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The Influence of Modified Waxy Maize Starch on The Quality of Low-Fat Yogurt

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THE INFLUENCE of adding different levels of modified waxy maize starch (1.0, 1.5 and 2.0 g/kg milk) as a fat replacer on the physicochemical, textural and sensorial properties of low-fat yogurts (1.5% fat) was studied during the cold storage at 1, 3, 7 days, compared with full-fat control yogurt (3.0% fat). The addition of modified waxy maize starch (MWMS) to low-fat yogurts was significantly ($P < 0.05$) increased for the acidity%, water holding capacity, apparent viscosity and decreased for the syneresis than those presented by full-fat control yogurt during the 7 days' cold storage. Textural measurments showed that low-fat yogurt with 2.0 g/kg milk MWMS had significantly higher for hardness values than of full-fat control yogurt and no significant difference existed between low-fat yogurts with 1.0 or 1.5 g/kg milk of MWMS and the control yogurt in respect to hardness attribute. The sensory analysis did not detect significant differences in both the appearance, whey-off scores of the experimental yogurt samples. The low-fat yogurts with 1.0 or 1.5 g/kg milk of MWMS showed insignificant difference with full-fat control yogurts in respect to firmness and smoothness scores. The low-fat yogurts with 2.0 g/kg milk of MWMS had a very firm texture, a starchy flavour which was unacceptable. Overall, the good quality of low-fat yogurt can be manufactured with 1.5 g/kg milk of MWMS which exhibited textural characteristics resemble those of full-fat control yogurts.

Keywords: Low-fat yogurt, Modified starch, Viscosity, Texture

Introduction

Nowadays, many consumers favour the consumption of low-fat yogurts (0.5-2% milk fat) which are more preferred because of health considerations. Therefore, great effort has been made to reduce the fat in yogurt without affecting its flavour and texture (Roller and Jones, 1996). Many researchers have developed ways to enhance the viscosity, texture, stability of low-fat yogurts by the addition of carbohydrate based ingredients, e.g. inulin, dextrin, maltodextrins and modified starches (Sandoval-Castilla et al., 2004, Guven et al., 2005 and Kip et al., 2006).

Starch can be modified by the chemical, physical and biotechnology means in order to improve the water holding capacity, minimized syneresis and improved viscosity of food product (Bertolini, 2009, Singh et al., 2010 and Behnia et al., 2013). Modified starches are widely used as a texture improver or thickener in low-fat yogurt or cheese products due to its easy processing, and low cost when compared with other hydrocolloids (Sipahioglu et al., 1999, Schmidt et al., 2001, Sandoval-Castilla et al., 2004 and Cui et al., 2014). Castilla et al. (2003) noted that the addition of modified tapioca starch to low-fat yogurts showed textural characteristics resemble those of full-fat yogurts. Williams et al. (2004) reported that the addition of starch to yogurt decreased syneresis, improved water holding capacity and improved smoothness. A similar effect was observed in the case of modified wheat starch with low-fat yogurt manufacture (Radi et al., 2009). Recently, Abbas et al. (2010) reviewed the definition and classifications of modified starches and their usages in selected food products.

The aim of the present research was to determine the influence of modified waxy maize starch as a fat replacer in different ratios (1.0, 1.5 and 2.0 g/kg) to low-fat yogurts manufacture (1.5% fat) on the physicochemical, textural and sensory properties during the cold storage at 1, 3, 7 days. Results obtained were compared with full-fat yogurt sample (3.0% fat) as a control.

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Materials and Methods

Materials

Buffalo's milk was obtained from the dairy pilot plant (Fayoum University, Faculty of Agriculture, Dairy department, Egypt). Modified waxy maize starch (Food Additive E1422), was obtained from MIFAD Company for food additives (Cairo, Egypt). Commercial freeze-dried starter culture from Chr. Hansen Inc., containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii ssp. bulgaricus* coded YC11 (Cophagen, Denmark) was used as a starter culture.

Methods

Experimental design

Four yogurt treatments were made using buffalo's milk as follows: a batch of full-fat yogurt (3،0% fat) and three batches of low-fat yogurt (1.5% fat) made with 1.0, 1.5, or 2.0 g/kg milk of modified waxy maize starch (MWMS), respectively. Each different batch were separately heated at 90°C for 5 min in a water bath and then its cooled to 45°C, inoculated with 2% of starter culture (w/v), dispersed into plastic cups (60 g), and incubated at 45 ± 1°C for 3hr. Following incubation, all samples were kept at room temperature for 30 min, then put at 4°C for 7 days and analyzed at 1, 3 and 7 days of the cold storage. Experimental yogurts were manufactured in our dairy pilot plant of Fac. of Agric., Fayoum Univ., Egypt.

physicochemical analysis

The samples were analyzed in triplicate for the % total solids, % fat and % titratable acidity contents (%TA) (AOAC, 2010). The electrode of the pH meter (model pH 510; Eutech Instruments) was inserted in the yogurt samples and pH value was recorded. Apparent viscosity was measured at room temperature (25± 1°C) with the HA-07 spindle at rotation of 60 rpm using a Brookfield digital Rheometer (Model HA DVIII Ultra, Brookfield Engineering Laboratories, Middleboro, MA) according to Sahan et al., (2008). Syneresis was measured by placing a 60 g of yogurt sample on a Whatman filter paper setting on a top of a funnel at room temperature for 2h. The clear supernatant was collected in a graduated cylinder and recorded as syneresis index (Delikanli and Ozcan, 2014). Water-Holding Capacity (WHC) in the experimental yogurt samples: 5 g of yogurt (w_i) was centrifuged at 4500 rpm for 30 min, the supernatant was removed, the pellet was collected and weighted (w_t). The WHC % was calculated as follows $\{1-w_t/w_i\}_{X\ 100}$ (Sahan et al., 2008).

Texture profile analysis

Texture Profile Analysis (TPA) of each yogurt sample was evaluated using a Universal Testing Machine (TMS-Pro Food Technology Corporation, Sterling, Verginia, USA) equipped with 2.5 N load cell and connected to a computer programmed with Texture ProTM texture analysis software. A flat rod probe (35 mm in diameter) to uniaxially compress the yoghurt samples with the following parameters conduction to 35% of their original height. Each sample was subjected to two subsequent cycles of compression-decompression. Data were collected on the computer and the texture profile parameters (Hardness, Cohesiveness, Springiness, Gumminess and Chewiness) were calculated from DEV TPA texture analyzer.

Sensory evaluation

Yogurt samples were evaluated for appearance (10 points), firmness (10 points), smoothness (10 points), wheying-off (10 points), flavour (60 points), and overall acceptability by ten panelists of the staff members at the Department of Dairy and Technology in Fayoum University, according to EL-shibiny et al. (1979).

Statistical analysis

The means and standard deviations were calculated for each parameter. Differences between means were determined by LSD test ($P < 0.05$) using one-way ANOVA analysis of XLSTAT Statistical software (Addinsoft, France).

Results and Discussion

Physicochemical properties

Table (1) shows mean values ± standard deviation for the physicochemical properties of the full-fat control and low-fat yogurt samples throughout the cold storage for 7 days. Generally, an increase in both acidity % and water holding capacity, a decrease in syneresis and apparent viscosity with storage time was observed in all experimental yogurts.

The TA % of low-fat yogurts incorporated with MWMS displayed significantly ($P < 0.05$) higher acidities than in the full-fat control yogurt, resulting in significantly lower pH in yogurts with respect to MWMS concentrations. This may be attributed to an enhanced growth and activity of the starter culture by the addition of MWMS (Guven et al., 2005 and Prasad et al., 2013). Low-fat yogurt with 2.0 g/kg of MWMS showed maximum increase in TA% followed by yogurt with 1.5 or 1.0 g/kg of MWMS.

TABLE 1. Effect of different concentrations of modified waxy maize starch (MWSN) on some physicochemical properties of low-fat yogurt during cold storage.

Paramter	Storage time (days)	Treatments			
		Full-fat yogurt	Low-fat yogurt with MWSN		
			1.0 g/kg milk	1.5 g/kg milk	2.0 g/kg milk
pH	1	5.07±0.02[a]	4.90±0.03[b]	4.70±0,04[b]	4.75±0.05[b]
	3	4.74±0.01[c]	4.62±0.03[b]	4.61±0.01[b]	4.53±0.04[c]
	7	4.67±0.03[a]	4.58±0.03[b]	4.55±0.01[b]	4.55±0.02[b]
Acidity (TA) %	1	0.62±0.2[b]	0.65±0.2[b]	0.73±0.3[a]	0.75±0.3[a]
	3	0.67±0.2[c]	0.72±0.2[b]	0.76±0.3[b]	0.82±0.3[a]
	7	0.72±0.1[c]	0.78±0.2[b]	0.90±0.3[a]	0.90±0.3[a]
Total Solids (%)	1	13.01±0.5[a]	12.21±0.5[c]	12.45±0.5[b]	12.50±0.6[b]
	3	13.07±0.4[a]	12.38±0.4[c]	12.48±0.5[b]	12.58±0.6[b]
	7	13.45±0.3[a]	12.44±0.4[c]	12.54±0.6[b]	12.64±0.6[b]
Fat (%)	1	3.00±0.1[a]	1.50±0.1[b]	1.50±0.1[b]	1.50±0.1[b]
	3	3.00±0.1[a]	1.60±0.1[b]	1.60±0.1[b]	1.60±0.1[b]
	7	3.00±0.1[a]	1.60±0.1[b]	1.60±0.1[b]	1.60±0.1[b]
Apparent viscosity (pa.s)	1	2.59±0.5[b]	1.23±0.4[c]	2.64±0.4[b]	3.64±0.5[a]
	3	2.48±0.3[b]	1.10±0.3[c]	2.34±0.5[b]	3.16±0.5[a]
	7	1.72±0.4[b]	1.02±0.3[c]	1.74±0.5[b]	2.79±0.2[a]
Syneresis (ml)	1	36.00±0.5[a]	21.00±0.6[b]	15.00±0.6[c]	12.00±0.4[d]
	3	28.00±0.5[a]	20.00±0.6[b]	14.00±0.6[c]	11.00±0.4[d]
	7	22.50±0.5[a]	18.00±0.6[b]	12.00±0.6[c]	10.00±0.4[d]
Water holding capacity (WHC) (%)	1	35.82±0.3[d]	66.35±0.3[c]	68.99±0.4[b]	70.94±0.3[a]
	3	73.69±0.3[d]	78.50±0.3[c]	79.88±0.4[b]	81.29±0.4[a]
	7	77.92±0.3[d]	81.47±0.3[c]	82.58±0.5[b]	85.68±0.5[a]

Means followed by the same letter in the same row are not significantly different (p<0.05) according to LSD test.

The apparent viscosity of low-fat yogurts manufactured with MWMS was significantly (P < 0.05) increased with increasing levels of MWMS as expected. Low-fat yogurts manufactured with 2.0 g/kg of MWMS showed the highest viscosity values, whereas low-fat yogurts manufactured with 1.0 g/kg of MWMS showed the lowest viscosity values. This could be probably due to starch granules imbibe water and Sewell to many times their original size, resulting in increased viscosity of the yogurt (Schmidt et al., 2001, Kora et al., 2003, Ares et al., 2007). A similar observation was reported by Williams et al. (2004) the viscosity of stirred low-fat yogurt increased when 1.0 g/kg of MWMS.

Regarding syneresis, it was significantly lower (P < 0.05) in the low-fat yogurt containing MWMS than those of full-fat control yogurt throughout storage period. Moreover, syneresis significantly decreased with increasing levels of MWMS. This could be attributed to the starch particles take up water from the surrounding protein matrix and would swell thereby limiting syneresis (Lucey, 2001).

The low-fat yogurts with MWMS had significantly higher WHC % than the full-fat control yogurt due to the ability of starch to bind more water consequently, thus these gels exhibited a smoothness texture (Lucey, 2001). Low-fat yogurt with 2.0 g/kg MWMS showed the highest WHC% followed by yogurt with 1.5 and 1.0 g/kg MWMS.

In our study, the addition of MWMS improved the increase of water holding capacity, minimize syneresis and enhance viscosity of low-fat yogurts which are in agreement with those reported by (Guven et al., 2005, Ares et al., 2007, Prasad et al., 2013) for the addition of modified starches to yogurt.

Textural properties

Table 2 shows the effect of MWMS addition at different concentrations on the meanvalues ± standard deviation of the textural properties for the experimental yogurts throughout the cold storage for 7 days. The most pronounced effects were observed with the addition of 2.0 g/kg milk of % starch to low-fat yogurt with was significantly harder, more gummier and chewier than of the full-fat control yogurt. This was probably due to the starch in the protein matrix can bind water limiting protein hydration thus increasing yogurt hardness and possibly chewiness and gumminess (Williams et al., 2004). No significant difference ($P < 0.05$) in hardness values was found in low-fat yogurt with 1.0 or 1.5 g/kg milk MWMS and full-fat control yogurt. There were no significant ($P < 0.05$) differences in springiness value of various treatments. Our findings agree with those of Prasad et al. (2013) who found that the addition of MWMS improved in the texture of low-fat yogurts. According to these results, using MWMS in low-fat yogurt manufacturing caused a more compact texture and so helped to improve the textural properties of low-fat yogurt.

Sensory evaluation

Table 3 shows the sensory evaluation for the control and experimental yogurts throughout the cold storage for 7 days as influence by MWMS concentrations. The results showed that there were no significant differences ($P < 0.05$) in both the appearance and whey-off scores of yogurt samples. Significant differences were found between low-fat yogurts containing 2.0 g/kg milk MWMS and full-fat control yogurt with respect to firmness and smoothness scores. This indicates that low-fat yogurts made with 1.0, 1.5 g/kg milk MWMS resembled full-fat control yogurt in its appearance, its smoothness, and its texture.

TABLE 2. Effect of different concentrations of modified waxy maize starch on texture properties of low-fat yogurt treatments during cold storage.

Paramter	Storage time (days)	Treatments			
		Full-fat yogurt	Low-fat yogurt with MWMS		
			1.0 g/kg milk	1.5 g/kg milk	2.0 g/kg milk
Hardness (g)	1	2.20±1.3[b]	2.30±0.4[b]	2.40±0.7[b]	2.80±0.9[a]
	3	2.92±0.9[b]	3.00±0.5[b]	3.10±0.3[b]	3.30±0.4[a]
	7	3.10±0.5[b]	3.60±0.6[b]	3.30±0.4[b]	4.50±0.6[a]
Cohesiveness (~)	1	0.63±0.2[b]	0.48±0.3[c]	0.41±0.2[c]	0.79±0.1[a]
	3	0.78±0.2[a]	0.48±0.2[b]	0.48±0.4[b]	0.79±0.4[a]
	7	0.76±0.1[a]	0.46±0.2[c]	0.43±0.3[c]	0.64±0.2[b]
Springiness (mm)	1	16.08±0.1[a]	16.09±0.3[a]	16.10±0.02[a]	16.08±0.0[a]3
	3	16.10±1.2[a]	16.09±1.5[a]	16.10±0.5[a]	16.09±0.6[a]
	7	13.33±0.7[a]	15.94±0.9[a]	15.15±0.9[a]	14.79±0.5[a]
Gumminess (g)	1	1.39±1.1[b]	1.20±0.7[b]	0.98±0.3[c]	2.21±0.6[a]
	3	2.28±0.2[a]	1.44±0.5[c]	1.18±0.5[d]	1.82±0.2[b]
	7	2.36±0.1[b]	1.66±0.4[c]	1.35±0.4[c]	2.88±0.4[a]
Chewiness (g/mm)	1	22.29±0.1[b]	17.76±0.4[c]	15.84±0.3[c]	35.57±0.2[a]
	3	36.67±0.3[a]	23.17±0.6[c]	20.97±0.5[d]	29.24±0.1[b]
	7	31.41±0.4[b]	26.40±0.3[c]	20.50±0.1[d]	42.60±0.2[a]

Means followed by the same letter in the same row are not significantly different ($p<0.05$) according to LSD test.

Flavour score of low-fat yogurts was significantly ($P < 0.05$) influenced by MWMS addition and the increase of the MWMS amounts impaired flavour scores. With regard to the overall acceptability of the yogurt samples, the full-fat control yogurt had got the highest score, followed by low-fat yogurts with 1.5 and 1.0 g/kg milk of MWMS and yogurts with 2.0 g/kg milk awarded lowest score. Low-fat yogurt containing 2.0 g/kg milk of MWMS is generally unacceptable due to its rough texture and starchy or gummy taste. It is concluded that a good quality low-fat yogurt with MWMS can be prepared by incorporating 1.0 or 1.5 g/kg milk MWMS.

TABLE 3. Effect of different concentrations of modified waxy maize starch on sensory evaluation values of low-fat yogurt treatments during cold storage.

	Storage time (days)	Treatments			
		Full-fat yogurt	Low-fat yogurt with MWS		
			1.0 g/kg milk	1.5 g/kg milk	2.0 g/kg milk
Appearance (10)	1	9.00±0.7[a]	9.00±0.1[a]	8.00±0.8[a]	8.00±0.1[a]
	3	8.00±0.3[a]	8.00±0.6[a]	7.00±0.4[a]	8.00±0.3[a]
	7	8.00±0.2[a]	8.00±0.5[a]	7.00±0.3[a]	7.00±0.4[a]
Firmness (10)	1	8.00±0.9[b]	7.00±0.4[b]	8.00±0.7[b]	8.50±0.3[a]
	3	8.00±0.4[b]	7.50±0.5[b]	8.00±0.5[b]	8.50±0.5[a]
	7	8.50±0.5[b]	7.50±0.4[b]	7.50±0.5[b]	9.00±0.4[a]
Smoothness (10)	1	8.00±0.4[a]	7.00±0.6[a]	8.00±0.4[a]	6.00±0.3[b]
	3	8.00±0.6[a]	7.00±0.6[a]	8.00±0.4[a]	6.00±0.3[b]
	7	9.00±0.4[a]	7.00±0.5[a]	8.00±0.2[a]	6.00±0.2[b]
Whey-off (10)	1	8.00±0.4[a]	8.00±0.4[a]	7.50±0.2[a]	8.00±0.4[a]
	3	7.00±0.5[a]	7.50±0.3[a]	7.00±0.3[a]	8.00±0.3[a]
	7	7.00±0.2[a]	7.00±0.2[a]	7.00±0.3[a]	7.50±0.3[a]
Flavour (60)	1	57.00±0.9[a]	52.00±0.9[b]	51.00±0.7[b]	45.00±0.4[c]
	3	57.00±0.3[a]	50.00±0.8[b]	50.00±0.5[b]	43.00±0.5[c]
	7	55.00±0.1[a]	50.00±0.8[b]	50.00±0.6[b]	40.00±0.5[c]
Overall acceptability	1	90.00±0.5[a]	82.00±0.6[b]	83.50±0.5[b]	75.50±0.3[c]
	3	88.00±0.4[a]	80.00±0.6[b]	80.00±0.5[b]	73.50±0.2[c]
	7	87.50±0.4[a]	79.50±0.5[b]	79.50±0.2[b]	68.50±0.4[c]

Means followed by the same letter in the same row are not significantly different ($p<0.05$) according to LSD test.

Conclusion

From the foregoing, we can conclude that modified waxy maize starch (MWMS) improved the texture of low-fat yogurt, resulting in a compact texture with less tendency to syneresis. For the manufacture of low-fat yogurt, the best results were obtained by adding MWMS at level of 1.5 g/kg milk whereas the higher levels were not satisfactory.

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تأثير إضافة نشا الذرة الشمعي المعدل علي جودة الزبادي المنخفض الدهن

في الآونه الأخيرة زاد وعي المستهلك تجاه الأغذية المنخفضه نسبيا في نسبة الدهن وذلك لاعتبارات صحية ، وقد دفع ذلك بعض المهتمين بصناعة الألبان إلي إنتاج زبادي منخفض الدهن ، لذا اتجهت العديد من البحوث نحو دراسة تأثير إضافة بعض المواد Carbohydrate-based fat replacers التي تقوم بدور الدهن حسيا وفيزيائيا في المنتج النهائي مثل الانيولين ، دكسترين ، النشا المعدل. وبشكل عام يستخدم النشا المستخلص من الذرة فى التصنيع الغذائى كمادة مالئة ورابطة ومعدلة للقوام وذلك لرخص ثمنه مقارنة بأسعار المواد الأخرى.

أجري هذا البحث لدراسة تأثير إضافة نشا الذرة الشمعي المعدل بنسبة (٠و١ ، ٥و١ ، ٠و٢ جم/كجم لبن) إلي الزبادي منخفض الدهن (٥و١٪ دهن) ومقارنته بالزبادي كامل الدسم (٣٪ دهن) خلال فترة التخزين لـ ١ ، ٣ ، ٧ يوم علي جودة الزبادي. وقد أجري علي الزبادي الناتج مجموعة من التحاليل الفيزوكيميائية (٪الحموضة ، ٪الجوامد الكلية ، اللزوجة ، والتشريش ، وسعة ارتباط الماء) والتحاليل الريولوجية (الصلابة) وكذلك التقييم الحسي لتحديد النسبة الاكثر قبول لدي المستهلك.

تبين نتائج الدراسة أن إضافة نشا الذرة الشمعي المعدل إلي الزبادي منخفض الدهن (٥و١٪ دهن) تؤدي إلي خفض قيم التشريش وزيادة كل من اللزوجة وسعة ارتباط الماء عن عينة المقارنة. كما انعكست إضافة (٠و١ أو ٥و١ جم/كجم لبن) من نشا الذرة المعدل بشكل ايجابي علي الصفات الريولوجية للزبادي منخفض الدهن. في حين لوحظ تدهور في بعض الصفات الحسية مثل الطعم عند إضافة (٠و٢ جم/كجم لبن) نشا الذرة المعدل حيث كان غير مقبول حسيا واتصف بقوام شبيه بقوام الجبن و ذو مذاق نشوي.

لذا يوصي من أجل تصنيع زبادي منخفض الدهن (١,٥٪ دهن) ذو خواص تركيبة جيده بإضافة نشا الذرة الشمعي المعدل حتي نسبة (١,٥ جم/كجم لبن) دون الاضرار بالصفات الحسية (طعم ونكهة ولون وقوام) للمنتج النهائي.