J. Food and Dairy Sci., Mansoura Univ., Vol. 9 (1): 13 - 17 , 2018

Influence of Adding Inulin as a Fat Replacer on the Characteristics of Yoghurt

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ABSTRACT

The effects of substituting milk fat with different levels of inulin as a fat replacer on the chemical, microbiological and sensory characteristics of yoghurt were examined. Samples of yoghurt were kept in refrigerator at (5± 2Cº), and examined when fresh, and after 2, 3 and 7 days of storage. Chemical composition, microbiological contents and sensory characteristics were examined. The obtained results indicated that addition of inulin resulted in a significant increase in the total solids, moisture contents, and the development of titratable acidity. On the other hand, less whey syneresis was observed during the storage of the yoghurt samples. On the other hand, replacing of milk fat by inulin was of no significant effect on the fat content. Addition of inulin stimulated the growth of lactic acid bacteria. The colony forming units of total bacterial counts, *Lactobacillus delbrueckii ssp. bulgaricus* and *Streptococcus thermophilus* increased up to the 3rd day of storage period, followed by decrease up to the end of the storage period. Sensory evaluations were almost stable during the first 7th days of storage, then decreased slightly until the end of storage the period. Yoghurt samples containing 1.2% of inulin showed minor difference in the sensory characteristics, compared with control, and of the most acceptable sample. In conclusion, inulin could be successfully used as a fat replacer in making of low fat yoghurt with additional nutritional benefits without affecting the physico-chemical properties of yoghurt.

keywords: fat replacers, inulin, quality of yoghurt.

INTRODUCTION

Yoghurt is among the most popular dairy products due to various health claims and therapeutic value. In addition, yoghurt had specific rheological and textural characteristics. Its texture results from the development of a three-dimensional network of milk proteins due to the aggregation of casein micelles with denatured whey proteins through hydrophobic and electrostatic bonds. The use fat replacers in the manufacture of dairy products is a growing trend in order to decrease the calorific content of food, without decreasing the physical and organoleptic properties of the final products. Fat replacers consist of mixtures of lipid originated fat substitutes, protein- or carbohydrate originated fat mimetics, or their combinations (Paseephol *et al.,*2008 Serafeimidou *et al.,*2012, and Huyghebaert *et al.,*1996).

Inulin, is a carbohydrate-derived fat replacer or dietary fiber extracted mainly from cliikony tubers. It has good gelling capacity, and can used as a functional food additive due to its prebiotic properties. Chemically, inulin consists of a long chain made up of fructose molecules and one glucose molecule at one end. The fructose molecules are connected by β-(2-1) bonds and the last fructose is linked with a glucose by an α-(1-2) bond as in sucrose) The average molecular weight and degree of polymerization of inulin depend on the source of inulin, the time of harvest and the process of production. In native chicory inulin, the number of fructose units linked together ranges from 2 to more than 60, with an average degree of polymerization of the order of 10 and the high-performance forms of inulin have an average degree of polymerization of 25(Kim, *et al.* ,2001 Franc, 2002 and Guven *et al.*, 2005).

The aim of this study was to investigate the possibility of using inulin in the manufacture of low-fat yoghurt, and study the effect of addition of inulin on chemical, microbiological and sensory properties of yoghurt during storage at refrigerator temperature.

MATERIALS AND METHODS

Fresh cow's milk was obtained from Collection Center, Arab El-awamer, Abnoub, Assiut Inulin was obtained from Oxford Laboratory Reagent (India). *Lactobacillus delbrueckii ssp. bulgaricus LB340 and Streptococcus thermophilus* were obtained from Dairy Enzymes Applications, Danisco, France.

Yoghurt was made from whole cow's milk (Control C1), skim cow's milk, and from supplemented skim cow's milk with 0.4, 0.8 and 1.2% inulin respectively. Milk was heated to 90ºC for 5 min., in water bath then cooled immediately to 40±1ºC. Inoculated milk with 2% of the mixed (1:1) yoghurt starters was dispensed in plastic cups of 100 ml, and incubated at 40±1ºC until the milk coagulation, followed by rapidly cooling to 5±1°C (Tamime and Robinson, 1999). Yoghurt samples were analyzed when fresh and after 2, 3 and 7 days of storage. All experiments were carried out in triplicate.

Titratable acidity and total solids were determined according to A.O.A.C. (2000). Fat and moisture contents were determined according to Ling (1963). Soluble nitrogen (S.N) was detected by using the Kjeldahel method according to A.O.A.C. (2000). Syneresis was determined by measuring the volume of separated whey was detected following the method described by Abd-EL-Salam *et al.*, (1991).

The total plate count (TPC) was determined by using the standard plate count technique (IDF, 1991), lactic acid bacteria (LAB) according to the International Standards IDF (1988), coliform bacteria as mentioned in the International Standards (IDF, 1971a). Counts of yeasts and moulds were carried out according to the International Standards (IDF, 1971b).

Sensory evaluation was assessed according to (Kebary and Hussein, 1999) when fresh and after 2, 3 and 7 days of storage by ten panelists of staff members at Department of Dairy Science, Food Technology Research Institute.

Statistical analyses were done using "F-test". Means were compared using least significant difference (L.S.D. test). Data were performed in computer using the SPSS package (SPSS 1998).

RESULTS AND DISCUSSION

Results obtained of the chemical composition Yoghurt manufactured by the addition of Inulin throughout the storage at 5± 2ºC are illustrated in Table (1). Results show that developed titratable acidity of yoghurt samples increased gradually ($p \leq 0.05$) as the storage period increased. These results are in agreement with those of Abd EL-Salam *et al.* (1996), Harby and EL-Sabie (2001), Kebary *et al.* (2004), Badawi *et al.* (2004) and Kebary *et al.* (2009).

Replacement of milk fat with inulin significantly increased the titratable acidity (Table 1). These results might be due to the prepiotic effect of inulin, which enhances the growth and ability of lactic acid bacteria to grow, to hydrolysis lactose (Gibson and Roberfroid, 1995; Hussein and Kebary, 1999; Kebary *et al.*, 2004 and Badawi *et al.*, 2008). Yoghurt containing 1.2% inulin was of the highest titratable acidity at the coagulation time, compared with other treatments, which came in agreement with that of Guven *et al.* (2005).

It could also be observed in Table (1), that yoghurt made from whole milk (C1) had significantly ($p \leq 0.05$) higher total solids (TS) when fresh and during storage, compared with other yoghurt samples. Whereas the least TS content was detected in yoghurt samples made from skim milk (C2). TS content of yoghurt fortified with inulin increased gradually by increasing the concentration of added inulin ($p \leq 0.05$). Also, the TS content of yoghurt in all treatments slightly increased during the storage period. Similar results were reported by Abd EL-Salam *et al*. (1996), Omar and Abou EL-Nour (1998), Kebary and Hussein (1999) and Hussein *et al*. (2004).

It could also be observed that the fortification of low fat yoghurt with inulin was of no effect on the fat content of the resultant yoghurt. These results are in agreement with those reported by Kebary *et al.* (1996), Kebary and Hussein (1999), Hussein *et al.* (2004) and Badawi *et al.* (2008). Results also showed slight changes, but significant in the soluble nitrogen of yoghurts from different treatments during storage. On the other hand, the soluble nitrogen contents increased in all treatments as the storage period progressed. These results agree with those of Abd EL-Salam *et al.* (1996), Kebary and Hussein (1999) and Kebary *et al.* (2004).

Table 1. Changes in the chemical composition of yoghurt as affected by Inulin through the storage at 5± 2ºC.

Determination	Samples	Storage Period /Days			
		0	2	3	7
Acidity %	C1	0.79^{B}	1.00^{A}	1.06^{A}	1.07^{A}
	C2	0.73^{C}	0.90^{BC}	1.00^{B}	1.03^{BC}
	T1	0.82^{B}	0.92^{B}	1.04^{A}	1.06^{AB}
	T2	0.87^{A}	0.88^{C}	0.89^{C}	1.04^{BC}
	T3	0.89^{A}	0.89^{BC}	0.91^{C}	1.03^{C}
	LSD	0.03	0.03	0.02	0.02
Total solids%	C1	12.15^{A}	12.17^{A}	12.27^{A}	12.69^{A}
	C2	10.42^{C}	10.45^{C}	10.53^{B}	10.83^{B}
	T1	10.82^{BC}	11.83^{AB}	11.91^{A}	12.73^{A}
	T2	11.12^{BC}	11.42^{B}	11.54^{A}	12.54^{A}
	T3	11.31^{B}	11.39^{B}	11.91^{A}	12.08^{A}
	LSD	0.50	0.55	0.85	0.77
Moisture %	C1	87.85^{B}	87.83^{C}	87.73^{B}	87.31^{B}
	C2	89.58^{A}	89.55^{A}	89.47^{A}	89.17^{A}
	T1	89.18^{A}	88.17^{BC}	88.09^{B}	87.27^{B}
	T2	89.51^{A}	88.58^{BC}	88.46^{AB}	87.46^{B}
	T3	89.61^{A}	88.79^{AB}	88.69^{AB}	87.92^{B}
	LSD	0.4	0.8	0.9	0.7
Soluble nitrogen %	C1	0.084^{C}	0.086^{D}	0.090^{D}	0.112^{C}
	C2	0.091^{A}	0.099^{B}	0.105^{C}	0.105^{D}
	T1	0.119^{E}	0.122^{A}	0.125^{A}	0.195^{A}
	T2	0.088^{B}	0.093^{C}	0.115^{B}	0.182^{B}
	T3	0.056^{D}	0.074^{E}	0.081^{E}	0.112^{C}
	LSD	0.002	0.002	0.003	0.002
Fat %	C1	3.5^{A}	3.5^{A}	4.0^{A}	4.2^{A}
	C2	0.8^{B}	0.8^{B}	0.9^{BC}	1.0^{BC}
	T1	0.8^{B}	0.8^{B}	0.9^{B}	1.0^{B}
	T2	0.7^{B}	0.7^{B}	0.7^{C}	0.8^{C}
	T3	0.7^{B}	0.7^{B}	0.8^{BC}	0.8^{BC}
	LSD	0.2	0.2	0.2	0.2

Means (n =3) with the same capital letters in the same column are not significantly different at $P \leq 0.05$.
C1: Control yoghurt manufactured from whole cow milk.
C2: Control yoghurt manufactured from cow skim milk without addition of inulin.
T1: Yoghurt manufactured from cow skim milk + 0.4 % inulin.
T2: Yoghurt manufactured from cow skim milk + 0.8 % inulin.
T3: Yoghurt manufactured from cow skim milk + 1.2 % inulin

Syneresis of whey was affected by the concentration of added inulin as shown in Table (2). Replacement of milk fat with inulin resulted in a significant ($p \leq 0.05$) reduction of whey syneresis from curd, and this reduction was proportional to the concentration of replacement. This might be due to the increased water capacity of added inulin. Similar results were reported by Kebary and Hussein (1999) and Farooq and Haque (1992). These results might also due of the effect of added of inulin, which leads to form a complex with casein micelles and prevent them from excessive fusion, and forming a fine meshed gel network which is less susceptible to whey separation and /or increasing the water holding capacity (Danneberg and Kessler, 1988). Syneresis from all yoghurt samples decreased gradually ($p \leq 0.05$) as storage period increased, and reached its minimum values at the seventh day of storage period. These results are in agreement with those reported by Farooq and Haque (1992), Kebary and Hussein (1999) and Kebary *et al*. (2009).

Table 2. Changes in the synersis in yoghurt as affected by inulin during the storage at 5± 2ºC.

Treatments	Storage period /Days			
	0	2	3	7
C1	31^{C}	27^{C}	28^{B}	26^{A}
C2	35^{AB}	27^{C}	28^{B}	28^{A}
T1	36^{A}	33^{A}	31^{A}	27^{A}
T2	34^{B}	31^{B}	30^{A}	27^{A}
T3	30^{C}	28^{C}	26^{C}	26^{A}

C1: Control yoghurt manufactured from whole cow milk.
C2: Control yoghurt manufactured from cow skim milk without addition of inulin.
T1: Yoghurt manufactured from cow skim milk + 0.4 % inulin.
T2: Yoghurt manufactured from cow skim milk + 0.8 % inulin.
T3: Yoghurt made from cow skim milk + 1.2 % inulin

Data presented in Table (3) illustrate that the total bacterial count (TBC) and lactic acid bacteria (LAB) followed similar trends of changes during storage. Both increased as storage period increased up to the third day, then decreased thereafter reaching their minimum at the end of the storage period. These results could be explained by the development of acidity. These results agree with those reported by Kebary *et al.* (1996), Kebary and Hussein (1999), Kebary *et al.* (2004), Kebary *et al.* (2007), Badawi *et al.* (2008) and EL-Sonbaty *et al.* (2008). The obtained results also showed that yoghurt with added inulin was of higher counts of LAB than the control, which came in harmony with Menne *et al.* (1997). The count of TBC and LAB counts increased by increasing the concentration of added inulin. These results might be due to the stimulation effect of inulin as a prebiotic on the growth of microflora (Gibson and Roberfroid (1995), Kebary *et al*. (2005), Donkor *et al*. (2007) and Oliveira *et al*. (2009). It could also be found that all samples were completely free from coliform bacteria during storage period. The same Table illustrate that samples were also free from yeasts and moulds during the first three days of storage, but they increased slightly then after until the end of storage period. These results agree with those reported by Mehriz *et al.* (1993)

Table 3. Changes in the microbiological characteristics of yoghurt manufactured by Inulin through the storage at 5± 2ºC. (cfu/g).

Treatments	TBC				LAB				Yeasts and molds			
	Storage period (Days)											
	0	2	3	7	0	2	3	7	0	2	3	7
C1	29.5×10^{5}	36×10^{5}	26.5×10^{5}	74×10^{4}	58.5×10^{4}	77.0×10^{4}	42.5×10^{4}	34.3×10^{4}	ND	ND	ND	10^{4}
C2	11.5×10^{5}	23.0×10^{5}	56.5×10^{5}	47.5×10^{4}	89.0×10^{4}	13.1×10^{5}	12.8×10^{5}	33.4×10^{5}	ND	ND	ND	2×10^{4}
T1	10.0×10^{5}	46.6×10^{5}	61.5×10^{5}	19.7×10^{5}	75.2×10^{4}	26.0×10^{5}	48.5×10^{5}	14.6×10^{5}	ND	ND	ND	1.3×10^{4}
T2	35.6×10^{5}	48.8×10^{5}	75.5×10^{5}	20.8×10^{5}	31.6×10^{5}	38.0×10^{5}	55.0×10^{5}	65.8×10^{4}	ND	ND	ND	10^{4}
T3	38.0×10^{5}	56.0×10^{5}	77.0×10^{5}	27.6×10^{5}	35.9×10^{5}	45.5×10^{5}	69.0×10^{5}	67.5×10^{4}	ND	ND	ND	2.5×10^{4}

C1: Control yoghurt manufactured from whole cow milk.
C2: Control yoghurt manufactured from cow skim milk without addition of inulin.
T1: Yoghurt manufactured from cow skim milk + 0.4 % inulin.
T2: Yoghurt manufactured from cow skim milk + 0.8 % inulin.
T3: Yoghurt manufactured from cow skim milk + 1.2 % inulin
TPC: Total plate counts
LAB: lactic acid bacteria
Y.M.: Yeast and mould

Organoleptic properties (flavor, body & texture, appearance, acidity and total scores) of the examined samples of yoghurt followed almost similar trends (Tables 4). Yoghurt made from skim milk without adding inulin (C2) gained the lowest scores for organoleptic properties, and was different from other yoghurt treatments (Tables 4). Fortification of skim milk with inulin improved the organoleptic properties of yoghurt. Treatment that made from skim milk fortified with 1.2% inulin gained similar scores in yoghurt made from whole milk (C1). Storage up to the 3rd day was of no effect on the scores of organoleptic properties. Scores of all yoghurt treatments decreased gradually up to the end of storage period. These results are in agreement with those reported by Kebary and Hussein (1999), and Kebary *et al*. (2004).

Table 4. Organoleptic properties of fermented milk (yoghurt) manufactured by Inulin through the storage period at 5± 2ºC.

Treatments	Storage period (days)	Properties				
		Flavour (45)	Body& texture (30)	Appearance (15)	Acidity (10)	Total (100)
	0	38.50	25.00	12.88	8.69	85.07
Control 1	3	37.55	27.23	12.91	7.77	85.46
(full fat milk)	7	36.83	27.83	12.00	7.83	84.49
	10	30.63	21.13	9.50	8.13	69.39
	0	32.88	23.13	11.25	8.44	75.70
Control 2	3	28.95	26.91	13.64	7.91	77.41
(skim milk)	7	35.83	23.17	14.00	7.50	80.50
	10	29.25	20.88	11.55	8.63	70.01
	0	33.50	24.63	11.50	8.00	67.63
	3	31.09	28.64	13.45	7.18	80.36
T1	7	38.00	23.50	12.83	7.17	81.56
	10	29.25	25.63	13.44	8.75	77.07
	0	33.88	24.75	12.00	7.69	78.32
	3	34.64	27.09	13.73	7.82	83.28
T2	7	35.50	27.83	13.67	6.67	83.67
	10	25.63	25.63	12.75	6.63	70.64
	0	34.45	25.50	12.75	7.81	80.51
	3	37.55	28.09	13.82	8.64	88.10
T3	7	40.00	25.33	13.00	8.17	86.50
	10	32.50	27.25	12.69	8.75	81.19

T1 :Yoghurt manufactured from cow skim milk + 0.4 % inulin
T2: Yoghurt manufactured from cow skim milk + 0.8 % inulin
T3: Yoghurt manufactured from cow skim milk + 1.2 % inulin

CONCLUSION

From the obtained results, it could be concluded that the yoghurt of acceptable quality could be made from skim cow's milk fortified with inulin. Addition of 1-2% inulin to skim milk resulted in yoghurt with comparable results to full fat cow's milk.

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تأثير الإنيولين كبديل للدهن على خصائص الزبادي

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تمت دراسة تأثيرات استبدال دهن اللبن بمستويات مختلفة من الإينولين على الخصائص الكيميائية والميكروبيولوجية والحسية للزبادي حيث تم تقسيم لبن البقر الخام إلى قسمين من الحليب كامل الدسم وجزء آخر من الحليب الخالي من الدسم الذي أضيف له أنولين بنسبة ٠,٠٪ و٠,٤٪ و٠,٨٪ و١,٢ ٪على التوالي.تمت مقارنة الزبادي التجريبي مع الزبادي الكنترول المنتج من الحليب الكامل والزبادي الكنترول المنتج من الحليب الخالي من الدسم دون إضافة الإنيولين. تم تخزين الزبادي من المعاملات المختلفة في الثلاجة وتم أخذ عينات منها عند الطازج وبعد ٢،٣ و٧ أيام من التخزين وتحليلها للتركيب الكيميائي والخصائص الميكروبيولوجية والحسية. وأظهرت النتائج أن إضافة الإنيولين تسبب في زيادة معنوية في إجمالي المواد الصلبة والرطوبة والحموضة بينما خفضت التشرش أثناء تخزين المعاملات الناتجة عن الزبادي. ومن ناحية أخرى، لم يكن لاستبدال دهن اللبن بالإينولين أي تأثير معنوي على محتوى الدهن. إضافة الإنيولين يحفز نموبكتيريا حامض اللاكتيك. زاد العدد الكلي للبكتيريا وعدد كل *Lactobacillus delbrueckii ssp. bulgaricus* and *Streptococcus thermophilus* حتى اليوم الثالث من فترة التخزين ثم حدث تناقص حتى نهاية فترة التخزين .وكانت نتائج التقييم الحسي مستقرة تقريبا خلال أول ٧ أيام من فترة التخزين ثم انخفضت قليلا حتى نهاية فترة التخزين .أظهر الزبادي الذي يحتوي على ١,٢٪ من الإينولين اختلافا طفيفا في الخصائص الحسية ثم الزبادي المتحكم فيه المصنوع من الحليب الكامل وأنه المعاملة الأكثر قبولا، ويوصى باستخدام الإنيولين لتصنيع زبادي قليل الدسم مع فوائد غذائية إضافية دون التأثير على الخصائص الفيزيائية والكيميائية للزبادي.