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Studying the effect of star anise on the physicochemical properties, color and texture of stirred buffalo milk yogurt

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ABSTRACT

Plain yogurt is low in antioxidant compounds such as phenolics, flavonoids, and anthocyanins. Bioactive ingredients—including polyphenols, minerals, and dietary fibers—can be incorporated to enhance yogurt's health-promoting properties. Aromatic herbal plants and fruits/vegetables have been explored for producing such functional yogurts. Star anise (*Illicium verum*) is a valuable seasoning worldwide with distinctive aroma and medicinal properties. This study evaluated the effect of adding star anise powder (SAP) at four levels (0, 0.1, 0.2, and 0.3% w/w) on physicochemical properties, color, firmness, and sensory acceptance of buffalo yogurt at two storage times (day 1 and day 14). Experiments were arranged as a completely randomized factorial design and analyzed with SPSS. Increasing SAP level significantly ($p < 0.01$) raised acidity, redness (a^*), yellowness (b^*), firmness, and overall acceptability, while pH, syneresis (whey separation), and lightness (L^*) decreased. Storage time also significantly affected several parameters: by day 14 acidity, redness, and firmness increased, whereas pH, syneresis, lightness, and overall acceptability decreased ($p < 0.01$). Yellowness (b^*) did not change significantly with storage ($p > 0.05$). Overall, supplementation with 0.3% SAP produced buffalo yogurt with desirable quality characteristics.

1- INTRODUCTION

Yogurt is the most widely consumed fermented dairy product. Therefore, efforts to improve the production process and enhance the quality of this product are essential. The nutritional and sensory properties of different types of yogurt have attracted a lot of attention from consumers. Among the various quality properties, the physicochemical properties, color, and texture of yogurt are of great importance and can directly affect the quality of yogurt even for ordinary consumers. Therefore, improving the quality properties of yogurt, such as pH, color, texture, structure, and others, has attracted the attention of food scientists in recent years [1].

The buffalo (*Bubalus bubalis*) is a highly adaptable livestock species, which has made it an important livestock species worldwide. In addition to its role as a draft animal, it is an important source of dairy and meat products, with buffalo milk accounting for approximately 15% of global milk production [2]. Compared to cow's milk, buffalo milk contains higher levels of casein proteins, such as α_1 -casein, α_2 -casein, β -casein, and κ -casein. Notably, the levels of α_2 -casein and κ -casein are approximately twice those of cow's milk [3]. In addition, buffalo milk has a higher concentration of lipids, lactose, and minerals, and its fat content is approximately twice that of cow's milk [4]. Buffalo milk also has significant health benefits [5], mainly due to its rich

content of bioactive compounds such as δ -valrubin and acetyl-L-carnitine. These compounds exhibit antioxidant and anti-inflammatory activities and help inhibit the proliferation of cancer cells [6]. Processing of buffalo milk-derived products is usually tailored to the specific characteristics of the final products and requires distinct production methods. These processing interventions systematically alter the compositional profile and physicochemical properties of buffalo milk, thereby affecting its bioactive potential and functional properties [7].

Yogurt is a dairy product that can be produced in a functional way and containing bioactive compounds to improve the nutritional and medicinal properties of the product. The use of plant products, especially various medicinal plants, in the production of yogurt can reduce the risk of chronic diseases such as cancers, osteoporosis, hypertension, diabetes, and heart disease. These plants contain compounds such as glucosinolates, antioxidants, anthocyanins, lycopene, carotenoids, and phenolic compounds such as flavonoids [8].

Star anise, known scientifically as *Illicium verum* Hook. F., belongs to the Magnoliaceae family. Its name, derived from the Latin word "Illicere" meaning "to seduce", refers to the attractive aroma emitted by its branches and leaves [9]. This evergreen species has star-shaped, octagonal fruits (Figure 1). The plant not only enhances the flavor of other foods, but also imparts a pleasant aroma [10].



Figure 1. Star anise and its powder

The global distribution and demand for star anise is very wide. Star anise prefers a subtropical climate with warm winters and cool summers, and is mainly distributed in East Asia, Southeast Asia, and southern North America. The main part of star anise is produced in East Asia (southern China), followed by regions and countries such as Vietnam, Cambodia, Myanmar, Sumatra in Indonesia, and Kalimantan in the Philippines. In North America, star anise is mainly found in Mexico, Haiti, and the state of Florida [11].

Different countries use star anise in a variety of ways that go beyond its traditional role as a seasoning. In Chinese medicine, its fruits have long been used for their medicinal benefits, while in Latin America, star anise tea is commonly prescribed to treat infant colic. In Europe, star anise tea is consumed to relieve stress. Characterized by its warming properties and pungent flavor, star anise offers numerous medicinal benefits, including warming the body and relieving colds. The plant is also used to treat rheumatic pains, wounds, abdominal discomfort, and other cold-related ailments. Modern research has identified many bioactive compounds in its roots, leaves, and fruits that have insecticidal, antibacterial, anti-inflammatory, analgesic, and other beneficial properties [12]. Beyond medicinal uses, extracts of star anise fruits and seeds are also used in perfumes, toothpastes, soaps, cosmetics, and insect repellents [13].

As mentioned, today, the use of various medicinal plants and aromatic vegetables in food formulations, including yogurt, has attracted the attention of researchers. However, there has been no report on the use of star anise or badian-e khataei in food formulations. The study by Jooyandeh and Alizadeh Behbahani [14] showed that the addition of bell pepper extract, especially the red type, caused significant changes in the physicochemical properties and color of yogurt samples. The samples containing bell pepper extract had lower pH, syneresis, and brightness than the control yogurt, while their dry matter content and a^* and b^* color indices were higher. These researchers stated that the reason for the higher

a^* and b^* color indices is probably due to the higher carotenoid compounds in the enriched samples. Considering the importance of synergism in yogurt acceptability and the effect of its addition in reducing synergism, these researchers recommended the use of various types of bell pepper extracts with different colors in the formulation of this product. Saatloo et al. [15] showed that the use of mallow or malva plant (panirak) powder in fruit yogurt formulation did not have a significant effect on acidity and pH, but the dry matter of the samples increased significantly with increasing malva powder ($P < 0.05$). By increasing the concentration of malva powder to 1%, the water content of the samples decreased and the viscosity increased, but an increase of 1.5% of malva powder caused an increase in water content and a decrease in viscosity. The results of the evaluation of color indices showed that the use of malva powder in the preparation of yogurt caused a significant decrease in the L^* and a^* indices of the yogurt samples. The results of the sensory evaluation of the yogurt samples showed that the control sample and the sample containing 0.5% malva powder obtained the highest sensory properties (color and taste). The lowest score was for the sample containing 1.5% malva powder. Based on the results of this study, the best quality properties such as viscosity, syneresis, and dry matter of yogurt (despite lower sensory properties) were obtained when using 1% malva powder; however, the sensory score of the samples containing 1% was within the good and acceptable range. Therefore, these researchers suggested using 1% malva powder for the successful production of apricot fruit buffalo yogurt. In another study, Heidari et al. [16] reported that adding *Amaranthus cruentus* grain powder to curd yogurt reduced the water holding capacity of curd yogurt samples. Also, the results of rheology tests showed that the addition of *Amaranthus cruentus* powder enhances the shear thinning behavior in enriched samples and reduces the elastic modulus level of enriched samples compared to control samples; however, among enriched samples, the elastic modulus of the 3% sample was determined to be higher than the 1% and 6% samples. In terms of overall acceptance, the yogurt extract containing 1% grain powder achieved the highest level of desirability compared to other yogurt extract samples. Also,

the pH of the samples decreased significantly during the storage period with the addition of *Amaranthus cruentus* grain powder ($p < 0.05$).

According to the review of studies conducted, no research has yet investigated the effect of adding star anise on the quality of dairy products, including buffalo yogurt. Therefore, the aim of this study was to examine the effect of adding star anise powder on the physicochemical properties, color, texture, and overall acceptance of buffalo yogurt during 14 days of refrigerated storage.

2- Materials and methods

2-1- Raw materials

Stirred buffalo yogurt samples were prepared using sterile milk with 4.5% fat (Pegah Khuzestan Company, Shush). Yogurt starter was produced by the method of Yademellat et al. [17]. After thermal processing of buffalo milk containing 4.5% fat (temperature 90 °C for 15 minutes), the milk was cooled to 45 °C. According to the recipe for preparing yogurt starter culture, some lyophilized powder of the starter (0.05%, w/v) was added to the milk. After fermentation and reaching acidity of 90 degrees Dornic, the yogurt starter was stored in the refrigerator and added to the milk at a rate of 3% when used and yogurt was prepared. Star anise was purchased from a local shop in Isfahan and after cleaning and washing it, anise powder was prepared. For this purpose, star anise was dried in an oven (Heraeus, model UT 5042, Germany) at 50°C until constant weight was reached. The dried anise was then powdered with a household electric grinder (Moulinex, model 320, Spain) and passed through a sieve with a mesh size of 35 and a diameter of 0.5 mm to obtain particles of uniform size [18].

2-2- Method for preparing stirred yogurt samples

Stirred buffalo yogurt samples (4.5% fat) were produced according to the method of Yademellat et al. [17]. Initially, 2% nonfat dry milk was added to 5 kg of sterile buffalo milk and mixed thoroughly for 30 minutes to ensure complete hydration of the proteins. Similar to the yogurt starter preparation method, buffalo milk was heat-processed at 90°C for 15 minutes and cooled to the inoculation temperature

(45°C). Then, the inoculated milk (containing 3% yogurt) was transferred to a incubator and incubated at 43°C for about 4 hours (until the pH reached 4.5). The prepared yogurt was then transferred to a refrigerator (temperature of 7°C). On the day after production, star anise powder was added to the yogurt in different proportions and at 4 levels of 0, 0.1, 0.2, and 0.3 percent (w/w) and mixed well. The yogurt samples were packaged in 100 cc plastic containers with lids and stored in the refrigerator until the tests (physicochemical, color, texture, and overall acceptance) were performed for 14 days (times 1 and 14 days). All yogurt samples were produced in 3 replicates and the relevant tests were also performed in 3 replicates. A yogurt sample without red anise powder or star anise was also produced as a control sample.

2-3- Evaluation of physicochemical properties

2-3-1- pH and acidity

The pH of the samples was measured using a digital pH meter at 25°C according to the AOAC method [19]. For this purpose, the pH meter was first calibrated with buffers 7 and 4. Then, the probe of the device was completely inserted into the sample and after the device number stabilized, the pH value was read and recorded.

In order to measure acidity, the titration method was used [19]. In this method, a 1:1 ratio of the sample and distilled water was weighed in a glass beaker and then 2 to 3 drops of phenolphthalein reagent were added as an indicator. The final mixture was titrated with 0.1 N sodium hydroxide solution until a pale pink color appeared. The volume of sodium hydroxide used was recorded. Equation (1) was used to calculate the percentage of acidity in terms of lactic acid.

$$\text{Acidity (\%)} = \frac{N \times 0.09 \times 100}{M} \quad \text{Equation (1)}$$

N: NaOH consumed (ml)

M: initial weight of sample

2-3-2- Syneresis

To measure the amount of whey separation or syneresis, 30 to 40 g of yogurt sample was weighed into centrifuge tubes and then the tubes were centrifuged in a centrifuge at 222 g for 10 min at 10°C. After centrifugation, the clear

serum released at the top of the test tube was weighed. The amount of syneresis was calculated as a percentage by dividing the amount of water released by the weight of the original yogurt [20].

2-4- Color characteristics

The color of yogurt samples during storage was measured using a Minolta 400CR series colorimeter, made in Japan, where L* (L value), b* (b value), and a* (a value) indicate whiteness, yellowness, and redness, respectively [21].

2-5- Evaluation of texture characteristic

To investigate the effect of adding star anise powder on the texture of yogurt, a TA.XT.PLUS texture measuring device (Micro stable system, made in England) was used. A cylindrical probe with a diameter of 0.5 mm (number P/5) was used with a frontal velocity of 2 mm/s and a test movement speed of 1 m/s, and the probe was lowered into the sample to a depth of 10 mm. In this study, the parameter of hardness/firmness (the maximum compression force required to penetrate the probe into the sample) was measured in milligrams of force [22].

2-6- Evaluation of overall acceptance of yogurt

Table 1. Results of analysis of variance (ANOVA) of the effect of star anise powder (SAP) on the physicochemical properties, color, and firmness of buffalo milk stirred yogurt during 14 days of storage at 4°C.

Treatments	df	pH	Acidity	Syneresis	Color values			Firmness
					L*	a*	b*	
SAP	3	0.089***	84.308***	5.118***	730.715***	85.162***	39.952***	1647.67***
Storage	1	0.311***	405.164***	2.761*	112.883***	0.952*	0.406 ^{NS}	116.909**
SAP×Storage	3	0.001 ^{NS}	6.893 ^{NS}	0.064 ^{NS}	0.286 ^{NS}	0.052 ^{NS}	0.087 ^{NS}	1.668 ^{NS}
Error	16	0.003	1.718	0.388	0.543	0.135	0.307	10.038

NS, *, ** and *** indicate non-significance and significance at the $p < 0.05$, $p < 0.01$ and $p < 0.001$ levels, respectively.

Figure 2 shows the effect of different amounts of SAP on changes in pH and acidity of buffalo yogurt samples. As can be seen, the changes in acidity of the samples showed that with increasing SAP percentage, the acidity increased

The overall acceptance score of buffalo yogurt samples was determined by 20 panelists (faculty members and students of Agricultural Sciences and Natural Resources University of Khuzestan) using a 9-point hedonic (preferential) method during 14 days of refrigerated storage [23].

2-7- Statistical analysis

In this research, four yogurt treatments containing different amounts of star anise powder (0, 0.1, 0.2, and 0.3%) were produced, and the characteristics of the yogurt samples were examined during refrigerated storage on days 1 and 14. The results were analyzed using a completely randomized factorial design in SPSS. Duncan's multiple range test was used to compare treatment means. All graphs were created using Excel

3- Results and discussion

3-1- pH and acidity values of yogurt

Table 1 shows the regression coefficients of the responses of pH, acidity, syneresis, color characteristics (brightness, redness, and yellowness), and firmness of the produced yogurt samples.

significantly from 98.15 degrees Dornic (control sample) to 107.01 degrees Dornic. Also, with increasing SAP percentage, the pH of the yogurt samples decreased significantly compared to the control sample ($p < 0.001$). The decrease in pH and increase in acidity of yogurt as a result of adding star anise powder is probably due to the

stimulating effect of this powder on yogurt starter bacteria, since it has been shown that at sub-inhibitory levels, microbial inhibitory compounds can act as mild stressors and stimulate the metabolism of lactic acid bacteria (LAB). Although SAP powder contains various antimicrobial compounds, especially phenolic compounds, a sublethal dose of these compounds may act as a stimulant and create “cellular memory”, while high concentrations may negatively affect bacterial growth and survival by interfering with nutrient uptake, affecting membrane integrity, or causing pH

imbalance [24]. In support of these results, Zaika and Kissinger [25] reported that oregano can stimulate, delay, or inhibit the growth of lactic acid bacteria, depending on the case. In addition, the increased acidity in the presence of SAP may be due to the suppression of competitors of LAB bacteria, which consequently increases the population of starter bacteria and ultimately increases the amount of lactic acid [26]. Hydrolysis of glycosidic bonds by yogurt starter bacteria may also release acyl groups into the matrix and reduce pH [27].

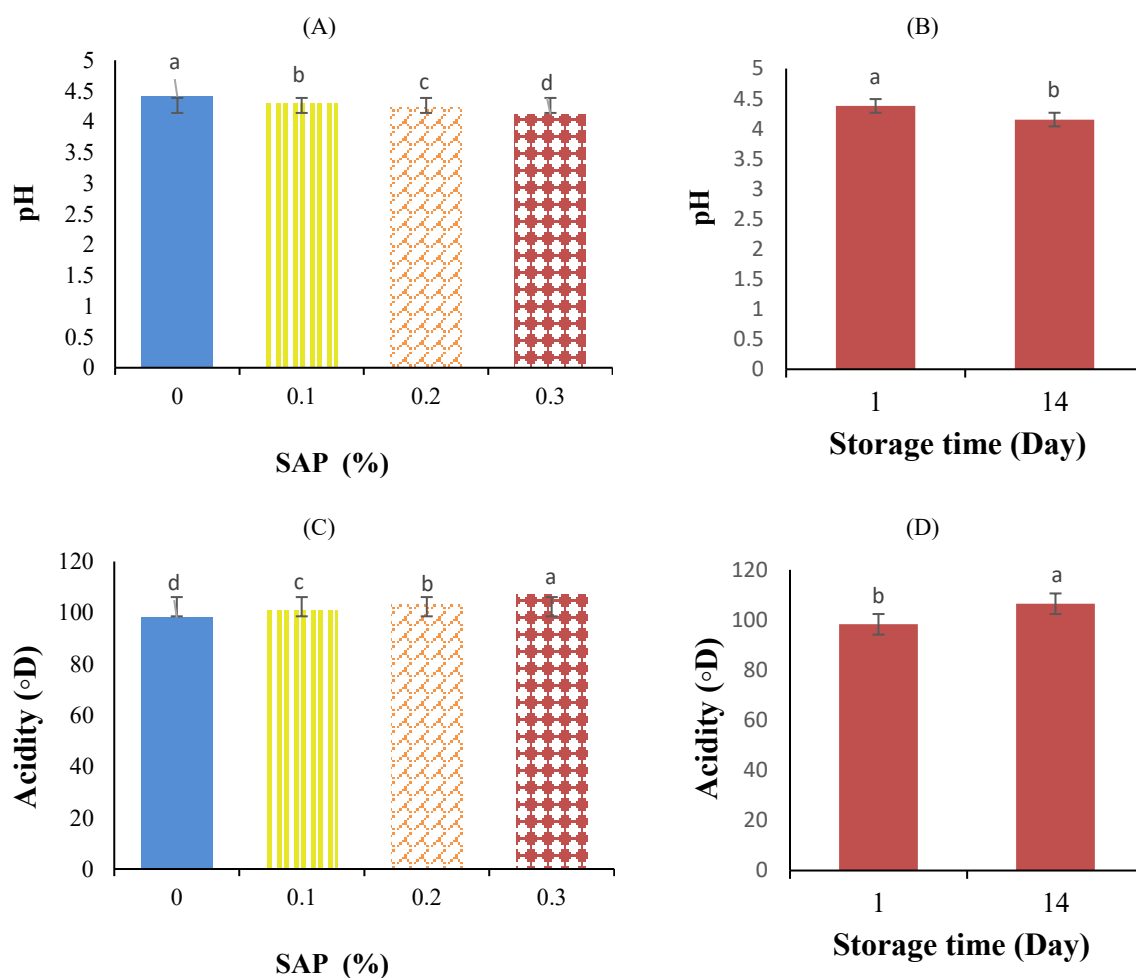


Figure 2. Effect of adding different amounts of star anise powder (SAP) on pH and acidity of buffalo yogurt samples during 14 days of refrigerated storage

In addition, the results of this study showed that with increasing storage time, the pH decreased and the acidity increased

significantly ($p < 0.001$). Considering the passage of storage time and the natural process of acidification of yogurt due to the activity of lactic acid bacteria and the production of lactic

acid, these changes are not far from expected [28]. The decrease in pH and increase in acidity of yogurt during refrigerated storage have been reported by other researchers [23, 29].

3-2- Syneresis evaluation

One important quality characteristics of yogurt is the amount of whey separation, or syneresis,

which has a significant impact on consumer acceptance. Figure 3 shows the effect of different amounts of SAP on syneresis in stirred buffalo yogurt samples. The results of this study showed that, with increasing SAP percentage, syneresis of the yogurt samples decreased significantly ($p < 0.001$); the control sample had the highest syneresis (10.2%), while the sample with 0.03% SAP had the lowest (8.10%).

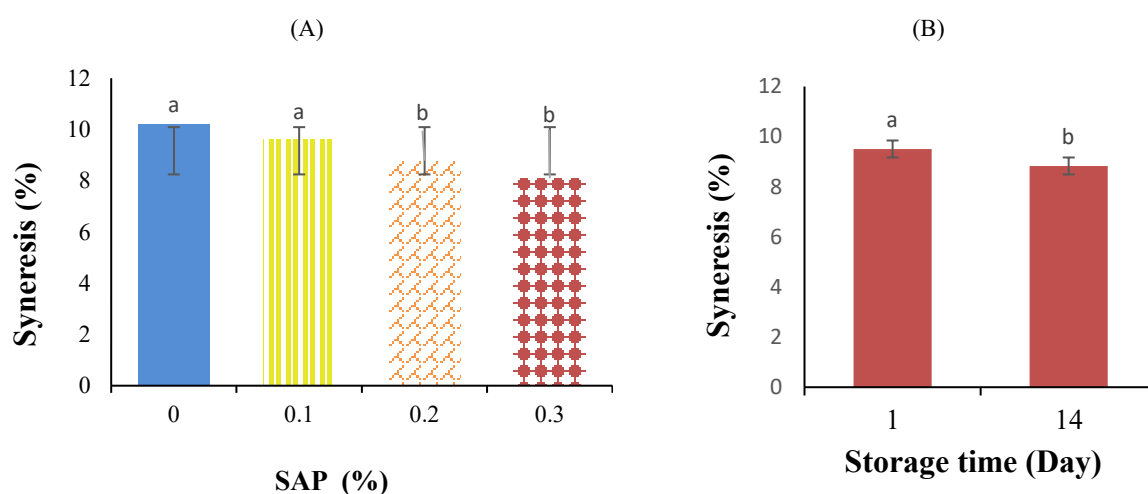


Figure 3. Effect of adding different amounts of star anise powder (SAP) on syneresis of buffalo yogurt samples during 14 days of refrigerated storage

The reduction in syneresis despite lower yogurt pH when adding star anise powder (SAP) could be due to SAP's solid particles (fibers, polysaccharides, and proteins) and hydrocolloid-like compounds that increase water-holding capacity and strengthen the yogurt gel network [30]. In this context, reactions between SAP polyphenols and yogurt proteins can alter protein structure and improve protein affinity, thereby increasing protein cohesion [31]. These physical/colloidal effects can overcome the weakening of the casein gel caused by acidification. Therefore, in this study, although the acidity of the yogurt samples increased with increasing SAP content, water release from the yogurt decreased. Zhang et al. [32] showed that adding Moringa leaf water extract powder to yogurt decreased syneresis values and increased water-retention capacity, which could be due to interactions between yogurt proteins and Moringa extract components; the yogurt gel matrix appears to be

strengthened by adding Moringa extract and can therefore retain more yogurt serum [32]. In addition, even low concentrations of polysaccharides or plant proteins can interact with casein micelles through electrostatic interactions or hydrogen bonding and affect the gel-formation process, while also changing the balance between capillary forces and network cohesion [33]. The reduction of yogurt water loss following the addition of herbal powders such as green tea and green coffee [34], rice berry extract powder [35], and tomato powder prepared by the cold-break method [36] has been previously reported. However, contrary to the results of this study, Vidana Gamage et al. [27] reported an increase in syneresis in yogurt after adding blue pea flower anthocyanin extract powder.

Also, changes in the water content of the samples during storage showed that with increasing days of storage, its amount decreased significantly from 9.51% in the fresh yogurt

sample to 8.83% at the end of 14 days of storage. In accordance with the results of the present study, a decrease in the amount of syneresis during storage has been reported in yogurts enriched with different types of plant gums [37, 38] and the malva plant [39]. The decrease in syneresis over time has been attributed to the increase in the number and strength of bonds between the components constituting the gel structure at low temperatures [38].

3-3- Color evaluation

Considering the important effect of color on dairy-product quality and consumer acceptance,

the color indexes of the yogurt samples were measured. Figure 4 shows the effect of different SAP amounts on the color characteristics of stirred buffalo yogurt samples. As shown, increasing SAP significantly changed the yogurt color ($p < 0.001$). Brightness (L^*) decreased with higher SAP, while redness (a^*) and yellowness (b^*) increased. The control sample had the highest brightness ($L^* = 81.27$), and the sample with 0.3% SAP had the lowest ($L^* = 55.77$) (Figure 4-A). Redness increased from -4.63 in the control to 4.05 with SAP (Figure 4-C), and yellowness rose from 19.42 to 63.51 (Figure 4-E).

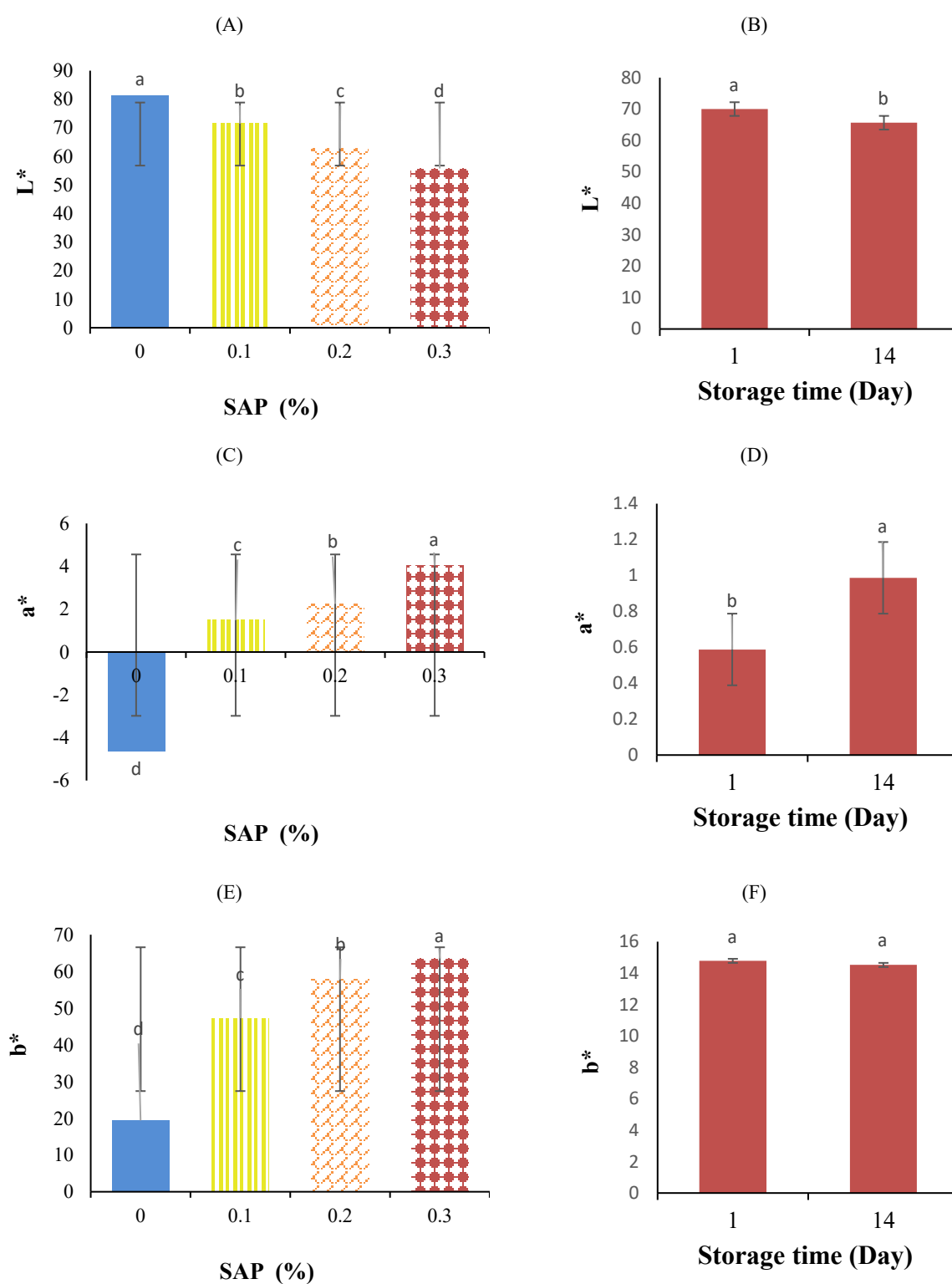


Figure 4. Effect of adding different amounts of star anise powder (SAP) on color characteristics of buffalo yogurt samples during 14 days of refrigerated storage

Consistent with our findings, Jooyandeh and Alizadeh Behbahani [14] reported that adding bell pepper extract, especially red pepper, significantly altered yogurt color: enriched samples had lower brightness and higher a^* and b^* values, attributed to carotenoid compounds in the extract. Given the importance of syneresis for consumer acceptance and bell pepper extract's reported reduction of syneresis, those authors recommended using bell pepper extracts of different colors in product formulation. Saatloo et al. [15] found that adding the malva plant (Panirak) to fruit yogurt significantly decreased the L^* index; however, contrary to our results, the a^* index also decreased there, likely due to high chlorophyll levels in Panirak. Jooyandeh et al. [40], optimizing a probiotic yogurt formulation containing eggplant puree, reported that eggplant pulp significantly ($p < 0.05$) reduced sample brightness, which they attributed to product darkening from eggplant and fiber's effect on serum content in yogurt.

In addition to the SAP fortification, the storage time variable also caused significant changes in the brightness ($p < 0.001$) and redness ($p < 0.05$) properties of yogurt samples; however, the yellowness of the samples did not change significantly during storage ($p = 0.267$). With the passage of storage time, the brightness of the samples decreased from 70.00 to 65.64 (Figure 4-B). The reason for this phenomenon could be the decrease in light scattering due to the increase in protein hydration during storage and, as a result, the decrease in whey spaces in the product [41]. Garcia et al. [42] also reported that the decrease in brightness of yogurt during storage is directly correlated with the decrease in pH. Similar to the results of this study, Mehdizadeh et al. [43] also reported a significant decrease in brightness in fruit yogurts during storage. Contrary to the results of this study, Jooyandeh et al. [40] reported an increase in brightness of yogurt containing eggplant during 14 days of storage in the refrigerator. These researchers attributed the increase in the L^* index of probiotic yogurt samples containing eggplant during storage to the breakdown of color compounds, especially anthocyanin and carotenoid compounds present in eggplant.

As can be seen in Figure 4-D, after 14 days of storage, the a^* value or the intensity of

greenness in the samples increased significantly; the lowest value (0.59) was observed at the beginning of the storage period and the highest a^* redness (0.99) was observed on day 14. Since syneresis in yogurt causes the release of serum containing riboflavin, which imparts green color to yogurt, one of the possible reasons for the increase in a^* (decrease in greenness) due to the addition of SAP and the passage of storage time can be attributed to the decrease in syneresis in this regard [44, 45].

Regarding the b^* index, the results of the study showed that the yellowness index decreased from 14.78 to 14.52 during the storage period of yogurt treatments, but as mentioned, these changes were not significant (Figure 4-F). Jooyandeh and Alizadeh Behbahani [14] also reported in a similar study that the yellowness index of yogurt samples containing 5% bell pepper extract did not change significantly during 21 days of storage, and the b^* value slightly decreased from 16.53 to 16.37. The decrease in yellowness of yogurt during storage may be due to the decomposition of pigments in the product [46]. The results of this study are consistent with the report of Khalifa and Goma [47]; they reported a decrease in the b^* value of yogurt drinks containing pigments extracted from compounds such as chayote flower calyx, yellow onion peel, and peanuts during storage. Contrary to the results of this study, Garcia et al. [42] reported an increase in the yellowness index of yogurt samples during cold storage and attributed it to the instability caused by acidification of casein micelles, resulting in protein aggregation and structural rearrangement. In addition, the increase in yellowness or higher b^* value of yogurt during cold storage could be due to enzymatic or non-enzymatic degradation and oxidation of natural pigments such as carotenoids in fruit and vegetable compositions or added colors to the product. Also, Maillard reactions or interactions between proteins and residual reducing sugars - even at cold temperatures for long periods - can produce a yellow to brown color [48].

3-4- Firmness evaluation

The firmness of yogurt can be defined as the maximum force measured when the probe of the texture measuring device enters the sample [49]. The effect of the percentage of SAP addition and storage time on the firmness of

yogurt samples is shown in Figure 5. According to these graphs, with increasing SAP content and storage time, the firmness of the samples increased and the sample containing 0.03% SAP showed the highest firmness at the end of 14 days of storage. As shown in Figure 5-A, the control sample with 105.04 mg force and the sample containing 0.3% SAP with 142.95 mg force had the lowest and highest firmness, respectively.

casein network and the lack of proper gel formation due to the decrease in yogurt acidity. The reason for the increase in yogurt firmness as a result of adding star anise powder, as mentioned in the pH and acidity results section, could be due to the stimulating effect of this powder on yogurt starter bacteria, increased acidity, and greater density of casein micelles [28].

As can be seen in Figure 5-B, storage time

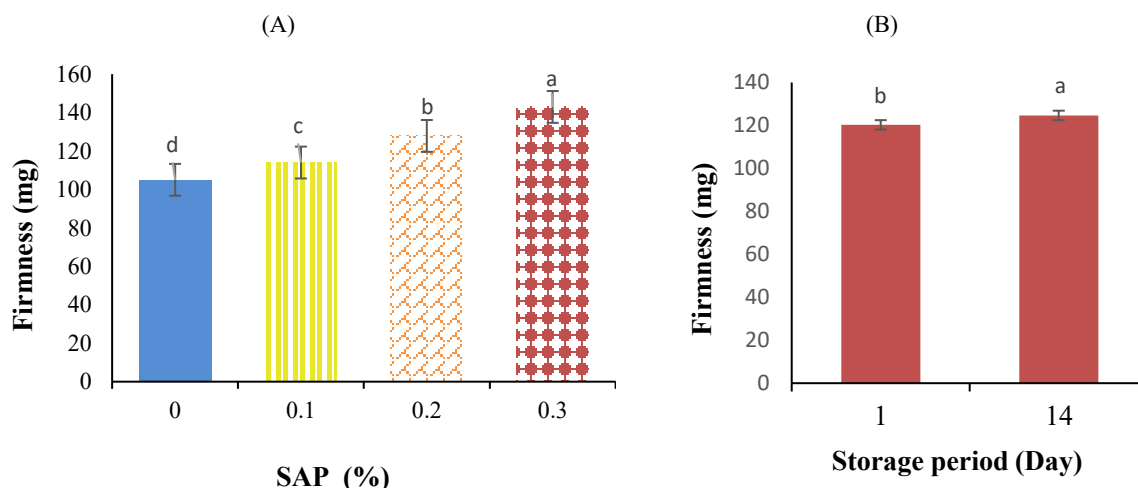


Figure 5. Effect of adding different amounts of star anise powder (SAP) on firmness of buffalo yogurt samples during 14 days of refrigerated storage

In similar results, Kalkan et al. [50], in investigating the physical, textural, microbiological and bioactive properties of probiotic yogurt enriched with different proportions of hazelnut milk (10, 20, 30, 40 and 50%) during 21 days of refrigerated storage, showed that the firmness increased significantly with increasing the proportion of hazelnut milk added to probiotic yogurt. As previously mentioned, lower levels of yogurt whey-off (serum separation) in SAP-enriched samples could lead to increased product consistency and firmness due to improved water-holding capacity. These results are consistent with the findings of Jiao et al. [51], who reported the development of a stronger gel network with higher viscosity when walnuts were used in the production of dairy-like yogurt. However, contrary to the results of the present study, Yang et al. [52] reported a decrease in firmness with increasing ginger extract content in a study of adding ginger extract to yogurt, and attributed the reason to increased product dilution, as well as to the disorganization of the

significantly increased firmness. The firmness of yogurt was determined to be 120.26 mg force at the beginning of the refrigerated storage period, which increased to 124.67 mg force after 14 days of storage. The increase in firmness of yogurt during storage is attributed to the change in the arrangement of the casein network and the improvement of the protein binding in the network [17]. In addition, this may be due to the ionic balance of the gel matrix due to the decrease in pH and the formation of a more stable gel during storage [53]. In accordance with the present study, Nikbakht Kashkouli et al. [54] reported an increase in firmness of yogurt (dairy) samples during 19 days of refrigerated storage.

3-5- Evaluation of total acceptance of yogurt

The results of sensory evaluation showed that the treatments studied, as well as the physicochemical properties, had a significant effect on the overall acceptance of low-fat molded yogurt samples. The results of this study showed that the amount of star anise powder (SAP) and storage time significantly affected this property (Figure 6). As can be seen in Figure 6-A, with increasing SAP content, the

overall acceptance score of yogurt samples improved. The overall acceptance score of the control sample and yogurt samples containing 0.1, 0.2, and 0.3 percent SAP powder was determined to be 7.67, 7.85, 8.07, and 8.19, respectively. Improvement of the overall acceptance score of yogurt by adding various herbal ingredients has been reported by researchers [14, 23, and 30].

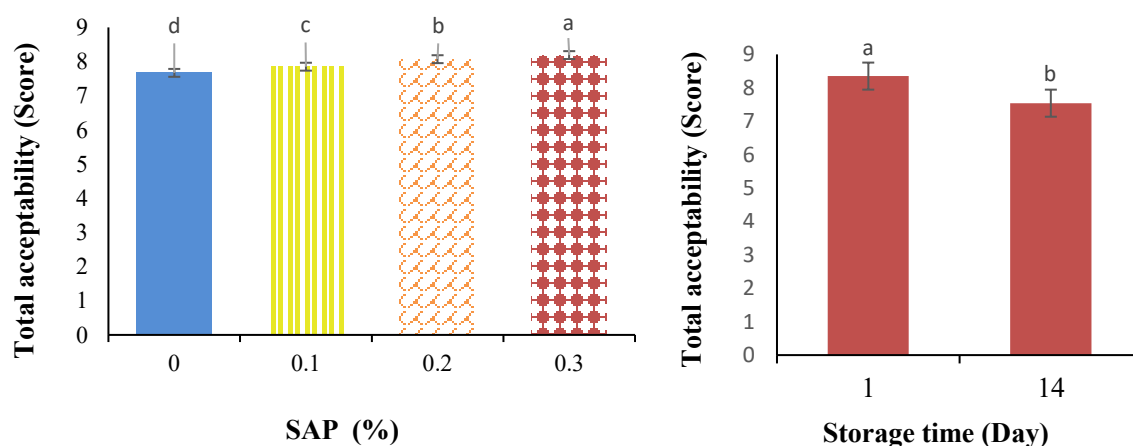


Figure 6. Effect of adding different amounts of star anise powder (SAP) on total acceptance of buffalo yogurt samples during 14 days of refrigerated storage

Contrary to the results obtained regarding the effect of SAP on improving the overall acceptance score of yogurt samples, storage time significantly decreased this score ($p < 0.001$), and the mean scores decreased from 8.35 at the beginning of storage to 7.54 after 14 days of storage (Figure 6-B). Decreases in sensory scores during storage have been reported in yogurt and other dairy products, including doogh [55], semolina yogurt [56], and kefir [57].

4- Conclusion

The use of medicinal plants has attracted the attention of the food industry due to their wide range of beneficial properties. In this study, a new functional buffalo yogurt was produced using star anise powder (SAP). The results of this study showed that the addition of SAP powder significantly improved the quality

characteristics and traits of the product and therefore has a good potential as a natural functional additive for the enrichment of buffalo yogurt and other dairy products. The physicochemical, textural, color and sensory properties of the product changed significantly with the addition of SAP. In particular, the addition of SAP increased the rate of acid production and reduced the pH, which is probably due to the stimulation of starter bacteria activity. Color changes (decreased brightness and increased redness and yellowness) were expected due to the pigments and volatile compounds present in star anise. The simultaneous reduction in syneresis and increase in firmness indicated improved structural stability and water retention capacity in yogurts containing SAP, which could play an effective role in improving yogurt quality and consumer satisfaction. Enrichment of yogurt with SAP, especially at the highest level (0.3%), improved the texture and structure of yogurt

and increased its sensory acceptability; therefore, based on the results of this study, the use of SAP is recommended for the production of functional buffalo yogurt.

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Data availability

Data will be made available on request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Author Contributions

Reza Ghasemi Asl: Data collection, Formal analysis, Resources & Writing - original draft.

Hossein Jooyandeh: Conceptualization, Project administration, Investigation, Visualization, Validation, Writing – review & editing.

Behrooz Alizadeh Behbahani: Conceptualization, Investigation, Methodology, Visualization & Validation.

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بررسی تأثیر انیسون ستاره‌ای بر ویژگی‌های فیزیکوشیمیایی، رنگ و بافت ماست هم‌زده شیر گاومیش

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ماست ساده فاقد ترکیبات آنتی‌اکسیدانی سلامت‌محور به‌ویژه مواد فنلی، فلاونوئیدها، آنتوسیانین‌ها می‌باشد. امروزه جهت بهبود و افزایش ویژگی‌های سلامت‌محور ماست می‌توان از ترکیبات مختلفی مانند پلی‌فنول‌ها، مواد معدنی، فیبرهای غذایی و نیز ترکیبات مختلف زیست فعال استفاده کرد. بدین منظور، استفاده از گیاهان دارویی معطر و انواع میوه و سبزی در تولید ماست‌های عمل‌گرا مورد توجه قرار گرفته است در سطح جهانی، انیسون ستاره‌ای یک چاشنی بسیار ارزشمند است که به دلیل عطر منحصر به فرد و خواص دارویی‌اش مورد توجه قرار گرفته است. در این پژوهش، اثر افزودن پودر انیسون ستاره‌ای (SAP) در چهار سطح (۰، ۱/۰، ۲/۰ و ۳/۰ درصد) بر ویژگی‌های فیزیکوشیمیایی، رنگ، سفتی و پذیرش کلی ماست هم‌زده گاومیش طی دو دوره نگهداری (روز ۱ و ۱۴) بررسی شد. داده‌ها با طرح کاملاً تصادفی در قالب فاکتوریل و نرم‌افزار آماری SPSS تجزیه‌تخلیل گردید. نتایج نشان داد با افزایش درصد SAP، مقادیر اسیدیته، قرمزی (a^*)، زردی (b^*)، سفتی و پذیرش کلی محصول به‌طور معنی‌داری افزایش و pH، آب‌اندازی و روشنایی به‌طور معنی‌داری کاهش یافت ($p < 0.01$). همچنین زمان نگهداری اثر معنی‌داری بر بسیاری از ویژگی‌های مورد بررسی داشت و پس از گذشت ۱۴ روز، مقادیر اسیدیته، قرمزی و سفتی افزایش و pH، آب‌اندازی، روشنایی و پذیرش کلی ماست کاهش قابل توجهی یافت. در هر حال، ویژگی زردی با گذشت زمان نگهداری تغییر چشمگیری ($p > 0.05$) نشان نداد. نتایج کلی نشان داد با افزودن ۰/۳ درصد SAP می‌توان ماست هم‌زده گاومیش با خصوصیات کیفی مطلوب تولید نمود.