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Textural and organoleptic properties of fat-free buffalo yogurt as affected by polydextrose

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ABSTRACT

The demand for functional, nutraceutical and low calories dairy products has grown in recent decades. The effects of using different concentrations of polydextrose (1.5%, 3%, and 5%) on the textural and organoleptic properties of fat-free buffalo set yogurt (FFBS) were investigated. Addition of polydextrose significantly \((P < .05)\) improved the water-holding capacity (WHC), sensory attributes and texture properties compared to the FFBS control yogurt. The sensory attributes, pH and WHC values were gradually decreased during cold storage of 21 days. Viability of yogurt culture was enhanced in the presence of 3% polydextrose compared with the FFBS control yogurt.

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KEYWORDS

Polydextrose; buffalo yogurt; water holding capacity; texture properties; organoleptic properties

Introduction

The demand of functional, nutraceutical and low calories dairy products has grown in the last decades. Yogurt is the most popular dairy product and has been considered as the first functional foods.\cite{1} Buffalo is the second global milk-producing animal all over the world and widely distributed throughout Asia. It is worth noting that more than 95.8% of the world populations of water buffalos are kept in Asia.\cite{2} Buffalo milk has a high content of fat, protein, lactose, vitamins, and minerals, and consequently high nutrient contents, which has attracted enormous attention by both academic researchers and dairy industry for various dairy products manufacturing.\cite{3} Furthermore, it has been reported that subjects with cow milk allergies are capable of tolerating buffalo milk.\cite{2} Milk fat plays a crucial role in yogurt quality attributes, and therefore fat reduction causes some undesirable qualities in yogurt such as lack of flavor, weak body, and poor texture.\cite{4} Different attempts have been performed to improve the properties of low-fat yogurt i.e. using transglutaminase (TG), increasing solid nonfat, addition of natural or synthetic stabilizers, and polysaccharides like starch and polydextrose.\cite{5}

Polydextrose, is a complex carbohydrate made from glucose, citric acid, and sorbitol, is a water-soluble dietary fiber with calorie content of 1 kcal/g.\cite{6} Polydextrose is an indigestible carbohydrate and has some health effects due to its laxative action and control of glucose and cholesterol levels in blood.\cite{7} Many countries approved using polydextrose as dietary fiber.\cite{8} In addition to its health benefits, polydextrose has some technological properties including forms a highly viscous gel-like matrix contributing to creaminess and mouthfeel.\cite{6} Therefore, it was used as fat replacer in low-fat dairy products. Srisuvor et al.\cite{9} added inulin and polydextrose in concentrations of 1% to 3% to improve physicochemical and sensory characteristics of low-fat yogurt. Furthermore, 6 and 10% polydextrose concentrations were utilized as bodying agents, and as fat replacers in ice cream.

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mixtures. In addition, polydextrose was added as prebiotic to produce nonfat symbiotic fermented milk. Addition of inulin and polydextrose mixtures showed promised replacement of sucrose in sugar-free chocolate.

Accordingly, the objective of this study was to evaluate the effect of adding polydextrose with different concentrations (1.5%, 3%, and 5%) as fat replacer on the physicochemical, sensory and rheological properties of fat-free buffalo set yogurt (FFBS). Yogurt quality indices as a function of polydextrose addition were investigated throughout the storage of 21 days at 4°C.

Materials and methods

Materials

Fresh buffalo milk was obtained from buffalo research institute farm, Nanning, China. Yogurt culture YF-1922 (Direct Vat Set), consisting of Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus, was purchased from Chr. Hansen A/S (Denmark). Polydextrose was obtained from Jiangsu Ruiduo Biological Engineering Co., Ltd (Jiangsu, China).

Yogurt preparation

Whole buffalo milk was separated, giving skim milk of 0.2% fat. Polydextrose was added to the buffalo skim milk at concentrations of 1.5%, 3%, and 5% (w/w). The mixtures were heat-treated at 90°C for 10 min followed by cooling to 45 °C and inoculated with yogurt culture (0.015%, w/w). The inoculated treatments were then filled into polystyrene cup (125 ml) and incubated at 42 °C until coagulation. All yogurts were stored in the refrigerator at 4 ± 1 °C for 21 days. Fat-free and full-fat buffalo set yogurts, without the addition of polydextrose, were prepared as control treatments. Physicochemical, sensory and microbiological analyses were carried out at 1, 7, 14, and 21 days of storage.

pH value and water-holding capacity (WHC)

The pH values were measured by pH-meter (PB-10, Sartorius, Germany). Samples were analyzed in triplicate. WHC was determined as described by Romeih and Hamad. In brief, 50-g yogurt was filled in centrifugation tubes and centrifuged for 15 min at 3000 × g at 20°C (Biofuge, Thermo Fisher Scientific, Germany). The amount of supernatant yogurt serum was removed and weighted.

\[
WHC(\%, \text{w/w}) = \frac{\text{Yoghurt}(g) - \text{Supernatent}(g)}{\text{Yoghurt}(g)} \times 100
\]

Sensory evaluation

Organoleptic properties of the FFBSY were assessed by 10 trained panelists from the Buffalo Research Institute using evaluation criteria as described by Romeih et al. The panel was asked to evaluate the yogurt treatments using a graduated scale of (30) for appearance, (30) for flavor, (40) for texture and/or (100) total acceptability. All samples were tested within random order in polystyrene plastic cups.

Instrumental textural properties

Texture characteristics, i.e. firmness, adhesiveness, and cohesiveness of the FFBS yogurts after 1d of storage at 4 ± 1°C were measured by a texture analyzer (TMS-PRO, Food Technology Corporation FTC, Virginia, USA) using a 5 kg load cell as described by Moschopoulou et al. Yogurt gels in the
cups were penetrated with 1 cm\(^2\) cylinder probe (P/1KP) to 10% of their original height. A force-time curve was obtained at a crosshead speed of 1.0 mm/s. The pretest and posttest speeds were 120 mm/min. Measurements were carried out in six replicates.

**Yogurt culture viability**

Ten grams of each yogurt treatments were diluted with 90 ml of sterile physiological saline (PS). Serial dilutions were prepared in 9 ml PS. One ml of each dilution was poured on MRS agar plate. MRS agar plates were incubated under anaerobic conditions for 48 h at 37 °C. The numbers of colony-forming units (CFU) were counted and presented as CFU/g.

**Statistical analysis**

The results are presented by the mean values ± standard deviations (SD). Two-way analysis of variance (ANOVA) was performed by IBM-SPSS (ver. 20.0, IBM, USA), followed by assessment of differences by the least significance difference method (LSD) at \(P < .05\).

**Results and discussion**

**pH values and WHC characteristics of FFBS yogurts after 1d storage**

Polydextrose was approved as a fat replacer and prebiotic materials in many countries to improve the physiochemical and texture properties of low-fat dairy products. The effects of different polydextrose concentrations on water-holding capacity and pH values of FFBS yogurts after 1d storage at 4 ± 1 °C are presented in Table 1. The results showed that pH values were significantly \((P < .01)\) decreased by increasing the polydextrose concentration and ranged from 4.16 to 4.56 (Table 1). Addition of polydextrose most probably enhanced the growth of yogurt starter culture that consequently resulted in high acid production and decrease in pH values. This result demonstrates the prebiotic effect of polydextrose on the yogurt culture and is in agreement with that of Oliveira et al.\(^{[14]}\) and Srisuvor et al.\(^{[9]}\) who reported that addition of polydextrose decreased the pH value compared with the control fermented milk. In contrast, Guven et al.\(^{[15]}\) reported no significant effect on pH values of yogurt by the addition of inulin as a fat replacer.

Regarding the water-holding capacity, results in Table 1 clearly revealed that the WHC percentage was significantly \((P < .01)\) increased by adding polydextrose compared to that of the control FFBS yogurt. The enhancement of WHC characteristic was a polydextrose concentration dependent. This finding reflects the ability to use polydextrose as stabilizer and bodying agents due to its potential capability to bind water. Similar results were reported by Srisuvor et al.\(^{[9]}\) who stated that the addition of inulin or polydextrose has increased the WHC percentage of low-fat yogurt produced from reconstituted milk. Additionally, the syneresis values of probiotic yogurt with 3% polydextrose

| Polydextrose Concentration | WHC (%)  | pH        |
|---------------------------|----------|-----------|
| Control                   | 56.23 ± 0.30\(^d\) | 4.56 ± 0.03\(^a\) |
| 1.5%                      | 58.48 ± 0.02\(^c\)  | 4.50 ± 0.01\(^b\)  |
| 3%                        | 60.43 ± 0.14\(^b\)  | 4.44 ± 0.01\(^c\)  |
| 5%                        | 61.75 ± 0.35\(^a\)  | 4.16 ± 0.01\(^d\)  |

Values are mean of triplicate measurements ± standard deviation (SD).

Means with different superscripts in the same column are significantly different \((P < 0.01)\).
were significantly lower than the control yogurt. Addition of fructans, a polymer of fructose molecules, and inulin led to a significant decrease in syneresis values of reduced-fat yogurts. It is worth noting that polydextrose addition at a concentration of 5% showed no significant ($P > .05$) effect on the WHC percentage compared to polydextrose of 3% addition. Regarding the yogurt production cost, the dairy manufacturer should consider this finding.

**Sensory evaluation**

The sensory evaluation data for the FFBS yogurts after 1d of storage at $4 \pm 1 ^\circ C$ are given in Table 2. FFBS yogurt with 3% of polydextrose received the best sensory evaluation and had significantly ($P < 0.05$) the highest total acceptability score. It is worth to add that FFBS yogurts with 3% and 5% polydextrose showed creamy mouth-feel and a homogenous good texture as described by the panelist. These findings may be due to the ability of polydextrose to form a highly viscous gel-like matrix, which contributing to creaminess and mouthfeel. Similarly, Srisuvor et al. reported that the addition of inulin or polydextrose has potentially improved the appearance, color, texture, and overall preference, however no such effect was found for odor or flavor parameters. In this context, it should be noted that no significant ($P > .05$) effect was noticed between FFBS yogurts in appearance and flavor parameters, whereas FFBS yogurt produced with 3% polydextrose received the highest texture and total acceptability score by the panelist. Accordingly, we have considered this finding together with the WHC result to redesign our experiments to produce FFBS yogurt with only 3% polydextrose addition and exploring the quality properties, in comparison with FFBS and full-fat buffalo set yogurts as controls, throughout 21 days cold storage.

**Texture properties**

The evolution of textural parameters firmness, cohesiveness, and adhesiveness of FFBS yogurts after 1d of storage at $4 \pm 1 ^\circ C$ is shown in Figure 1. Milk-fat is known to play a crucial role on the texture properties of dairy products, particularly those produced from buffalo milk as milk fat represents the highest portion of the total solids. Addition of 5% polydextrose showed significantly ($P < .05$) the highest textural among the different yogurt treatments. Whereas control FFBS yogurt showed the least significant ($P < .05$) textural values, which was an expected result due to the deficiency linked to milk fat removal. As may be seen from data in Figure 1, no significant effect ($P > .05$) noticed between 1.5% and 3% polydextrose treatments, however these two treatments exhibited significant ($P < .01$) positive impact on textural properties compared to the control FFBS yogurt. Similar trend of firmness result was reported by Helal et al. in low-fat yogurt produced with inulin.

The texture results go in parallel with the WHC findings. It is worth noting that there were no significant differences ($P > .05$) in textural parameters between 3% and 5% FFBS yogurts. The instrumental texture findings are in parallel with the sensory attributes' results, which guide us to select the FFBS yogurt with 3% polydextrose for more evaluation during the storage as mentioned earlier. The yogurts were examined at 1, 7, 14, 21 days of cold storage for pH, total acceptability, and viability of the yogurt culture and the results were compared with FFBS and full-fat buffalo set control yogurts.

| Table 2. Impact of polydextrose addition on sensory properties of the experimental fat-free buffalo set yogurts (FFBS). |
|-----------------|-------------------|-----------------|-------------------|-----------------|
| Polydextrose %  | Appearance (30)   | Flavor (30)      | Texture (40)      | Total score (100) |
| Control         | $25 \pm 2^a$      | $23 \pm 4^a$    | $16 \pm 3^c$      | $64 \pm 3^c$    |
| 1.5             | $25 \pm 1^a$      | $25 \pm 1^a$    | $21 \pm 4^bc$     | $71 \pm 4^b$    |
| 3               | $27 \pm 1^a$      | $26 \pm 2^a$    | $25 \pm 5^ab$     | $78 \pm 4^a$    |
| 5               | $25 \pm 2^a$      | $26 \pm 3^a$    | $20 \pm 1^bc$     | $71 \pm 4^b$    |

Values are mean of 10 replicates ± standard deviation (SD). Means with different superscripts in the same column are significantly different ($P < 0.05$).
Effect of cold storage on pH, WHC and organoleptic properties

As it can be seen from the data presented in Table 3, the pH values were decreased significantly ($P < .05$) during the storage period for all yogurt treatments. FFBS yogurt with 3% polydextrose showed significantly ($P < .05$) the lowest pH values during the storage period compared to those of fat-free and full-fat buffalo set yogurts. This could be due to the prebiotic influence of polydextrose that enhances the bacterial growth of yogurt cultures. These results are in agreement with those of Helal et al.\[18\] who reported a significant decrease in pH values during the storage of low-fat yogurt with different concentration of inulin.

With respect to the WHC percentage, FFBS yogurt with 3% polydextrose had significantly ($P < .05$) higher WHC percentage compared to that of FFBS control yogurt, and lower than WHC value of full-fat control buffalo set yogurt (Table 3). Overall, there was a significant ($P < .05$) decrease in the WHC values during the cold storage period for all yogurts. This could be attributed to the higher acidity and may be
a bit of milk protein hydrolysis during the storage which led to weak gel network and increase the serum loss from the yogurt gel matrix. In the same manner, addition of pine honey or grapeseed oil to set yogurt improved the WHC during 28 days of cold storage.

Regarding the organoleptic total acceptability, no significant differences (P > .05) were noticed between FFBS yogurt with 3% polydextrose and full-fat yogurt treatments in the same period of storage (Table 3). However, the control FFBS yogurt showed significantly (P < .05) the lowest total acceptability values. It is worth noting that the total acceptability score was gradually decreased during the cold storage in all yogurt samples. The reduction in total acceptability score was significantly (P < .05) after 14 and 21 days of cold storage. This observation could be attributed to the lower pH values and WHC percentages at 14 and 21 days of storage.

### Yogurt bacterial count during cold storage

The effect of adding 3% polydextrose on yogurt culture viability during the storage period was studied and results were compared to FFBS and full-fat buffalo set control yogurts. Yogurt culture counts (CFU/g) of yogurt treatments during storage at 4°C are shown in Table 4. At 1 day storage, viability of yogurt culture in FFBS yogurt with 3% polydextrose was significantly (P < .01) higher than that of FFBS and full-fat control yogurts. This is mainly correlated to the prebiotic effect of the polydextrose. In agreement with this finding, Srisuvor et al. [9] who reported that the counts of *S. thermophilus* and *L. bulgaricus* with the use of inulin or polydextrose were significantly higher than low-fat yogurt control. Additionally, using the inulin as prebiotic had increased the yogurt culture counts compared with low-fat yogurt. [18] The yogurt culture viability was decreased significantly (P < .01) during cold storage in all yogurt treatments. It is worth noting that viability

### Table 3. Changes in pH, organoleptic total acceptability and WHC of the different full-fat and experimental fat-free yogurts during storage at 4 ± 1°C.

| Storage period (days) | FFBS yogurt with 3% Polydextrose | FFBS control yogurt | Full-fat control yogurt |
|-----------------------|----------------------------------|--------------------|------------------------|
| **pH**                |                                  |                    |                        |
| 1                     | 4.44 ± 0.01<sup>Aa</sup>         | 4.52 ± 0.03<sup>Ba</sup> | 4.69 ± 0.01<sup>Aa</sup> |
| 7                     | 4.24 ± 0.01<sup>Cb</sup>         | 4.46 ± 0.01<sup>Bb</sup> | 4.58 ± 0.02<sup>Cb</sup> |
| 14                    | 4.19 ± 0.02<sup>Cc</sup>         | 4.31 ± 0.01<sup>Bc</sup> | 4.54 ± 0.03<sup>Cb</sup> |
| 21                    | 4.18 ± 0.01<sup>Cc</sup>         | 4.21 ± 0.01<sup>Bd</sup> | 4.42 ± 0.01<sup>Cc</sup> |
| **Total acceptability (100)** |                                  |                    |                        |
| 1                     | 91.67 ± 2.52<sup>Ab</sup>        | 79.33 ± 5.62<sup>Ba</sup> | 91.67 ± 5.13<sup>Ab</sup> |
| 7                     | 91.25 ± 2.22<sup>Ab</sup>        | 80.50 ± 6.29<sup>Ba</sup> | 91.25 ± 1.71<sup>Ab</sup> |
| 14                    | 82.75 ± 4.19<sup>Bb</sup>        | 70.75 ± 7.89<sup>Bb</sup> | 83.25 ± 2.99<sup>Bb</sup> |
| 21                    | 79.00 ± 4.40<sup>Bb</sup>        | 69.00 ± 6.24<sup>Bb</sup> | 80.50 ± 6.14<sup>Bb</sup> |
| **WHC (%)**           |                                  |                    |                        |
| 1                     | 60.43 ± 0.14<sup>Ab</sup>        | 56.23 ± 0.30<sup>Ca</sup> | 64.32 ± 0.31<sup>Ca</sup> |
| 7                     | 56.59 ± 0.33<sup>Bb</sup>        | 53.30 ± 0.18<sup>Cb</sup> | 60.07 ± 0.70<sup>Bb</sup> |
| 14                    | 55.38 ± 0.20<sup>Bc</sup>        | 50.95 ± 0.08<sup>Cc</sup> | 57.48 ± 0.59<sup>Cc</sup> |
| 21                    | 53.17 ± 0.43<sup>Bc</sup>        | 48.56 ± 0.30<sup>Cd</sup> | 56.80 ± 0.20<sup>Cc</sup> |

Values of pH and WHC are mean of triplicate measurements ± SD. Total acceptability values are mean of 10 replicates ± SD. Means with different capital letters in the same row are significantly different (P < 0.05). Means with different small letters in the same column are significantly different (P < 0.05). FFBS; fat-free buffalo set yogurt.

### Table 4. Changes in yogurt culture counts (10<sup>8</sup> CFU/g) in full-fat and experimental fat-free yogurts during storage at 4 ± 1°C.

| Storage period (days) | FFBS yogurt With 3% polydextrose | FFBS control yogurt | Full-fat control yogurt |
|-----------------------|----------------------------------|--------------------|------------------------|
| 1                     | 111.00 ± 1.41<sup>Ab</sup>       | 28.00 ± 2.83<sup>Ba</sup> | 29.00 ± 1.41<sup>Ab</sup> |
| 7                     | 21.15 ± 0.35<sup>Ab</sup>        | 10.14 ± 0.15<sup>Bb</sup> | 20.50 ± 0.71<sup>Ab</sup> |
| 14                    | 5.89 ± 0.13<sup>Ac</sup>         | 0.40 ± 0.10<sup>Bc</sup> | 5.70 ± 0.14<sup>Ac</sup> |
| 21                    | 1.53 ± 0.11<sup>Ad</sup>         | 0.45 ± 0.11<sup>Bc</sup> | 1.55 ± 0.64<sup>Ad</sup> |

Values are mean of triplicate measurements ± SD. Means with different capital letters in the same row are significantly different (P < 0.05). Means with different small letters in the same column are significantly different (P < 0.05). FFBS; fat-free buffalo set yogurt.
numbers of yogurt culture in the presence of 3% polydextrose were remained significantly \( P < .01 \) higher than viability of yogurt culture in control FFBS yogurt. These results are in parallel with Sah\(^2\) who reported higher *S. thermophilus* and *L. bulgaricus* counts of yogurt with inulin after 28 days of cold storage compared to the control yogurt. In addition, set yogurt with pine honey or grapeseed oil had highest yogurt culture viability during storage at 4°C.\(^{19,20}\)

**Conclusion**

This study demonstrated that polydextrose may be utilized as an alternative source of fat replacer and prebiotic material to enhance the quality attributes of fat-free buffalo set yogurt (FFBS). Polydextrose addition to FFBS significantly increased the WHC and texture characteristics, as well as positively altered the organoleptic attributes. It is worth noting that the addition of 3% polydextrose received the best sensory attributes score as indicated by the assessors. In comparison to fat-free and full-fat buffalo set yogurts’ controls, 3% polydextrose showed potential improvements in WHC, pH values, and viability of yogurt culture, and received almost similar sensorial total acceptability of full-fat control yogurt throughout storage of 21d at 4 ± 1 °C. Overall, the addition of polydextrose 3% offers a promising option to overcome the inferior quality of fat-free variants and to develop FFBS yogurt with satisfactory organoleptic characteristics preferred by consumer.

**Conflict of interest**

The authors declare that there is no conflict of interest.

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