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Utilization of Carob Bean Pulp and Seeds in Preparing Functional Cup-Cake and Tortilla Bread

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ABSTRACT

Developing a technology to produce functional bakery products with increased nutritional value, considering the constantly growing number of people who, for health reasons, are forced to follow functional food, poses a challenge to the food business. Which encouraged to investigate the possibility of (i) utilizing roasted carob powder (130° C/ 30 min) from carob bean pulp as a natural sweetener to replace sugar at 0, 25, 50, and 75% in cacao cupcakes formula; (ii) utilizing carob bean gum from carob bean seeds as a by-product of pods in tortilla bread at 0, 0.5, 1.0 and 1.5%; and (iii) evaluating the sensory, physicochemical and texture properties of the produced cupcakes and gluten-free bread. Roasted carob powder had significant total phenols (205.53 mg/100g) and antioxidant activity (91.78%). The aqueous dispersion (1%) of carob bean gum showed pseudoplastic behavior with an apparent viscosity (***η***) from 2110 to 438.33 cP. Cupcakes with roasted carob powder up to 50% showed a significant increase in compositional nutrients of the protein, ash, and fiber and a non significant increase in appearance, crust color, crumb texture, odor, and acid value compared with the control sample. Gluten-free bread with carob bean gum up to 1% exhibited significant soft texture, shape symmetry, bright color, and higher overall acceptability. This study recommends the utilization of (i) roasted carob powder as a natural sweetener to replace sugar, which may suit a low glycemic diet, and (ii) carob bean gum as a binder in gluten-free bread, which can meet celiac patient needs.

1. Introduction

The production and development of foods that enhance human health pose a challenge to the food business. Additionally, it increases scientific curiosity about food ingredients with suitable nutritional, technological, and functional qualities that will raise the value of food. (Galanakis, 2021). Carob has attracted a lot of attention lately, mostly because it appears to be a food with practical and functional uses. In addition, it is a valuable crop for the economy due to its composition, nutrition, and industrial worth (Boublenza et al., 2017; Brassesco et al., 2021). Carob *(Ceratonia siliqua* L.) is a typical Mediterranean tree species introduced to the temperate regions of Central America, Australia, and Africa (Palaiogianni et al., 2022). Carob pods have a nutritional value of a high level of carbohydrate (67.48%), appreciable amounts of protein (6.64%) and low level of fat (2.24%), and dietary fibers (~11%). Also, carob is a rich source of minerals (Mg, Fe, P, Zn, Ca, K, Na) and significant amounts of phenolic compounds (gallic acid, tannins) and vitamins (D, E, C, B6, folic acid), (Higazy et al., 2018; Papageorgiou et al., 2020).

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The carob fruit, also called carob pod, generally consists of the pulp/ endosperm (80–90%) and the germ/ seed (10–20%) by weight , each one of which is used in a great variety of bakery products and as food additives and dietetic products (Tounsi et al., 2019; Palaiogianni et al., 2022). Crob powder can be produced from carob fruit pods after discharge of the seeds, followed by roasting at 120 and 180 °C (typically, 150 °C) for 10- 60 min to obtain several degrees of roasting (low, medium, and high roast) (Román et al., 2017; Papageorgiou et al., 2020). The roasted carob powder is sweeter, has a dense caramel-like taste, and has an extra cacao-like aroma at low-roasting temperatures. However, it has a more astringent taste, coffee-like flavor, and roasted aroma at a high roasting temperature. Besides, its low glycemic index food and low glycemic load make it a cocoa alternative and natural sweetener in bakery products, particularly cocoa-containing cake recipes and dietetic food (Román et al., 2017; Papageorgiou et al., 2020; Dos Santos et al., 2015; Loullis & Pinakoulaki 2018; Pawłowska et al., 2018; Castro-Muñoz et al.,2022) . That may fulfil the current trend for sugar reduction by 10 to 20% in bakery products, using novel strategies such as replacing added sugar with natural sweeteners, bulking agents, intensive sweeteners, and/or sweet bulking ingredients, especially the demand for naturally derived sweeteners has dramatically grown in the last decade because consumers have become more mindful of their health and they perceive naturalness as a beneficial characteristic of food items (Sahin et al., 2019; Saraiva et al., 2020). Globally, around 1% of people have celiac disease, with 200 potential symptoms. That has driven the growth of gluten-free products on the global market, which is predicted to reach $8.3 billion by 2025 and is likely to be worth $7.5 billion by 2027 (Market analysis Report, 2022). However, the manufacture of gluten-freebaked goods is complicated because the lack of gluten makes the dough unable to hold enough air during mixing and carbon dioxide from the yeast during proving, leading to a less cohesive structure (Elgeti et al., 2015). To improve the quality of gluten-free bread, it is necessary to use components that have characteristics similar to gluten. There have been numerous attempts by researchers to employ proteins, hydrocolloids, emulsifiers, enzymes, or a mix of them (Waziiroh et al., 2022). For that, carob seeds are used to produce Locust Bean Gum (LBG), which could be used as a thickener, hydrocolloid, stabilizer, emulsifier, and gelling agent in the food industry, and is approved in most areas of the world; chemically known as E410 to mimic the viscoelastic properties of gluten to improve dough handling and to improve the overall quality of finished baked products. LBG is characterized by biodegradability, low toxicity, and costs contributing to its significant utilization in various products (Benkadri et al., 2021; Palaiogianni et al., 2022). The EFSA Panel on Food Additives (Mortensen et al., 2017) provided a scientific conclusion that there is no requirement for a numerically acceptable daily intake (ADI) for LBG (E410). Also, there is no safety concern for the general public regarding the genotoxicity, reproductive and developmental toxicity, or carcinogenicity of locust bean gum in 90-day trials conducted on rodents. Accordingly, the present research work aimed to (i) utilize the roasted carob powder (130° C/ 30 min) from the pulp as a natural sweetener in replacement with sugar at 0, 25, 50, and 75% in cacao cupcakes formula; (ii) utilize carob bean gum from seeds as a by-product of pods in gluten-free bread at 0, 0.5, 1.0 and 1.5 %, (iii) assess the chemical, viscosity and antioxidant properties of the raw materials, (iv) evaluate the sensory, physicochemical and texture properties of the produced cupcakes and gluten-free bread.

2. Materials and Methods

Materials

Wheat flour extraction rate of 72% was obtained from the South Cairo Mill Company, Al Giza, Egypt. Yellow corn flour 97 % was obtained from Egyptian Company for Maize Products, 10^{th} Ramadan City, Egypt. Carob pods and baking ingredients: dry yeast, cane sugar, corn oil, baking powder, and salt were obtained from local market, Al Giza, Egypt. All chemicals were used in the experiment were obtained from Egyptian Scientific Company

El-Dokki, Al Giza, Egypt.

Methods

Preparation of roasted carob bean powder from carob pulp

Carob bean pods were manually cleaned, freed of impurities, and washed with running water. The seeds were separated and kept away for the extraction of the gum. The obtained pulp was roasted in a convection oven Memmert, Cambridge, UK) at 130° C for 30 minutes according to Boublenza *et al.* (2017), then ground to obtain fine powder passed through a 125 µm sieve. Finally, the obtained powder was kept in polyethylene pages at -18° C for further use.

Extraction of carob bean gum from carob bean seeds

Carob bean gum was extracted from carob bean seeds using a hot water method as described by (El Batal and Hasib 2013) with few modifications. Carob bean seeds (100 g) were dehusked after soaking in 800 ml boiling water for 2 h to facilitate the mechanical discarding of the husks and germs. The obtained endosperms were dried in a convection oven Memmert, Cambridge, UK) at 40° C for 18 hrs. The dried endosperms were added to distilled water in a ratio of 1: 197and the pH was adjusted to 8 with NaOH (1M). Then the suspension was submitted to a water bath at 97º C, under shaking (450 rpm), for 36 min. Solid to liquid separation was done by centrifugation at 21875 rpm/4° C for 1h. The residue was discarded, and an equal volume of isopropanol was added to the supernatant to precipitate the carob bean gum. The solution was kept for 18 h at 4 ºC, and carob bean gum was skimmed off and rinsed with isopropanol. After drying under *vacuum* at 30°C for 18 h, the precipitate was ground to a fine powder and kept in polyethylene pages at -18° C for further use.

Preparation of cupcakes

Formulations presented in Table 1 were used to produce cupcakes according to the method described by Doweidar (2001) with some modifications, where sugar was replaced by roasted carob powder at 0, 25, 50, and 75 %. Briefly, egg and vanilla were whipped, then corn oil was added to the egg-vanilla mixture gradually and well beaten at low speed for 5 min. After that, cane sugar / roasted carob powder/ cacao powder was added, well beaten at low speed for 5 min. Finally, the other dry ingredients were added to the mixture and blended with a hand mixer for 2 min at high speed. Cupcake batter was poured into greased mini cupcake pans and baked at 180°C for 25 min. The cupcakes were allowed to cool, packed in polypropylene bags, and stored for further analyses.

Table 1. Formula of Cupcakes

Ingredients (g)	Control	F_{25}	F_{50}	F_{75}
Wheat flour 72%	100	100	100	100
sugar	60	45	30	15
RCP	-	15	30	45
Eggs	25	25	25	25
Skimmed milk	10	10	10	10
Corn oil	20	20	20	20
Baking powder	4.5	4.5	4.5	4.5
Salt	1	1	1	1
Vanilla	1	1	1	1
Cacao powder	10	-	-	-

RCP: Roasted carob bean powder

Preparation of gluten-free bread

Formulations presented in Table 2. were used to produce tortilla bread according to the method described by (Zahran 2013) with some modifications. Corn flour was mixed with dry yeast, corn oil, and salt. Carob bean gum was dispersed in half of the of the water to be used in dough formulation by using a high-speed homogenizer.

Then the dispersion was heated at 80° C for 15 min within continuous mixing and added to the corn flour mixture. The rest of the water was added and the dough was rested at 30° C/15 min/85% relative humidity, then divided into portions each of 125 g. The divided portions were flattened to 3 mm thickness and fermented at 30° C / 25 min/ 85% relative humidity. Finally, the fermented dough is baked at 350-400° C for 1-31.5 min. gluten-free bread was allowed to cool before sensory scoring.

Table 2. Formula of gluten- free bread

Ingredients (g)	Control	$F_{0.5}$	F_1	$F_{1.5}$
Corn flour	100	100	100	100
CBG	-	0.5	1.0	1.5
Corn oil (ml)	5	5	5	5
Dry yeast	1	1	1	1
Salt	1	1	1	1
Boiling water (ml)	90	91	91.7	92.5

CBG: Carob bean gum

Sensory evaluations

Sensory evaluation was carried out on cupcakes according to (Larmond 1977). The cupcakes were scored for taste, odor, appearance, crust color, crumb color, crumb texture, and overall acceptability (OAA). Sensory evaluation was carried out on gluten-free bread according to (Johnson and Harrisn 1989). The bread samples were scored for general appearance, crust color, texture, taste, odor, roundness, layer separation, and overall acceptability (OAA). The panelists were members of the Food Technology Research Institute, Agricultural Research Center (n=10: 7 females & 3 males). Cupcake and gluten-free bread samples were delivered to panelists on a tray at room temperature and were all coded with three-digit random numbers. The servings were distributed randomly, and the panelists were asked to rinse their mouths with water between samples. The scoring was on a 9-hedonic scale (9=like extremely, 8=like very much, 7=like moderately, 6=like slightly, 5= neither like nor a dislike, 4=dislike slightly, 3=dislike moderately, 2=dislike very much, 1= dislike extremely).

Chemical analysis for raw materials, cupcakes, and gluten-free bread

Chemical composition was performed on raw materials, cupcakes, and gluten-free bread. The contents of moisture, protein, fat, ash, fiber, minerals (Iron, Calcium and Zinc), and acid value were determined according to the (AOAC 2012) Approved Methods 934.08, 200.11, 920.58, 938.08, 978.10, 999.11, and 940.28. Protein content was calculated as N × 6.25 for roasted carob bean powder and carob bean gum and, N × 5.7 for all samples. Total carbohydrates was calculated by difference. The energy (Kcal)was calculated according to equation (1):

$$\mathbf{E(Kcal) = 4 \times (Carbohydrate\ \% + protein\ \%) + 9 \times (fat\ \%)} \qquad \mathbf{(1)}$$

Determination of total phenolic content (TPC) and antioxidant activity (AOA)

The TPC content of carob powder before and after roasting was determined according to (Singleton & Rossi 1965) using a Folin-Ciocalteu reagent. Samples were measured at 765 nm, and the concentration was expressed as milligrams of Gallic acid equivalents (GAE)/100g. The AOA of carob powder before and after roasting was evaluated by measuring free radical *2,2*-diphenyl-*1*-picrylhydrazyl (DPPH˙) scavenging capacity according to (Blois 1958). The absorbance was measured against pure methanol at 515 nm, and the absorbance was measured against pure methanol at 515 nm. and the AOA was calculated as percent discoloration from the following equation (2):

$$Inhibition\ (\%) = \left[1 - \left(\frac{A_1}{A_0}\right)\right] \times 100 \qquad (2)$$

where A_0 is the absorbance of the pure methanol control at the beginning of the reaction (t = 0) and A_1 is the absorbance of sample extract at the end of the reaction (t = 30 min). All chemical tests were averaged from three replicates.

Measurement of the Viscosity (η) of the carob bean gum

The dispersion of 1% carob bean gum in distilled water under vigorous stirring for 1 h, at room temperature, followed by heating the dispersion at 85°C in a water bath for 30 min according to (Garcia-Ochoa and Casas 1992). The apparent viscosity (η, Cp) of carob bean gum dispersion was measured using Brookfield Engineering labs, DV-III Ultra Rheometer, and SC4-21 spindle. The shear rate was varying from 9.30 - 55.80/s, and the viscometer was operated between 10 and 60 RPM.

Physical characteristics of the cupcake and gluten-free bread

Water activity (a_w)

The a_w of the cupcakes and gluten-free bread was measured using Rotronic Hygrolab 3 CH-8303, Switzerland as mentioned by Cadden (1988).

Color measurements

The color of the cupcakes and the crust of the gluten-free bread were measured in triplicate using a colorimeter (CR-400, Konica Minolta Sensing Inc., Japan). The color values were recorded as L^* =lightness (0 = black, 100 = white), a^* ($-a^*$ = greenness, $+a^*$ = redness) and b^* ($-b^*$ = blueness, $+b^*$ = yellowness).

Textural Profile analysis (TPA)

The TPA of cupcakes and gluten-free bread were measured using Brookfield Engineering Lab., Inc., Middleboro, MA. 02346-1031, USA, based on AACC International (2012), method 74-09. From the force-time curves, the following were calculated: Firmness or hardness (N): the amount of force needed for biting the cupcakes or gluten-free bread with a compression force at 25 % deformation; Adhesiveness (NS^{-1}): the energy needed to overcome attractive forces between the cupcakes or gluten-free bread contact surface; Resilience: the ability of the cupcakes or gluten-free bread to return to their original shape after being compressed. Five replicates of the texture measurement of each sample were averaged.

Statistical Analysis

The data of compositional, physical and sensory evaluations were analyzed using computer software CoStat 6.303, CoHort, USA, 1998–2004 for Windows 8.1; an analysis of variance (ANOVA) followed by Duncan's multiple range tests at $P \leq 0.05$ to compare between means according to (Snedecor and Cochran 1967).

3. Results and Discussion

Chemical composition of raw materials

Table 3. represents the chemical composition and minerals of the raw materials on a dry weight basis. It could be noticed that wheat flour contained the highest significant value of protein. . This was likely due to the fact that wheat is a rich source of gluten protein with prolamins that are predominantly gliadins and glutenins (Taghvaei et al., 2021). The results for the chemical composition of wheat and corn flour were near to the data found by (Youssef et al., 2013). Roasted carob powder contained the highest significant values of fiber and ash. The highest values of fiber and ash supported the assumption that the roasting process decreased the moisture content of carob powder and facilitated condensation of its significant components (Boublenza et al., 2017). The result of chemical composition for roasted carob powder was in the range of Amer et al. (2019), who reported the carob powder contained 5.1 % protein, 0.55 % fat, 3.5 % ash, and 10.99 % fiber. Carob bean gum had the highest significant total carbohydrates contents, this is due to the galactomannan makes up the majority of gum, and after seed processing, crude galactomannan can go through additional steps to remove both protein content and contaminants (Gioxari et al., 2022). (El- Kholy et al., 2015) analyzed the chemical composition of carob bean gum, and they found that carob bean gum contained 11.17, 0.74, 0.92, 0.73, 0.65, and 96.96% of moisture, crude protein, fat, crude fiber, ash, and total carbohydrates, respectively.

The results showed that roasted carob powder was the highest significant in Fe, Ca, and Zn compared with wheat and corn flour. Carob powder contained 22.76 and 23.74 folds of Fe in wheat flour and corn flour, respectively. It is established that carob powder is a good source of macroelements, particularly calcium, while also providing microelements (iron and zinc), which work as cofactors of enzymatic antioxidants to safeguard the body from oxygen-free radicals created during oxidative stress (Higazy et al., 2018; Gioxari et al., 2022). Also, roasted carob powder had 6.0 and 4.56 folds of Ca in wheat and corn flour, respectively. This is because carob bean is considered to be one of the natural source of calcium, sometimes it reach 3x more than calcium in milk, which exerts a sustainable opportunity for metabolic health (Higazy et al., 2018 and Gioxari et al., 2022).

Table 3. Chemical composition and minerals of raw materials on dry weight basis

Sample	Moisture (g/100 g)	Protein (g/100 g)	Fat (g/100 g)	Ash (g/100 g)	Fiber (g/100 g)	TC (g/100 g)	Fe (mg/100g)	Ca (mg/100g)	Zn (mg/100g)
Wheat flour 72%	10.72±0.12^{a}	10.83±0.1^{a}	0.81±0.2^{c}	0.47±0.3^{d}	0.62±0.01^{c}	76.55±1.0^{b}	1.7±1.1^{c}	38.1±0.62^{cd}	0.52±0.02^{c}
Corn flour 97%	11.53±0.08^{a}	7.51±0.01^{b}	2.11±0.2^{a}	1.60±0.2^{b}	1.30±0.2^{b}	75.95±1.1^{b}	1.63±0.02^{c}	50.1±0.02^{c}	1.83±0.02^{b}
RCP	9.03±0.05^{b}	6.72±0.1^{c}	1.51±0.2^{b}	2.73±0.1^{a}	7.11±011^{a}	72.90±0.4^{c}	38.7±0.06^{a}	228.5±0.07^{a}	3.1±0.01^{a}
CBG	7.05±0.37^{c}	0.55±0.77^{d}	0.39±0.77^{d}	0.68±0.03^{c}	ND	91.33±0.55^{a}	2.97±0.2^{b}	164.33±0.05^{b}	1.75±0.06^{b}

RCP: Roasted carob bean powder, CBG: Carob bean gum; TC: Total carbohydrates, ND: not detected
Data are presented as means ± SDM (n = 3) and means within a column with different letters are significantly different at $P \leq 0.05$

Total phenolic content (TPC) and antioxidant activity (AOA) in carob powder

Figure 1. displays the TPC as GAE before and after roasting at 130° C for 30 minutes. It could be noticed that the TPC of carob powder was increased P ≤0.05 from 185.6 to 205.53 mg/100g. The same Figure 1. showed that roasting of carob at 130° C caused a P ≤0.05 increase in AOA from 30.76 to 91.78%. These results agreed with (Boublenza et al., 2017) who reported that roasting carob caused an increase in polyphenols and antioxidant activity. During roasting, polyphenols are released from certain polymers, making them available for absorption. In addition, antioxidant activity was proportional to total phenolic compounds, as a high antioxidant activity is expected to be caused by its high content in polyphenols. During the roasting process of carob powder, important chemical reactions including sugar caramelization and Maillard reaction take place, which causes significant changes in product quality. Many studies have focused on the properties of Millard reaction products, particularly on the antioxidant activity of Millard reaction products in food products (Şahin et al., 2009).

Apparent viscosity of the aqueous dispersion of the carob bean gum

Figure 2. displays the apparent viscosity (η, cP) of 1% aqueous dispersion of carob bean gum at different shear rates (s^{-1}). It could be noticed that the gum solution showed pseudoplastic behavior, which means that the dispersion of the carob bean gum is a non-Newtonian fluid. It was assumed that carob bean gum consists of a mannan backbone that tends to coil with the formation of intra-molecular hydrogen bonds. Therefore, interact less with linear amylose molecules due to the lower number of hydroxyl groups available to form intermolecular hydrogen bonding, hence pseudoplasticity decreases (Hussain et al., 2017).

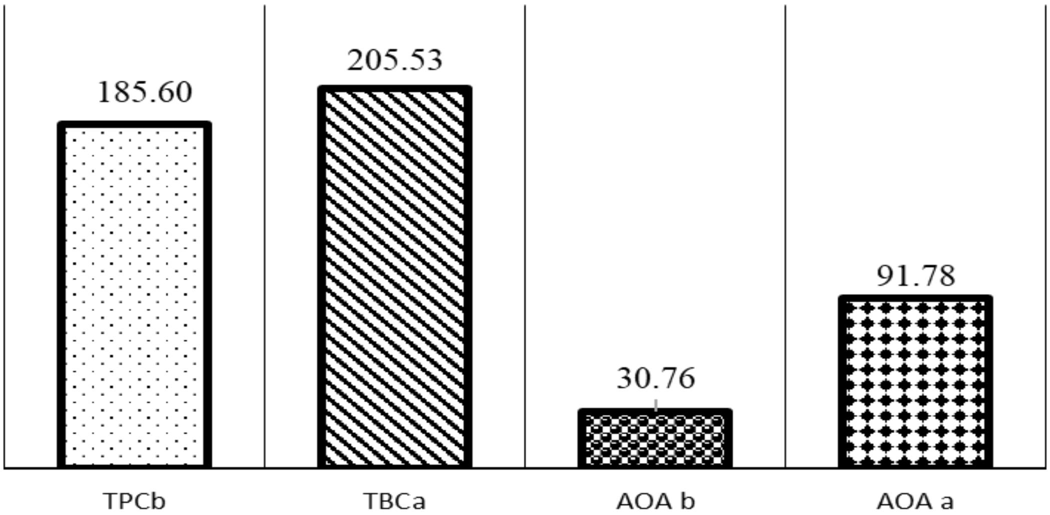

Figure 1. Total phenolic compounds (mg/100g GAE) and antioxidant activity (%) in carob bean powder from pulp before and after roasting.

TPCB: Total phenolic contents before roasting

TPCA: Total phenolic contents after roasting

AOAB: antioxidant activity before roasting

AOAA: antioxidant activity after roasting

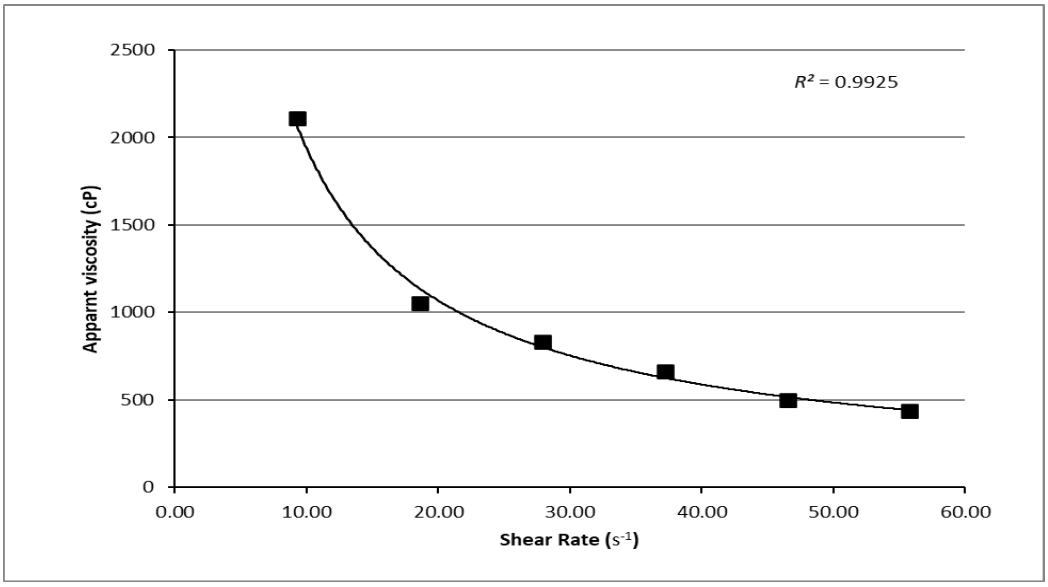

Figure 2. Apparent viscosity (η,cP) of 1% aqueous dispersion of carob bean gum at different Shear Rates (s^{-1})

Sensory acceptability of cupcakes and gluten-free bread

Table 4. represents the sensory acceptability scores of cupcakes. The sensory scores for appearance, crust color, crumb texture, and odor of cupcakes sweetened with 25 and 50% roasted carob powder was not $p \geq 0.05$ different compared to the control. Although the OAA of cupcakes sweetened with 75% roasted carob powder had the lowest $p \geq 0.05$ score but still with good OAA. These results are supported by (Papageorgiou et al., 2020), who recommended producing a cake with good quality and acceptable sensory quality attributes with the addition of 50 % carob powder. Table 5. represents the sensory acceptability scores of the gluten-free bread. The results showed scores were $p \geq 0.05$ with increasing the level of carob bean gum. Gluten-free bread containing 0.5 and 1.0% carob bean gum had higher $p \geq 0.05$ OAA with brighter crust, symmetric shape with well-separated

layers, firm texture with no holes or deformation, and no p≥0.05 changes in taste and odor compared to control. Meanwhile there was a p ≥ 0.05 decrease in sensory scores of the gluten-free bread containing 1.5% carob bean gum, which is characterized by asymmetrically shaped bread with sticky bottoms and no separation of layers, and a much firmer crumb texture in places, small cracks in the crust, very pale crust color and watery or moist taste. These results are supported by (Schwarzlaff et al., 1996); Sabanis and Tzia 2011), who reported an increased level of addition from locust bean (1.0%), guar (4%), and xanthan (2%) gums is strongly correlated with texture firmness, bread volume and reduced consumers' perception of the gluten-free bread.

Table 4. Sensory quality scores of cupcakes

Sample	Appearance	Crust color	Crumb color	Crumb texture	Odor	Taste	OAA
	(9)	(9)	(9)	(9)	(9)	(9)	(9)
Control	8.50±0.5^{a}	8.5±0.5^{a}	8.5±0.1^{a}	8.5±0.3^{a}	8.8±0.1^{a}	8.7±0.3^{a}	8.7±1.0^{a}
RCP 25%	8.2±0.2^{a}	8.5±0.2^{a}	8.0±0.2^{b}	8.5±0.2^{a}	8.8±0.2^{a}	8.5±0.5^{a}	8.6±0.5^{a}
RCP 50%	8.2±0.3^{a}	8.0±0.3^{a}	8.0±0.4^{b}	8.0±0.2^{a}	8.7±0.2^{a}	8.0±1.0^{b}	8.0±0.4^{b}
RCP 75%	7.5±0.5^{b}	7.5±0.5^{b}	7.0±0.3^{c}	7.0±0.5^{b}	8.5±0.5^{a}	5.0±0.5^{c}	6.99±1.0^{c}

RCP: Roasted carob bean powder; OAA: overall acceptability.
Data are presented as means ± SDM (n = 10, a 9-point hedonic scale) and means within a column with different letters are significantly different at $P \leq 0.05$

Table 5. Sensory quality scores of gluten-free bread

Sample	Appearance	Crust color	Taste	Odor	Separation of Layers	Texture	Rouess Rate	OAA
	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)
Control	7.32±0.3^{b}	7.0±1.0^{b}	8.0±0.5^{a}	8.5±0.5^{a}	7.5±0.5^{ab}	7.0±1.0^{ab}	6.9±0.5^{b}	7.2±0.8^{c}
CBG 0.5%	8.5±1.0^{a}	8.0±0.5^{a}	8.0±1.0^{a}	8.5±0.5^{a}	8.0±1.0^{a}	8.0±0.7^{a}	9.0±0.0^{a}	8.8±1.0^{a}
CBG 1%	8.0±0.5^{a}	8.0±1.0^{a}	8.0±1.0^{a}	8.5±0.3^{a}	8.0±0.5^{a}	8.0±0.3^{a}	8.0±1.0^{a}	8.0±0.5^{b}
CBG 1.5%	6.8±0.5^{c}	6.0±0.5^{c}	5.0±0.5^{b}	8.0±0.3^{a}	5.0±1.0^{c}	5.0±0.5^{c}	5.0±0.1^{c}	5.0±0.5^{d}

CBG: Carob bean gum ; OAA: overall acceptability.
Data are presented as means ± SDM (n = 10, a 9-point hedonic scale) and means within a column with different letters are significantly different at $P \leq 0.05$

Nutritional quality of cupcakes and gluten -free bread

Table 6. exhibits the chemical composition of cupcakes and gluten-free bread on a dry weight basis. Data proved that the protein, fat, ash, and fiber increased with the increased level of addition of all cupcakes compared with the control. So that the cupcake sweetened with 75% roasted carob powder contained the highest p≥0.05 values of protein, fat, ash, and fiber among all cupcake samples. On the other hand, the roasted carob powder caused a p≥0.05 decrease in the total carbohydrates. These results agreed with (Ibrahim et al., 2015), who reported that carob caused an increase in protein, fat, ash, and fiber in bakery products. The results in Table 6. showed that adding carob bean gum to the gluten-free bread at 0.5, 1.0, and 1.5% had no p≥0.05 effects on the nutritional quality or the values of protein, fat, ash, fiber, total carbohydrates, or energy, in compared to the control. That is because carob bean gum acts as a binding agent or a substitute for gluten in gluten-free bread formulations based on corn starch with an improvement in the final texture and adds viscosity to the dough

with no effects on the nutritional quality of these bread formulations (Barak & Mudgil, 2014; Benkadri et al., 2021; Brassesco et al., 2021).

Table 6. Nutritional quality of cupcakes and gluten-free bread on dry weight basis

Samples	Protein (g/100 g)	Fat (g/100 g)	Ash (g/100 g)	Fiber (g/100 g)	TC (g/100 g)	Energy Kcal/100g
			Cupcakes			
Control	8.5±0.2[C]	20.6±0.3[a]	2.6±0.3[ab]	0.63±0.22[c]	67.67±0.1[a]	490±0.11[a]
RCP 25%	8.9±0.1[b]	20.75±0.4[a]	2.86±0.11[a]	1.33±0.22[b]	66.16±0.17[b]	487±0.11[b]
RCP 50%	9.51±0.3[a]	20.82±0.2[a]	2.98±0.1[a]	1.64±0.33[b]	65.05±0.1[c]	485.6±0.1[b]
RCP 75%	9.75±0.1[a]	20.91±0.2[a]	3.15±011[a]	2.05±0.11[a]	64. 14±0.51[d]	484±0.11[c]
			Gluten-Free Bread			
Control	6.82±0.12 [a]	4.56±0.21[ab]	2.11±0.11[ab]	1.00±1.2[ab]	85.51±1.0[a]	410.36±1.0[a]
CBG 0.5%	6.82±0.21[a]	4.57±0.11[ab]	2.21±0.10[ab]	1. 12±0.7[ab]	85.28±0.22[ab]	409.53±0.22[a]
CBG 1%	6.82±0.21[a]	4.57±0.1[ab]	2.33±0.20[a]	1.09±0.25[ab]	85.19±1.0[ab]	409.17±1.0[ab]
CBG 1.5%	6.83±0.12[a]	4.61±0.11[a]	2.34±0.21[a]	1.30±0.31[a]	84.92±1.0[ab]	408.49±1.0[ab]

RCP: Roasted carob bean powder ; CBG: Carob bean gum; TC: Total carbohydrates
Data are presented as means ± SDM (n = 3) and means within a column with different letters are significantly different at $P \leq 0.05$

Physical characteristics of the cupcake and the gluten-free bread

Water content and water activity (aw) of the cupcake and gluten-free bread

The results in Table 7. revealed that the water contents of the cupcakes and the gluten-free bread $p \geq 0.05$ increased with steady increase of roasted carob powder/ carob bean gum compared to the control samples. That may be due to the higher $p \geq 0.05$ fiber contents (Table 6.) in carob cupcakes and the higher viscosity of the gum (Figure 2.), which absorbs or hold more water than cane sugar/ corn flour. Data in Table 7. proved that the highest $p \geq 0.05$ aw was recorded for the cupcakes sweetened with 75%, followed by 50%, and 25% roasted carob powder, and for the gluten-free bread with 1.5%, followed by 1.0%, and 0.5% carob bean gum. That may be related to their $p \geq 0.05$ water contents.

Water activity (a_w) is a measurement of the availability of water for biological reactions. (Cook and Johnson 2010) stated that a_w is a significant parameter for spoilage of bakery products like bread and cakes with values above 0.94. A higher level of water activity, making the potential for mold and other microbial infestations a serious issue. The mold species that are responsible for the spoilage of gluten-free bread and bakery goods have been identified; they include fungi from the genera Penicillium, Cladosporium, Neurospora, or Rhizopus, as well as Aspergillus, Fusarium, Mucor, *Endomyces, Chrysonilia,* etc. Mold contamination produces mycotoxins and off flavors, which endanger human health, cause financial losses, and annoy customers. Additionally, bacteria from the genus Bacillus and yeasts from the genera Pichia, Candida, or Torulaspora can attack baked goods, particularly gluten-free bread with *B. amyloliquefaciens* being the primary species responsible for rope spoiling. The same microbes also cause food to deteriorate (Šmídová and Rysová, 2022). Accordingly, it could predict stability, safety, and quality of cupcakes/ gluten-free bread, where they had aw ≤ 0.94.

The color of cupcake and gluten-free bread

Table 7. represents the color values of the cupcakes and the gluten-free bread. It could be noticed that all of the cupcakes sweetened with roasted carob powder became $p \geq 0.05$ darker in color, as

they all had L* values < 50, they have higher rates of reflectance for light, as they classified all as dark (Rosa et al., 2015). For the gluten-free bread, the lightness (*L**) of crust with 0.5 & 1.0% carob bean gum showed no $p \geq 0.05$ differences from the control one. However, the *L** of the gluten-free bread crust with 1.5% carob bean gum showed the highest $p \geq 0.05$ value (88.90±0.23). This difference can be attributed to the effect of the higher percentage of the gum addition on water distribution, which impacts Maillard browning and caramelization and reflects a pale tonality (Mezaize et al., 2009). From the same Table 7., *a** and *b** values showed a $p \geq 0.05$ decrease in both products with a steady increase in the roasted carob powder/carob bean gum level. Lower significant value of a* and b* parameters reflect in products with slight reddish and yellowish colors (Esteller et al., 2006).

The texture of the cupcakes and gluten-free bread

Table 7. represents the texture results of the cupcakes and the gluten-free bread. Data showed that the firmness of the cupcake was $p \geq 0.05$ increased with an increased level of the roasted carob powder, with no $p \geq 0.05$ changes in the adhesiveness values among all the tested samples. These results were supported by (Papageorgiou et al., 2020 and Amer et al., 2019), who reported that the higher fiber constituent of carob powder leads to increase the firmness of the final product in comparison to the control one. For gluten-free bread, the hardness of the samples ranged from 13.59 to 16.0 N. Control gluten-free bread was the $p \geq 0.05$ hardest one. Adding carob bean gum caused a $p \geq 0.05$ decrease in the hardness values of the gluten-free bread, but with no $p \geq 0.05$ difference in the values between gluten-free bread samples containing 0.5, and 1.0, respectively. However, gluten-free bread containing 1.5% carob bean gum was the $p \geq 0.05$ firm one with some noticeable shape deformation. The same observations were recorded by (Demirkesen et al., 2010; Tunç and Kahyaoglu 2016), who reported that carob bean gum was significant and needed for the acceptable hardness values of gluten-free bread. Meanwhile, the adhesiveness and the resilience were $p \geq 0.05$ increased with increasing the level of carob bean gum, making the bread appear to be more symmetrical in shape and moist than the control one with no incidence of cracks, as hardness is defined as the force that is required to achieve a given deformation of a certain product (Szczesniak, 2002). Also, resilience is given by the symmetry of gluten-free bread in the first compression, which relates to the degree that a sample recovers after compression (García Calabuig, 2012). These phenomena were associated with the pseudoplasticity of the carob gum dispersions, which prevents lumps during dough formation and improves homogeneity during kneading. In addition, higher viscosity and ability of the gum to retain water and form a gelling network during proofing and baking will give elasticity and symmetrical to the gluten-free bread and may compensate for the absence of the gluten (Tunç and Kahyaoglu, 2016).

Fat stability of cupcakes during the storage period of four weeks at 20±5°C

The acid value (AV) is an important parameter to evaluate the quality of oil since it measures the content of FFAs formed after the hydrolytic degradation of lipid molecules and can be used to indicate the degree of rancidity in oil hydrolysis (Cong et al., 2020). Figure 3. depicts the changes in acid value (AV) of cupcakes during the storage period of four weeks at 20±5° C. It could be noticed that the AV of cupcakes sweetened with roasted carob powder at 25, 50, and 75 % showed no $p \geq 0.05$ increase compared with the value of the control. That may be due to the antioxidant effects of carob powder that can delay or inhibit lipid oxidation and high -fat foods or other molecules by inhibiting the initiation or propagation of oxidizing chain reaction. Nowadays, antioxidants arused for preserving or retarding lipid peroxidation (Hollman& Katan1999, Boublenza et al., 2017).

Table 7. Physical characteristics of cupcakes and gluten-free bread

Samples	Water content		Color			Texture		
	Moisture (%)	a_w	$L*$	$a*$	$b*$	Firmness/ Hardness (N)	Adhesive-ness ($N.s^{-1}$)	Resilience
Cupcakes								
Control	25.82±0.5[d]	0.76±0.3[a]	53.32±3.3[a]	9.7±0.43[a]	18.38 ±1.4[a]	8.66±0.2[c]	0.23±1.1[b]	0.25±0.02[a]
RCP 25%	26.98±1.0[c]	0.81±0.2[a]	49.36±2.6[ab]	7.67±0.6[b]	11.53 ±0.9[b]	20.10±0.5[b]	0.31±0.1[ab]	0.21±0.03[b]
RCP 50%	28.54±0.5[b]	0.88±0.2[a]	47.84±3.0[ab]	7.82±0.08[b]	10.96± 0.6[b]	23.55±0.2[b]	0.33±1.2[ab]	0.20±0.03[b]
RCP 75%	29.77±0.7[a]	0.94±0.2[a]	46.26±3.6[b]	6.13± 0.37[c]	7.04±0.43[c]	26.11±0.06[a]	0.34±1.0[ab]	0.20±0.1[b]
Gluten-Free Bread								
Control	29.11±0.5[ab]	0.85±0.2[a]	82.32± 3.0[b]	2.37±0.54[c]	33.38±1.4[a]	16.0±0.02[a]	-4.5±0.7[a]	0.20±0.1[c]
CBG 0.5%	29.55±0.55[a]	0.90±0.2[a]	83.65± 1.3[b]	9.08±0.3[b]	19.62±0.08 b	14.53.0±0.01[b]	-.81±0.55[c]	0.26±0.02[a]
CBG 1%	29.91±1.0[a]	0.92±0.2[a]	85.17±5.0[b]	10.78±0.53 a	18.42±2.3[c]	14.52.0±0.22[b]	-2.55±1.1[b]	0.25±0.1[ab]
CBG 1.5%	30.54±0.5[a]	0.94±05[a]	88.90±0.23[a]	10.98±0.31 a	18.72±0.91[c]	13.59±0.10[c]	-3.01±1.1[b]	0.26±0.04[a]

RCP: Roasted carob bean powder ; CBG: Carob bean gum ; **L* (lightness with *L* = 100 for lightness, and L = zero for darkness), *a* [(chromaticity on a green (−) to red (+)], *b* [(chromaticity on a blue (−) to yellow
Data are presented as means ± SDM (n = 5) and means within a column with different letters are significantly different at $P \leq 0.05$

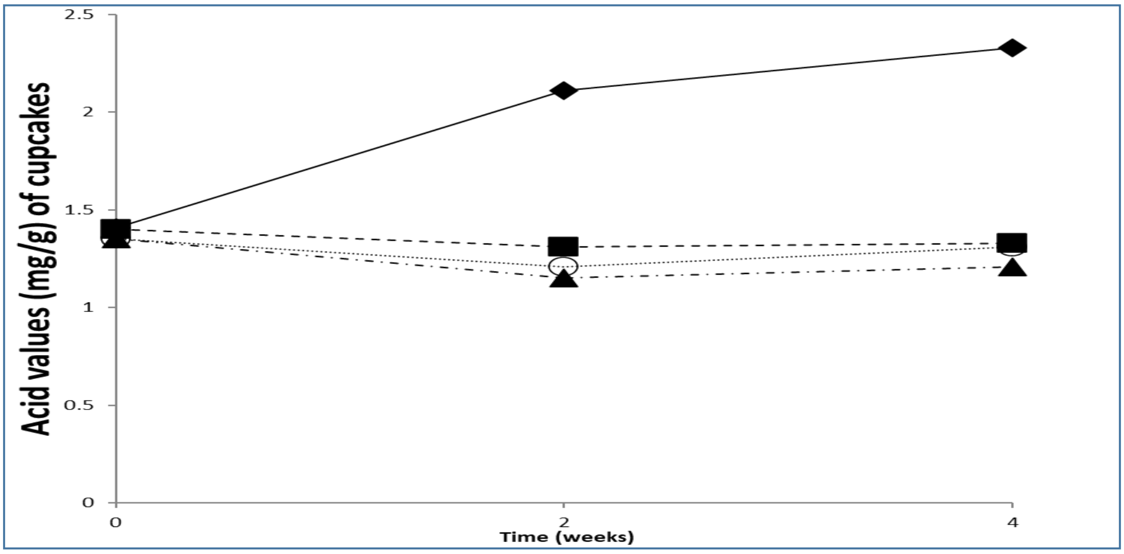

Figure 3. Changes of **acid value (AV) of cupcakes during storage period of four weeks at 20±5° C** Control- (▬♦▬), cupcake sweetened with 25% roasted carob powder (---■---), cupcake sweetened with 50% roasted carob powder - (¨○¨), cupcake sweetened with 75% roasted carob powder - (-.- ▲ -.-).

4. Conclusions, research limitations and implications

Based on the experimental results, it could be concluded that roasted carob pulp can be successfully incorporated into cacao cupcakes as an alternative for sugar, even at 25 and 50% doses. That is significant from the nutritional point of view, as roasted carob pulp has potential and appreciable compositional nutrients, besides the significant antioxidants that extend the shelf life of the cupcakes. Make it authoritative for low glycemic and diabetic cake recipes. Another concern is the pseudoplasticity of the carob gum added viscosity and improved the texture of the gluten-free bread, particularly the crumb texture Carob bean gum was significant and needed for the accepted texture and sensory properties at doses up to 1.0 % in gluten-free bread. That is functional and may compensate for the absence of gluten in a gluten-free diet targeted for celiac disease patients. For future applications, we must move beyond the experimental stage and introduce these functional products to the market; however, the major stumbling block or challenge here is consumer perception of these new products. Also, future studies are needed to characterize the types of sugars in roasted carob powder and carob gum and investigate the interaction of these sugars with the main ingredients, particularly the gluten of cupcake dough or the starch of corn flour, and how these interactions affect pasting behaviour, gelatinization temperature, network development, an increase or decrease in yeast activity, the number and volume of air cells, as well as an enhancement of the colloidal system. Also, we need to investigate the effect of roasted carob powder and carob gum on microbial growth and the shelf life of these products.

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