3 followed by T_2, T_1 and control frozen yoghurt treatment which made by replacing 60, 40, 20 and Zero % of milk fat with inulin (Frutafit HD®), respectively then treatment T_4 and T_5. These results might be due to the progressive aggregation of inulin crystals especially the long chain inulin which consequently improve the sensory quality of the frozen yoghurt (Tungland and Meyer, 2002 and Torres *et al.,* 2010). The total scores of all treatment did not change significantly ($p > 0.05$) during the first four weeks of storage then decreased slightly ($p \leq 0.05$) up to the end of storage period. These results are in accordance with those reported by Zedan *et al.* (2001), Kebary *et al.* (2004) and Hamed *et al.* (2014).

It can be concluded that replacement of milk fat with inulin caused an obvious increase in melting resistance and reduction in caloric value and this effect was proportional to the rate of replacement. Increasing the rate of replacement up to 60% increased the overrun and improved the acceptability of the resultant frozen yoghurt, while increasing the replacement rate above that decreased the overrun and the scores of organoleptic properties. Therefore, it could be recommended that it is possible to make a good quality low-fat, prebiotic frozen yoghurt by reducing the milk fat up to 60% and reducing caloric value by 13.20% using the inulin (Frutafit HD®) as a fat replacer which is also a prebiotic that exhibited a lot of health benefits and bifidogenic effect.

TABLE 6

Table (7). Statistical analysis of frozen yoghurt properties.

Frozen yoghurt properties	Effect of treatments							Effect of storage period (weeks)							
	Multiple comparisons●							Multiple comparisons●							
	Mean squares	C♦	T_1	T_2	T_3	T_4	T_5	Mean squares	0	2	4	5	6	8	10
Titratable acidity(%)	0.025*	F	E	D	C	B	A	0.020	A	A	A		A	A	A
pH values	0.439*	A	B	B	C	D	E	0.020	A	A	A		A	A	A
Total solids (%)	0.305	A	A	A	A	A	A	1.156	A			A			A
Ash (%)	0.048	A	A	A	A	A	A	0.089	A			A			A
Protein (%)	0.023	A	A	A	A	A	A	0.018	A			A			A
Fat (%)	20.258*	A	B	C	D	E	F	0.012	A			A			A
Carbohydrate (%)	15.680*	F	E	D	C	B	A	0.273	A			A			A
Caloric value	602.865*	A	B	C	D	E	F	9.652	A			A			A
Organoleptic properties:															
Flavor	18.733*	C	B	AB	A	D	D	36.733*	A	A	AB		B	BC	C
Body and texture	18.333*	A	A	A	A	A	B	35.933*	A	A	AB		B	BC	C
Melting properties	0.883	A	A	A	A	A	A	3.483	A	A	A		A	A	A
Appearance	5.95*	AB	A	AB	A	AB	B	3.55*	A	A	AB		B	BC	C
Total scores	120.15*	B	B	B	A	C	D	149.35*	A	A	AB		B	BC	C

♦ See Table (1).

● For each effect the different letters in the same row means the multiple comparisons are different from each other, letter A is the highest mean followed by B, C, … etc.

REFERENCES

Ahmadi, A., E. Milani, A. Madadlou, S.A. Mortazavi, R.R. Mokarram and D. Salarbashi (2014). Synbiotic yoghurt-ice cream produced via incorporation of microencapsulated *Lactobacillus acidophilus* (La-5) and fructooligosaccharide. J. Food Sci. and Technol., 51: 1568 – 1574.

Akalin, A.S. and D. Erisir (2008). Effect of inulin and oligofructose on the rheological characteristics and probiotic culture survival in low-fat probiotic ice cream. J. Food Sci., 73: 184 – 188.

Akbari, M., M.H. Eskandari, M. Niakosari and A. Bedeltavana (2016). The effect of inulin on the physicochemical properties and sensory attributes of low-fat ice cream. Inter. Dairy J., 57: 52 – 55.

Akin, M.B., M.S. Akin and Z. Kirmaci (2007). Effect of inulin and sugar levels on the viability of yoghurt and probiotic bacteria and the physical and sensory characteristics in probiotic ice cream. Food Chem., 104: 93 – 99.

A.O.A.C (2007). Official Method of the Association of Analytical Chemists. 17th Ed. Published by the Association of Official Analytical Chemists, Po. Box 540.

Benjamin Franklin Station, Washington, D.C. 20044.

Arbuckle, W.S. (1986). "Ice Cream" 4th Ed., the AVI publishing Co. INC. West Port. Connecticut, U.S.A.

Arcia, P.H., E. Costell and A. Tarreg (2010). Thickness suitability of prebiotic dairy desserts: Relationship with rheological properties. Food Res. Inter., 43: 2409 – 2416.

Badawi, R.M., I.I. Badran, K.M.K. Kebary, Seham I. Farag and Afaf Said (2010). Effect of replacing skim milk powder with dried butter milk on ice milk quality. Proc. 11th Egyptian Conf. Dairy Sci. and Technol., pp. 511 – 521.

Badawi, R.M., A.I. Hamed, K.M.K. Kebary and Hweda A. El-Sayed (2008). Effect of replacing milk fat with fat replacers on the quality of stirred yoghurt. Egyptian J. Diary Sci., 36: 197 – 206.

Brighenti, F. (2007). Dietary fractans and serum triacylglycerols: a meta-analysis of randomized controlled trials. J. Nutr., 11: 2552 – 2556.

Buriti, F.C.A., I.A. Castro and S.M.I. Saad (2010). Effects of refrigeration, freezing and replacement of milk fat by inulin and whey protein concentrate on texture profile and sensory acceptance of synbiotic guava mousses. Food Chem., 123: 1190 – 1197.

Burke, A.D. (1947). "Practical Ice Cream Making." The Olsen Publishing Co. Milwaukee, Wis. U.S.A.

Chang, Y. and R.W. Hartel (2002). Development of air cells in a batch ice cream freezer. J. Food Eng., 55: 71 – 78.

Cruz, A.G., R.N. Cavalcanti, L.M. Guerreiro, A.S. Santana, L.C. Nogueira, C.A. Olieveira, R. Deliza, R.L. Cunha, J.A. Faria and H.M. Bolini (2013). Developing a prebiotic yoghurt: Rheological, physic-chemical and microbiological aspects and adequacy of survival analysis methology. J. Food Eng., 114: 323 – 330.

Cummings, J.H., S. Christie and T.J. Cole (2001). A study of fructo oligosaccharides in the prevention of travellers'diarrhoeo. Alimentary Pharmacology and Therapeutics, 15: 1139 – 1145.

Franck, A. (2002). Technological functionality of inulin and oligofructose. British J. Nutr., 87: 287 – 291.

Gibson, G.R. and M.B. Roberfroid (1995). Dietary modulation of the human colonic microbiota: Introducing the concept of prebiotics, J. Nutr., 125: 1401 – 1412.

Goda, E., I.A. Att, S.A. Salem and M.S. Kamar (1993). Studies on frozen yoghurt manufacturing method. Egyptian J. Food Sci., 2: 157 – 166.

Gonzalez-Tomas, L., J. Coll-Marques and E. Costell (2008). Viscoelasticity of inulin-starch-based dairy systems. Influence of inulin average chain length. Food Hydrocolloids, 22: 1372 – 1380.

Guven, M. and O.B. Karaca (2002). The effects of varying sugar content and fruit concentration on the physical properties of vanilla and fruit ice cream type frozen yoghurts. Inter. J. Dairy Technol., 55: 27 – 31.

Hamed, A.I., K.M.K. Kebary, R.M. Badawi, O.M. Salem and Nevein S. Omar (2014). Manufacture of low fat prebiotic ice milk. Menoufia J. Agric. Res., 39: 1317 – 1329.

Hussein, S.A. and R.M. Badawi (1999). Effect of fat substitutes on physicco, chemical and organoleptic properties of low fat ice milk. Menoufia J. Agric. Res., 24: 923 – 935.

Hussein, S.A., R.M. Badawi and I.I. Badran (2004). Quality of fat free yoghurt made with fat repalcers. Menoufia J. Agric. Res., 29: 1295 – 1315.

Kamaly, K.M., K.M.K. Kebary, A.H. El-Sonbaty and Khadega R.M. Badawi (2011). Effect of fortification ingredients on the quality of yoghurt made from cow's milk. Menoufia J. Agric. Res., 36: 1591 – 1609.

Kebary, K.M.K. (1996). Viability of *Bifidobacterium bifidum* and its effect on quality of frozen zabady. Food Res. Inter., 29: 431 – 439.

Kebary, K.M.K. and S.A. Hussein (1997). Quality of ice cream as influenced by substituting non-fat dry milk whey-bean proteins coprecipitates. Egyptian J. Dairy Sci., 25: 311 – 325.

Kebary, K.M.K. and S.A. Hussein (1999). Manufacture of low fat Zabady using different fat substitutes. Acta Alimentaria, 28: 1 – 14.

Kebary, K.M.K., R.M. Badawi, S.F. Mahmoud and A.S. El-Sisi (2009). Manufacture of low fat Domiati cheese using fat mimetics. Menoufia J. Agric. Res., 34: 1887 – 1899.

Kebary, K.M.K., A.I. Hamed, R.M. Badawi, O.M. Salem and Nevein S. Omar (2015). Preparation and properties of low-fat ice milk fortified with inulin. Egyptian J. Dairy Sci., 43: 169 – 176.

Kebary, K.M.K., S.A. Hussein and R.M. Badawi (2004). Impact of fortification of cow's milk with a modified starch on yoghurt quality. Egyptian J. Dairy Sci., 32: 111 – 124.

Khuenpet, K., M. Fukuoka, W. Jittanit and S. Sirisansaneeyakul (2017). Spray drying of inulin component extracted from Jerusalem artichoke tuber powder using conventional and ohmic-ultrasonic heating for extraction process. J. Food Eng., 194: 67 – 78.

Kip, P., D. Meyer and R.H. Jellema (2006). Inulin simprovesunsoric and textural properties of low-fat yoghurts. Inter. Dairy J., 16: 1098 – 1103.

Krasaekoopt, W. and S. Watcharapoka (2014). Effect of addition of inulin and galactooligo saccharide on the survival of microencapsulated probiotics in alginate beads coated with chitosan in stimulated digestive system-yoghurt and fruit juice. LWT-Food Sci. and Technol., 57: 761 – 766.

Ling, E.R. (1963). A Text Book of dairy Chemistry, Vol. 2 Practical 3rd ed. Chapman & Hall, Ltd., London.

Lomax, A. and P.C. Calder (2009). Prebiotics, immune function, infection and inflammation: A review of the evidence. British J. Nutr., 101: 633 – 658.

Marshall, R.T. (2001). Frozen dairy desserts. In: Marth, E.H.; Steele, J.L. (eds). Applied dairy microbiology. Deecer Press, New York, pp. 93 – 127.

Mattila, T. Sandholm, P. Myllarinen, R. Crittenden, G. Mogensen, R. Fonden and M. Sarrela (2002). Technological challenges for future probiotic foods. Inter. Dairy J., 12: 173 – 182.

Meyer, D. and M. Stasse-Woltuis (2009). The bifidogenic effect of inulin and oligofructose and its consequences for gut-health, European J. Clinical Nutr., 63: 1277 – 1289.

Meyer, D., S.A. Bayarri, A. Tarrega and E. Costell (2011). Inulin as texture modifier in dairy products.Food Hydrocolloids, 25: 1881 – 1890.

Naskar, B., A. Dan, G. Soumen and S.P. Moulik (2010). Characteristic physiochemical features of the biopolymer inulin in solvent added and deplted states. Carbohydrate Polymers, 81: 700 – 706.

Oliveira, C., M.R.D. Guimaräes and L. Domingues (2011). Recombinant microbial systems for improved B-galactosidase production and biotechnological applications. Biotechnol. Adv., 29: 600 – 609.

Rajasckaran, M. and R.B. Rajor (1989). Manufacture of frozen yoghurt like products from soybean and skim milk / butter milk solids. Indian J. Dairy Sci., 42: 132 – 135.

Reid, W.H.E. and W.E. Painter (1933). "The freezing properties, stability and physical quality of chocolate ice cream". Missouri, Agric. Exp. Sta. Bull., p. 185.

Rezaei, R., M. Khomeiri, M. Alami and M. Kashaninejad (2014). Effect of inulin on the physicochemical properties, flow behavior and probiotic survival of frozen yoghurt. J. Food Sci. and Technol., 51: 2809 – 2814.

Roberfroid, M.B. (2000). Prebiotics and probiotics: are they functional foods? American. J. Clinical. Nutr., 71: 1682 – 1687.

Salama, F.M.M. and F.A.M. Hassan (1994). Manufacture of new yoghurt like products. Egyptian J. Dairy Sci., 22: 31 – 38.

Schaller-Povolny, L.A. and D.E. Smith (2001). Viscosity and freezing point of a reduced fatice cream mix as related to inulin content. Milchwissenschaft-Milk Sci. Inter., 56: 25 – 29.

Sofjan, P. Rosalina and Richard, W. Hartel (2004). Effects of overrun on structural and physical characteristics of ice cream. Inter. Dairy J., 14: 255 – 262.

Soukoulis, C., D. Lebesi and C. Tzia (2009). Enrichment of ice cream with dietary fibre: Effects on rheological properties, ice crystallization and glass transition phenomena. FoodChem., 115: 665 – 671.

Srisuvor, N., N. Chinprahast, C. Prakitchaiwattana and S. Subhimaros (2013). Effects of inulin and polydextrose on physicochemical and sensory properties of low-fat set yoghurt with probiotic-cultured banana purée LWT-Food Sci. and Technol., 51: 30 – 36.

Tarrega, A. and E. Costell (2006). Effect of inulin addition on rheological and sensory properties of fat-free starch-based dairy results. Inter. Dairy J., 16: 1104 – 1112.

Torres, J.D., A. Tarrega and E. Costell (2010). Storage stability of starch-based dairy desserts containing long-chaininulin: Rheology and particle size distribution. Inter. Dairy J., 20: 46 – 52.

Tungland, B.C. and D. Meyer (2002). Non digestible oligo- and polysaccharides (dietary fiber): Their physiology and role in human health and food, Comprehensive Reviews in Food Sci. and Food Safety, 1: 73 – 92.

Villegas, B. and E. Costell (2007). Flow behaviour of inulin-milk beverages. Influence of inulin average chain length and of milk fat content. Inter. Dairy J., 17: 776 – 781.

Winton, A.L. (1958). Analysis of Foods. 3rd printing {p. 6} John Wiley and Sons Ince. New York.

Zedan, M.A., A.N. Zedan, K.M.K. Kebary and S.F. Mahmoud (2001). Effects of fortification of cow's milk with acetylated whey protein concentrates on the quality of set yoghurt. Egyptian J. Dairy Sci., 29: 285 – 297.

جودة اليوجورت المجمد المنخفض الدهن والداعم للحيوية

كمال محمد كمالى ، خميس محمد كامل كعبارى ، على حسن السنباطى ، خديجة رجب بدوى
قسم علوم وتكنولوجيا الألبان – كلية الزراعة –جامعة المنوفية – شبين الكوم

الملخص العربى

اهتمت الدراسة فى هذا الجزء بدراسة تأثير إستبدال دهن اللبن بنسبٍ مُختلفةٍ بواسطة الإنيولين (Frutafit HD) على الخواص الكيميائية والريولوجية والحسيَّة لليوجورت المُجمد ، ولقد تم تصنيع ٦ مُعاملات ، وكان تركيب المُعاملة الكنترول كالتالى :

٤% دهن لبنى + ١٣% جوامد صلبة لبنية لا دهنية + ١٥% سكر + ٠.٥% مُثبت . أما المعاملات T_1و T_2 و T_3 و T_4 و T_5 ، فقد تم تصنيعهم بنسب استبدال ٢٠ ، ٤٠ ، ٦٠ ، ٨٠ ، ١٠٠% من دهن اللبن بإنيولين (Frutafit HD®) وتم تخزين المُعاملات فى الفريزر على –٢٠°م لمدة ١٠ أسابيع ، حيث أُخذت العينات وهى طازجة وبعد ٢ ، ٤ ، ٥ ، ٦ ، ٨ ، ١٠ أسابيع وذلك لإجراء التحليلات الكيماوية والريولوجية والحسية عليها.

ولقد أوضحت النتائج المُتحصل عليها بعد تحليلها إحصائياً ما يلى :

- اختلفتنسبة الحموضة وأيضاً قيم الـ pH لمخاليط اليوجورت المُجمد عن بعضها وهذا يدل على أن استبدال دهن اللبن بالإنيولين أثَّر معنوياً على حموضة مخاليط اليوجورت المُجمد وكانت أعلى قيمة للحموضة للعينة التى احتوت على أعلى نسبة من الإنيولين .
- أدى استبدال دهن اللبن بواسطة الإنيولين إلى زيادةٍ ملحوظةٍ فى لزوجة مخاليط اليوجورت المُجمد وهذه الزيادة كانت تتناسب طردياً مع مُعدل الإضافة .
- أدى استبدال دهن اللبن بواسطة الإنيولين إلى زيادةٍ ملحوظةٍ فى الكثافة النوعية والوزن بالجالون لمخاليط اليوجورت المُجمد وهذه الزيادة كانت تتناسب طردياً مع مُعدل الإضافة .
- حدثت زيادة فى الريع لليوجورت المُجمد باستبدال دهن اللبن بالإنيولين بزيادة مُعدل الاستبدال حتى ٦٠% بينما أدى زيادة الاستبدال إلى ٨٠ ، ١٠٠% إلى انخفاضٍ ملحوظ فى الريع .
- أدى استبدال دهن اللبن بالإنيولين (Frutafit HD®) إلى زيادةٍ معنويةٍ فى الكثافة النوعية والوزن بالجالون لليوجورت المُجمد بزيادة مُعدل الاستبدال .
- أدى استبدال دهن اللبن بالإنيولين إلى زيادة المُقاومة للانصهار وكانت هناك علاقة طردية بين زيادة المُقاومة للانصهار ومُعدل الاستبدال .
- أدى استبدال دهن اللبن بالإنيولين إلى ارتفاع نسب الحموضة وانخفاض قيم الـ pH ولم تختلف نسب الحموضة وقيم الـ pH أثناء فترة التخزين .
- لم يُؤثر استبدال الدهن بالإنيولين على نسب الجوامد الصلبة الكلية والبروتين الكُلِّى والرماد لليوجورت المُجمد . ومن ناحيةٍ أخرى لم تتأثر نسب الجوامد الصلبة والبروتين الكلى والرماد معنوياً فى كل المعاملات أثناء فترة

التخزين .

- احتوت العينة الكنترول على أعلى نسبة للدهن بينما حدث انخفاض فى الدهن بخفض الدهن فى اللبن . ولم تتغير نسبة الدهن فى كل المعاملات أثناء فترة التخزين .
- ازدادت نسبة الكربوهيدرات بزيادة نسبة استبدال دهن اللبن بالإنيولين . ومن ناحيةٍأخرى لم تختلف نسب الكربوهيدرات معنوياً فى كل المعاملات أثناء فترة التخزين .
- حدث انخفاض فى الطاقة الكلية بزيادة نسبة استبدال الدهن بالإنيولين . ومن ناحيةٍ أخرى لم تختلف الطاقة الكلية فى كل العينات معنويا أثناء فترة التخزين .
- اتخذت الخواص الحسِّية المُختلفة (النكهة ، القوام ، التركيب ، المجموع الكلى) نفس الاتجاهات تقريباً . ومن ناحيةٍ أخرى فقد حصلت العينة T_3 المصنعة باستبدال ٦٠% من دهن اللبن على أعلى الدرجات . لم تتغير الدرجات الممنوحة لكل المعاملات معنوياً أثناءالأربع أسابيع الأولى من التخزين ثم بدأت هذه الدرجات فى الانخفاض بنهاية فترة التخزين .

Table (6). Effect of replacing milk fat with inulin (Frutafit HD®) on organoleptic scores of frozen yoghurt.

Treatments ♦	Flavour (45)						Body and texture (35)						Melting quality (10)						Appearance (10)						Total score out of (100)					
	Storage period (weeks)																													
	0	2	4	6	8	10	0	2	4	6	8	10	0	2	4	6	8	10	0	2	4	6	8	10	0	2	4	6	8	10
C	43	42	42	40	41	39	34	34	34	31	30	31	8	8	8	8	9	9	8	8	8	8	7	7	93	92	92	87	87	86
T_1	44	43	42	41	41	40	33	32	32	32	30	30	8	8	9	8	9	8	9	8	8	8	8	8	93	91	91	89	88	86
T_2	43	43	42	42	42	40	34	33	32	32	30	29	8	8	7	8	9	8	8	8	8	8	8	7	94	92	89	90	89	84
T_3	44	43	43	43	41	41	34	33	33	33	31	31	9	8	8	8	9	9	9	9	9	8	8	8	96	93	93	92	89	89
T_4	42	42	41	40	38	37	33	33	32	31	31	30	7	8	8	8	8	9	8	8	8	7	7	7	90	91	89	86	84	83
T_5	43	41	41	39	38	39	31	31	31	29	29	27	7	8	8	7	9	9	8	7	7	7	6	6	88	87	87	82	82	81

♦ See Table (1).