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ORIGINAL ARTICLE

Investigation of the use of whey powder and buttermilk powder instead of skim milk powder in yogurt production

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Abstract The aim of this study was to determine some physical, chemical, microbiological and organoleptic properties of set-type yogurts made with six different skim milk powder (SMP), whey powder (WP) and buttermilk powder (BMP) during a 21-day period. Samples were taken from yogurts on day 1, 7, 14 and 21. Analyses were carried out on the total solids, fat, non-fat solids, protein, ash, viscosity, syneresis, pH, titratable acidity values. The counts of *Streptococcus salivarius* subsp. *thermophilus, Lactobacillus delbrueckii* subsp. *bulgaricus* and yeasts-molds were enumerated. Also, sensory evaluations were performed at the same times. The substitution effect of WP and BMP for SMP on ash, viscosity, syneresis and titratable acidity values of yogurts were found to be significant ($p < 0.05$), while total solids, non-fat solids, protein contents, pH value and *S. thermophilus, L. bulgaricus* and yeasts-molds counts were not statistically significant. The effect of storage period on protein, ash, viscosity, and titratable acidity values, and *L. bulgaricus* and yeasts-mold counts was found to be significant ($p < 0.05$) statistically. However, it was observed that the changes of total solids, fat, non-fat solids, syneresis, pH values, and *S. thermophilus* counts were insignificant during the storage period. The sensory evaluations showed that sample D was most preferred by panelists.

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Keywords Yogurt · Skim milk powder · Whey powder · Buttermilk powder

Introduction

It is reported that the consumption of milk and dairy products in the world has increased continuously. On the other hand, milk production is estimated increases by 1.5% each year to meet consumer needs. With the increase in consumption of dairy products such as cheese or butter, the production of dairy by-products such as whey or buttermilk is also increasing (Ahmed and Razig 2017). Yogurt, a traditional fermented milk product in Turkey, Balkans, and the Middle East, is now consumed worldwide and considered as beneficial for health (Anbukkarasi et al. 2014; Tamime and Deeth 1980). One of the main problems in yogurt production is to obtain a product with desirable consistency and stability. For the production of a high-quality yogurt, it is necessary to have a suitable consistency with minimal serum separation (Parnell-Clunies et al. 1986). For this purpose, the level of total solids in milk used for yogurt production should be standardized and accordingly, the consistency and flavor of the product should be improved. In particular, it is known that increasing the total dry matter content of milk, improving the yogurt consistency and contributing to the production of a more viscous product (Tamime and Deeth 1980).

It is recommended that the level of the non-fat dry matter in milk used for yogurt production to be between 12.0 and 12.5%. Lactose has no effect on gelling capacity and physical properties of the final product. Approximately 30–35% of lactose is used by yogurt bacteria during fermentation. Therefore, the main purpose of increasing the milk dry matter content in yogurt production is to increase the protein concentration. In yogurt production, the non-fat dry matter in the milk can be increased by various methods (Ozer 2006; Tamime and Deeth 1980). One of the methods is also the addition of whey powder or buttermilk powder (BMP). In yogurt production, whey protein concentrate or whey powder (WP) is added to yogurt mix with skim milk powder (SMP) at a certain level. Generally, the addition of whey protein powder into the yogurt mix changes between 0.6 and 4%, but the recommended level is around 1–2% as a replacer for SMP. The higher levels of whey supplementation can lead to flavor deviations and a softer consistency in yogurt. Partially-delactosed WP may also be used, to a maximum of 2%, for yogurt production without the addition of SMP (Gonzalez-Martinez et al. 2002; Sienkiewicz and Riedel 1990; Tamime and Deeth 1980).

Addition to these, whey proteins are also very sensitive to heating. Various processes have been developed to use whey protein aggregates in food formulations. Some of their industrial applications are, however, limited due to the water-holding capacity of denatured whey proteins. Therefore, the combination of buttermilk and whey could be the key to better exploit their constituents in food formulation by reducing their individual negative effects (Saffon et al. 2013).

It is suggested that buttermilk (a by-product of butter) released during the churning of cream in butter production it may be used instead of milk powder in yogurt production. It is also reported that the buttermilk is very rich in milk fat globule membrane (MFGM) (Romeih et al. 2014). To provide the desired sensory and physical properties in yogurt production, the recommended maximum amount of buttermilk powder is 2%. However, it is stated that the butter concentrate or its powder obtained by ultrafiltration can be used between 2.5 and 4.5% (Ozer 2006).

The goal of this study was to develop a new approach to the use of whey and buttermilk, which is generally considered as waste and is the dairy by-products. These by-products are rich in valuable components with nutritious and functional properties such as MFGM, phospholipid, whey protein. This reason, by using buttermilk powder along with whey powder, substituted at certain ratios with skim milk powder. In accordance with this purpose, the changes of some physicochemical, microbiological and organoleptic properties of partially replacing SMP with WP and BMP in yogurt manufacture were investigated during the storage period.

Materials and methods

Raw cow's milk used in the manufacture of yogurt was obtained from the dairy farm of Atatürk University. Skim milk powder (SMP) was purchased from Pınar Industry Inc. (İzmir, Turkey). Whey powder (WP) and buttermilk powder (BMP) were bought from Enka Milk Inc. (Konya, Turkey). Commercial freeze-dried starter culture containing *Streptococcus salivarius* ssp. *thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* was obtained from Mayasan Food Inc. (Istanbul, Turkey).

Yogurt production

The milk (total solid 13.10 ± 0.303%, milk fat 4.05 ± 0.07%, protein 4.08 ± 0.223%, pH 6.62 ± 0.113 and titratable acidity 0.18 ± 0.011%) was clarified (model ALFA LAVAL 313T, centrifugal clarifier/separator), homogenized at 14.7 MPa. Then, the milk was divided 6 equal portions (each 5L), coded with letters from A to F. Skim milk powder (SMP) with whey powder (WP) and buttermilk powder (BMP) was replaced as seen in Table 1.

The mixture (see Table 1) was heated to 85 °C and held at this temperature for 20 min followed by cooling to 44 °C ± 1 using a cold water bath.

Direct vat set (DVS) yogurt cultures containing *Streptococcus salivarius* subsp. *thermophilus, Lactobacillus delbrueckii* subsp. *bulgaricus,* were inoculated at the rate of 20 g/100L milk and incubated 43 °C ± 1 until the pH reached to 4.7 ± 0.1. Yogurt samples were stored at 4 ± 1 °C for 21 days and analyzed on days 1, 7, 14 and 21st of cold storage. The yogurts were manufactured in duplicate using two different batches of milk.

Analytical methods

Total solids and ash contents were analyzed by the gravimetric method, protein by Kjeldahl method, fat content by Gerber method as described by Kurt et al. (2015). The non-fat solids content of yogurt samples were calculated from dry matter and fat analyzes. The apparent viscosities of yogurt samples were measured by using a viscometer (a model Brookfield Viscometer DV-II) equipped with spindle #5, at 50 rpm (sample temperature 3 ± 1 °C). The

Table 1 Codes of experimental yogurts and ratios of SPM, WP and BMP in yogurt milks

Code	SMP (%)	WP (%)	BMP (%)
A	3.0	0	0
B	1.0	2.0	0
C	1.0	1.5	0.5
D	1.0	1.0	1.0
E	1.0	0.5	1.5
F	1.0	0	2.0

viscosity values were directly read from the instrument as centipoise (cP) (Abrahamsen and Holmen 1980).

Syneresis of yogurt samples was assessed with a drainage method, described by Atamer and Sezgin (1986), 25 g of the experimental yogurts was taken and filtered at 4 ± 1 °C for 2 h. The filtrate obtained from the sample obtained was measured volumetrically and synerezis rate was expressed as mL of drained whey per 25 g of yogurt. The titratable acidity was determined as the lactic acid percentage by titrating with 0.1 N NaOH, using the phenolphthalein indicator (Kurt et al. 2015). Measurement of pH was carried out using a digital pH-meter (model Mettler Toledo Seven Compact) fitted with a combined glass electrode.

MRS agar (Merck) was used for enumeration of the total viable counts of *Lactobacillus delbrueckii* subsp. *bulgaricus*. The plates were incubated at 37 °C for 72 h under anaerobic conditions. This condition was obtained using Anaerocult A system (Merck, Darmstadt, Germany) (Chouchouli et al. 2013). The counts of *Streptococcus salivarius* subsp. *thermophilus* were enumerated on M-17 agar (Merck). The inoculated plates were incubated at 37 °C for 48 h under aerobic conditions (Torriani et al. 1996).

Potato dextrose agar (PDA) acidified with 10% tartaric acid (Merck) was used for enumeration of the total counts of yeasts and molds. The plates were incubated at 25 °C for 5 days (Koburger and Marth 1984).

In the evaluation of the results of sensory analysis, the score sheet given in TS 1330 was used by modifying. For this purpose, the sensory qualities of yogurt samples such as appearance, consistency (by spoon), consistency (by mouth), smell and taste were evaluated using a hedonic scale of 1–5 (1, very poor; 5, very good) by six panelist groups familiar with yogurt on 1, 7, 14 and 21st days of the storage. The overall acceptability was calculated as the sum of the scores of the parameters evaluated (Anonymous 2006; Bodyfelt et al. 1988).

Statistical analysis

Statistical analysis was carried out according to Randomized Complete Block Design by 6 (whey powder + buttermilk powder + skimmilk powder level) × 4 (storage period) factorial experiment. The obtained data were subjected to variance analysis using the SPSS 13 Package program (SPSS Inc., Chicago, IL). Duncan's Multiple Range Test was used to determine statistically different groups and the level of significance was set at $p < 0.05$.

Results and discussion

Physicochemical properties of the experimental yogurts

General means of total solids, non-fat solids, protein, fat, ash, syneresis, viscosity, titratable acidity, pH values and statistical evaluations of yogurts in terms of yogurt type and storage times, are shown in Table 2. The lowest mean value of total solids was determined in sample A and the highest mean value in sample C. As seen in Table 2, the fortification of WP and BMP caused an increase of dry matter contents in all samples of fortified yogurts, but these differences between all samples were not significant ($p > 0.05$) statistically. A similar trend was observed for fat and non-fat contents of the experimental yogurts and during storage periods (see Table 2). The obtained values were similar to those reported by Guler et al. (1996) for yogurts made with buttermilk powder. On the other hand, Arslaner (2002), Güven and Karaca (2003) and Macit (2011) reported the lower values in their investigations. It is thought that the difference between the dry matter contents of the experimental yogurt samples was due to the changes in SMP, WP and BMP combinations.

As shown in Table 2, protein contents of the examined yogurt samples changed irregularly, and the varying fortifications of WP and BMP had no significant effect on the experimental yogurts. On the other hand, the highest mean value of protein in the yogurt samples was determined on day 7 of storage and the lowest mean value was found on day 14 of storage, and it was observed that these differences were statistically ($p < 0.05$) significant (Table 2). The protein values obtained were similar to those reported by Guler et al. (1996). In contrast, the determined values in this study were higher than those reported by Arslaner (2002), Kavaz (2006) and Macit (2011).

The highest ash mean value was determined in sample D and F, and the lowest mean value in sample A. There were significant ($p < 0.05$) differences in ash contents between the samples added WP and BMP and sample A. This might be due to the effect of fortification ratios and interactions of SMP, WP and BMP in yogurts investigated. The highest mean value of ash was determined on day 21 of storage and the lowest value was determined on day 1 of storage, and these differences were statistically significant ($p < 0.05$) (Table 2). Similar changes were observed by Eissa et al. (2011) in yogurts produced from camel and cow milk.

Yogurts prepared with WP and BMP had lower viscosity values than that of prepared with only SMP (sample A) and differences between the sample A and the other yogurts were found statistically significant at $p < 0.05$ level. On the other hand, the viscosity values of the samples showed

Table 2 Mean values of some physicochemical properties of the experimental yogurts and their statistical evaluations in terms of SMP, WP and BMP fortifications and storage time (days)

Experimental yogurts	Total solids (%)	Fat	Solids non-fat (%)	Protein (%)	Ash (%)	Viscosity (cP)	Syneresis (mL/25 g)	Titratable acidity (LA %)	pH
A	15.50 ± 0.77^{a}	4.18 ± 0.29^{a}	11.33 ± 0.83^{a}	5.03 ± 0.32^{a}	0.82 ± 0.09^{a}	5748.13 ± 1299.31^{b}	7.40 ± 0.62^{a}	1.36 ± 0.04^{c}	4.20 ± 0.13^{a}
B	15.63 ± 0.36^{a}	4.23 ± 0.24^{a}	11.40 ± 0.47^{a}	4.96 ± 0.43^{a}	0.91 ± 0.06^{b}	3227.88 ± 554.76^{a}	8.81 ± 0.82^{b}	1.26 ± 0.10^{a}	4.23 ± 0.14^{a}
C	15.78 ± 0.46^{a}	4.15 ± 0.18^{a}	11.63 ± 0.44^{a}	5.10 ± 0.92^{a}	0.93 ± 0.05^{b}	3673.50 ± 527.30^{a}	8.55 ± 0.60^{b}	1.31 ± 0.04^{bc}	4.21 ± 0.13^{a}
D	15.76 ± 0.59^{a}	4.20 ± 0.16^{a}	11.56 ± 0.65^{a}	5.34 ± 0.66^{a}	0.95 ± 0.05^{b}	4205.50 ± 739.14^{a}	8.36 ± 0.91^{b}	1.27 ± 0.10^{ab}	4.21 ± 0.17^{a}
E	15.76 ± 0.55^{a}	4.19 ± 0.15^{a}	11.57 ± 0.61^{a}	5.39 ± 0.57^{a}	0.94 ± 0.07^{b}	4166.75 ± 868.25^{a}	8.31 ± 0.39^{b}	1.32 ± 0.11^{bc}	4.17 ± 0.10^{a}
F	15.71 ± 0.71^{a}	4.18 ± 0.19^{a}	11.53 ± 0.80^{a}	4.89 ± 0.28^{a}	0.95 ± 0.04^{b}	3773.13 ± 348.33^{a}	8.40 ± 0.61^{b}	1.33 ± 0.05^{c}	4.16 ± 0.11^{a}
Storage time (days)									
1	15.90 ± 0.77^{a}	4.07 ± 0.20^{a}	11.83 ± 0.79^{a}	5.31 ± 0.75^{bc}	0.88 ± 0.10^{a}	4538.50 ± 1287.68^{b}	7.91 ± 0.91^{a}	1.23 ± 0.08^{a}	4.27 ± 0.11^{a}
7	15.74 ± 0.47^{a}	4.18 ± 0.19^{a}	11.56 ± 0.56^{a}	5.43 ± 0.48^{c}	0.91 ± 0.06^{ab}	3642.42 ± 819.00^{a}	8.38 ± 0.62^{a}	1.28 ± 0.06^{b}	4.22 ± 0.08^{a}
14	15.50 ± 0.43^{a}	4.22 ± 0.17^{a}	11.28 ± 0.39^{a}	4.81 ± 0.44^{a}	0.93 ± 0.06^{ab}	4364.50 ± 1055.07^{ab}	8.61 ± 0.85^{a}	1.35 ± 0.05^{c}	4.16 ± 0.13^{a}
21	15.62 ± 0.52^{a}	4.28 ± 0.19^{a}	11.33 ± 0.60^{a}	4.92 ± 0.35^{ab}	0.94 ± 0.07^{b}	3984.50 ± 1063.31^{ab}	8.32 ± 0.62^{a}	1.38 ± 0.04^{c}	4.14 ± 0.13^{a}

The means bearing different letters differ from each other at level of $p < 0.05$, all others not

A: Yogurt with no added WP and BMP (3.0%SMP)

B: Yogurt with 1.0%SPM, 2.0%WP, 0%BMP

C: Yogurt with 1.0%SPM, 1.5%WP, 0.5%BMP

D: Yogurt with 1.0%SPM, 1.0%WP, 1.0%BMP

E: Yogurt with 1.0%SPM, 0.5%WP, 1.5%BMP

F: Yogurt with 1.0%SPM, 0%WP, 2.0%BMP

an irregular change during storage, and the differences among the days of storage were statistically ($p < 0.05$) significant (Table 2). A similar trend was found by Eissa et al. (2011) and Erkaya (2009) for yogurts examined. This phenomenon can be explained by the effect of proteases produced by starter bacteria during storage period (Kosikowski 1982).

Syneresis is described as the shrinkage of gel. Shrinkage of the gel occurs concomitantly with the expulsion of liquid or whey separation. This situation, which is related to instability of the gel network, results in the loss of the ability to retain all the serum phase (Walstra 1993).

As seen in Table 2, the addition of WP and BMP caused syneresis in different grades in the experimental yogurts and the resulting differences were statistically significant at $p < 0.05$ level. This could be explained by different water-holding capacities of SMP, WP and BMP (Sharma et al. 2012).

On the other hand, there was an increase in the syneresis values of yogurt samples until the 14th day, then a decrease between the 14th day and the 21st day was observed, but these differences were statistically insignificant. Different results have been reported in some of the earlier studies on this subject. For example, Arslaner (2002), Barrantes et al. (1994) and Korkmaz (2005) reported that the serum separation values were decreasing during the storage period, whereas Athar et al. (2000), El-Sayed et al. (2002), Küçüköner and Tarakçı (2003) and Mumtaz et al. (2008) reported that serum separation values continue to increase over the period of storage.

The titratable acidity value is usually dependent on dry matter content of the yogurts and the lactose fermentation, and this value should be within a certain range so that the desired flavor is formed (Bonczar et al. 2002; Tamime and Deeth 1980).

Changes in the titratable acidity (as lactic acid %) value of the yogurt samples are given in Table 2. These differences among the experimental yogurts were statistically significant ($p < 0.05$). This could be attributed to the effect of the different combination of SMP, WP and BMP, and also their ratios used. As shown from the table, titratable acidity values of the experimental yogurts increased during the 21-day storage period, except for the difference between 14 and 21 days, the effect of the storage was found to be statistically significant at $p < 0.05$ level.

The titratable acidity values of the yogurt samples examined were found to be lower than that the values reported by Guler et al. (1996), similar to the values determined by Arslaner (2002) and Macit (2011) and higher than that the values indicated by Kavaz (2006). However, our findings on storage time were in agreement with the findings of some authors, who found that the effects of storage time on the titratable acidity values of yogurt were significantly affected.

As seen in Table 2, the pH value of each yogurt sample is different, although these differences among the samples were statistically insignificant (Table 2). The pH values obtained in the present study were similar to the findings of some researchers conducting research on yogurt (Moneim et al. 2011; Romeih et al. 2014), but differed from the findings of some other researchers (Arslaner 2002; Erkaya 2009; Guler et al. 1996; Kavaz 2006; Macit 2011). The storage period did not significantly affect pH values, although a decreasing trend was observed during the storage period (Table 2). These results can be explained by the influence of the high buffering capacity of some components such as whey proteins (Gonzalez-Martinez et al. 2002).

Microbiological properties of the experimental yogurts

As a result of the metabolic activities of yogurt bacteria, the characteristic flavor is formed and many aromatic components, mainly lactic acid and acetaldehyde, are formed (Ozer 2006).

The changes in the mean viable counts of *S. salivarius* ssp. *thermophilus* in the experimental yogurts and in the storage times are shown in Table 3. There were no significant differences between the yogurt samples in terms of the viable cell counts. On the other hand, the mean counts of *S. salivarius* ssp. *thermophilus* showed an increase until the 14th day of storage and there was a decrease in the bacterial counts in the following days, but these differences between the days were not statistically significant.

The change in the number of *S. salivarius* ssp. *thermophilus* determined in the yogurt samples were similar to that found in the study conducted by Macit (2011). On the other hand, Erkaya (2009) and Korkmaz (2005) found that the number of *S. salivarius* ssp. *thermophilus* colonies in all yogurt samples increased until the 7th day of storage and then decreased.

The mean viable counts of *Lactobacillus delbrueckii* ssp. *bulgaricus* in the samples and the change in the storage times are shown in Table 3. As seen from the table, the highest mean count of *L. delbrueckii* ssp. *bulgaricus* was observed in sample C and the lowest mean value was observed in sample D. Only small differences in the viable cell counts of *L. delbrueckii* ssp. *bulgaricus* were observed, but this was not statistically significant (Table 3). Addition to, it was observed that the numbers of *L. delbrueckii* ssp. *bulgaricus* in the experimental yogurts were affected by storage times ($p < 0.05$).

It is thought that the change in the mean viable counts of bacteria of the experimental yogurts is caused by the

Table 3 Mean values of some microbiological properties of the experimental yogurts and their statistical evaluations in terms of SMP, WP and BMP fortifications and storage time (days)

Experimental yogurts	*S. salivarius* ssp. *thermophilus* count (log cfu/g)	*L. delbrueckii* ssp. *bulgaricus* count (log cfu/g)	Yeast and molds count (log cfu/g)
A	7.53 ± 1.60^{a}	6.57 ± 1.53^{a}	$< 2 \pm 0.00^{a}$
B	7.30 ± 1.74^{a}	6.75 ± 1.43^{a}	2.15 ± 0.71^{a}
C	7.51 ± 1.68^{a}	6.79 ± 1.28^{a}	$< 2 \pm 0.00^{a}$
D	7.63 ± 1.81^{a}	6.50 ± 1.37^{a}	2.23 ± 0.93^{a}
E	7.51 ± 1.74^{a}	6.77 ± 1.11^{a}	3.54 ± 1.79^{b}
F	7.48 ± 1.83^{a}	6.51 ± 1.14^{a}	2.87 ± 1.44^{ab}
Storage time (days)			
1	7.17 ± 1.78^{a}	6.88 ± 1.43^{ab}	$< 2 \pm 0.00^{a}$
7	7.22 ± 1.85^{a}	7.46 ± 0.83^{b}	2.32 ± 1.03^{ab}
14	8.43 ± 0.50^{a}	6.03 ± 0.48^{a}	2.42 ± 1.23^{ab}
21	7.16 ± 1.85^{a}	6.23 ± 1.54^{ab}	3.10 ± 1.55^{b}

The means bearing different letters differ from each other at level of $p < 0.05$, all others not

A: Yogurt with no added WP and BMP (3.0%SMP)

B: Yogurt with 1.0%SPM, 2.0%WP, 0%BMP

C: Yogurt with 1.0%SPM, 1.5%WP, 0.5%BMP

D: Yogurt with 1.0%SPM, 1.0%WP, 1.0%BMP

E: Yogurt with 1.0%SPM, 0.5%WP, 1.5%BMP

F: Yogurt with 1.0%SPM, 0%WP, 2.0%BMP

change in the acidity values of the samples during the storage period. Similarly, it was reported that decreased pH due to increased acidity during storage reduced the counts of yogurt bacteria in the study conducted by Trigueros et al. (2011).

The selective counting of the yeasts and the molds was carried out on the Potato Dextrose Agar (PDA). The mean viable counts of yeasts and the molds in the yogurts and the change in the storage times are shown in Table 3. The difference in yeast and mold numbers of the samples was statistically ($p < 0.05$) significant. On the other hand, yeast and mold counts of all yogurts increased during the storage period and this was statistically ($p < 0.05$) significant. The results showed that yeast-mold counts of the samples were in agreement with TS 1330. Küçüköner and Tarakçı (2003) also reported that the counts of yeast and mold in all yogurt samples showed a significant increase. However, Erkaya (2009) reported that during storage, yeast and mold growth occurred only in cow milk yogurts, but no growth was observed in yogurts produced with buffalo, sheep and goat milk. The yeast and mold growth could be attributed to contamination from air, the addition of WP and BMP, and the environment of production.

Sensory evaluations of the experimental yogurts

The mean scores of the sensory characteristics of the experimental yogurts are given in Table 4. The addition of WP and BMP to yogurt in different proportions significantly ($p < 0.05$) affected the scores for consistency (by mouth), taste intensity, smell, and overall acceptability, whereas a significant effect was not observed for consistency (by spoon) and appearance by the addition of WP and BMP.

It was also observed that the storage time affected the evaluations of panelists in terms of consistency (by mouth) while all of the other sensory parameters tested were not affected by storage period (Table 4).

Conclusion

All batches of yogurt made by adding skim milk powder (SMP), whey powder (WP) and buttermilk powder (BMP) revealed different patterns in manufacture and storage time. Physicochemical, microbiological and sensory analyses of yogurt samples indicated that the SMP, WP, and BMP can be used in equal proportions. As a result of sensory evaluations, it was found that the sample D, which was equally supplemented with SMP, WP, and BMP, had the highest score and this sample was significantly different in terms of other parameters investigated from the other samples. In addition, it was considered that the WP and BMP fortifications, which are rich in serum proteins and phospholipids, in yogurt production, will be beneficial by improving the nutritional value of the product. Finally, by

Table 4 Mean values of sensory characteristics of the experimental yogurts and their statistical evaluations in terms of SMP, WP and BMP fortifications and storage time (days)

Experimental yogurts	Appearance	Consistency (by spoon)	Consistency (by mouth)	Smell	Taste intensity	Overall acceptability
A	4.38 ± 0.28^{a}	4.30 ± 0.30^{a}	4.13 ± 0.35^{a}	3.94 ± 0.57^{a}	3.60 ± 0.54^{a}	20.06 ± 2.23^{a}
B	4.31 ± 0.40^{a}	4.19 ± 0.27^{a}	4.17 ± 0.24^{a}	4.32 ± 0.41^{abc}	3.91 ± 0.20^{ab}	20.73 ± 0.66^{ab}
C	4.50 ± 0.33^{a}	4.44 ± 0.32^{a}	4.35 ± 0.29^{ab}	4.48 ± 0.33^{bc}	4.21 ± 0.37^{bc}	21.98 ± 1.04^{bc}
D	4.44 ± 0.18^{a}	4.46 ± 0.26^{a}	4.53 ± 0.22^{b}	4.71 ± 0.28^{c}	4.58 ± 0.41^{c}	22.67 ± 1.11^{c}
E	4.31 ± 0.26^{a}	4.27 ± 0.31^{a}	4.23 ± 0.18^{a}	4.40 ± 0.32^{abc}	4.06 ± 0.12^{b}	21.27 ± 0.35^{abc}
F	4.26 ± 0.40^{a}	4.23 ± 0.27^{a}	4.17 ± 0.20^{a}	4.10 ± 0.24^{ab}	3.81 ± 0.23^{ab}	20.46 ± 0.86^{ab}
Storage time (days)						
1	4.43 ± 0.26^{a}	4.42 ± 0.28^{a}	4.36 ± 0.30^{b}	4.37 ± 0.39^{a}	4.13 ± 0.51^{a}	21.61 ± 1.58^{a}
7	4.26 ± 0.41^{a}	4.25 ± 0.31^{a}	4.11 ± 0.22^{a}	4.40 ± 0.56^{a}	3.90 ± 0.37^{a}	20.88 ± 1.18^{a}
14	4.41 ± 0.23^{a}	4.20 ± 0.23^{a}	4.20 ± 0.23^{ab}	4.26 ± 0.36^{a}	4.01 ± 0.49^{a}	20.86 ± 1.55^{a}
21	4.37 ± 0.31^{a}	4.39 ± 0.31^{a}	4.38 ± 0.29^{b}	4.26 ± 0.44^{a}	4.08 ± 0.45^{a}	21.43 ± 1.56^{a}

The means bearing different letters differ from each other at level of $p < 0.05$, all others not

A: Yogurt with no added WP and BMP (3.0%SMP)

B: Yogurt with 1.0%SPM, 2.0%WP, 0%BMP

C: Yogurt with 1.0%SPM, 1.5%WP, 0.5%BMP

D: Yogurt with 1.0%SPM, 1.0%WP, 1.0%BMP

E: Yogurt with 1.0%SPM, 0.5%WP, 1.5%BMP

F: Yogurt with 1.0%SPM, 0%WP, 2.0%BMP

increasing the use of WP and BMP in the dairy and/or food industry, the environmental contamination with these byproducts can be reduced or completely prevented.

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