Jerusalem Artichoke Paste as a Fat Replacer in the Manufacture of Low-Fat Yoghurt

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ABSTRACT

The influence of different levels of Jerusalem Artichoke (*Helianthus tuberosus*) paste (JAP) on the quality of low-fat yoghurt was investigated. The JAP was added to low fat milk (0.1% fat) to give solids of paste levels of 1, 2, 3 and 4 %. The experimental yoghurt samples were compared with control yoghurt produced from full fat milk (3.1% fat). Acetaldehyde, soluble tyrosine contents, total solids, pH, titratable acidity, synersis, firmness, organoleptic properties and microbiological analysis were determined in the yoghurt after 1, 3, 5, 7 and 14 days. Addition of JAPat more than 1% increased synersis and decreased firmness. Acetaldehyde, pH and titratable acidity were not influenced by addition of JAP. Soluble tyrosine levels were negatively affected by JAP addition. With respect to the organoleptic quality of yoghurt, the parameters studied for all the different treatments were significantly accepted by the panelists. Overall, the yoghurt samples containing 1% of JAP were similar in quality characteristics and not different from the control yoghurt made with whole milk. On the other hand, It seems that 1% JAP affected positively like a prebiotic on the lactic acid bacteria growth .

Key words : fat replacers, Jerusalem artichoke ,inulin low-fat yoghurt, functional food

INTRODUCTION

During the last decade, increased scientific effort has been invested in so-called 'functional foods', a concept that combines nutrition and health and is one of the leading trends in the food industry, especially in the dairy industry. The development of new types of fermented milks depends to a large extent on the ingredients or formulations employed. Although the milk fat has an important role in the texture, flavour and colour development of dairy products ,nowadays, consumers are becoming increasingly aware of health risks associated with a high fat-high calorie diet. As a result, there is an increased demand for low fat-low calorie foods including dairy products, mainly due to dietary concern to reduce the overall fat and sweetener intake (Massoud *et al.*,2005). Fat reduction can cause some defects in yoghurt and non-fat ice cream such as lack of flavour, weak body and poor texture (Huyghebaert *et al.*, 1996; Haque & Ji 2003). Although the manufacture of low- or nonfat dairy products has been possible for many years, the use of fat replacers in the manufacture of dairy products is still novel. Fat replacers, which decrease the calorific value of food, can be used to solve some physical and organoleptic problems originating from low-fat levels in the final products. Fat replacers consist of mixtures of lipidoriginated fat substitutes, protein- or carbohydrate originated fat mimetics, or their combinations (Huyghebaert *et al.*, 1996). Inulin, a carbohydrate-derived fat replacer or dietary fibre, has a gelling capacity with water, and is a functional food additive due to its prebiotic properties (O'Brein *et al.*, 2003). It is not digested in the small intestine, but is fermented in the colon by lactic acid bacteria such as yoghurt starter cultures. Consequently, inulin promotes the growth of healthy bacteria and enhances calcium and magnesium absorption and immune functions, and reduces the level of cholesterol and serum lipids (Rowland *et al.*, 1998; Dello Staffolo *et al.*, 2004; Ohr 2004). Furthermore, the fermentation of inulin may stimulate the formation of short-chain fatty acids such as acetate, propionate and butyrate, the latter being the preferred energy substrate for colonocytes (Kruse *et al.*, 1999). Inulin, in water-based foods such as dairy products, when used as a fat replacer, gives a fat-like mouth feel and texture (Izzo & Franck 1998; Zimeri & Kokini 2003). Jerusalem artichoke tubers (JA) (*Helianthus tuberosus*) are considered one of the most interesting potential sources of inulin and its derivatives which acting as anti-arrhythmic, anti-tuberculosis, anti-carcinogenic, anti-coagulating and fibrinolytic effects (Reshetnik *et al.*, 1999).

Jerusalem artichoke is a plant that can serve as an alternative source of carbohydrate. The tubers contain 14-15% inulin, 0.8-0.9% minerals and 0.6-1.5% raw fibre as basic components of healthy nutrition. On the other hand, JA inulin is used as food ingredient for fat and sugar replacement and as a texturizing agent (Hui Ru *et al.*, 2002) without bitterness comparing with chicory roots. The extracted inulin could be incorporated into bio-fermented milk (synbiotically) to improve the number of probiotic bacteria during product self life and consequently, in the colon or functionally to improve bone mineralization (Bosscher *et al.*, 2006).

This research focuses on evaluating the consumption of functional food in respect to citizens' lifestyle as well as cultural backgroundby investigate the possibility of using Jerusalem artichoke paste in the manufacture of low-fat yoghurt, and the effect of addition of Jerusalem artichoke paste on chemical, physical and sensory properties of yoghurt during storage.

MATERIALS AND METHODS

Materials

Raw cow's milk was obtained from the dairy pilot plant (Dairy Science & Technology Department, Faculty of Agriculture, Alexendria University). Lyophilized mixed yoghurt starter cultures containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* were obtained from Hansen's Laboratories, Copenhagen/ Denmark. Jerusalem artichoke cultivars were obtained from Sabahia Horticultural Research Station, Agriculture Research Center, Alexandria.

Methods

Preparation of Jerusalem artichoke paste (JAP)

Jerusalem artichoke paste(JAP) was prepared from JA tubers according to Salem *et al.*, (2003). Raw JA was cleaned, washed, pealed and warmed in water at 60 °C for 10 min., blended and stored frozen at –20°C. The composition (%) of JA according to (Amin *et al.*, 2005) was:

Carbohydrate 12.51, Protein 8.5, Fat 0.2, Ash 1.62, Fat 0.2, Ash 1.62, Inulin 9.76 and 22.83 Total solids.

Yoghurt manufacture

Both of milk (3.1% fat) or low fat milk (0.1%) were heated to 90°C for 10 min. with continuous stirring, cooled to 45°C and inoculated with 3% yoghurt starter. Low fat milk (0.1%) was divided into 5 portions. Diffirent concentrations from JAP were added (0, 1, 2, 3 and 4% JA paste). All treatments were incubated at 42°C. After complete coagulation, the samples were stored in a refrigerator (5-7°C) for 14 days. The yoghurt from both milk contains 3.1%fat or 0.1% fat without JAP were used as control 1 and control 2, respectively .

Microbiological analysis

Moulds and yeasts were counted on potato dextrose agar as described by APHA, (2005).On the other hand, lactic acid bacteria were enumerated according to standard procedures (Marshall, 1993).

Analytical methods:

The pH , acidity, total solids contents of yoghurt were determined according to AOAC (1995). Acetaldehyde content was determined as described by Robinson *et al.*, (1977). Syneresis was measured as described by Schmidt & Bouma (1992). A 20-g sample of yoghurt was spread in a thin layer over a Whatman No.2 filter paper, fitted into a 10-cm diameter Büchner funnel, and vacuum filtered for 10 min. Syneresis, expressed as % free whey, was calculated as follows:

$$\% \text{ Free whey} = \text{weight of initial sample} - \text{weight of sample after filtration} / \text{weight of initial sample} \times 100$$

Tyrosine content was determined according to Hull, (1947) whereas firmness was examined according to Mohamed & Morris (1987) by using the Texture Analyzer (CNF-farnell,England). All determinations were carried out in triplicate.

Sensory evaluation

Yoghurt samples were organoleptically scored when fresh and throughout the storage period by 10 panelists of the experienced staff members of Dairy Department according to the International Dairy Federation IDF (1997) .

Statistical analysis

Data were analyzed using completely randomized block design. Analysis of variance of treatment difference was performed according to Steel & Torrie (1980). Statistical analysis was done by ANOVA , F- test and Duncan's Multiple Range test procedures available within the SAS software package (ver 9.1, 2002). Significant differences were determined at $p \leq 0.01$.

RESULTS AND DISCUSSIONS

Physical and chemical properties of the yoghurt were determined throughout storage period . The pH values (Fig.1) were between 5.2 and 5.3 on day 1(fresh), and 4.85 and 4.93 on day 14. Use of JAP as a fat replacer did not affect the pH values. Barrantes *et al.*, (1994) reported that fat replacers did not negatively change the activity of yoghurt starter bacteria. The pH values of the yoghurt decreased during storage.

Titratable acidity of the samples (Fig. 2) was not affected by different ratios of JAP additions, and increases were found during storage . Some differences were observed during storage, and titratable acidity possessed the highest value at day 14. Yoghurt samples which containing 1% JAP had the highest titratable acidity content.This result agrees with findings of Guven *et al.*, (2005).

Whey synersis is an important defect in yoghurt. JAP addition to yoghurt milk increased whey separation values. The whey separation of yoghurt sample No. 3 was the lowest for all storage times, while yoghurt sample No. 6 had the highest level of whey synersis (Fig. 3).The values were 3.2, 6.9, 7.4 and 8.1% in fresh samples Nos.3, 4, 5 and 6, respectively compared with. 3.6, 4.1% in control 1and control 2, respectively. The whey separation of yoghurt samples with 1% JAP were lower than control. This has been observed by other workers (Farooq & Haque 1992, Tamime *et al.*, 1996).

Different concentrations of Jerusalem artichoke paste (JAP) based inulin were added to yoghurt aiming for the suitable and efficient concentration used as a fat replacer regarding to total solids indicated in (Fig. 4).The total solids increased from 8.51% in control 2 to 9.67,10.53,11.54,12.65 in fresh samples contain 1, 2,3,4 % JAP, respectively. During the storage period, there was a slight increase in the total solides in all treatments and this may be attributed to loss of moisture content during storage .These results agree with those of El-Nagar& Brennan (2001).

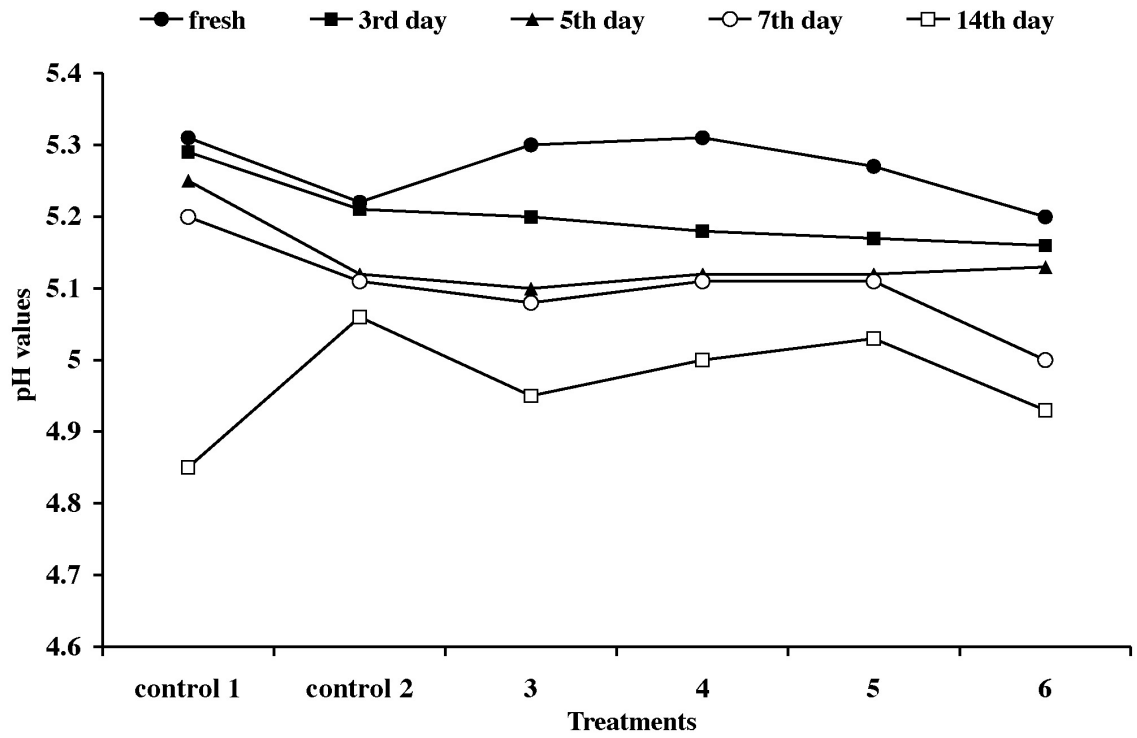
Acetaldehyde is the major flavour component in fermented milk products, belong to yoghurt. The level of acetaldehyde should be sufficient to produce desired flavour, as the threshold level of acetaldehyde for development of characteristic yoghurt flavour is about 0.4 ppm (Shah *et al.*, 1997). Therefore, it was necessary to determine the effect of the incorporation of such additives as fat replacer on acetaldehyde content in yoghurt. The changes in the acetaldehyde contents during storage of yoghurt supplemented with different concentrations of JAP are presented in Figure (5).

An increase in acetaldehyde content was noticed in all treatments particularly sample No. 4 which contained 2% of JAP. This may be attributed to the fact that prebiotic supports growth and metabolic activities of the starter culture. During the storage, acetaldehyde content in general increased and reached the maximum after 7 days of storage and then gradually decreased with extending the storage period; these results may be attributed to the demonstrated ability of numerous micro storage (El-Nemr & Mostafa 2007).or may be attributed to the alcoholdehydrogenase activity of yoghurt starters on the relationship between acetaldehyde and ethanol (Tamime & Deeth 1980).

The high levels of tyrosine indicate proteolytic degradation of proteins in yoghurt (Fig.6). Tyrosine contents increased during storage and these findings are in agreement with the results obtained by other workers (Rasic & Kurmann 1978, Tamime & Deeth 1980, Mistry & Hassan 1992).

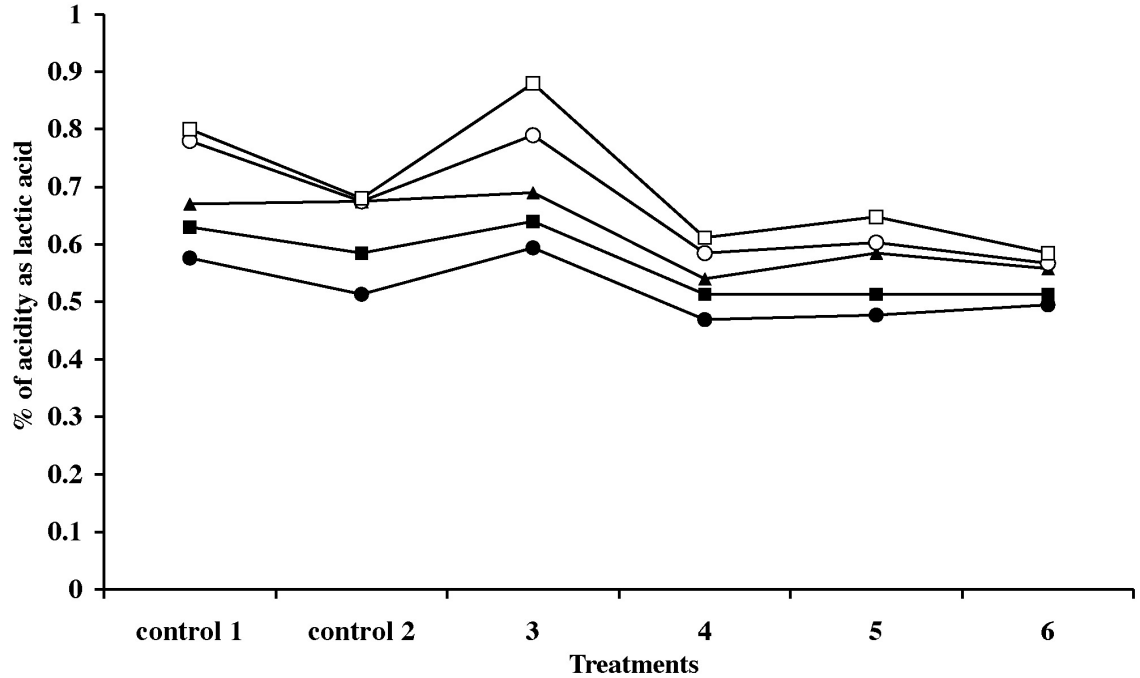
Curd stability in yoghurt is one of its most important physical properties. The factors which influence curd stability are total solids and protein contents, heating process, homogenization, acidity of yoghurt, storage temperature, and activity of yoghurt starter bacteria (Rasic & Kurmann 1978). As shown in Fig.(7), Samples Nos. 4, 5, 6 had the lowest firmness values during storage period , may be as a result of forming viscosity due to the linear chain of fructooligosaccharides in JAP. Sample No.3 which contained 1% JAP had the highest firmness.

The changes of counts on MRS media during the storage period of different treatments are present in (Fig. 8.) As shown, the initial counts of total yoghurt bacteria with JAP during storage period exhibited higher counts with 1% than that founded with addition of 2, 3 and 4 % JAP.It seems that the JAP affected positively as a prebiotic the lactic acid bacteria growth .The results of the present study are consistent in qualitative term with those reported by Bruno *et al.*, (2002); Martinez-Villaluenga *et al.*, (2006) and El-Nemr & Mostafa (2007). Those authors reported significantly higher retention of viability when probiotic bacteria were grown in the presence of prebiotic compared with the control without prebiotic. Yeasts and Moulds were in range of legislations (10 cfu /gm).



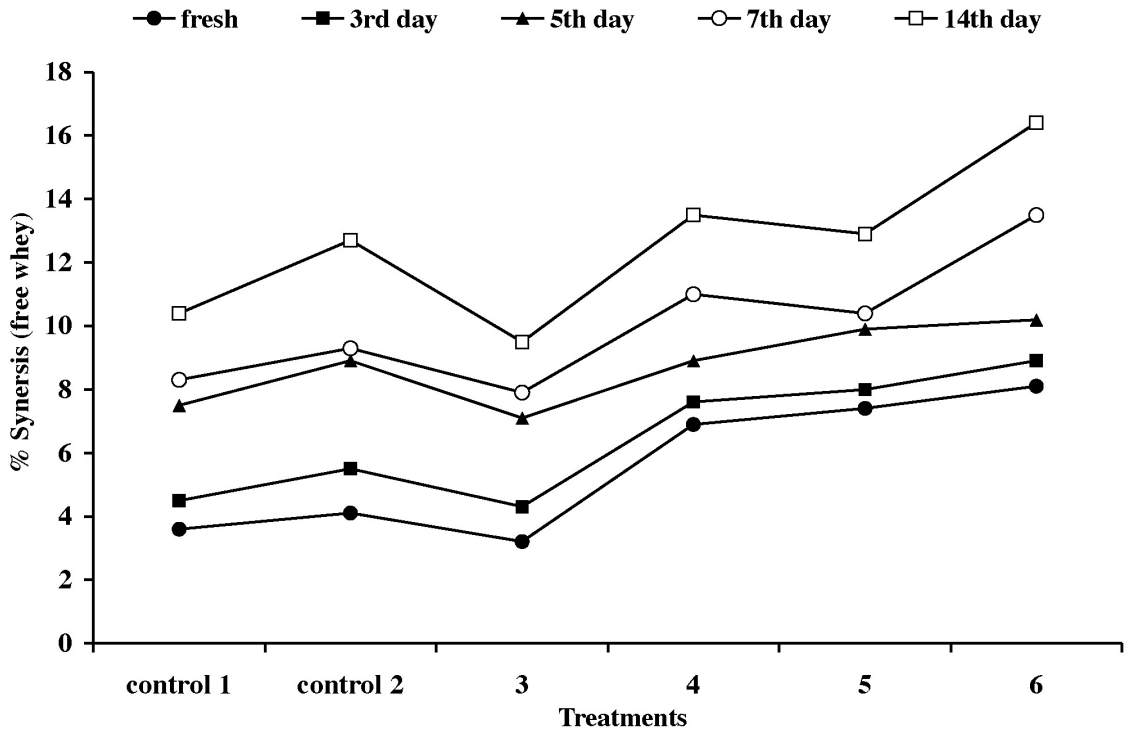
Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig.1: Changes in pH values of yoghurt samples with different concentrations of JAP during storage period



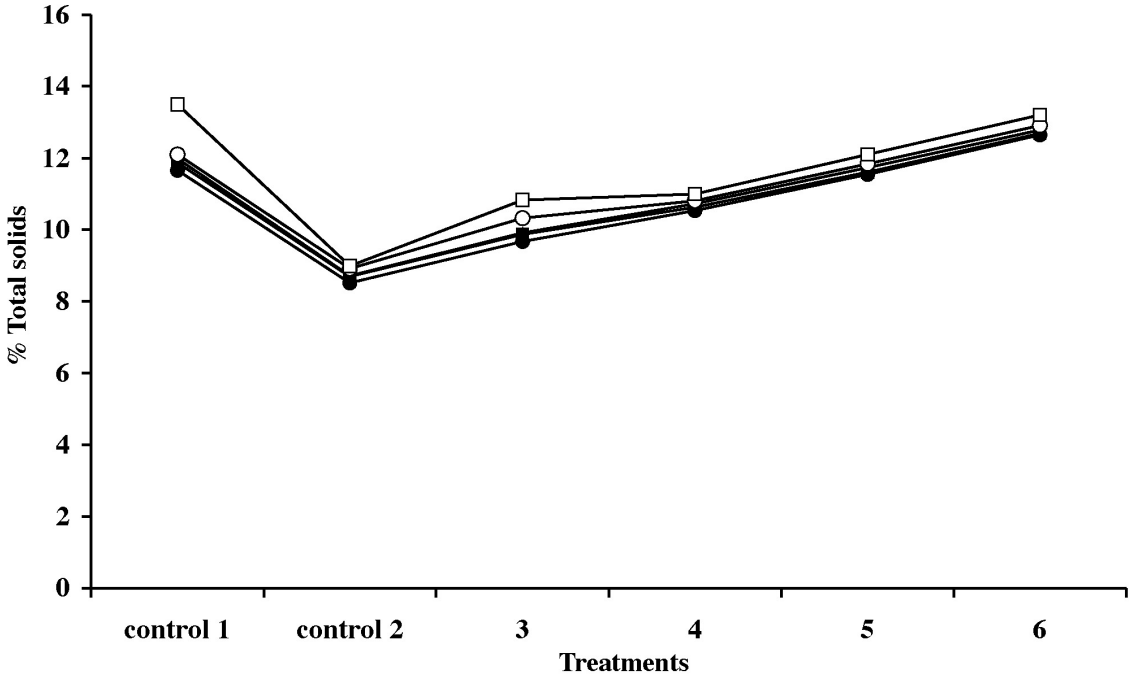
Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig. 2: Changes in acidity of yoghurt samples with different concentrations of JAP during storage period



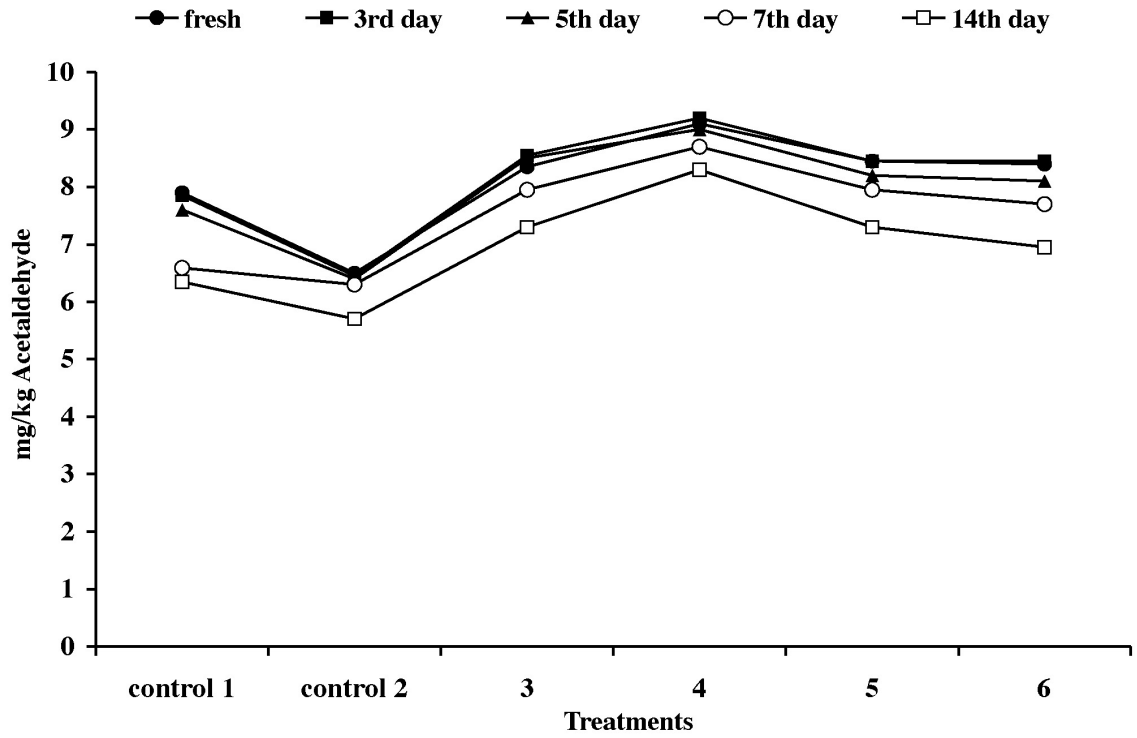
Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig. 3: Changes in Synersis of yoghurt samples with different concentrations of JAP during storage period



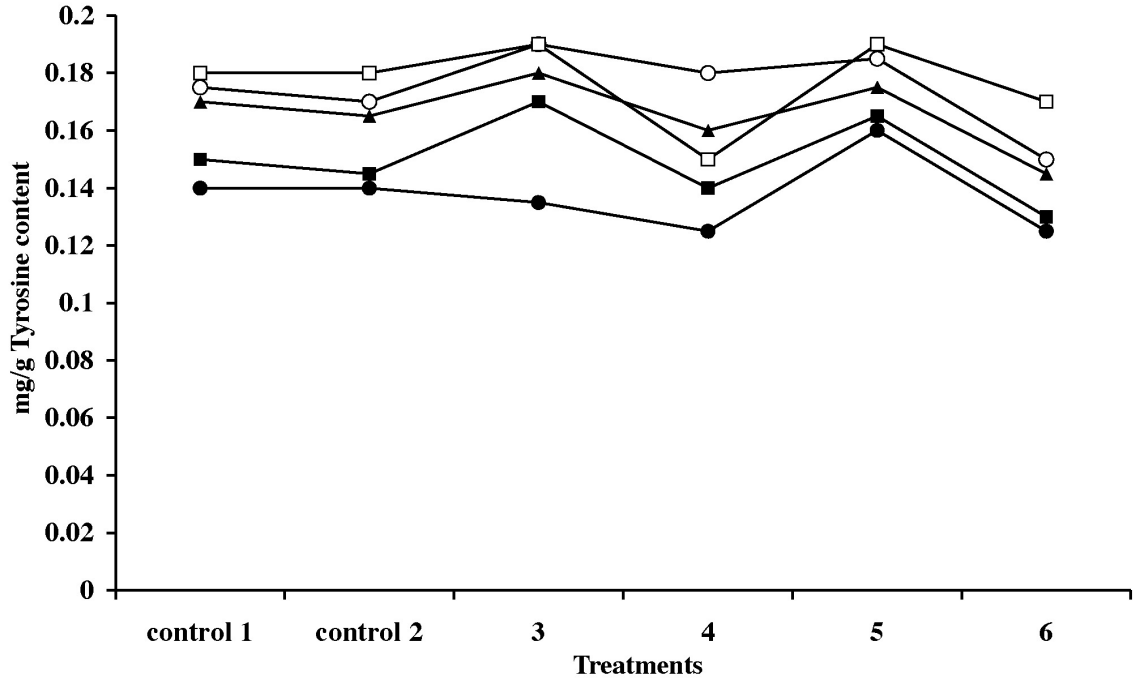
Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig. 4: Changes in total solids of yoghurt samples with different concentrations of JAP during storage period



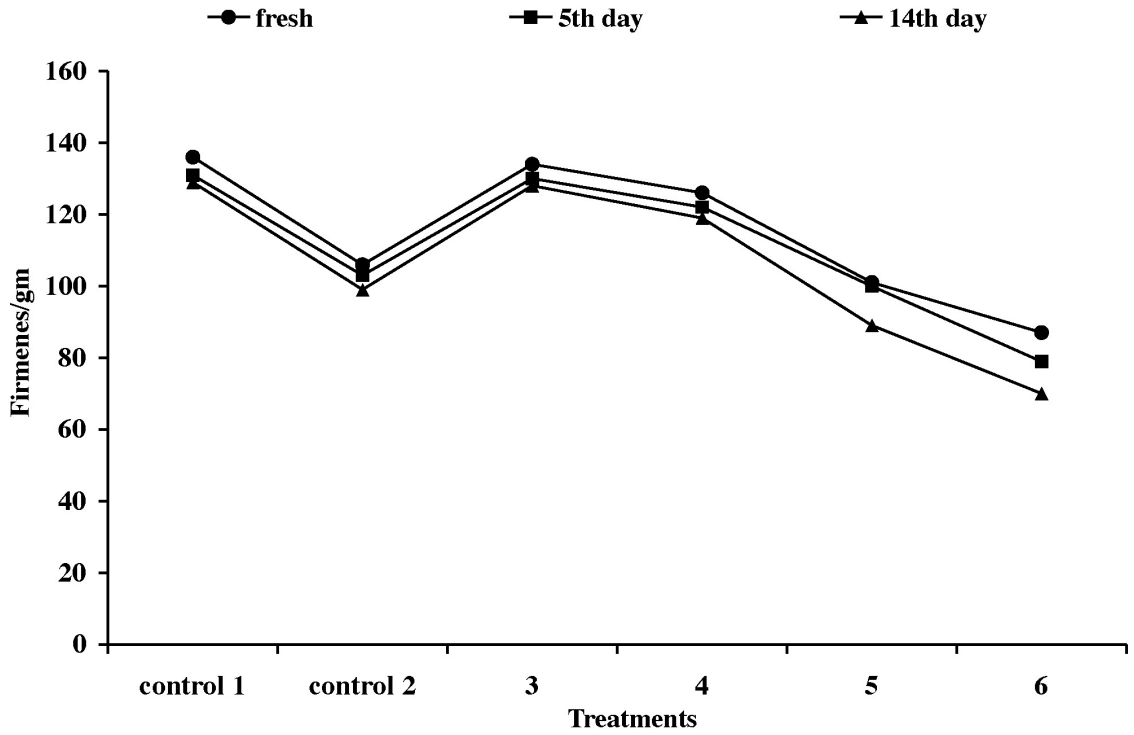
Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig. 5: Changes in acetaldehyde content of yoghurt samples with different concentrations of JAP during storage period



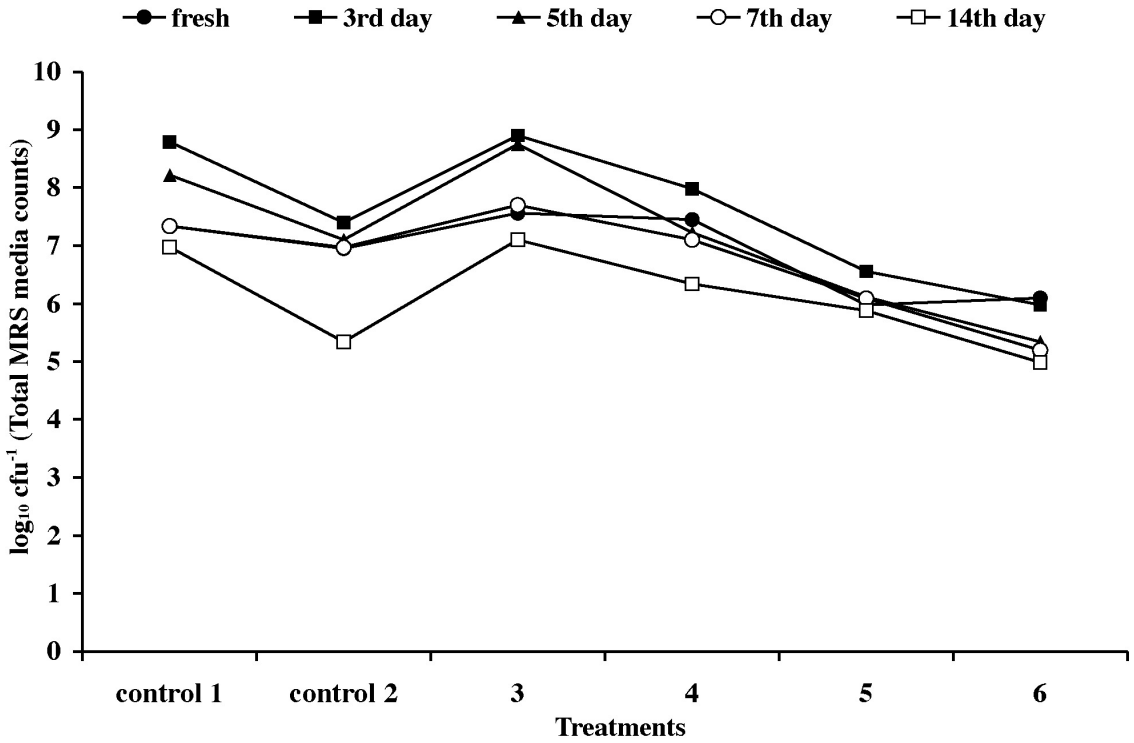
Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig. 6: Changes in soluble tyrosine content of yoghurt samples with different concentrations of JAP during storage period



Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig. 7: Changes in firmness of yoghurt samples with different concentrations of JAP during storing period



Control 1: 3.1%fat, 0% JA paste control 2 : 0.1% fat, 0% paste 3: 0.1%fat, 1% JA paste
4: 0.1%fat, 2% JA paste 5: 0.1%fat, 3% JA paste 6: 0.1%fat, 3% JA paste

Fig. 8: Changes in total counting on MRS media of yoghurt samples with different concentrations of JAP during storage period

Organoleptic properties of experimental yoghurt samples are shown in Table (1). The parameters studied for all the different treatments were significantly accepted by the panelists (Tabl 2). With respect to general acceptability of the yoghurt samples, samples Nos.3, 4 gained the highest score, followed by samples Nos.5 and 6 that contained 3 and 4% of JAP, respectively. Overall, the yoghurt samples containing 1 and 2 % of JAP were similar in quality characteristics to control yoghurt made with whole milk. It has been reported that the use of Jerusalem artichoke paste had no adverse effect on the flavour of low fat ice cream but its body and texture tended to be softer and smoother than control ice cream (Salem *et al.*, 2003).Meanwhile, Frank, (2002) reported that, inulin presented in Jerusalem artichoke paste allows the development of low fat food without compromising on taste, or texture such as butter- like products ,dairy spreads, cream cheese and processed cheese. Also , inulin,

Table 1: Organoleptic properties of yoghurt samples with different concentrations of JAP during storage period

Treatments	Parameters*	Storage period (day)				
		1	**3**	**5**	**7**	**14**
Control 1 (3.1% fat)	Appearance	9.5	9.4	8.3	8.0	7.6
	Body and texture	9.0	9.0	8.5	8.4	7.9
	Taste and aroma	9.6	9.5	8.2	8.1	7.9
	General acceptability	9.3	9.1	8.5	8.3	7.9
	Total	**37.4**	**37.0**	**33.5**	**32.8**	**31.3**
Control 2 (0.1% fat)	Appearance	8.4	8.1	8.0	7.8	7.4
	Body and texture	7.8	7.8	7.5	7.3	6.7
	Taste and aroma	8.7	8.4	8.1	7.9	7.6
	General acceptability	8.3	8.1	8.0	7.9	7.6
	Total	**33.2**	**32.4**	**31.6**	**30.9**	**29.3**
3 (1%JAP)	Appearance	9.3	9.1	9.0	8.6	8.3
	Body and texture	9.0	9.0	9.0	8.5	8.4
	Taste and aroma	9.5	9.5	9.0	8.5	8.1
	General acceptability	9.2	9.1	9.0	8.5	8.3
	Total	**37.0**	**36.7**	**36.0**	**34.1**	**33.1**
4 (2%JAP)	Appearance	9.3	9.3	9.2	9.1	8.8
	Body and texture	9.3	9.3	9.2	9.1	8.8
	Taste and aroma	9.3	9.3	9.2	9.1	8.5
	General acceptability	9.3	9.1	9.0	8.7	8.1
	Total	**37.2**	**37.0**	**36.6**	**36.0**	**34.2**
5 (3%JAP)	Appearance	9.2	9.0	9.0	7.9	7.4
	Body and texture	9.4	9.0	9.0	8.0	7.4
	Taste and aroma	9.0	8.7	8.5	7.9	7.5
	General acceptability	8.9	8.8	8.5	7.9	7.4
	Total	**36.5**	**35.5**	**35.0**	**31.7**	**29.7**
6 (4%JAP)	Appearance	8.7	7.8	7.5	6.9	6.5
	Body and texture	8.9	7.9	7.5	6.9	6.9
	Taste and aroma	8.1	7.7	7.1	6.6	6.0
	General acceptability	8.7	7.8	7.5	6.9	6.5
	Total	**34.4**	**31.2**	**29.6**	**27.3**	**25.9**

*Maximum value of each evaluation parameter was 10 points

Table 2: Statistical analysis of organoleptic properties of yoghurt samples with different concentrations of JAP during storage period

Treatments	Mean				
	Appearance	Body texture	Taste & aroma	General acceptability	Total
Control 1 (3.1% fat)	8.44^{ab}	8.560^{a}	8.660^{bc}	8.620^{ab}	34.40^{ab}
Control 2 (0.1% fat)	7.940^{bc}	7.420^{b}	8.140^{d}	7.980^{c}	31.48^{c}
3 (1% JAP)	8.860^{a}	8.780^{a}	8.920^{ab}	8.960^{a}	35.38^{ab}
4 (2% JAP)	9.140^{a}	9.140^{a}	9.240^{a}	8.840^{a}	36.20^{a}
5 (3% JAP)	8.560^{ab}	8.560^{a}	8.320^{cd}	8.300^{bc}	33.68^{b}
6 (4% JAP)	7.480^{c}	7.620^{b}	7.100^{e}	7.480^{d}	29.68^{c}
Mean	8.403	8.347	8.380	8.360	33.470
Sx	0.1625	0.1414	0.1095	0.1039	0.4578
C.V %	4.32	3.78	3.32	2.79	3.06
Storage period (day)	**Mean**				
	Appearance	Body texture	Taste & aroma	General acceptability	Total
1	9.100^{a}	8.900^{a}	9.033^{a}	9.000^{a}	35.95^{a}
3	8.780^{a}	8.667^{a}	8.850^{a}	8.733^{ab}	34.97^{ab}
5	8.500^{ab}	8.450^{ab}	8.350^{b}	8.417^{b}	33.72^{bc}
7	8.067^{bc}	8.033^{bc}	8.017^{bc}	8.033^{c}	32.13^{cd}
14	7.567^{c}	7.683^{c}	7.650+	7.633^{d}	30.58^{d}
Mean	8.403	8.347	8.380	8.360	33.470
Sx	0.1483	0.1291	0.1140	0.09487	0.4179
C.V (%)	4.32	3.78	3.32	2.79	3.06

Means followed by the same letters are not significant , but the different letters are significant

when thoroughly mixed with water or another aqueous liquid, it forms a particle gel net work resulting in a white cream structure with a short spreadable texture, which can easily be able to replace fat up to 100% . El-Nagar& Brennan (2001) reported that, Inulin plays a key role in enhancing the taste and texture of all natural vat-set yoghurt products. The fat-substituting property of inulin is based on the product's ability to stabilize water into a creamy structure, which has an excellent fat – like mouthfeel and almost taste free.

CONCLUSIONS

It was concluded that the use of JAP as a fat replacer in low-fat yoghurt positively affected some physical properties of yoghurt .Yoghurt samples containing 1% of JAP showed similar characteristics to the control yoghurt containing 3.1% of milk fat. Also, the use of JAP in the manufacture of low fat yoghurt is recommended due to its possible beneficial effects on health.

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الطرطوفة (خرشوفة القدس) كبديل للدهن فى تصنيع الزبادي منخفض الدهن

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تمت دراسة تأثير اضا فة مستويات مختلفة من معجون الطرطوفة (خرشوفة القدس) علي صفات الزبادي منخفض الدهن .حيث تمت اضافة معجون خرشوفة القدس علي لبن يحتوي علي ٠,١ ٪ دهنا لاعطاء جوامد من المعجون بنسب ١، ٢، ٣، ٤ ٪ . وقورن الزبادي الناتج بالزبادي الكونترول الناتج من اللبن الكامل (٣,١ ٪ دهن) و تم تقدير الخواص الطبيعية و الكيماوية مثل (pH والحموضة والتشريش والاسيتالدهيد والتيروسين الذائب والجوامد الكلية) و كذلك قوة الصلابة والخواص الحسية و الخواص الميكروبيولوجية للزبادي الناتج بعد ١، ٣، ٥، ٧، ١٤ يوما. أدت اضافة معجون خرشوفة القدس بمستويات أعلى من ١٪ الي زيادة التشريش و اضعاف الصلابة. ولم يتأثر محتوي الأسيتالدهيد، ال pH والحموضة باضافة خرشوفة القدس . كما تأثر محتوي التيروسين الذائب سلبيا بهذة الاضافة . اما بالنسبة للخواص الحسية فقد حصلت جميع المعاملات علي قبول المحكمين وبصفة عامة كانت عينات الزبادى المحتوية علي ١٪ معجون خرشوفة القدس متشابهة في خواصها النوعية للكونترول المصنع من اللبن الكامل ولم تختلف معنويا عنة في درجات التقييم الحسي .ومن ناحية اخرى أثر معجون خرشوفة القدس ايجابيا كمدعمات لنمو بكتريا حمض اللاكتيك.