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Development of a Stirred Yogurt Enriched with Carob Syrup and Powder

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Abstract

Yogurt is a widely consumed dairy product appreciated for its taste, nutritional quality, and versatility. Carob (Ceratonia siliqua L.), a naturally gluten-free leguminous fruit, is rich in sugars, dietary fiber, and antioxidant compounds. Its consumption is associated with several health benefits, including weight management, relief from digestive disorders and diarrhea, and potential protective effects in individuals with hypertension or kidney stones. Recognized as safe by the U.S. Food and Drug Administration (FDA), carob represents a valuable functional ingredient.

This study aimed to evaluate the incorporation of carob powder and syrup into yogurt to develop a functional dairy product with improved nutritional and physicochemical properties. Three formulations were prepared: a control E (without carob), E1 (1% powder, 15% syrup), and E2 (3% powder, 9% syrup). E1 showed the highest acidity, °Brix, and viscosity, reflecting the strong structuring effect of combined carob powder and syrup. E2 exhibited intermediate values, while the control had the lowest measurements.

The results demonstrate that carob addition enhances yogurt's nutritional profile, texture, and overall quality. The strategic combination of powder and syrup provides both functional and technological benefits, creating a marketable product that aligns with consumer preferences and health-promoting properties

Keywords: *carob powder, carob syrup, functional yogurt, physicochemical analysis, sensory evaluation*

I. Introduction

The carob tree (Ceratonia siliqua L.) is a leguminous species cultivated throughout the Mediterranean region for its drought tolerance and versatile fruit (Biner et al., 2007; Avallone et al., 1997). In Algeria, it primarily grows in northern areas (Boublenza et al., 2019) and has recently attracted attention in the food industry due to its functional properties. Carob syrup, rich in sugars, serves as an energy source, while carob powder can be used as a caffeine-free cocoa substitute with favorable sensory characteristics (Tetik et al., 2011; Ayaz et al., 2009). Despite its potential, carob remains underutilized in dairy products in Algeria, particularly in the Bejaia region. The fermented yogurt sector,especially stirred yogurt, is expanding rapidly because of its soft, homogeneous texture and widespread consumer acceptance. This texture makes it suitable for incorporating functional ingredients such as carob. Previous studies have mainly focused on carob pods or single ingredients in dairyformulations. The present work aims to develop an innovative stirred yogurt enriched with both carob powder and syrup, evaluating its physicochemical and sensory properties. This approach explores the synergistic effects of combined carob ingredients, offering a new strategy to enhance yogurt's nutritional value, texture, and consumer appeal.

II. Material and methods

1. Preparation of Carob Powder: Carob pods were first cleaned by rinsing with cold water to remove dust and impurities. The pods were then spread on a tray lined with aluminium foil and dried in an oven at 40 °C until brittle, preventing bacterial growth and preserving the nutritional quality of the carob. After drying, the pulp was separated from the seeds and cut into smaller pieces. The pulp was then ground using a mortar and pestle to obtain a fine powder, which was finally sieved through a 250 µm mesh to ensure uniform particle size.

2. Physico-chemical analysis:

Carob powder: Titratable acidity was measured according to NF V 05-101 (1974). The pH was then determined by dissolving 1 g of powder in10 mL of distilled water using a calibrated glass electrode (NF V 05-108, 1970). Moistureand ash content were determined following AACC methods 44-19.01 and 08-01.01 (2000), respectively. Total sugars were quantified using the method of Dubois et al. (1956), dietary fiber content was measured following AACC method 32-

10.01, and lipid content was determined according to ISO 659 (1998).**Carob syrup**: Titratable acidity was assessed as described above. The pH was measured directly using a glass electrode. Soluble solids (°Brix) were determined by refractometry (AFNOR, 1970), and viscosity was measured at 25 °C using a rotary viscometer and expressed in mPa·s.

3. Phytochemical analysis: The total phenolic content (TPC) of carob extracts was determined using the Folin-Ciocalteu colorimetric method (Singleton et al., 1999). Total Flavonoid ContentFlavonoids were quantified using the aluminum chloride method (Bahorun et al., 1996). Condensed tannins were determined using the vanillin-HCl method, based on the formation of a red-violet complex with ferric chloride (Mole and Waterman, 1987; Bate-Smith, 1973).

4. Stirred Yogurt Preparation: Milk used for yogurt preparation corresponded to a standard industrial formulation for stirred yogurt. The milk was enriched with skimmed milk powder to increase total solids and ensure appropriate texture, then homogenized at 150 bar to achieve uniform distribution of solids. Pasteurization was carried out at 85 °C for 5 min, followed by rapid cooling to 42 °C.

The milk was inoculated with a commercial lactic starter culture (*Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*). Fermentation was conducted in thermostatic tanks at 42 °C for 6 h. After coagulation, the yogurt was gently stirred to obtain a uniform consistency, and carob powder and syrup were added according to the formulations: E (control, without carob), E1 (15 g powder + 1 g syrup per 84 g base), and E2 (9g powder + 3 g syrup per 88 g base).

Finally, the yogurt was rapidly cooled to 4 °C to halt fermentation, portioned into sterile containers, and stored at 4 °C until physicochemical and sensory analyses were performed.

5. Enriched Yogurt Formulations: Three yogurt samples were prepared by incorporating carob powder and syrup into the yogurt base: E (Control) without carob, E1containing 3 g powder and 9 g syrup per 84 g base, and E2 containing 1 g powder and 15 g syrup per 88 g base.

6. Sensory Analysis: A panel of 16 healthy adult volunteers (10 men aged 29–47 and 6 women aged 21–48) evaluated the yogurt samples for overall appearance, texture, aroma, and taste (Lefebvre and Bassereau, 2003).

7. Statistical analysis: All data represent the average of three trials. For data processing, a statistical study was conducted using JMP software. The significance level of the results is taken at a probability of $p < 0.05$.

Theoretical package

Carob (Ceratonia siliqua L.) is rich in bioactive compounds, including polyphenols, flavonoids, and tannins, which contribute to antioxidant activity and potential health benefits. The Folin-Ciocalteu reagent is widely used to quantify total phenolic content because it oxidizes phenolic compounds, producing a blue complex whose intensity is proportional to phenolic concentration (Singleton et al., 1999). Similarly, flavonoids form yellow complexes with aluminum chloride through chelation of Al^{3+} ions, allowing spectrophotometric quantification (Bahorun et al., 1996; Ribéreau-Gayon and Gautheret, 1968).

The physicochemical properties of yogurt, such as viscosity and soluble solids (°Brix), are directly influenced by its composition, including added carob powder and syrup. Viscosity reflects the resistance to flow, affecting texture and mouthfeel, and is measured with a rotary viscometer (Decodts and Flamarion, 1985). Soluble solids measured by refractometry indicate sugar concentration, which is crucial for sweetness and overall sensory quality (AFNOR, 1970).

Understanding these principles provides a scientific basis for enriching yogurt with carob, predicting its impact on nutritional, physicochemical, and sensory properties, and guiding formulation strategies.

III. Results and discussion

1. Carob pulp powder composition: The analysis of carob pulp (Table 1) shows a mildly acidic pH of 5.2 ± 0.01 and titratable acidity of 4.8 ± 0.50%, reflecting its organic acid content. The pulp is rich in dietary fiber (13.97 ± 0.03%) and natural sugars (40.31±1.2), making it suitable for functional food applications. Moisture (10.02 ± 0.3%), ash (2 ± 0.4%), and lipid (1.02 ± 0.14%) contents indicate good stability and low-fat content. Bioactive compounds, including total phenolics (25.30 ± 2.1 mg/g), flavonoids (0.8± 0.06 mg/g), and tannins (2,99 ± 0.2 mg/g), suggest significant antioxidant potential, supporting the use of carob pulp to enhance both nutritional and functional properties in dairy products.

2. Physicochemical quality of carob syrup: The carob syrup exhibited a slightly acidic pH of 5.11 and a low titratable acidity of 0.88 ± 0.01%, indicating mild acidity suitable for food formulations. The °Brix value of 70.3% reflects a high sugar concentration, consistent with its function as a natural sweetener. The syrup viscosity was measured at 413.2 mPa·s, indicating a thick consistency that can influence texture and mouthfeel when incorporated into yogurt or other food products. Overall, these characteristics suggest that carob syrup can enhance sweetness, viscosity, and functional properties in enriched dairy formulations.

Tableau 1. Physicochemical properties of carob powder

Parameter	pH	Titratable acidity %	Fibres %	Moisture %	Ash %	Lipids %	Total sugar %	Polyphenols (mg/g)	Flavonoids (mg/g)	Tannins (mg/g)
Carob pulp	5,2±0,01	4,80±0,40	13,97±0,03	10,02±0,3	2±0,4	1,02±0,14	40,31±1.2	25,30 ± 2,1	0,8 ± 0,06	2,99 ± 0,2

Tableau 2. Physicochemical properties of carob syrup

Paramètre	pH	Acidité titrable %	Brix %	Viscosité CP (m.Pa.s)
Valeur	5,11	0,88±0,01	70,3	413,2

3. The physico-chemical characteristics of yogurt enriched with carob powder and syrup: The results are presented in Table 3. The chemical characteristics of theyogurt formulations differed significantly in pH, titratableacidity (°D**)**, °Brix, and apparent viscosity. The control formulation exhibited the highest pH (4.95 ± 0.05) and the lowest titratable acidity (73 ± 1 °D). Enrichment with carobpowder and syrup resulted in a decrease in pH and an increase in titratable acidity, consistent with the known inverse relationship between these parameters. Specifically, formulation E1 (1% powder, 15% syrup) had the highest titratable acidity (103.5 ± 1.5 °D**)** and a pH of 4.80 ± 0.10, whereas E2 (3% powder, 9% syrup) exhibited intermediate values (98 ± 1 °D, pH 4.79 ± 0.09). The slightly higher pH of enriched yogurts suggests that carob components modulate acid production during fermentation, likely through the buffering effect of its sugars and fibers as well as the activation of lactic cultures (Toker et al., 2013; Tounsi et al., 2019).

Tableau 3. Physicochemical properties of yoghurt enriched with carob powder and syrup.

Formulation	pH	Acidité °D	Brix	Viscosité cp (m Pa s)
E1(15%syrup -1%powder)	4,80±0,1 [b]	103,5± 1,5[a]	28,1±0,1[a]	18800±100[a]
E2 (9%syrup-3%powder)	4,79± 0,09 [ab]	98± 1 [b]	21,5± 0,5 [b]	16720± 120 [b]
E(control)	4,95±0,05[a]	73± 1 [c]	18± 0,1 [c]	3500± 100 [c]

Titratable acidity (°D) followed a similar trend: the increase in acidity of enriched yogurts can be attributed to enhanced growth of lactic acid bacteria promoted by carob fibers and phenolic compounds, which provide fermentable substrates and stimulate microbial activity (Radia et al., 2022; Öncel&Ozdemir, 2023).

The content of soluble solids (°Brix) increased with carob addition, reaching 28.1% in E1 compared to 18% in thecontrol. This increase reflects the contribution of sugars and galactomannans from carob syrup and powder, enhancing both the nutritional value and sensory properties of the yogurt (Tounsi et al., 2021). These carbohydrates also support lactic fermentation, contributing to the characteristic acidity and flavor.

The apparent viscosity increased markedly with carob enrichment: E1 reached 18,800 ± 100 mPa·s, E 16,720 ± 120 mPa·s, while the control had only 3,500 ± 100 mPa·s. This improvement is mainly due to galactomannans and soluble solids in carob syrup and powder, which enhance waterretention, reduce syneresis, and strengthen the yogurt matrix (Tounsi et al., 2021). The higher syrup content in E1 explains its superior viscosity despite E2 containing more powder.

Overall, carob enrichment improves the technological and functional properties of yogurt, including texture, stability, and sensory quality, demonstrating its potential as a natural functional ingredient.

4. The sensory evaluation of yogurts enriched with carob powder and syrup: The sensory evaluation revealed clear differences among the three formulations (E1: 1% powder + 15% syrup, E2: 3% powder + 9% syrup, E: control) in terms of appearance, texture, odor, and taste. In terms of appearance, E exhibited the highest homogeneity and a balanced level of particles and gloss, while E2 was the glossiest but showed lower homogeneity and more visible particles, and E1 appeared uniform and particle-free but less shiny. Texture analysis indicated that E was the creamiest and smoothest sample, E1 slightly less so, and E2 showed a slightly granular mouthfeel, which may be related to the higher addition of syrup and carob solids. Odor perception was mild in E1, moderate in E2, and strongest in E, reflecting the influence of the different syrup and powder proportions.

Regarding taste, all samples showed low acidity, but sweetness was highest in E and E2 andmoderate in E1, while bitterness was negligible overall.

Overall, these results demonstrate that higher syrup content enhances gloss, sweetness, and aroma intensity but may reduce homogeneity and smoothness, whereas higher powder content favors visual uniformity and a milder sensory profile. However, the control formulation (E3) provided the most balanced and harmonious combination of sensory attributes and was generally preferred. This finding highlights a trade-off between the improvement of functional properties through carob enrichment (higher fiber content, increased °Brix and viscosity) and the maintenance of optimal sensory quality, and should be carefully considered in future formulation strategies.To overcome this limitation, future formulations should focus on optimizing the level and ratio of carob syrup and powder, for example by testing intermediate or lower inclusion levels that maintain fiber enrichment while minimizing adverse effects on texture and sweetness. In addition, the use of complementary flavoring strategies (such as vanilla, fruit preparations or natural sweeteners) could help to enhance sweetness perception and mask potential off-flavors associated with carob. Finally, carob-enriched yogurt may be specifically positioned for health-conscious consumer segments who are more willing to accept fewer sweet products in exchange for higher fiber content and additional functional benefits

IV. Conclusions

This study characterized carob powder and syrup and assessed their impact on enriched yogurt. Carob powder, rich in fiber and phenolic compounds, provided structure and bioactive properties, while the syrup, with high °Brix and sugar content, enhanced sweetness, viscosity, and solids content. The combination of powder and syrup allowed modulation of yogurt physicochemical and sensory attributes, demonstrating that their proportions can be adjusted to optimize stability, nutritional value, and consumer acceptability. These results highlight the potential of carob as a functional ingredient in dairy products.

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