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Effects of Polysaccharides from Mango' Peel on Physiochemical and Sensory Properties of Non-Fat Yoghurts

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Abstract

Plant polysaccharides derived from fruits and vegetables are natural fibre materials with a low calorie content that can be used as a healthy alternative to gum stabilisers and starches for structuring free-fat yoghurt. This study aims to evaluate the effect of the supplementation of polysaccharides from Mango' Peel (as fat replacers) on the quality attributes of free-fat yoghurt. Polysaccharides at 0.05, 0.10 and 0.15 g/100 mL of reconstituted milk, were used also carboxymethyl cellulose (CMC) with 0.15 g/100 mL was used for evaluation of the product's properties. The results showed that the addition of polysaccharides accelerated the rate of pH reduction and induced earlier gelation. The gel viscoelastic properties were enhanced with addition of polysaccharides. This was accompanied with progressive reduction in the syneresis and contributing to the stronger gel network. Flavour, structure, acidity, appearance and colour of yoghurt with polysaccharides received high scores. For the first time, the addition of fruit polysaccharides could improve physical and sensory properties of the yoghurt and 0.05 g of polysaccharides/100 mL was the most suitable level.

Keywords: Mango; Polysaccharides; Yoghurt; Physical and sensory properties

Introduction

Fat plays an important role in controlling the firmness, viscosity and perceived creaminess of yoghurt due to the formation of a larger number of small fat particles during homogenization when they are stabilized by milk proteins and interact with the protein matrix. Partial or total removal of fat in a yoghurt formulation can cause some deficiencies such as weak body texture, higher whey separation and poor sensory quality [1].

Reduced fat yoghurt can be produced by partially replacing the fat content of the milk with either milk protein solids such as skim milk powder, sodium caseinate, or whey protein concentrates, or by including other fat replacers such as starch granules [2]. Polysaccharides are increasingly being used to provide better texture and to improve consistency by modifying the rheological properties of acidified milk gel network [3,4].

Numerous attempts were done to separate and purify inulin and oligofructose for utilisation as fat replacers and nutritional additions. At the present time, inulin and oligofructose are utilized a pure form as ingredients in many food products [5]. Industrial production methods have been created to produce the non-digestible carbohydrates (NDCs) from normal sources, by hydrolyzing polysaccharides, enzymatic and chemical synthesis from disaccharide, direct extraction to produce soybean oligosaccharides and rafinose, and isomerization reaction to produce lactulose [6].

Utilization of polysaccharide as fat replacers often leads to improve taste and texture [7]. When fat replacers used in bakery products and breakfast cereals, this presents a major progress in comparison with classical dietary fibers. Polysaccharides give more freshness and extension in snacks and cereals and they prolong shelf life. They also keep breads and cakes wet and fresh long time. Their solubility lets fibre incorporation in liquid systems such as drinks, dairy products and table spreads. Fat replacers is also often utilized as a dietary fibre in tablets and in functional foods, particularly in an entire range of dairy products and breads, as prebiotic ingredients that motivate the viability of health intestinal bacteria [8,9]. Because of gelling properties, polysaccharide improves low-fat foods and the quality of certain dairy products such as chocolate, yoghurt, dairy spreads, butter-like products, fresh cheese-based table spreads cream cheeses and processed cheeses. It is mainly offers a simple processing, a true fatty mouthfeel, allows the substitute of considerable quantity of fat and the constant of the emulsion [10].

Mangifera pajang polysaccharides showed strong fermentation and non- digestibility properties, and thus it might be a prebiotic [11], which increased viability and activity of probiotic such as *Bifidobacterium pseudocatenulatum* G4, *B. longum* BB 536 in yoghurt [12]. However, properties of yoghurts has not been investigated in the presences of *Mangifera pajang* peel polysaccharides thus the objective of this study was to investigate the effect of polysaccharides addition on the rate of pH reduction, viscoelastic properties, whey loss and sensory properties of low-fat set yoghurt.

Materials and Methods

Preparation of *Mangifera pajang* peels

To prepare *Mangifera pajang* peels (MPP), *M. pajang* Kort. Fruits were obtained from Sarawak, Malaysia. The healthy and fully ripe fruits peel was collected immediately after peeling. After blanched at 83°C for 5 min to avoid a browning reaction, the peels were mixed with water (1:2) and blended using a CB10BT blender (Waring Commercial, Torrington, USA). The peel mixture was then spread out on trays and dried at 50 ± 2°C for 18 h to bring the moisture content to 4%. The dried peels were powdered using a centrifuge ball mill (Zn100, Retsch, Germany) and were sieved through a 250-µm mesh. The peels were then stored at 23°C in a tightly sealed plastic container for further uses [13].

Extraction and purification of polysaccharides from MPP

Crude polysaccharide was extracted using hot water following the method of Al-sheraji et al. [14] Briefly the peel powder was decocted for 3 × 2 h, with 20 mL of water. The combined mixture was deproteinated with trichloroacetic acid. The supernatant was intensively dialysed against the running tap water for three days and then against distilled water for one day. The nondialysate fraction was concentrated under reduced pressure using a rotary evaporator (Buchi Rotavor R-200, Flawil, Switzerland). Four volumes of 95% alcohol were added slowly into the mixture, and then incubated for overnight at -10°C. The resulting precipitated was obtained by centrifugation at 1500 g for 15 min at 20°C using Hettichi centrifugation (Zentrifugen, Germany) and lyophilisation using a freeze-dryer (Virtis Gardiner, New York, USA). The lyophilised sample regarded as the crude *M. pajang* peel polysaccharides (MPPP) was used for further analysis.

Preparation of yoghurt

Yoghurt was prepared according to method described by Al-Sheraji et al. [15] with some modifications. Skim milk powder instant (NZMP, Fonterra, Auckland, New Zealand) was weighed, dissolved in water to constitute 12.00% skim milk (w/v) and divided into five experimental lots; one lot was fortified with 1.5 g L^{-1} polysaccharides (T1), the second lot with 1.0 g L^{-1} polysaccharides (T2), the third lot with 0.50 g L^{-1} polysaccharides (T3), the fourth lot with 1.5 g L^{-1} CMC (T4) and the fifth lot with 30 g L^{-1} Skim milk powder (T5). In addition, whole milk powder instant was weighed, dissolved in water to constitute 12.00% whole milk (w/v) and fortified with 30 g L^{-1} Skim milk powder (T6). After mixing the mixtures were separately homogenised with an APV homogeniser (Albertslund, Denmark) until all ingredients were dissolved in the milk. The homogenates were then pasteurised at 85°C for 30 min and cooled by immersion of the flasks in an ice water bath until they reached temperatures of 40-43°C. Exactly 3% (v/v) yoghurt starter culture; *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* were added to each lot. The mixtures were distributed into 100-mL plastic cups and were then incubated at 40°C, until they reached a pH of 4.55, followed by cooling to 4°C and storage at that temperature.

Determination of chemical composition of all samples

Moisture content was determined gravimetrically (70 ± 1°C for 6 h in a vacuum oven) using 4-5 g of sample. Lipids, protein and ash were analyzed according to AACC [16] methods. Carbohydrate was determined using the 985.29 AOAC [17] method.

Determination of titratable acidity

The titratable acidity was analysed according to recommendations of AOAC [18].

Determination of syneresis

Syneresis was determined using a procedure adopted from Riener, et al. [19]. The whole yoghurt sample (50 g) was gently transferred onto a 120 mesh screen strainer. The whey was separated and dripped into the 25 mL measuring cylinder at room temperature and the final volume was recorded after 15,30,45,60,90 min. The syneresis was reported as g of the separated whey out of the total weight (100 g) of the yoghurt.

Measurement of viscosity

Viscosity measurements were carried out on day 1 and at weekly intervals during storage at 4°C using a Dynamic Controlled Stress Rheometer (Thermoelectron Corporation, Germany). The yoghurt was gently stirred for 20s before analysis and all samples were treated at a constant shear rate from 10 to 20 at 20°C. All determinations were repeated at least three times.

Sensory evaluation

Yoghurt samples were coded with random numbersand served at 10°C to panelists (staff and students of Food Technology Department). This group of panelists had acuity in four basic tastes and had experiences in assessing food products by different sensory tests. The samples were randomly presented to the panelists in the morning [20].

Statistical Analysis

All the data are presented as the mean ± standard deviation (SD). Group differences were analysed using a one-way ANOVA (SPSS version 19.0., SPSS, Inc., Chicago, IL, USA) followed by a least significant difference (LSD) test. Significance was set at $p<0.05$.

Results and Discussion

Chemical composition

The chemical composition of all batches of yoghurt with or without fat replacers is presented in Table 1. The statistical analysis showed that polysaccharides significantly increased ($p<0.05$) chemical composition of yoghurt. The addition of polysaccharides resulted in increased chemical composition in all batches of yoghurt from 15.43% in T1 to 15.84% in T3 compared to CMC which increased the chemical composition 15.77%. Although polysaccharides exhibited an increased chemical composition than that of CMC but the addition of CMC significantly increased the chemical composition of the yoghurt more than the control (15.40 %). The chemical composition increased during manufacturing of yoghurt possibly due to using high temperature long time. The result of this study is in agreement with the study of Villegas et al. [21] which reported that The TSS contents of new prebiotic low-fat milk beverages also varied increasingly with increasing levels of inulin and sucrose. Also, Debon et al. [22] reported that increase in inulin and oligofructose resulted in higher TS contents of fermented milk. The addition of fiber increased by 1 g/100 g the total solids (total weight-moisture) of the heat treated milk bases.

Post-acidification and total titratable acidity

The addition of polysaccharides promoted a statistically significant ($p<0.05$) reduction in the initial acidity of all heat-treated skim milk bases, specifically from 0.95 in control milk to 0.78 in milks supplemented with 0.15% polysaccharides and to 0.93% in that supplemented with 0.15% CMC After 1 day of cold storage (Table 2). At the end of 2 weeks of shelf life (14 days), the post-acidification exhibited almost higher results as those of initial acidity in Table 2. Similarly, Espírito Santo et al. [23] reported that the pH of açai yoghurts fermented by the Bl04 strain was significantly higher (p<0.05) than that of their respective controls without fruit, which indicates that the Bl04 strain in the presence of some fruity products may reduce its organic acid production.

Treatments	Total solids %		Total Protein %		Fat %		Ash %		Carbohydrate %	
	1day	7day	1day	7day	1day	7day	1day	7day	1day	7day
T1	15.43^{b}	15.37^{c}	4.34^{b}	4.51^{a}	0.10^{b}	0.10^{b}	1.19^{c}	1.34^{c}	9.80^{a}	9.41^{a}
T2	15.78^{b}	15.58^{b}	4.48^{a}	4.52^{ab}	0.10^{b}	0.10^{b}	1.28^{ab}	1.51^{a}	9.93^{a}	9.45^{a}
T3	15.84^{b}	15.62^{b}	4.50^{a}	4.57^{a}	0.10^{b}	0.10^{b}	1.34^{a}	1.51^{a}	9.91^{a}	9.44^{a}
T4	15.77^{b}	15.58^{b}	4.48^{a}	4.52^{ab}	0.10^{b}	0.10^{b}	1.35^{a}	1.52^{a}	9.84^{a}	9.43^{a}
T5	15.40^{c}	15.34^{c}	4.27^{b}	4.33^{c}	0.10^{b}	0.10^{b}	1.22^{b}	1.42^{b}	9.77^{a}	9.49^{a}
T6	16.77^{a}	16.23^{a}	4.32^{b}	4.43^{b}	3.45^{a}	3.56^{a}	1.06^{c}	1.11^{c}	7.95^{b}	7.13^{b}
P-value	<0.0001	<0.0001	0.0001	0.0023	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001
SME	± 0.06	± 0.05	± 0.03	0.02	± 0.05	± 0.03	± 0.03	± 0.02	± 0.05	± 0.06

[a]All results are presented as the means of three independent experiments, and each analysis was done in triplicate (*n*=9 ± SD). Means in the same column with different small letter superscripts are significantly different (p<0.05). (T1)=Free Fat Yoghurt with 0.15% Polysaccharide, (T2)=Free Fat Yoghurt with 0.10% Polysaccharide, (T3)=Free Fat Yoghurt with 0.05% Polysaccharide, (T4)=Free Fat Yoghurt with 0.15% CMC, (T5)=Free Fat Yoghurt and (T6)=Whole Fat Yoghurt.

Table 1: Effect of CMC and level of polysaccharides chemical composition of free-fat set yoghurt [a].

Treatments	Acidity %	
	1 day	7 day
T1	0.78^{c}	0.93^{d}
T2	0.84^{b}	1.04^{c}
T3	0.86^{b}	1.12^{b}
T4	0.93^{a}	1.21^{a}
T5	0.95^{a}	1.25^{a}
T6	0.74^{c}	0.92^{d}
P-value	<0.0001	<0.0001
MSE	± 0.0196	± 0.018

[a]All results are presented as the means of three independent experiments, and each analysis was done in triplicate (*n*=9 ± SD). Means in the same column with different small letter superscripts are significantly different (p<0.05). (T1)=Free Fat Yoghurt with 0.15% Polysaccharide, (T2)=Free Fat Yoghurt with 0.10% Polysaccharide, (T3)=Free Fat Yoghurt with 0.05% Polysaccharide, (T4)=Free Fat Yoghurt with 0.15% CMC, (T5)=Free Fat Yoghurt and (T6)=Whole Fat Yoghurt.

Table 2: Effect of CMC and level of polysaccharides on acidity of free-fat set yoghurt[a].

Viscosity of yoghurt

The viscosities of all batches of yoghurt with or without fat replacers are presented in Table 3. The statistical analysis showed that polysaccharides significantly increased (p<0.05) the viscosity of yoghurt. The addition of polysaccharides resulted in significantly increased (p<0.05) viscosity in all batches of yoghurt from 0.73 at the beginning of storage to 1.78 at the end of storage compared to inulin which increased the viscosity from 0.67 at the beginning of storage to 1.39 at the end of storage and the control yoghurts. Although polysaccharides exhibited increased viscosity than that of inulin but the addition of inulin significantly increased the viscosity of the yoghurt more than the control. The viscosity increased during storage as well as, possibly due to hydration [24].

The increment in viscosity due to the addition of polysaccharides could be attributed from the interactions between the polysaccharides and dairy proteins [25-27]. Yazici and Akgun [28] reported that samples without fat replacer had the lowest viscosity while samples with 0.75% fat replacer the highest.

Fat replacers	Viscosity (mPa.s)				
	Storage time (days)				
	0	7	14	21	28
T1	0.74 ± 0.01^{cA}	0.98 ± 0.01^{cB}	1.15 ± 0.04^{dC}	1.30 ± 0.09^{cD}	1.78 ± 0.10^{dE}
T2	0.73 ± 0.01^{cA}	0.98 ± 0.01^{cB}	1.15 ± 0.05^{dC}	1.28 ± 0.05^{cD}	1.78 ± 0.14^{dE}

T3	0.73 ± 0.01^{cA}	0.97 ± 0.02^{cB}	1.11 ± 0.06^{cC}	1.30 ± 0.01^{cD}	1.75 ± 0.06^{dE}
T4	0.67 ± 0.01^{bA}	0.78 ± 0.01^{bB}	0.99 ± 0.01^{bC}	1.11 ± 0.05^{bD}	1.39 ± 0.08^{cE}
T5	0.62 ± 0.03^{aA}	0.73 ± 0.02^{aB}	0.90 ± 0.01^{aC}	1.00 ± 0.02^{aD}	1.14 ± 0.07^{aE}
T5	0.63 ± 0.03^{aA}	0.75 ± 0.02^{aB}	0.93 ± 0.01^{aC}	1.08 ± 0.02^{bD}	1.19 ± 0.07^{bE}

[a]All results are presented as the means of three independent experiments, and each analysis was done in triplicate (*n*=9 ± SD). Means ± standard deviation in the same column with different small letter superscripts are significantly different and means in the same row with different capital letter superscripts are significantly different. (T1)=Free Fat Yoghurt with 0.15% Polysaccharide, (T2)=Free Fat Yoghurt with 0.10% Polysaccharide, (T3)=Free Fat Yoghurt with 0.05% Polysaccharide, (T4)=Free Fat Yoghurt with 0.15% CMC, (T5)=Free Fat Yoghurt and (T6)=Whole Fat Yoghurt.

Table 3: Viscosities of yoghurt samples prepared by addition polysaccharides or CMC as a fat replacers during storage[a].

Syneresis

Syneresis is a common defect during storage of fermented dairy products such as yoghurt. Manufacturers try to reduce syneresis. It is known that faster rates of acidification results higher levels of syneresis [29], but in this study we found that polysaccharides caused faster rates of acidification and decreased syneresis. The syneresis of all batches of yoghurt with or without fat replacers is presented in Table 4. The statistical analysis showed that polysaccharides significantly decreased ($p<0.05$) the syneresis of yoghurt. The addition of polysaccharides resulted in significantly decreased ($p<0.05$) syneresis of yoghurt from 26 ml of the control to 14.6 ml at 0.15 g polysaccharides/100 ml milk compared to 0.15 g CMC/100 ml milk which decreased the syneresis from 26 ml to 17.4 ml. Although polysaccharides exhibited significantly decrease syneresis than that of CMC but the addition of CMC significantly decreased the syneresis of the yoghurt more than the control. The syneresis increased during time. Reduction the syneresis of the yoghurt with polysaccharides addition indicating that the milk protein-polysacharides network was relatively consistence through the whole yoghurt. The result of this study on the reduction of syneresis with the reduction of CWP concentration is in agreement to that reported by Garcia-Perez et al. [30] who found that lower concentration of orange fibre increased the yoghurt gel strength and decreased the syneresis.

Treatments	Tim (min)				
	15	30	45	60	90
	Volume of whey separation (mL)				
T1	14.6 ± 0.5^{aA}	22.4 ± 0.9^{bB}	26.2 ± 0.8^{aC}	32.8 ± 0.8^{aD}	34.0 ± 0.8^{aE}
T2	15.0 ± 0.6^{aA}	20.6 ± 0.9^{aB}	28.0 ± 0.7^{bC}	33.0 ± 0.8^{aD}	38.4 ± 0.9^{cE}
T3	16.0 ± 0.7^{bA}	28.0 ± 0.7^{cB}	31.2 ± 0.8^{cC}	36.0 ± 0.7^{cD}	40.8 ± 0.7^{cE}
T4	17.4 ± 0.8^{cA}	30.0 ± 0.8^{dB}	30.6 ± 0.6^{cB}	34.0 ± 0.9^{bC}	39.0 ± 0.5^{cD}
T5	26.0 ± 0.9^{dA}	31.2 ± 0.9^{eB}	36.0 ± 0.9^{dC}	40.4 ± 0.6^{dD}	44.0 ± 0.8^{dE}
T6	15.0 ± 0.5^{aA}	20.0 ± 0.7^{aB}	29.0 ± 0.7^{bC}	32.0 ± 0.5^{aD}	36.6 ± 0.6^{bE}

[a]All results are presented as the means of three independent experiments, and each analysis was done in triplicate (*n*=9 ± SD). Means ± standard deviation in the same column with different small letter superscripts are significantly different ($p<0.05$) and means in the same row with different capital letter superscripts are significantly different. (T1)=Free Fat Yoghurt with 0.15% Polysaccharide, (T2)=Free Fat Yoghurt with 0.10% Polysaccharide, (T3)=Free Fat Yoghurt with 0.05% Polysaccharide, (T4)=Free Fat Yoghurt with 0.15% CMC, (T5)=Free Fat Yoghurt and (T6)=Whole Fat Yoghurt.

Table 4: Syneresis of yoghurt samples with polysaccharides or CMC during storage at 4C[a].

Sensory properties of yoghurt

The results are given in Table 5 shows the effect of fat replacers in free fat yoghurt. In general, the two fat replacers improved various characteristics of the yoghurt in comparison with the free fat yoghurt. The addition of polysaccharides and CMC significantly ($p<0.05$) affected flavor; in addition, polysaccharides alone significantly ($p<0.05$) affected, appearance, color, structure and acidity, but no significant effect was found for CMC. Also, polysaccharides seemed to yield the product with better sensory properties, especially when added at levels (0.05 g/100 mL).

Sensory textural score was in accordance with physical property values. Also, the higher appearance scores for the polysaccharide-samples seemed to be related to the lower syneresis. Good quality yoghurt should maintain strong curd integrity without any sign of shrinkage and disintegration into lumps and whey-off. It should also possess pleasant flavor and, especially with the set yoghurt, the defect of syneresis, which relates to the appearance and mouthfeel, can adversely affect acceptability or preference of consumers. Therefore, it is of great concern that proper amount of any fat replacer should be used in the development of free-fat set yoghurt.

Treatments	Quality							
	Flavor		Structure		Acidity		Appearance and Color	
	45%		35%		10%		10%	
	1 day	7 day	1 day	7 day	1 day	7 day	1 day	7 day
T1	43.30[a]	42.15[a]	33.80[a]	32.65[a]	8.35[a]	9.00[a]	8.85[a]	8.90[a]
T2	39.35[bc]	41.50[ab]	32.70[ab]	32.60[ab]	7.30[ab]	8.90[a]	8.30[ab]	8.60[bc]
T3	40.70[abc]	42.15[a]	32.00[bc]	32.20[ab]	7.90[ab]	8.75[ab]	8.05[ab]	8.70[bc]
T4	42.10[ab]	39.20[b]	30.95[c]	29.90[c]	8.10[ab]	8.10[b]	8.20[ab]	8.00[cd]
T5	37.90[c]	35.80[c]	30.80[c]	30.50[bc]	7.20[b]	6.90[c]	7.25[b]	7.20[d]
T6	42.70[a]	42.80[a]	33.90[a]	33.55[a]	8.30[a]	9.10[a]	8.90[a]	9.60[a]
P-value	0.0064	<0.0001	0.0001	0.0094	0.134	<0.0001	0.047	<0.0001
SME	± 1.06	± 0.92	± 0.54	± 0.76	± 0.37	± 0.26	± 0.39	± 0.31

[a]All results are presented as the means of ten replicates (n=10 ± SD). Means in the same column with different small letter superscripts are significantly different (p<0.05). (T1)=Free Fat Yoghurt with 0.15% Polysaccharide, (T2)=Free Fat Yoghurt with 0.10% Polysaccharide, (T3)=Free Fat Yoghurt with 0.05% Polysaccharide, (T4)=Free Fat Yoghurt with 0.15% CMC, (T5)=Free Fat Yoghurt and (T6)=Whole Fat Yoghurt.

Table 5: Sensory properties of free-fat set yoghurt containing various levels of polysaccharides and CMC[a].

In our study, it was evident that either polysaccharides or CMC could improve physical and sensory properties of the product. Addition of polysaccharides to milk can result in a phase separation into a polysaccharide-enriched and casein-enriched phase if the concentration exceeds a certain value [31]. Consequently, gum (or hydrocolloid) and protein concentrations need to be optimized to allow for maximum interaction between the two biopolymers. As long as the gum-to-protein concentration is not optimized, the hydrocolloid hydrocolloid or protein protein interactions may predominate, thus affecting milk reactivity [32], which appears to be highly dependent on gum concentration [33]. In this study, polysaccharides at 0.05 g/100 mL was more suitable for ensuring the product's better qualities and will be chosen for further development of the low-fat set yoghurt supplemented with the probiotic-cultured.

Conclusions

Type and amount of fat replacers improved physicochemical and sensory properties of the free fat yoghurt. Polysaccharide (0.05 g/100 mL) was the most suitable for incorporation into such product aimed for commercial production.

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