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Quality evaluation of non-fat goat milk yogurt supplemented with purple sweet potato flour

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Abstract

In the present work, the supplementation of purple sweet potato flour as a prebiotic at concentrations of 1, 2, and 3% enhanced the probiotic efficacy. These three concentrations of purple sweet potato flour reduced the fermentation time from 4.5 – 5.5 h as compared to the control (C) recipe (7.5 - 8.0 h). Panellists scored highest overall acceptability for non-fat goat milk yogurt with 1% purple sweet potato flour (S1 recipe). The S1 recipe was selected to evaluate the quality change during storage for 27 days at 4°C. The L* and b* values decreased, whereas the a* value increased. Non-fat goat milk yogurt had low hardness. The supplementation of purple sweet potato flour did not significantly affect yogurt hardness, and reduced the percentage of whey separation during the storage period. Purple sweet potato flour also promoted the survival of *Streptococcus thermophilus* but reduced viable cells of *Lactobacillus delbrueckii* subsp. *bulgaricus.* The S1 recipe was demonstrated as a healthy food with a shelf-life of 27 days, and could appeal to the health-conscious consumers.

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Introduction

Goat milk contains high proteins, free amino acids, short to medium chain fatty acids, calcium, phosphate, and vitamins A and B. It is easier to digest than cow milk, with lower allergenicity and lactose content, thus suitable for people with lactose intolerance (Chye *et al*., 2012). Goat milk has profitable effects for health maintenance, physiological functions, and therapeutic values in medicine and human nutrition (Damunupola *et al*., 2014).

Previously reported products derived from goat milk include low-fat goat milk ice cream (McGhee *et al*., 2015), goat milk supplemented with quinoa extract (El-Shafei *et al*., 2019), goat milk yogurt supplemented with *Pistacia atlantica* resin extract and *Saccharomyces boulardii* (Hadjimbei *et al.*, 2019), fermented goat whey (Santos *et al*., 2019) and Camembert cheese (Gebreyowhans *et al*., 2020). Yogurt has gained increasing interest in recent years, and manufacturers are continuously searching for value-added ingredients such as probiotics and prebiotics to attract health-conscious consumers (Allgeyer *et al*., 2010). Yogurt made from goat milk can relieve gastrointestinal intolerance. Goat milk fat globules are smaller than those in cow milk, with lower content of α_{s1}-casein. Products derived from goat milk have smooth textures, and are more delicate and less viscous as compared to cow milk (Yangilar, 2013). Goat milk also has lower buffer capacity, thus causing rapid increase of acidity during yogurt fermentation (Mituniewicz-Malek *et al*., 2017).

Probiotics are living organisms, when administrated in sufficient amounts, confer health benefits on the host (FAO and WHO, 2002) such as improving the integrity of mucosa and intestinal tight junctions, reducing pathogenic microorganism colonisation in the intestinal tract, and enhancing immune functions (Irvine and Hekmat, 2011). *Streptococcus thermophilus* and *Lactobacillus* spp. are important starter cultures for traditional yogurt fermentation (Mituniewicz-Malek *et al*., 2017); they beneficially affect the host by selectively stimulating or inhibiting bacterial growth in the colon, thus resulting in improved health (Allgeyer *et al*., 2010). They increase the nutrient value of milk, and improve the adsorption of calcium, phosphorus, and

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magnesium (Vrese and Schrezenmeir, 2008). The efficacy of probiotics can be improved by supplementation with prebiotics. Purple sweet potato flour is an interesting prebiotic with potential health-promoting properties because it contains high amounts of fermentable carbohydrates (oligosaccharides and fibres) and anthocyanin (Gibson *et al*., 2017; Shen *et al*., 2018). Furthermore, purple sweet potato flour is resistant to gastric acidity and hydrolysis by enzymes; it is non-absorbable in the human small intestine, thus can reach the colon to be fermented by beneficial microorganisms. It also promotes the growth and metabolism of probiotics in the gut microbiota (Albuquerque *et al*., 2020).

The present work thus investigated the effect of purple sweet potato flour concentration on non-fat goat milk yogurt fermentation time and sensory properties. Quality changes in non-fat goat milk yogurt were also determined in terms of pH, titratable acidity, colour, texture, whey separation, and microbiological analysis during storage at refrigerated temperature (4°C).

Materials and methods

Goat milk preparation

Fresh raw goat milk was obtained from a local farm in Phra Nakhon Si Ayutthaya province. The fat was separated using a cream separator until the desired fat content (0%) was obtained. The non-fat goat milk was collected and kept at -20°C until subsequent analyses.

Proximate analysis

Fresh raw and non-fat goat milk were analysed for fat, protein, lactose, milk solid, and not-fat milk solid using Milkoscan FT2.

Yogurt preparation

One thousand grams of non-fat goat milk was heated to 60°C, then 50 g of sugar and 0.01 g of xanthan gum were added together with purple sweet potato flour at concentrations of 1, 2, and 3% (w/v). The non-fat goat milk supplemented with purple sweet potato flour was pasteurised at 95°C for 5 min, and then cooled to 43°C. A commercial yogurt starter culture (Lyofast Y350A) comprising *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* was inoculated into the mixture at approximately 3 UC. The samples were incubated at 43°C until a pH value of 4.5 was attained, and stored in a refrigerator at 4°C until subsequent analyses.

Fermentation time

The pH of the yogurt was determined using a Docu pH meter (Sartorius, USA), and titratable acidity was determined by titration with 0.1 N NaOH. The pH values of non-fat goat milk supplemented with purple sweet potato flour at 1, 2, and 3% were determined after incubation at 43°C for 0, 1, 2, 3, 4, 4.5, 5, 5.5, 6, 7, 7.5, and 8 h, until a pH value of 4.5 was reached. All measurements were performed in triplicate.

Sensory evaluation

Sensory evaluation was conducted following the method of Kuikman and O’Connor (2015) with 40 untrained panellists from Rajamangala University of Technology, Suvarnabhumi. Sensory parameters evaluated were colour, odour, taste, texture, and overall acceptability using a nine-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Yogurt samples were served in cups with a randomised order, and coded with three random digits. Non-fat goat milk yogurt without the supplementation of purple sweet potato flour served as the control.

pH and titratable acidity

Recipes obtaining the highest levels of acceptance from the panellists were selected for further investigation. The pH and titratable acidity measurements were conducted after fermentation at 0, 3, 7, 10, 12, 15, 18, 21, 24, and 27 days under storage at 4°C as earlier described.

Colour analysis

The colour of the yogurt was measured using a colour meter (UltraScan, VIS-Hunter Associates Laboratory, USA).

Texture analysis

Texture analysis was carried out using a Universal Texture Analyser TA-XT2 (Stable Micro Systems, UK). The penetrometric test was performed using an aluminium cylinder type P/0.5. The depth of penetration was 25 mm with a penetration rate of 1 mm/s. The fracture TPA algorithm was applied to investigate the hardness and cohesiveness of non-fat goat milk yogurt.

Whey separation

Approximately, 30 g of non-fat goat milk yogurt was weighed and stirred with a stirring rod, clockwise and counterclockwise, for 20 times. The mixture was rested at 4°C for 2 h, and then centrifuged for 15 min at 3,000 rpm at room temperature. The supernatant or expelled whey was poured into a beaker, and weighed. Whey separation was calculated using Eq. 1:

$$Whey\ separation\ (\%) = \frac{W_F}{W_I} \times 100 \qquad \text{(Eq. 1)}$$

Where, W_F = supernatant weight, and W_I = initial sampling weight.

Microbiological analysis

The viabilities of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* were quantified using M-17 agar supplemented with lactose, and MRS agar at pH 5.2, and incubation at 37°C for 24 - 48 h under anaerobic condition.

Statistical analysis

All experiments were performed in triplicate. Differences were considered significant at $p < 0.05$. Results were analysed for statistical significance with ANOVA and Duncan's test, and expressed as mean ± standard deviation (SD).

Results and discussion

Proximate composition

Fresh raw goat milk had protein and fat contents of 3.36 and 3.72%, respectively, higher than values reported by Mituniewicz-Malek *et al*. (2017) at 2.69 and 3.38%, respectively. They noted that the compositions differed owing to breeding, lactation period, feeding method, and genetic and environmental conditions. Fat content of non-fat goat milk after separation was 0%. Non-fat goat milk also had significantly lower proximate contents than fresh raw goat milk. It contained higher total solid (7.47 ± 0.44%) and not-fat total solid (7.62 ± 0.06%) as compared to lactose (4.00 ± 0.19) and protein (2.47 ± 0.06).

Fermentation time

Yogurt production fermentation time was evaluated until the pH reached 4.5. The initial pH of non-fat goat milk was 6.43 (Figure 1), lower than reported by Bruzantin *et al*. (2016) and Mituniewicz-Malek *et al.* (2017), at 6.66 and 6.89, respectively.

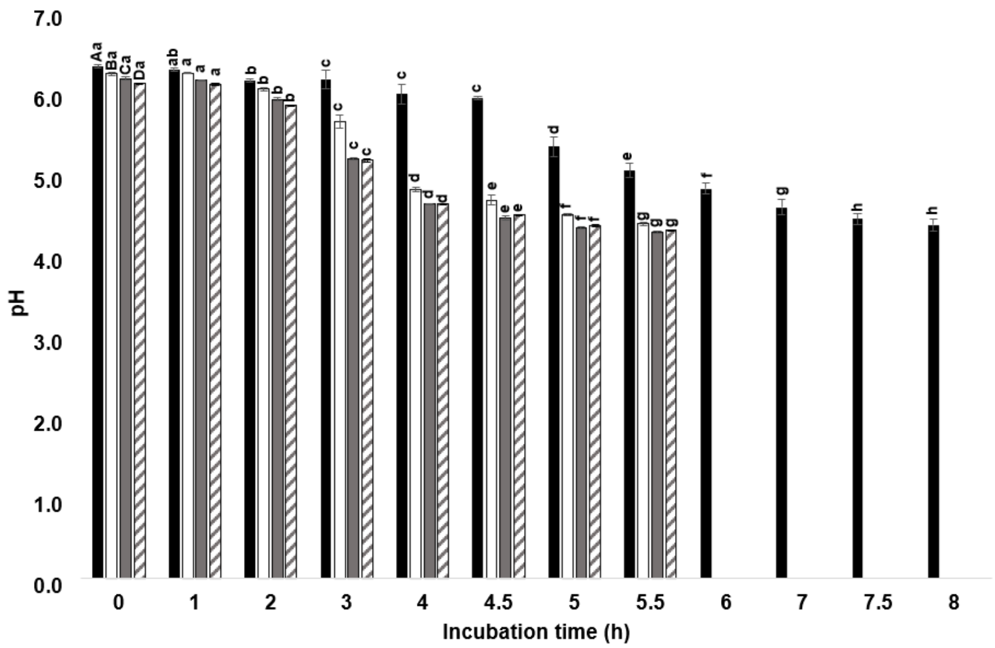

Figure 1. Incubation time of non-fat goat milk yogurt production. Yogurt without purple sweet potato flour (C) (■); non-fat goat milk yogurt with 1% (S1) (□); 2% (S2) (■); and 3% (S3) (▨) purple sweet potato flours. Lowercase letters indicate significant differences in pH values of each recipe during fermentation period ($p < 0.05$). Uppercase letters indicate significant differences in pH values among four recipes in the same storage time ($p < 0.05$).

Purple sweet potato flour decreased the pH as the concentration increased, which was consistent with the finding of Mustika *et al*. (2018) who found that purple sweet potato purée decreased the pH of yogurt. Fermentation time of non-fat goat milk yogurt without purple sweet potato flour (C recipe) was 7.5 - 8.0 h, and this decreased as the concentration of purple sweet potato flour increased. Yogurt supplemented with 1% purple sweet potato flour (S1 recipe) had incubation time at 5.0 - 5.5 h, whereas the S2 and S3 recipes had incubation times of 4.5 - 5.5 h. These results indicated that purple sweet potato flour containing fibre acted as a prebiotic by promoting the growth and fermentation of starter cultures, and decreasing the fermentation time of non-fat goat milk yogurt. Dewi *et al*. (2015) also found that cilembu sweet potato starch at concentrations of 1 - 3% supported the growth of LAB during yogurt fermentation, and decreased fermentation time due to the prebiotic property of oligosaccharide in sweet potato.

Sensory acceptance

No significant differences were recorded by the panellists for colour, odour, texture, and overall acceptability among the four recipes. Colour scores ranged from 7.13 - 7.47 as 'like moderately' to 'like very much', whereas odour scores ranged from 6.30 - 6.80 as 'like slightly' to 'like moderately' because the yogurt produced from non-fat goat milk had a specific odour. This result concurred with Gomes *et al*. (2013) who found that the flavour of goat milk was intense, and this limited the consumers' acceptance. During fermentation, the odours of sour and sweet potato impacted the sensory acceptance of the yogurt. Taste scores decreased when purple sweet potato flour concentration increased. The S1 recipe gave higher scores of odour, taste, texture, and overall acceptability than the other recipes, with overall acceptability score of 7.04 ± 1.19. This concurred with Irvine and Hekmat (2011) who reported that yogurt supplemented with mashed sweet potato gained optimal overall acceptability scores as compared to plain probiotic yogurt and yogurt supplemented with other prebiotic fibres derived from banana, honey, and spinach. Therefore, the S1 recipe containing 1% purple sweet potato flour was considered an innovative goat dairy product, with prebiotic components that delighted the taste of modern consumers (Sepe and Argüello, 2019). The S1 recipe was selected to further investigate the pH, titratable acidity, colour, texture, whey separation, and microbiological analysis during storage at 4°C.

pH and titratable acidity

The pH values of the C and S1 recipes ranged from 3.56 - 4.48 and 3.55 - 4.50, respectively. The pH values of both recipes decreased slightly throughout the storage period (Figure 2).

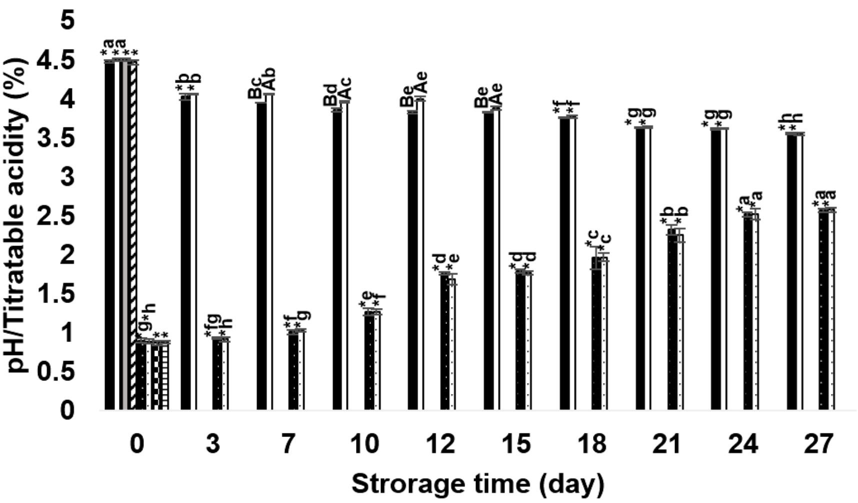

Figure 2. pH values of C (■), S1 (□), S2 (▢), and S3 (▨) recipes; and titratable acidity values of C (■), S1 (⬚), S2 (▦), and S3 (⊟) recipes during storage at 4°C. Lowercase letters indicate significant differences in pH or titratable acidity values of each recipe during storage period ($p < 0.05$). Uppercase letters indicate significant differences in pH or titratable acidity values of different recipes in the same storage time ($p < 0.05$). Asterisks (*) indicate no significant difference in pH or titratable acidity values of different recipes in the same storage time ($p > 0.05$).

This result concurred with Lucas *et al*. (2004) and Bruzantin *et al*. (2016) who reported that post-fermentation acidification occurred from the continued metabolic activity of lactobacilli during cooling and at 4°C, although at a slower rate. The pH of the C recipe was lower than the S1 recipe between day 7 and 15, while no significant differences in pH values between the C and S1 recipes were recorded up to the end of storage. Both recipes had lower pH values on day 27 than found by Paz *et al*. (2014) and Dimitrellou *et al*. (2019). They reported that goat milk yogurt had pH values of 4.4 and 3.83 ± 0.03 on day 28 of storage, respectively. Titratable acidity values of both recipes increased when storage time increased, in accordance with decreasing pH value. No significant differences were recorded in titratable values between the C and S1 recipes during the storage period. Titratable acidity values of the C and S1 recipes at the end of storage were 2.57 ± 0.02 and 2.58 ± 0.03%, respectively, which were higher than that reported by Damunupola *et al*. (2014); control yogurt and beetroot-supplemented yogurt had titratable acidity values of 0.80 and 0.84% on day 21, respectively. Our results suggested that the supplementation of purple sweet potato flour did not change the pH and titratable acidity values of non-fat goat milk yogurt during storage at 4°C for 27 days.

Colour

The L* and b* values of non-fat goat milk yogurt decreased, whereas the a* value increased when the concentration of purple sweet potato flour increased (Figure 3); as a result of the purple colour of the anthocyanin pigment compound in purple sweet potato flour. During storage at 4°C, the L* value of the C recipe was higher than the S1 recipe, while L* values of both recipes decreased slightly during storage. The a* value of S1 also slightly decreased but remained constant in the C recipe. These results occurred because anthocyanin is sensitive to light and oxygen (Delgado-Vargas and Paredes, 2003). The b* values of both recipes increased during storage.

Texture

No significant differences in hardness were found among the four recipes, with values ranging from 0.038 to 0.043 N (Figure 4A). This indicated that the supplementation of purple sweet potato flour did not affect the hardness. Our hardness values were lower than reported by Domagala (2009) and Mituniewcz-Malek *et al*. (2017) who recorded hardness values of yogurt from goat milk as 0.19 and 0.20 - 0.54 N, respectively. The hardness of goat milk yogurt had poor consistency. This result concurred with Joon *et al*. (2017) who noted that yogurt prepared from goat milk showed weak gel with low hardness and adhesiveness as a result of low α_{s1} casein and calcium contents (Salvador and Fiszman, 2004), and small diameters of fat globules and casein micelles (Domagala, 2009). The hardness of the C and S1 recipes increased after 10 and 12 days of storage, respectively, and then remained constant. This result conflicted with Domagala (2009) who reported that no significant difference in hardness of goat milk yogurt after 14 days of cold storage. The supplementation of sweet purple potato flour increased the cohesiveness of goat milk yogurt. Cohesiveness values of the C1 and S1 recipes increased after storage for 12 to 15 days, and then slightly decreased (Figure 4B).

Whey separation

The percentage of whey separation in the C1 recipe (51.79 ± 0.65%) was higher than the S1, S2, and S3 recipes (44.05 - 46.40%), with no significant differences in the percentages of whey separation at 1 - 3% supplementation of purple sweet potato flour to goat milk yogurt. This result suggested that purple sweet potato flour played a major role in decreasing the percentage of whey separation. Percentages of yogurt supplemented with all three concentrations of purple sweet potato flour were lower than that recorded by Domagala (2009) who reported that goat milk yogurt had syneresis of 47%. During refrigerated storage, the S1 recipe gave lower percentage of whey separation (46.11 - 52.79%) than the C recipe (51.79 - 58.79%). This result was consistent with Saleh *et al*. (2020) who reported that 1% sweet potato starch decreased syneresis and improved yogurt firmness.

Microbial loads

Initial viable cells of *S. thermophilus* in the C and S1 recipes ranged from 10.98 ± 0.03 and 11.17 ± 0.00 log CFU/mL, respectively, whereas viable cells of *L. delbrueckii* subsp. *bulgaricus* ranged from 5.70 ± 0.03 and 5.62 ± 0.05 log CFU/mL, respectively. The C recipe gave the highest viable cells of *S. thermophilus* on day 15, and this value then slightly

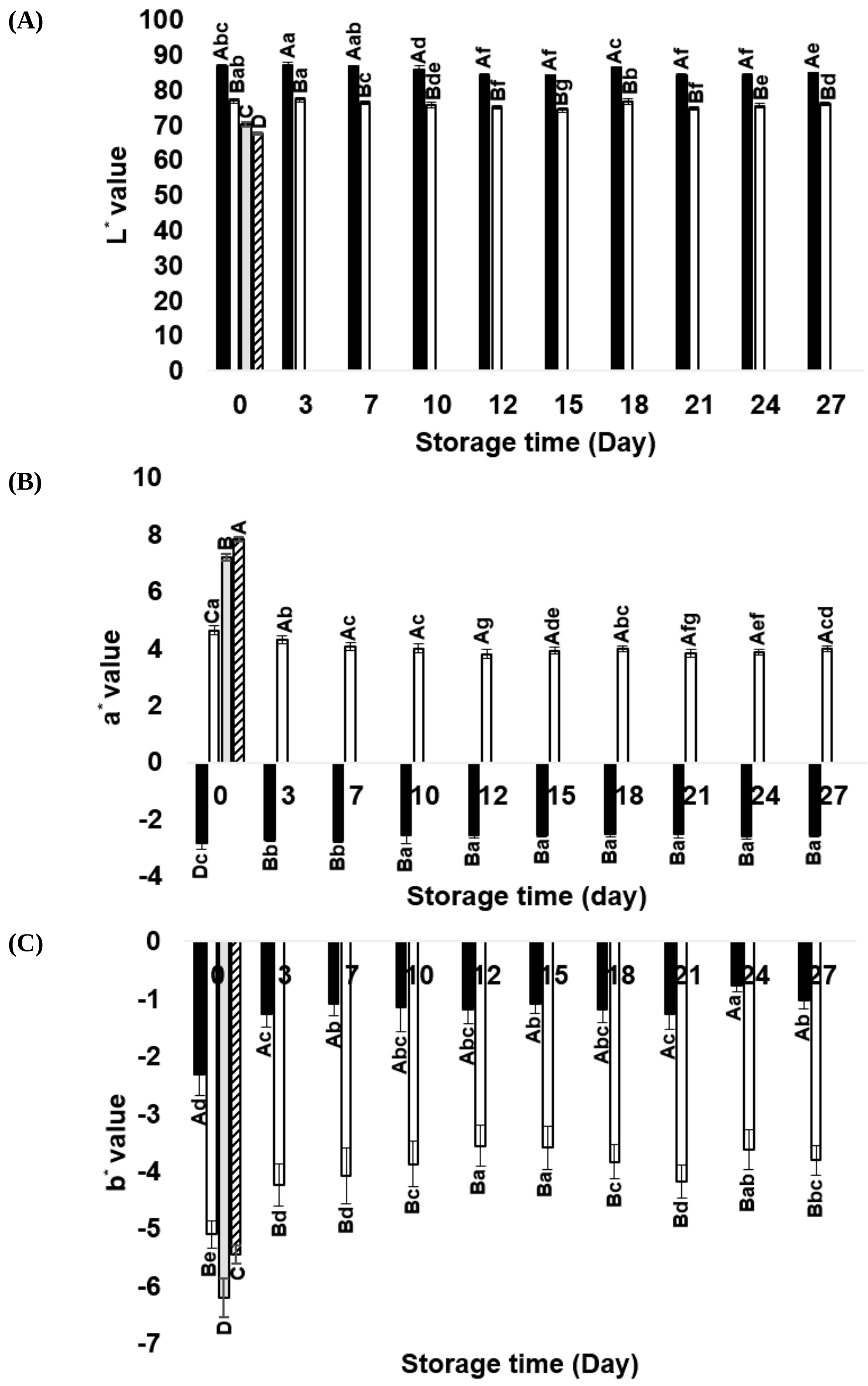

Figure 3. Colour analysis of C (■), S1 (□), S2 (▢), and S3 (▨) recipes during storage at 4°C. Lowercase letters indicate significant differences in colour values of each recipe during storage period ($p < 0.05$). Uppercase letters indicate significant differences in colour values of different recipes in the same storage time ($p < 0.05$).

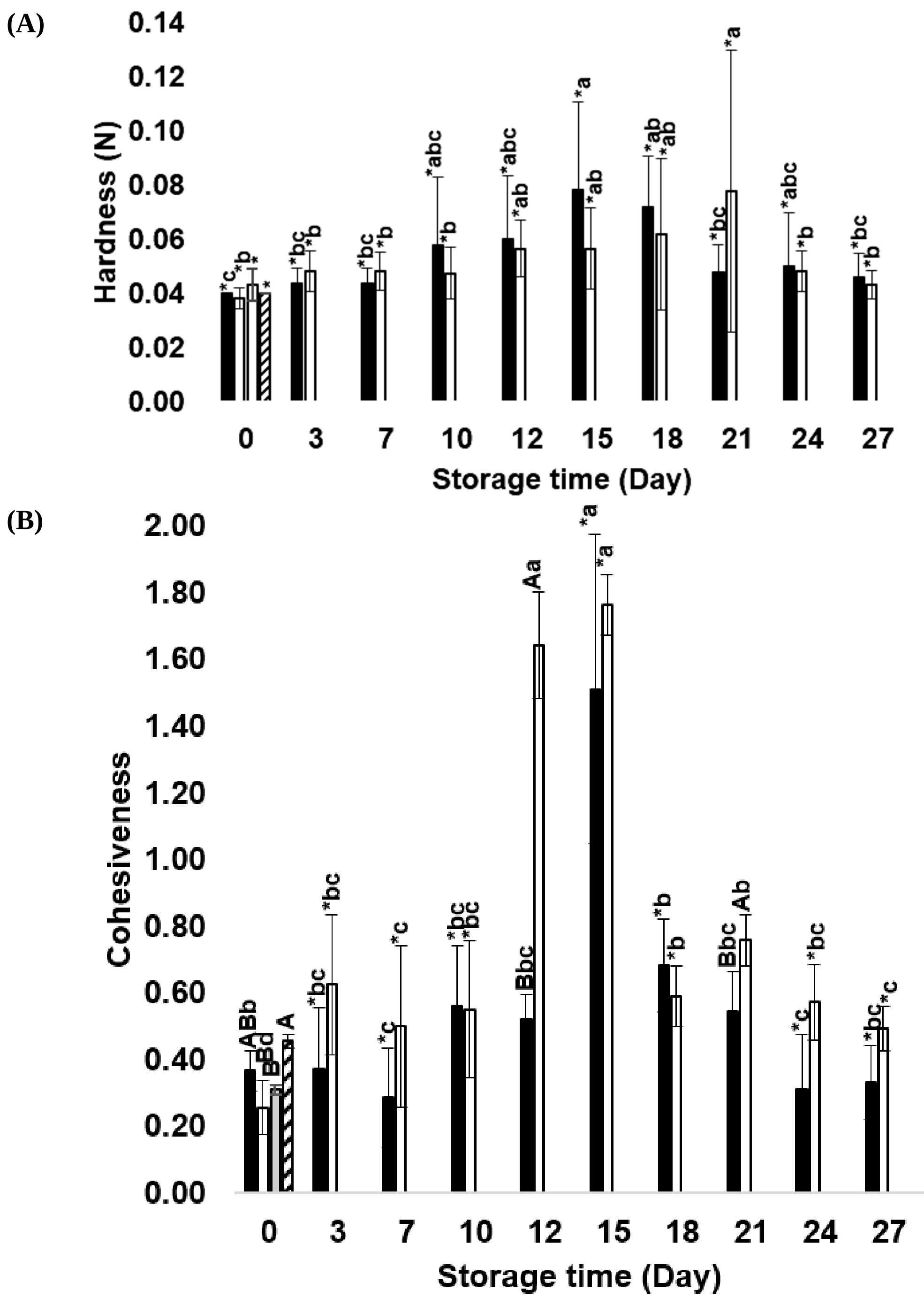

Figure 4. Texture analysis of C (■), S1 (□), S2 (□), and S3 (▨) recipes during storage at 4°C. Lowercase letters indicate significant differences in hardness or cohesiveness values of each recipe during storage period ($p < 0.05$). Uppercase letters indicate significant differences in hardness or cohesiveness values of different recipes in the same storage time ($p < 0.05$). Asterisks (*) indicate no significant difference in hardness or cohesiveness values of different recipes in the same storage time ($p > 0.05$).

decreased (Figure 5); whereas the S1 recipe showed the highest viable cells on day 12, and then remained constant until the end of storage. This result concurred with Retnati *et al.* (2009) who reported that the supplementation of sweet potato extract increased the total cell count in yogurt. However, there were no significant differences in viable cells of *S. thermophilus* in both recipes, at the end of the storage period of 12.43 - 12.52 log CFU/mL. Cells of *S. thermophilus* were higher than reported by Farnsworth *et al*. (2006) and Mituniewicz-Malek *et al*. (2017). They found that goat milk yogurt contained *S. thermophilus* at 8.61 and 8.7 - 7.5 log CFU/mL, respectively. The C recipe showed higher viable cells of *L. delbrueckii* subsp. *bulgaricus* than the S1 recipe throughout the storage period. The highest viable cells of *L. delbrueckii* subsp. *bulgaricus* in the C and S1 recipes were observed on day 12 and 10, respectively, and then slightly decreased. These results indicated that purple sweet potato flour supported and maintained the survival of *S. thermophilus* but had a negative effect on survival of *L. delbrueckii* subsp. *bulgaricus*. Decreasing viable cells of the starter cultures occurred with decreasing pH of the yogurt, and impacted growth during refrigerated storage (Shori and Baba, 2012). Cells counts of *S. thermophilus* were higher than *L. delbrueckii* subsp. *bulgaricus* in goat milk yogurt throughout the storage period. This result agreed with Tamime *et al.* (1999) and Dimitrellou *et al.* (2019) who reported that lactobacilli had lower survival than streptococci after storage in refrigerated condition. *S. thermophilus* can survive at low temperature (Dimitrellou *et al*., 2019). Cell count ratios of *L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* for the C and S1 recipes were 1:1.58 and 1:1.56, respectively. Both recipes produced high-quality yogurt with ratios of viable cells for *L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* ranging from 1:1 - 1:2.7 (Persic, 1991). Viable cells of *S. thermophilus* in both goat milk yogurts remained above the acceptable level (6 - 7 log CFU/mL), and considered as probiotic foods throughout the 27 days storage period, thus indicating that yogurt from goat milk could be an outstanding carrier for probiotic cultures. Increasing interest in goat milk containing relatively high concentrations of probiotics is now being shown by the dairy industry (Tarola *et al*., 2019).

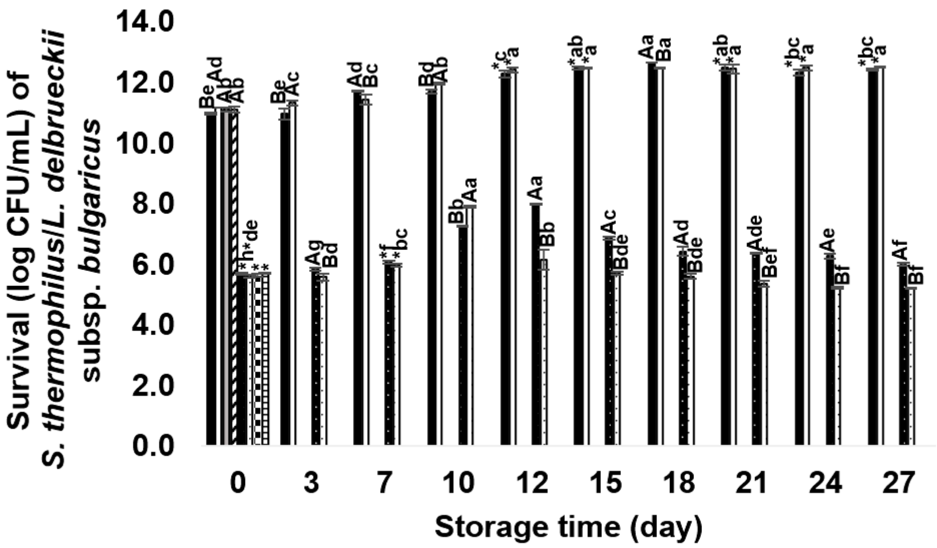

Figure 5. Survival (log CFU/g) of *S. thermophilus* in C (■), S1 (□), S2 (□), and S3 (▨) recipes; and survival (log CFU/g) of *L. delbrueckii* subsp. *bulgaricus* in C (■), S1 (□), S2 (▩), and S3 (⊟) recipes during storage at 4°C. Lowercase letters indicate significant differences in cell counts of *S. thermophilus* or *L. delbrueckii* subsp. *bulgaricus* of each recipes during storage period ($p < 0.05$). Uppercase letters indicate significant differences in cell counts of *S. thermophilus* or *L. delbrueckii* subsp. *bulgaricus* of different recipes in the same storage time ($p < 0.05$). Asterisks (*) indicate no significant difference in cell counts of *S. thermophilus* or *L. delbrueckii* subsp. *bulgaricus* of different recipes in the same storage time ($p > 0.05$).

Conclusion

The S1 recipe had fermentation time of 5.0 - 5.5 h, and was rated by the panellists with the highest scores in all parameters of sensory evaluation, except for colour. However, the texture of the S1 recipe was gel-like with low hardness. *S. thermophilus* showed dominance over *L. delbrueckii* subsp. *bulgaricus* throughout the 4°C storage period. The S1 recipe had a shelf-life of 27 days, with viable cell counts of probiotic starters above the acceptable level. Therefore, this recipe showed promise as an alternative functional food suitable for health-conscious consumers, and offered an interesting marketing opportunity for the dairy industry.

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