Goats' milk yogurt with passion fruit pulp: Impact of the addition on antioxidant activity, physico-chemical and sensory properties

TONG XIANG YANG – ZHAO HAN LIU – YI NUO ZHANG – YUE HOU – KONG YANG WU – XU DUAN

Summary

Passion fruit is now grown worldwide as a delicious edible fruit for the food industry. In order to analyse the influence of the addition of passion fruit pulp on the quality of goats' milk yogurt, the physico-chemical, sensory and antioxidant properties of the yogurt during refrigerated storage were investigated by measuring pH value, titratable acidity, susceptibility to syneresis, viscosity, hardness and antioxidant capacity. The results showed that supplementation with passion fruit pulp improved some of the physico-chemical and sensory characteristics. During 2 weeks of storage, viscosity and susceptibility to syneresis continuously increased and hardness was higher compared to that of the control group. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) and OH radical-scavenging rate as well as Fe^{3+} reducing capacity increased, goats' milk yogurt with 20 $g \cdot kg^{-1}$ passion fruit pulp showed a higher antioxidant activity. However, pH of the yogurt decreased. Overall, the results support the hypothesis that passion fruit pulp is a promising option as a dietary supplement to produce novel dairy products that have high nutritional value and high antioxidant activity.

Keywords

passion fruit pulp; goats' milk yogurt; antioxidant activity; physico-chemical property; sensory property

In recent years, goats' milk and food products made from it received great attention in many parts of the world, in particular in Asia, Europe and Africa [1]. This interest was prompted by its higher nutritional value [2]. Compared to cows' milk, goats' milk has higher contents of zinc, iron, magnesium and has better digestibility, higher alkalinity and higher buffering capacity [3], and is less allergenic probably due to the low level of α_s-1-casein [4]. Furthermore, goats' milk contains more short and medium chain fatty acids as well as lipoprotein lipase associated with the fat phase, providing nutrition for children, young adults and the elderly, especially those who are allergic to cows' milk [5, 6].

Interest in dairy products from goats' milk has increased due to many functional benefits and indisputable dietetic properties, combined with the current trend of health-promoting diet [7]. However, some consumers dislike its goaty flavour derived from caprylic (octanoic), capric (decanoic) and caproic (hexanoic) acids, which are present in this milk and dairy products [8]. Incorporation of fruits and/or their derivatives into goats' milk yogurt may help mask the characteristic unpleasant flavour and potentially increase its acceptability among consumers [9]. Several studies reported the improvement of quality characteristics of goats' milk yogurt when added with fruits, jujube pulp, Isabel grape or beetroot juice [4, 10–12]. Besides those, other ingredients were also added during goats' milk fermentation, such as honey, cyclodextrins or transglutaminase [13–15].

The passion fruit (*Passiflora edulis* f. *flavicarpa*) is a tropical fruit produced in subtropical and tropical countries. Yellow passion fruit juice is popular for its pleasant unique aroma and flavour [16]. Passion fruit may be used to produce a functional food flavour additive because it is rich in soluble fibre and numerous polyphenolics with high antioxidant capacities [16, 17]. It could enhance the nutritional value and mask the goaty flavour in the

Tong Xiang Yang, Zhao Han Liu, Yi Nuo Zhang, Yue Hou, Xu Duan, College of Food and Bioengineering, Henan University of Science and Technology, Kaiyuan Road 236, Luoyang, 471023, China.
Kong Yang Wu, College of Life Science, Luoyang Normal University, Jiqing Road 6, Luoyang, 471934, China.

Correspondence author:
Tong Xiang Yang, e-mail: txyamy@163.com
Xu Duan, e-mail: duanxu_dx@163.com

development of fermented goats' milk products [13]. The influence of passion fruit peel powder on the texture profile and bacterial viability in probiotic yogurts was reported [17]. However, the addition of passion fruit pulp to goats' milk yogurt is a challenge. This is due to the fact that goats' milk forms a softer curd during the fermentation process [18]. In addition, previous studies provided some empirical evidence that fermentation and the fragile equilibrium of the yogurt structure can be affected by any fibre added into milk as well as by the milk type itself [19].

Studies about the use of passion fruit pulp as an ingredient in the formulation of dairy products are still scarce and, to the best of our knowledge, no study is available about incorporation of passion fruit pulp to goats' milk yogurt. Considering this, the present work was carried out to study a new dairy product with functional properties, a goats' milk yogurt with added passion fruit pulp. In order to characterize this product and to evaluate the influence of passion fruit pulp on the quality of the final product, the physico-chemical characteristics, sensory charateristics and the antioxidant activity were evaluated after production during 21 days of storage.

MATERIALS AND METHODS

Reagents and materials

2,2-Diphenyl-1-picrylhydrazyl (DPPH) was purchased from Sigma-Aldrich (St. Louis, Missouri, USA). All other chemicals were of analytical grade and obtained from Aolong Chemical (Luoyang, China). Fresh passion fruit was purchased from Dazhang Group (Luoyang, China). Fresh goats' milk was obtained from a farm (Donggang, Luoyang, China).

Preparation of pulp and yogurt

Tab. 1 provides data on physico-chemical composition of fresh passion fruit, which were determined according to the methods described by Dos Reis et al. [20] and Liu et al. [21] for the analysis of total soluble solids, total phenolic compounds, lipids and pH. Fresh passion fruits were cleaned under running water, cut it into two parts and the pulp was scooped out with a sterile spoon. Fresh goats' milk containing 36 g·kg^{-1} fat (approximately 83 g·kg^{-1} non-fat solids) was filtered through gauze to remove impurities, 70 g·kg^{-1} cane sugar was added and the mixture was stirred continuously. The mixture was then pasteurized at 95 °C for 5 min. The samples were packed separately in sterile glass bottles and cooled to 45 °C in an ice water bath. Passion fruit pulp was added to the experimental milk samples at 0 g·kg^{-1}, 10 g·kg^{-1}, 15 g·kg^{-1} and 20 g·kg^{-1} levels, the sample without addition served as a control sample. The mixture was inoculated with 30 ml·kg^{-1} re-activated YO-MIX187 starter (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*; Danisco, Copenhagen, Denmark), incubated at 42 °C for 6 h and stored at 4 °C.

Physico-chemical analyses

Physico-chemical analyses were done at 0, 3, 7, 14 and 21 days of refrigerated storage in triplicates for each sample. The pH value was measured using a pHS-3C digital pH meter (Leici, Shanghai, China). Titratable acidity was determined using a titrator system according to the national standard method CFSS (GB 5009.239-2016) [22]. Hardness of yogurt samples was determined using a texture analyser TA-XT plus equipped with 1 kg head (Stable Micro Systems, Godalming, United Kingdom) following a method described by Varghese and Mishra [23] with little modification. The probe (P/0.5) penetrated the samples to a depth of 15 mm (50% compression) at a test speed of 1.0 mm·s^{-1}. The force exerted on the probe was recorded automatically. The fracture TPA algorithm was used to investigate the hardness of the samples. The apparent viscosity of the yogurt samples was measured with an NDJ-8S digital viscometer (Fangrui Instrument, Shanghai, China) with rotor number 3. The shear velocity was 720 Hz respectively.

Susceptibility to syneresis was determined using the drainage method according to Hassan et al. [24] with a modification. Each sample was transferred into a funnel fitted with a 0.125 mm stainless steel mesh. The volume of the whey collected over 2 h was measured in a 100 ml graduated cylinder. The following formula was used to calculate susceptibility to syneresis:

$$STS = \frac{m_1}{m_2} \times 100 \quad (1)$$

Tab. 1. Physico-chemical characteristics of passion fruit pulp.

Parameters	Value
Total soluble solids [%]	14.4 ± 0.4
Total phenolic compounds [mg·kg^{-1}]	12.6 ± 0.0
Lipids [%]	4.7 ± 0.1
pH	2.6 ± 0.1

Results presented are mean values ± standard deviation of three experiments each in triplicate.

where *STS* is susceptibility to syneresis, m_1 is volume of whey collected after drainage and m_2 is volume of the yogurt sample.

Sensory evaluation

For sensory evaluation, 10 trained panellists from College of Food and Bioengineering, He'nan University of Science and Technology (Luoyang, China) were selected according to the scheme described by Hamad et al. [25] with slight modifications. Panellists were selected based on their availability and their sensory acuity. They were trained regarding basic tastes, acidity, aromas, texture and flavours [26]. Samples were evaluated after 0, 3, 7, 14 and 21 days of refrigerated storage through acceptability tests, focusing on attributes of appearance (10 points), acidity (10 points), texture (20 points), flavour (20 points), aroma (20 points) and mouthfeelness (20 points).

Antioxidant capacity assay

Samples were prepared by dissolution of 1 g yogurt in 9 ml anhydrous ethanol. Antioxidant capacity was determined by the DPPH method according to Zhao et al. [27]. The Fe^{3+} reducing power was determined according to the method of Nguyen and Hwang [28]. The hydroxyl radical ($^{\bullet}OH$) scavenging activity was assayed as described by Sah et al. [29]. Analyses were performed in triplicate.

Statistical analysis

One-way analysis of variances (ANOVA) with Duncan's multiple range test were carried out in the statistical analysis using SPSS software (SPSS, Chicago, Illinois, USA) to identify the difference between the experimental data at a significance level of 5 % ($p < 0.05$).

RESULTS AND DISCUSSION

Physico-chemical analysis during storage

The average pH and titratable acidity of goats' milk yogurt samples containing passion fruit pulp are shown in Fig. 1. Overall, pH values of all formulations decreased over time (Fig. 1A), while the titratable acidity values increased (Fig. 1B). The decrease in pH was positively related to the amount of passion fruit pulp addition, according to the lower pH value of passion fruit pulp (Tab. 1). Meanwhile, the increase in titration acidity was also basically proportional to the addition of passion fruit pulp.

In addition, significant differences in both the acidity and the pH values of goats' milk yogurt were observed between the sample with 20 $g\cdot kg^{-1}$ passion fruit pulp addition and control group during the monitored storage period ($p < 0.05$) (Fig. 1). Interestingly, the change in acidity of goats' milk yogurt with 15 $g\cdot kg^{-1}$ passion fruit pulp addition was not obvious during the first three days of storage, nor was there a significant difference between samples stored for one week to two weeks ($p > 0.05$). The goats' milk yogurt with 15 $g\cdot kg^{-1}$ passion fruit pulp addition showed a weak post-acidification phenomenon. These results indicated that passion fruit pulp had effects on the acid production by lactic acid bacteria.

The results about pH and titratable acidity of goats' milk yogurt with passion fruit pulp are in agreement with those reported by Feng et al. [10] and Senaka Ranadheera et al. [9]. Acidification of yogurt is affected by many factors, including growth characteristics, specific growth rate, fermentation time, sugar or amino acid contents, and product yields or various additives used [10, 30]. The decrease in the pH value is mainly due to the production of organic acids by lactic acid bacteria during fermentation, then due to the lower pH value of passion fruit pulp (Tab. 1), and some organic acids can be also produced by decomposition of carbohydrates [7, 31]. Organic acids produced by *Str. thermophilus* and *Lb. delbrueckii* ssp. *bulgaricus* may further affect the shelf life of yogurt during storage time. [10, 32].

Hardness is an important parameter to evaluate the quality of fermented milk products. The effect of adding different amounts of passion fruit pulp on hardness of the goats' milk yogurt during storage period at 4 °C is shown in Fig. 2. Hardness of goats' milk yogurt with added passion fruit pulp was significantly different from control samples during the storage time ($p < 0.05$) except for 20 $g\cdot kg^{-1}$ passion fruit pulp addition at 3 days. There was an obvious increase in the hardness in goats' milk yogurt with 10 $g\cdot kg^{-1}$, 15 $g\cdot kg^{-1}$ and 20 $g\cdot kg^{-1}$ passion fruit pulp addition from first day onwards up to 14 days of storage ($p < 0.05$) and then hardness gradually decreased except for the sample with 20 $g\cdot kg^{-1}$ passion fruit pulp addition. This may be because passion fruit pulp is beneficial to strengthening the gel state of goats' milk yogurt, increasing intermolecular forces in its structure. However, with the extension of the storage period, the structure of goats' milk yogurt was apparently destroyed, the intermolecular forces were disrupted (data not shown), the growth of lactic acid bacteria was also affected (data not shown), the gel was reduced and the network structure was unstable, resulting in a decrease in hardness [33]. This corresponded with

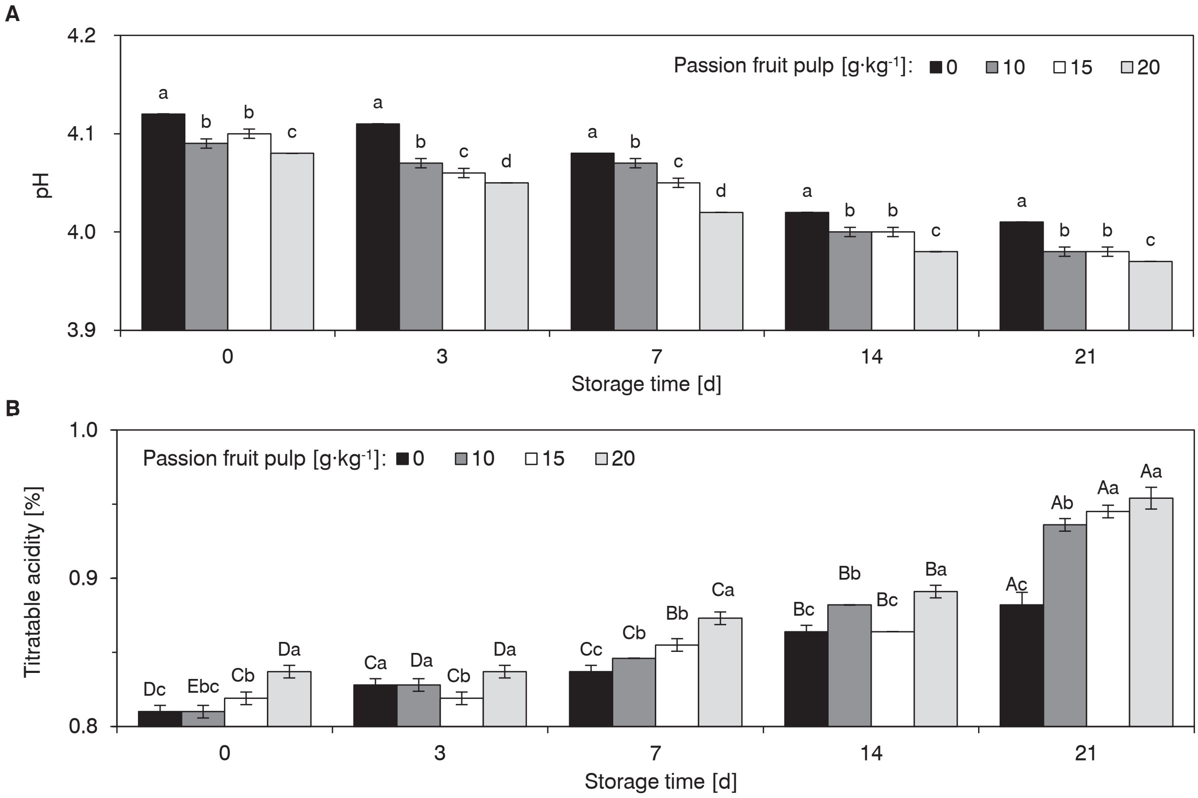

Fig. 1. Effects of added passion fruit pulp on pH and titratable acidity of goats' milk yogurt during storage.

A – pH, B – titratable acidity.
Lowercase letters (a–d) indicate significant differences between samples with different addition of passion fruit pulp during each storage period ($p < 0.05$). Uppercase letters (A–D) indicate significant differences between samples stored for a different time for each level of passion fruit pulp addition ($p < 0.05$).
Titratable acidity is expressed as percentage of lactic acid (titrated with 0.1 mol·l^{-1} NaOH).

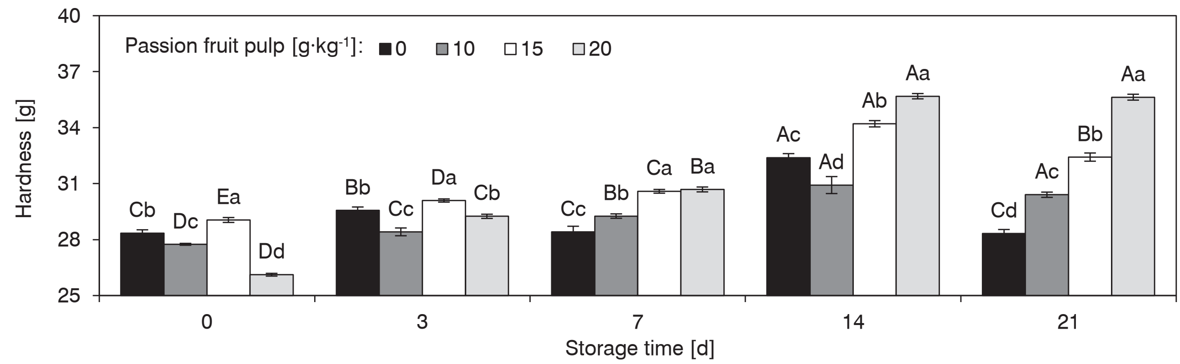

Fig. 2. Effects of added passion fruit pulp on hardness of goats' milk yogurt during storage.

Lowercase letters (a–d) indicate significant differences between samples with different addition of passion fruit pulp during each storage period ($p < 0.05$). Uppercase letters (A–D) indicate significant differences between samples stored for a different time for each level of passion fruit pulp addition ($p < 0.05$).

the change in viscosity of goats' milk yogurt during the storage period in this study.

Viscosity of goats' milk yogurt increased with the increase in passion fruit pulp content within two weeks of storage and was obviously higher than that of the control yogurt ($p < 0.05$; Fig. 3). Meanwhile, an increase in viscosity was clearly seen from the first day to 14 days ($p < 0.05$), except for 10 g·kg^{-1} passion fruit pulp addition at the first three days. These results indicated that passion fruit pulp may play a major role in the increased viscosity of the product by improving the hardness of gel formed during the fermentation process of goat milk due to the contained pectin. Pectin is well known as anionic hydrocolloid and can be classified as adsorbing polysaccharide, which interacts with the casein network, increasing its ability to prevent whey flowing out from the gel network structure [34]. The structure of the yogurt may be stabilized by positive interaction between pectin from fruit and exopolysaccharides produced by lactic acid bacteria [35, 36]. After two weeks' storage, the viscosity of goats' milk yogurt decreased compared to the control yogurt ($p < 0.05$), but remained still higher than the control sample. This may be due to the fibre contained in passion fruit which damaged the protein-protein interaction, resulting in a decrease in viscosity [36].

The effects of adding various amounts of passion fruit pulp on susceptibility to syneresis during the storage period are demonstrated in Fig. 4. Compared to the control yogurt, susceptibility to syneresis gradually increased with the increasing passion fruit pulp content, which was probably related to the solids and proteins content of the yogurt. Meanwhile, with the extension of the storage period, susceptibility to syneresis of goats' milk yogurt increased continuously, which may be due to that the fibre of passion fruit pulp physically destructed the protein network. Similar results were obtained by Wu et al. [37]. Some studies have also pointed out the occurrence of covalent or non-covalent interaction between polyphenols and proteins, which may affect the properties of yogurt with added rich polyphenol compounds [12].

Sensory evaluation

Consumer acceptance of goats' milk yogurt is generally low due to its "goaty" flavour. In this study, the sweet and edible passion fruit pulp was added to goats' milk to improve the fla-

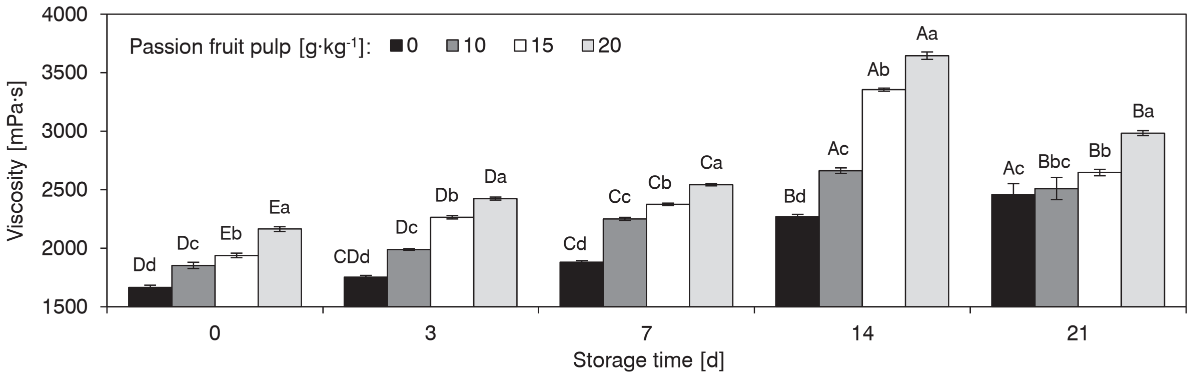

Fig. 3. Effects of added passion fruit pulp on viscosity of goats' milk yogurt during storage.

Lowercase letters (a–d) indicate significant differences between samples with different addition of passion fruit pulp during each storage period ($p < 0.05$). Uppercase letters (A–D) indicate significant differences between samples stored for a different time for each level of passion fruit pulp addition ($p < 0.05$).

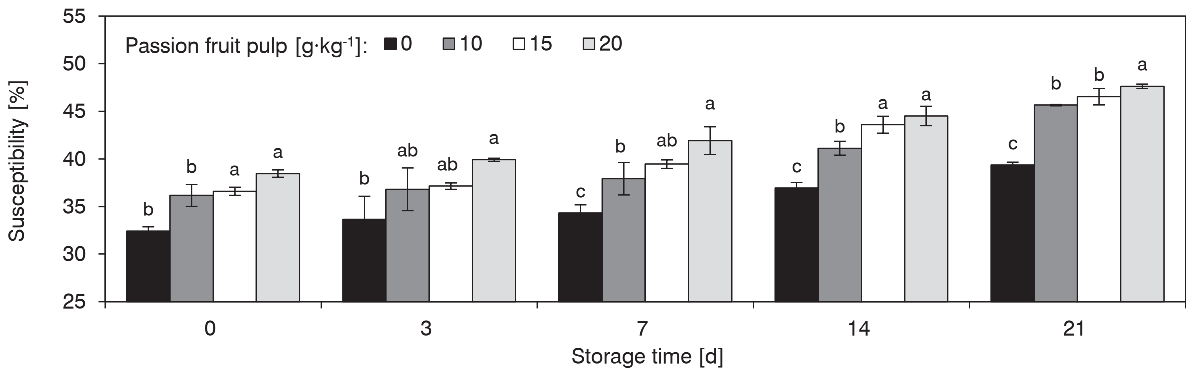

Fig. 4. Effects of added passion fruit pulp on susceptibility to syneresis of goats' milk yogurt during storage.

Lowercase letters (a–d) indicate significant differences between samples with different addition of passion fruit pulp during each storage period ($p < 0.05$).

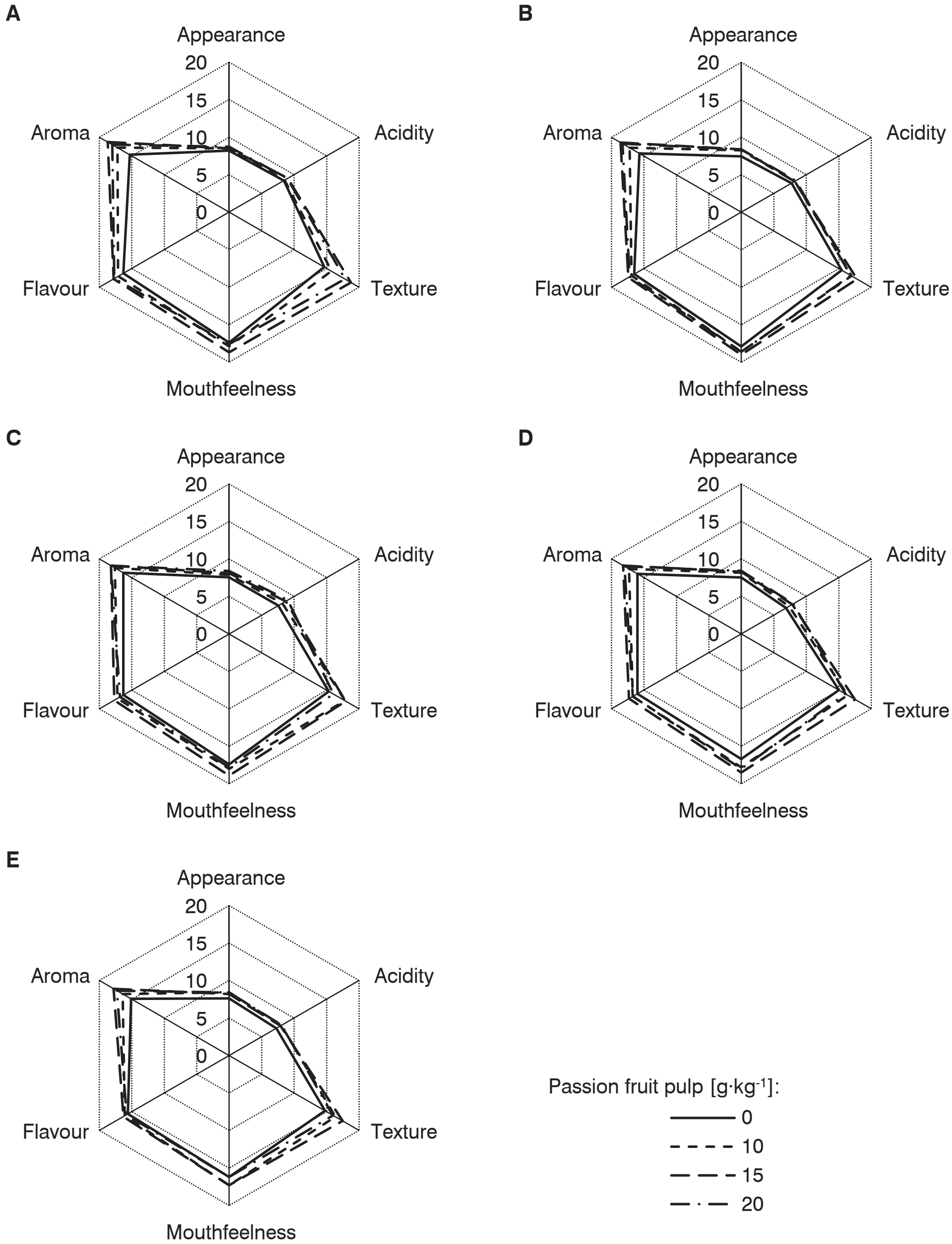

Fig. 5. Results of sensory evaluation of goats' milk yogurt with passion fruit pulp and control during storage.

A – storage time 0 days, B – storage time 3 days, C – storage time 7 days, D – storage time 14 days, E – storage time 21 days.

vour, aroma, texture and mouth feel of goats' milk yogurt. The results of the sensory analysis (Fig. 5) showed that all passion fruit pulp-containing yogurts were scored higher on average by the panellists than the control yogurt sample. On the one hand, with increasing amount of passion fruit pulp addition, the sensory score of goats' milk yogurt raised firstly and then dropped, and the score of goats' milk yogurt containing 15 g·kg^{-1} passion fruit pulp was the highest, indicating that the addition of passion fruit pulp can improve the flavour, texture and aroma of goats' milk yogurt. On the other hand, with the extension of the storage period, the sensory scores of goats' milk yogurt increased and then decreased, reaching a maximum value at 7 days. The sensory scores for texture, flavour and aroma of the passion fruit yogurt with 15 g·kg^{-1} passion fruit pulp addition was the highest, and the yogurt was sweet, sour and delicious with aroma of fresh passion fruits. Similarly, several previous studies found that the addition of fruit juice or pulp positively influenced the acceptance of goats' milk yogurt, improving its taste, texture and mouth feel, suggesting a positive influence of compounds naturally found in the fruits on these sensory attributes [10, 12, 31]. Recently, Ma et al. [38] reported that the addition of blue honeysuckle juice affected the microstructure and sensory score of fermented goats' milk and the fermented goats' milk with 40 $ml\cdot l^{-1}$ blue honeysuckle juice exhibited the highest overall acceptability.

Antioxidant activity of yogurts

Data on antioxidant activity of goats' milk yogurt with or without passion fruit pulp determined using the DPPH, $^{\bullet}OH$ radical and Fe^{3+} reduction method are shown in Fig. 6A, Fig. 6B and Fig. 6C, respectively. It can be seen from them that the DPPH and $^{\bullet}OH$ free radical-scavenging activities and Fe^{3+} reduction increased with extension of the storage period in all yogurt formulations, while the goats' milk yogurt with passion fruit pulp displayed stronger antioxidant activities than the control samples. The DPPH and $^{\bullet}OH$ radical-scavenging activity of goats' milk yogurt with 20 $g\cdot kg^{-1}$ passion fruit pulp addition reached 66.5 % and 52.3 % respectively on Day 0, then raised to 86.0 % and

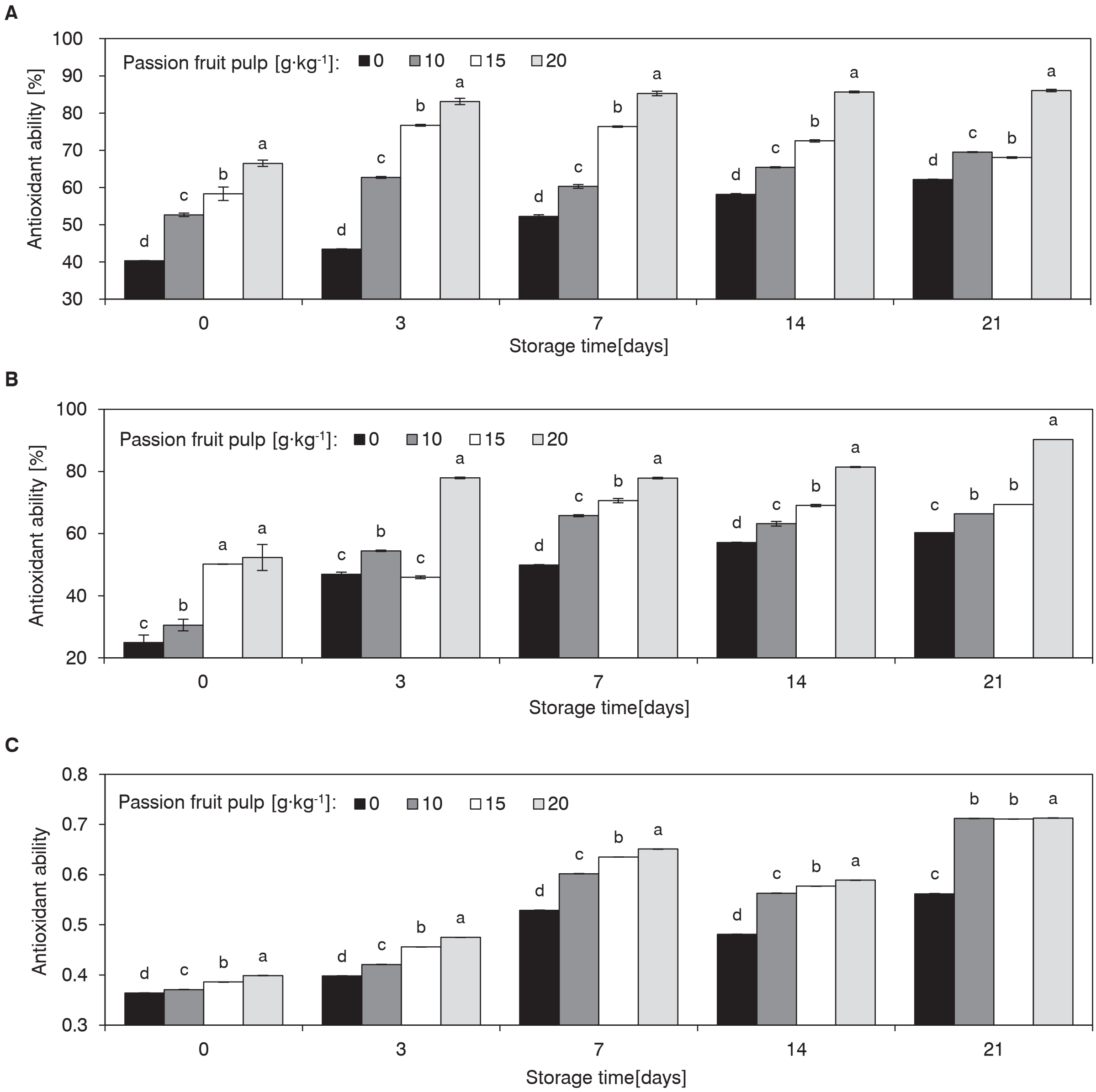

Fig. 6. Effects of added passion fruit pulp on antioxidant activity of goats' milk yogurt during storage.

A – DPPH radical scavenging ability, B – hydroxyl radical scavenging ability, C – ferric reducing antioxidant power.
Lowercase letters (a–d) indicate significant differences between samples with different addition of passion fruit pulp during each storage period ($p < 0.05$).
Ferric reducing antioxidant power is expressed as absorbance.

90.2 % after storage for 21 days, which was significantly higher than the values for the control sample (Fig. 6A, Fig. 6B). Meanwhile, the Fe^{3+} reducing power of goats' milk yogurt evidently increased with the increased addition of passion fruit pulp ($p < 0.05$) at the same storage time (Fig. 6C). It could also be seen that the Fe^{3+} reducing power of goats' milk yogurt with 20 $g \cdot kg^{-1}$ passion fruit pulp addition was 0.39 at Day 0 and reached 0.71 after storage for 21 days. This may because biologically active compounds in passion fruit are better electron donors [39], such as phenolic compounds, which was determined and shown in Tab. 1. The electrons provided can not only reduce Fe^{3+} to Fe^{2+}, but also directly react with free radicals to form more stable compounds. Thus, the goats' milk yogurt with passion fruit pulp showed high antioxidant activity regarding reduction of Fe^{3+} as well as DPPH and $^{\bullet}OH$ free radical scavenging.

In general, goats' milk yogurts exhibit antioxidant activities mainly due to the contained amino acids and small peptides with antioxidant activity produced during fermentation [10, 40]. This may explain the determined antioxidant activity of the control yogurt without passion fruit pulp addition. Furthermore, xanthones and other phenolic compounds were reported to effectively improve the antioxidant activities of goats' milk yogurt [10, 31]. The more passion fruit pulp was added, the higher DPPH free radical-scavenging activity and $^{\bullet}OH$ radical-scavenging activity was determined. This revealed that passion fruit pulp containing high amounts of polyphenols could greatly increase the antioxidant activity of goats' milk yogurt. So the biologically active substances produced by lactic acid bacteria at fermentation of goats' milk yogurt together with the active ingredients of the added passion fruit peel lead to a product exhibiting antioxidant activity. Therefore, goats' milk yogurt with passion fruit pulp could be a novel goats' milk-based dairy product with health benefits.

CONCLUSIONS

In the present study, the addition of passion fruit pulp appeared to directly influence the physico-chemical properties of the prepared goats' milk yogurt over the storage time. Goats' milk yogurt with passion fruit pulp addition had a better sensory acceptance, acidity, hardness, viscosity and syneresis. Likewise, the goats' milk yogurt formulation containing 15 $g \cdot kg^{-1}$ passion fruit pulp addition presented the best sensory properties. Furthermore, goats' milk yogurt with passion fruit pulp addition presented higher antioxidant activity compared to control sample. It is worth mentioning that DPPH scavenging activity and $^{\bullet}OH$ free radical-scavenging activity of goats' milk yogurt were improved in particular at 20 $g \cdot kg^{-1}$ passion fruit pulp addition. Such yogurt could be of potential interest as a food product with good nutritional and functional properties.

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