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ORIGINAL PAPER

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THE INFLUENCE OF HAWTHORN (*CRATAEGUS* SPP.) COMPOSITE ON THE FUNCTIONALITY AND QUALITY ATTRIBUTES OF STIRRED YOGURT

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ABSTRACT

Background. The aim of the study was to determine changes in the physicochemical and rheological properties, antioxidant activity and sensory attributes of stirred yogurts containing hawthorn composite (HC).
Materials and methods. In this study, the peel and pulp of hawthorn were used to obtain a composite which was incorporated into stirred yogurts in different concentrations (0.0 to 0.5% w/w) coded as Y_0, $Y_{0.1}$, $Y_{0.3}$ and $Y_{0.5}$. Acidification kinetics during yogurt production were evaluated, as well as sensory attributes at day 5 of storage, antioxidant capacity, physicochemical and rheological properties at days 1 and 21.
Results. Addition of 0.5% HC decreased the fermentation time from 8 (Y_0) to 5.80 h ($Y_{0.5}$). The incorporation of HC generated higher protein, ash, and fiber concentrations in the yogurts. The syneresis of the yogurts with added HC decreased by 18.0% compared to Y_0. The flow behavior of the yogurts was described by the Ellis model ($R^2 = 0.99$), where η_0 and λ exhibited higher values as the HC concentration increased. The highest percentage of inhibition was 53 ±1.50 % ($Y_{0.5}$), and the lowest was 39.57 ±0.62 % (Y_0), maintaining antioxidant activity at the end of storage. Yogurts $Y_{0.1}$ and $Y_{0.3}$ obtained an overall acceptability of 3.92 ±0.79 and 4.12 ±0.72 on a 5-point scale.
Conclusion. These results suggest that hawthorn composite (HC) can serve as a functional ingredient in fermented dairy products such as stirred yogurt. The addition of HC reduced total fermentation time and improved the yogurt's physicochemical, antioxidant and sensory properties.

Keywords: sensory attributes, hawthorn fruits, antioxidant ability, syneresis, rheology

INTRODUCTION

The *Crataegus* genus belongs to the Rosaceae family. It is a perennial tree found throughout the northern hemisphere, mainly in Asia, Europe, and North America (Nieto-Ángel et al., 2009). In 2023, 5,355.4 tons were produced in Mexico (SIAP, 2023). It is considered a crop for the production of liqueurs, jellies, and jams and it is also used as an emulsifier, a microcapsule wall agent, in the formulation of dietary supplements, in functional foods and in pharmaceuticals (Zhang et al., 2022). Hawthorn fruits have potential applications

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in the regulation of glucose and lipid metabolism, the alleviation of inflammatory responses, and the modulation of gut microbiota. These benefits are linked to the rich supply of phenolic compounds in hawthorn fruits (Li et al., 2023). These compounds can be classified into procyanidins, flavonoids, phenolic acids, lignans, and others based on their chemical structures. Procyanidins, especially oligomeric procyanidins, are the main phenolic compounds in the pulp and peel of hawthorn fruits. The major components of procyanidins are the monomer epicatechin and the dimer procyanidin B2, which contain 1.93–11.7 mg/g dry matter and 2.06–12.36 mg/g dry matter, respectively. Hawthorn fruits are also rich in pectin (9.94–19.10%) with higher viscosity and better emulsification and stability than commercial citrus and apple pectin (Li et al., 2021).

Yogurt is a fermented dairy product obtained by the lactic acid fermentation of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. Yogurt has recently been reported to have particularly high nutritional value, as well as antimicrobial, anticancer, and blood cholesterol-fighting properties (Cho et al., 2020b). However, yogurt tends to exhibit syneresis, which is considered a defect due to whey separation (Paz-Díaz et al., 2021). The structure of yogurt is most often controlled by the addition of stabilizers, but hawthorn composite has never been used as a yogurt stabilizing agent. The most commonly used stabilizers in yogurt are polysaccharide hydrocolloids. Along with casein micelles, they cooperate in forming 3D gel networks which maintain the aqueous phase. Pectin is a prevalent hydrocolloid utilized in this way, and it has been observed that pectin adsorbs on caseins at the beginning of acidification, so that it affects conformation of the casein micelles in the pH range 5.0–5.8. By lowering the pH or increasing the pectin concentration, the zeta (ζ) potential becomes more negative. Thus, the yogurt's stability is enhanced due to strong steric repulsion generated between pectin chains (Paz-Díaz et al., 2021).

Given these considerations, the objective of this work was to evaluate the effects of the addition of hawthorn composite on the physicochemical, mechanical, antioxidant and sensory preference properties of stirred yogurt.

MATERIALS AND METHODS

Preparation of hawthorn composite (HC)

10 kg of hawthorn (*Crataegus* spp) fruits of variety DOAR 02 (Fig. 1) were collected from the Germplasm Bank of the Universidad Autonoma Chapingo (coordinates 19°29'N, 98°53'W) (Texcoco, State of Mexico, Mexico). The fruits were washed with a 2% w/v sodium hypochlorite solution and then blanched at 80°C for 10 min, and the seeds were manually removed. The pulp and peel (100 g) were homogenized in a food grinder (mod. 465-15/13 2V, 500W motor, Osterizer, Sunbeam Mexicana, SA de CV, Mexico City, Mexico) for 3 min. Finally, the composite was manually crushed in a mortar until a uniform composite was obtained, which was packaged in hermetically sealed bags and stored at –25.9°C in a freezer (LABH-17-FM, LabRepco, Pennsylvania, USA) (Senadeera et al., 2018).

Fig. 1. Fruits of hawthorn (*Crataegus* spp) variety DOAR 02

Physicochemical characterization of hawthorn composite.

The pH values of the HC were obtained using a potentiometer (pH 120, Conductronic, Puebla, Mexico); moisture, titratable acidity and ash content were calculated according to AOAC methods (1996). The protein content was estimated by the Lowry method (Lowry et al., 1951). An ethanolic extract was obtained following the method reported by Vit et al. (2014). The ethanolic extract was used to estimate the total content of sugars, phenolic compounds, and antioxidant activity. Total sugars were quantified by the phenol/sulfuric, Folin-Ciocalteu reagent (Sigma-Aldrich México, Toluca, State of Mexico, Mexico) was used to determine the total polyphenol content (TPC) and the antioxidant activity was determined using the free radical DPPH$^{\bullet}$ (2,2 Diphenyl-1-picrylhydrazyl) (Sigma-Aldrich México, Toluca, State of Mexico, Mexico), the methods of Franco-Mora et al. (2010) were followed.

Preparation of yogurt variants

HC dispersions were hydrated (0.1, 0.3, and 0.5% w/w) at 35 ±1°C applying magnetic stirring for 30 minutes. Subsequently, whole milk powder (NIDO, Nestlé S.A. de C.V., Mexico) was added (40 ±1°C, using a water bath with moderate stirring) until 3.2 ±0.1 g of milk fat/100 g and 12.0 ±0.1 g of total milk solids/100 g had been obtained. A treatment without the addition of HC was also prepared as a control (Y_0). The method of Ramírez-Santiago et al. (2010) was followed for the preparation of the yogurts.

Fermentation kinetics

pH and titratable acidity values were monitored every hour during yogurt fermentation in a thermostat (HS-41, Riossa Digital, Ciudad de México, México). The kinetic parameters V_{MAX} (maximum acidification rate, expressed in pH units × 10^{-3}/min), t_{MAX} (time to reach maximum acidification rate; h), $t_{pH5.0}$ (time to reach pH 5.0; h), and t_f (total fermentation time; h) were calculated as indicated (Kwon et al., 2019).

$$V_{\max} = \left(\frac{dpH}{dt}\right)_{\mathrm{MAX}} \qquad (1)$$

where

dpH = pH change
dt = time change.

Proximate composition of yogurt variants

After three days of storage, the chemical composition of the yogurt variants was analyzed. The oven-drying, Kjeldahl, and Gerber methods were employed to determine sample moisture, protein, and fat content, respectively. The ash content was quantified by muffle incineration at 550°C, and the crude fiber content was calculated by the AOAC method 2009.01 (1996).

pH, titratable acidity, and syneresis of yogurts

pH and titratable acidity were evaluated following the method described by Cho et al. (2020a). The percentage of syneresis was calculated as the supernatant generated after centrifugation (222 × g/10 minutes) of 14 g of yogurt and expressed as % by weight (Cho et al., 2020b).

Rheological analysis

A Physica rheometer, MCR 301 (Anton Paar, Dynamic Shear Rheometer, Messtechnik, Stuttgart, Germany) equipped with a cone-plate geometry (1° cone angle, 50 mm diameter with a gap of 0.05 mm) was used for rheological analysis. The yogurt samples were carefully transferred into the measuring system and allowed to stand for 15 min at 4°C. Flow curves of the yogurts were obtained by varying the shear rate from 10^{-3} to 10^{3} s^{-1} and the corresponding apparent viscosity values of the yogurts were measured. The flow curve data were fitted to the Ellis model (Hernández-Rodríguez et al., 2017).

$$\eta = \frac{\eta_0}{[1 + (\lambda\gamma)^2]^p} \qquad (2)$$

where

η = apparent viscosity
γ = shear rate
η_0 = viscosity at low shear rate
λ = constant time associated with the relaxation time of the biopolymers in solution
p = shear thinning index.

Antioxidant activity

The method reported by Cho et al. (2020a) was followed. The results were expressed as a percentage of inhibition of the DPPH$^{\bullet}$ radical.

$$\%\ \text{inhibition} = \left(\frac{AC - AA}{AC}\right) \times 100 \qquad (3)$$

where

AC = control absorbance

AA = absorbance of yogurt with HC.

Sensory evaluation

Aged five days, the yogurt variants were evaluated by untrained panels made up of 20 males and 20 females, aged between 20 and 30 years old, who received training on the properties of yogurt products. Each of the variants was placed into a 20 mL plastic glass, coded with a three-digit random number, and randomly presented to the panelists, who were asked to score their preference for aroma, appearance, creaminess, acidity, graininess, flavor, aftertaste, and overall acceptability (Ghasempour et al., 2020). Each consumer's yogurt preference was scored on a five-point hedonic scale (1 = Dislike very much, 2 = Dislike moderately, 3 = Neither like nor dislike, 4 = Like moderately, and 5 = Like very much) (Hernández-Rodríguez et al., 2017).

Statistical analysis

All experiments were performed in triplicate with independent samples using a randomized experimental design. The data were analyzed using an ANOVA, and the Tukey test was used for comparison of means with a significance level of $p \leq 0.05$ using the *R* statistical package, version 4.2.0.

RESULTS AND DISCUSSION

Hawthorn composite characterization

The HC had a moisture content of 69.5 ±0.9%. The pH and titratable acidity results (4.0 ±0.1 and 0.4 ±0.05 g malic acid/100 g, respectively) indicated that the HC was acidic. The total sugar content was 83.4 ±0.6 mg/g, and the soluble protein content was 0.3 ±0.0%. Franco-Mora et al. (2010) reported similar results (moisture 72.3 ±0.4%, 64–129 mg/g total sugars, and 3.0–4.5 pH) in hawthorn fruits; factors such as variety, production zone and maturity stage determine the precise composition. HC exhibited a TPC of 22.3 ±0.1 mg of EAT/g, although Franco-Mora et al. (2010) (8.1–22.3 mg tannic acid/g) previously indicated that only 6% of hawthorns exceeded values of 20 mg tannic acid/g fresh weight of pulp. Tannic acid/g content higher than 20 mg in HC can be attributed to polyphenols provided by the peel (procyanidins) and pulp, genetic and environmental factors. The percentage inhibition of HC was 54.3 ±0.2%, a result similar to that reported for ethanolic extracts of hawthorn fruits (20.5–51.5%). DPPH radical scavenging activity has previously been reported to be directly correlated with TPC and the arrangement of the hydroxyl groups in these compounds (Li et al., 2022)

Fermentation kinetics

The addition of HC increased V_{MAX} ($Y_{0.5}$) and reduced the time to reach $t_{ph\ 5.0}$ and t_F up to 1.6-fold compared to Y_0 (Fig. 2). $Y_{0.5}$ reached V_{MAX} in the fourth hour of fermentation, while the control reached it after six hours. Also, $Y_{0.5}$ had the highest value of V_{MAX}, requiring less time to complete fermentation, and presented a decrease of 26% and 27.5% in $t_{pH\ 5.0}$ and t_F, respectively. Similarly, Kwon et al. (2019) and Oh et al. (2016) reported similar increases in fermentation kinetic parameters in yogurts supplemented with chia and *Cudrania tricuspidata* seed extracts, respectively. Higher levels of HC produced greater changes in the fermentation kinetic parameters of the yogurts. This may be due to the fiber and polyphenols (acid chlorogenic) contributed by the composite (Herrera et al., 2023), which serve as prebiotics and promote the growth of

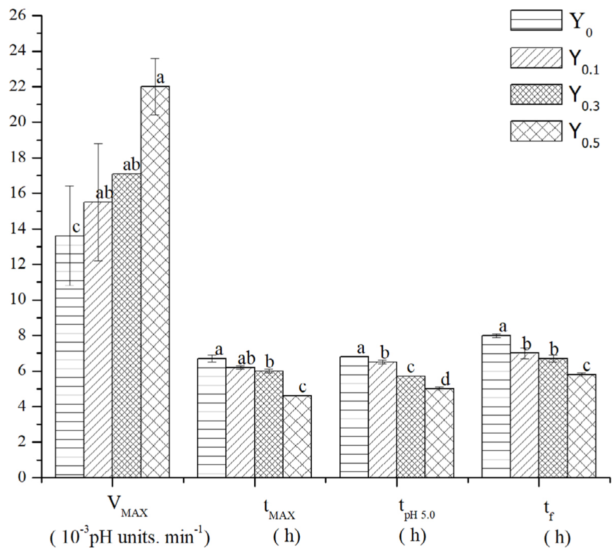

Fig. 2. Acidification kinetics during the preparation of yogurts; Y_0 (control without addition of HC); $Y_{0.1}$, $Y_{0.3}$, $Y_{0.5}$ (0.1%, 0.3%, and 0.5% w/w of added HC respectively)

lactic acid bacteria (Moradi et al., 2023). An increase in lactic acid bacteria leads to a more rapid decrease in pH during yogurt fermentation and reduces the time required to reach pH 5.0 and the total fermentation time (Oh et al., 2016).

Chemical composition of yogurt variants

The fat percentages of the variants were in the range 2.09 ±0.14–2.24 ±0.02% and did not show significant differences. The incorporation of HC significantly increased the protein content in $Y_{0.3}$ and $Y_{0.5}$ (3.5515 ±0.02 and 3.5525 ±0.05 % respectively), possibly due to the amount of protein present in HC. Another significant variation was observed in crude fiber content since $Y_{0.5}$ (0.1 ±0.02 %) presented double the amount of fiber compared to the control Y_0 (0.05 ±0.01%), probably due to the pectin provided by the hawthorn fruit (3% in pulp; Cuevas-Bernardino et al., 2016). Similarly, the ash content was significantly higher in $Y_{0.5}$ (0.75 ±0.02 %), probably due to the minerals provided by the HC (0.4 ±0.0%).

Changes in pH, titratable acidity (TA), and syneresis of yogurts depending on HC addition

On day one, the yogurts with the highest amount of HC presented the highest acidity levels (Table 1), which can possibly be explained by the presence of organic acids in the HC that caused the acidification of the yogurts. The same behavior has previously been reported in yogurts enriched with apple pomace (Wang et al., 2019). At day 21, there was a significant increase in acidity in all variants. This trend may be related to the conversion of lactose to lactic acid by lactic acid bacteria. It is important to note that yogurts supplemented with HC showed higher acidity (Table 1), results that are congruent since these variants showed higher acidification rates (Fig. 1), possibly due to the contribution of dietary fiber, total sugars and polyphenols present in HC, which generate an increase in the metabolic activity of lactic acid bacteria. The same behavior has been reported in yogurts with fruit incorporation (Cho et al., 2020b). Syneresis is considered a defect due to whey separation, which causes the presence of two phases in yogurt (Paz-Díaz et al., 2021). On day one, a general trend of reduction in the percentage of syneresis was observed in the varieties with HC compared to Y_0 (Table 1). The lower percentage of syneresis may be related to the pectin added by the HC, since it has been reported that pectin solubilizes during the heating phase and adsorbs on the surface of casein micelles, giving it better stability and reducing syneresis in yogurt (Wang et al., 2019). On day 21. there was an increase in the degree of syneresis. According to Cho et al. (2020a), an increase in acidity causes rearrangements in the casein network, leading to a higher percentage of syneresis during storage. During this period, only $Y_{0.1}$ did not show a significant difference in the percentage of syneresis, while Y_0 and $Y_{0.5}$ exhibited the highest percentages. The $Y_{0.5}$ variant may experience increased syneresis due to the insoluble

Table 1. pH, percentage of lactic acid and syneresis of yogurts

Parameter	Day	Y_0	$Y_{0.1}$	$Y_{0.3}$	$Y_{0.5}$
pH	1	4.20 ±0.00^{Da}	4.16 ±0.00^{Cb}	4.12 ±0.00^{Bb}	4.10 ±0.00^{Ab}
	21	4.20 ±0.00^{Da}	4.15 ±0.00^{Ca}	4.10 ±0.00^{Ba}	4.07 ±0.00^{Aa}
% Lactic acid	1	0.95 ±0.02^{Aa}	0.96 ±0.02^{Ba}	0.97 ±0.00^{Ba}	1.03 ±0.01^{Ca}
	21	1.17 ±0.01^{Ab}	1.21 ±0.01^{Bb}	1.28 ±0.04^{Bb}	1.37 ±0.02^{Cb}
% Syneresis	1	9.50 ±0.90^{Ba}	6.02 ±0.70^{Aa}	7.16 ±0.30^{Aa}	7.10 ±0.80^{Aa}
	21	12.65 ±0.40^{dB}	6.08 ±0.40^{Aa}	8.20 ±0.09^{Bb}	10.30 ±0.02^{Cb}

Abbreviations: Y_0 – control; $Y_{0.1}$, $Y_{0.3}$, and $Y_{0.5}$ – yogurt with the addition of 0.1%, 0.3%, and 0.5% w/w of HC, respectively.
Different letters (a, b) in the same column and (A, B) in the same row indicate a significant difference between treatments ($p < 0.05$).

fiber of the HC, which can disrupt the gel structure and cause more syneresis. Our findings are consistent with previous studies on yogurts containing 0.5% and 1% w/w apple pomace, which showed a 29% increase in syneresis compared to treatments with lower concentrations of apple pomace (0.1%) (Wang et al., 2019).

Rheology of yogurts

Figure 3 shows the flow properties of the yogurts. All treatments exhibited a Newtonian region at low shear rates (0.0009–0.00133 1/s) followed by a shear thinning region at intermediate shear rates (0.00133–100 1/s). The same behavior has been reported for yogurts enriched with carrot fiber (Venica et al., 2020). At low shear rates, the Brownian force acts by randomizing the particles, forming aggregates, and maintaining constant viscosity. However, as higher shear rates are reached, the interactions between the chains of molecules are interrupted, decreasing the viscosity.

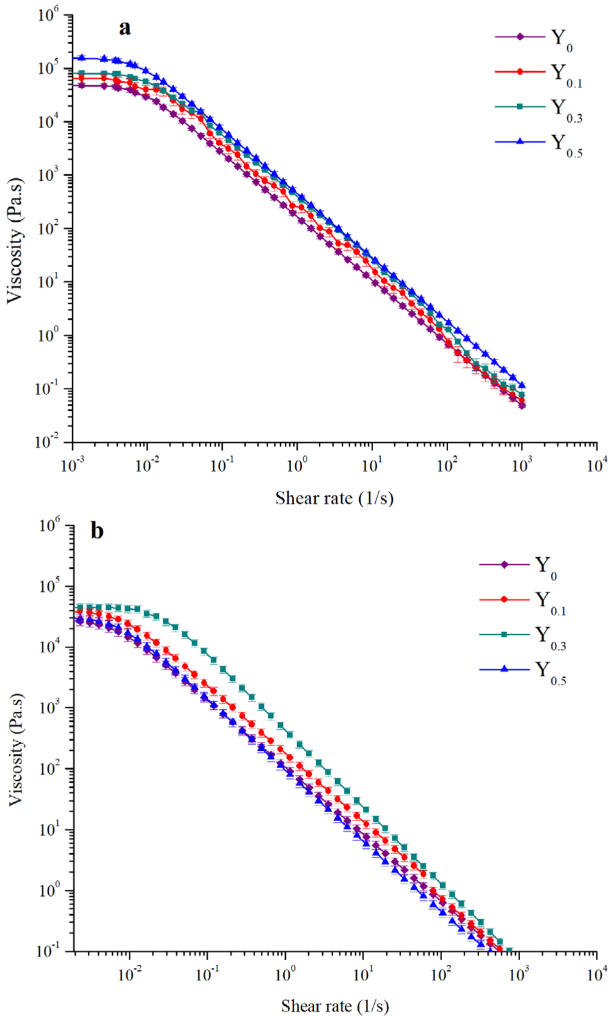

Fig. 3. Flow curves of yogurts on day 1 (a) and day 21 (b) of storage at 4°C; Y_0 (control without addition of HC); $Y_{0.1}$, $Y_{0.3}$, $Y_{0.5}$ (0.1%, 0.3%, and 0.5% w/w of added HC respectively)

The experimental data of the flow curves were fitted to the Ellis model (R^2>0.99) (Table 2).

On day one, $Y_{0.5}$ exhibited the highest values of η_0, p, and λ. These results suggest that at a higher concentration of HC, the interactions of pectin and polyphenols of HC with the casein network could be intensified, giving rise to a stronger and viscous gel (η_0) (Khubber et al., 2021). Additionally, the three-dimensional network required more time and energy to disintegrate (λ) (Cuevas-Bernardino et al., 2016),with a more pronounced shear-thinning behavior ($p < 1$).

This suggests that yogurts containing HC improved drag resistance and viscosity dissipation to a greater extent by day one. On the 21st day of storage, all yogurts showed a significant decrease in η_0. A similar decrease in this rheological parameter has been reported in a previous paper, which attributed it to the rearrangement of gel particles (Mokoonlall et al., 2016). $Y_{0.5}$ and Y_0 had the lowest values of η_0 and the highest percentages of syneresis during this storage period (Table 1). A relationship between increased syneresis during storage and decreased η_0 has been reported. This is due to the breakdown of gel particles, which affects viscosity and increases syneresis (Guénard-Lampron et al., 2020). On the other hand, regarding the parameter p, Rao (1999) reported that it tends towards a value of 1-n, where n represents the power law flow rate (Cuevas-Bernardino et al., 2016). Therefore, higher values of p correspond to lower values of n, resulting in more extensive shear thinning behavior. It is worth noting that all yogurts exhibited p-values less than 1, indicating more extensive shear thinning behavior (Cuevas-Bernardino et al., 2016).

Antioxidant activity

$Y_{0.5}$ (50.99 ±2.28%) exhibited the highest percentage of inhibition, probably due to the TPC present in HC. Similar results have been reported for yogurts with olive leaf extracts. As the extract concentration

Table 2. Rheological parameters of the Ellis model

Parameter	Day	Y_0	$Y_{0.1}$	$Y_{0.3}$	$Y_{0.5}$
η_0 (Pa.s)	1	44 193 ±309[a]	49 996 ±1221[b]	69 501 ±341.5[c]	82 225 ±155.5[d]
	21	30 210 ±1435[a]	39 491 ±31.8[b]	54 912 ±152.7[c]	30 863 ±986.1[a]
p	1	0.55 ±0.00[a]	0.58 ±0.01[ab]	0.58 ±0.01[ab]	0.59 ±0.00[b]
	21	0.55± 0.00[a]	0.58± 0.00[ab]	0.56± 0.00[ab]	0.56± 0.00[ab]
(s)	1	118.3 ±1.9[a]	121.3 ±4.3[b]	148.9 ±0.9[b]	158.6 ±1.1[d]
	21	118.3 ±1.9[a]	147.1 ±2.9[b]	148.9 ±0.9[b]	136.9 ±2.8[a]

Abbreviations: Y_0 – control; $Y_{0.1}$, $Y_{0.3}$, and $Y_{0.5}$ – yogurt with the addition of 0.1%, 0.3%, and 0.5% w/w of HC, respectively.
Different lowercase letters in the same row are significantly different ($p < 0.05$).

increased, the antioxidant activity increased by 39%. Although the increase in antioxidant activity is a function of the concentration of the functional ingredient added, the structure of the polyphenols could influence antioxidant activity (Cho et al., 2020b). On the other hand, the antioxidant activity exhibited by Y_0 (40.44 ±0.08 and 39.57 ±0.62%, day 1 and 21, respectively) can be attributed to peptides identified in the protein sequence of the four caseins (β, κ-, αs1-, and αs2--casein) which are responsible for the antioxidant and antimicrobial activity (Nielsen et al., 2022) produced during the fermentation process (Cho et al., 2020b). It is important to note that for all yogurts, the antioxidant activity did not undergo statistically significant changes during storage, which can be attributed to the fact that lipophilic-phase antioxidants are more stable during refrigeration (Najgebauer-Lejko et al., 2014). This represents a positive aspect for this research.

Sensory evaluation

The incorporation of HC could provide fiber such as pectin, improving water holding capacity and viscosity in yogurt. However, adding higher levels of HC ($Y_{0.5}$) may result in increased graininess (Table 3) and inadequate mouthfeel due to the particles, which can negatively affect consumer acceptability (Ardabilchi Marand et al., 2020). A relationship between flavor and acidity has been reported, as both influence sensory acceptability (Al-Shawi et al., 2020). The accumulation of organic acids can have a negative impact on the flavor score. $Y_{0.5}$ had the highest percentage of lactic acid (Table 1), which could adversely affect the taste perceived by the panelists, resulting in low scores for acidity and flavor attributes (Table 3).

This phenomenon has previously been reported in yogurts supplemented with flaxseed, where treatments with lower acidity received higher scores for acidity

Table 3. Sensory evaluation of yogurts on day five

Treatment	Aroma	Appearance	Creaminess	Acidity	Granularity	Flavor	Residual flavor	Global acceptance
Y_0	3.2 ±1.2[a]	3.0 ±1.3[b]	2.5 ±1.2[b]	3.3 ±1.3[b]	3.5 ±1.1[a]	2.5 ±1.1[c]	2.9 ±1.3[b]	3.4 ±1.3[b]
$Y_{0.1}$	3.5 ±1.2[a]	3.6 ±1.0[a]	3.5 ±1.3[a]	3.5 ±1.4[b]	3.2 ±1.3[ab]	3.5 ±1.1[b]	3.3 ±1.1[a]	4.0 ±0.8[a]
$Y_{0.3}$	3.4 ±1.2[a]	3.8 ±1.1[a]	3.6 ±1.2[a]	3.7 ±1.2[a]	2.8 ±1.2[b]	4.2 ±0.7[a]	2.9 ±1.2[b]	4.1 ±0.7[a]
$Y_{0.5}$	3.2 ±1.2[a]	2.4 ±0.7[c]	2.7 ±0.9[b]	2.1 ±1.1[c]	2.2 ±1.2[c]	2.2 ±1.3[c]	2.1 ±1.2[c]	3.2 ±1.4[b]

Abbreviations: Y_0 – control; $Y_{0.1}$, $Y_{0.3}$, and $Y_{0.5}$ – yogurt with the addition of 0.1%, 0.3%, and 0.5% w/w of HC, respectively.
Values correspond to mean ±SD (n = 3). Data with different lowercase letters in each row are significantly different ($p < 0.5$).

acceptability from a panel of evaluators (Ardabilchi Marand et al., 2020). $Y_{0.1}$ and $Y_{0.3}$ had the best appearance scores, which was expected due to their low percentages of syneresis (Table 1) and superior rheological parameters (Table 2). These characteristics indicate a better structure that was visually detected by the panelists. $Y_{0.1}$ and $Y_{0.3}$ obtained the best overall acceptability.

CONCLUSIONS

This study is the first report on the production of hawthorn composite (HC) and its application in the production of stirred yogurt. The addition of HC reduced the total fermentation time by 27.5%. Yogurts with HC showed significant increases in protein, soluble fiber, and ash content. The addition of soluble fiber and polyphenols strengthened the structure of the yogurts, resulting in higher viscosity values (η_0) and leading them to require more time and energy to disintegrate (λ). The addition of HC to the yogurt structure reduced syneresis by up to 31% during storage for $Y_{0.1}$. This improvement positively affected sensory evaluation, with $Y_{0.1}$ and $Y_{0.3}$ receiving the highest overall acceptability ratings. $Y_{0.3}$ and $Y_{0.5}$ exhibited the highest percentages of DPPH radical inhibition during the twenty-one days of storage. These findings suggest that hawthorn composite can serve as a functional ingredient in fermented dairy products, such as stirred yogurt.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

DECLARATIONS

Data statement

All data supporting this study has been included in this manuscript.

Ethical Approval

Not applicable.

Competing Interests

The authors declare that they have no conflicts of interest.

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