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Influence substitution of cocoa powder and sugar with carob pulp powder on the chemical composition and quality attributes of cupcake

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ABSTRACT

This study aimed to produce healthy cupcakes and low in calorific, fat, and sugar by substitution cocoa powder (CP, high fat) and sugar (one of the main ingredients of cupcakes) with carob pulp powder (CPP). The levels of substitution of CPP used in the cupcake formula were 0, 25, 50, 75, and 100% from CP and sugar. The results showed that fibre, natural sugars, and carbohydrates in CPP were higher than those found in CP. While, the CP exhibited a higher content of fat and total calorific. In addition, CPP had higher in phosphorus, calcium, iron, and manganese compared to CP that had higher in potassium, magnesium, zinc, and copper. The CCP were regarded an important source of most essential and nonessential amino acids if compared to CP. On the other hand, substitution of CP and sugar with CPP increased the content of protein, fibre, and minerals and a decrease in lipid, carbohydrate, and calorie content in cupcakes compared with control sample in parallel with increasing the level of substitution. Cupcake weight and darker colour increased with increasing substitution, while the volume and specific volume decreased. Caused increasing substitution levels of CP and sugar with CPP (0 to 100%) in increased the hardness (3.65±0.04 to 6.82±0.02 N) and decreased cohesiveness (0.71±0.02 to 0.52±0.03 mm³). In general, sensory evaluation of cupcakes not showed significant difference ($p > 0.05$) with replacement of up to 50% of CP and sugar with CPP in the colour, appearance, odour, taste, and overall acceptability.

Keywords: Cupcakes, Carob pulp powder, Cocoa powder, Sugar, Sensory attributes.

INTRODUCTION

Bakery products are essential sources of nutrients that satisfy the human diet's protein and calorie needs; they are a critical objective of the industry and can be manufactured in a multitude of methods. The cupcakes are a type of bakery product that is ready to consume, which made from cereals, and can be produced in a brief amount of time (Ukom *et al*., 2022; Abdel Samie *et al*., 2023). Cupcakes are prepared using soft wheat flour, sugar, eggs, and oil in a variety of formulas. They may have their ingredients changed to meet a variety of dietary requirements (Silva *et al*., 2020). Protein, fat or oil, and many carbs are all included in cupcakes. However, they contain small amounts of dietary fibre and minerals required for bodily metabolism (Saraç *et al*., 2022).

Sugar is one of the primary constituents utilized in the production of cupcakes; up to 30% of it is employed as a sweetener. Several health problems, including obesity, have arisen because of the rising consumption of sugar, due to its high caloric value (Gökçe *et al*., 2023). On the other hand, cocoa has high fat content and high amounts of hydrophobic polysaccharides, and its capillary structure traps air bubbles because it has low solubility (Rosa *et al*., 2015). Therefore, the industry of food seeks to provide customers with low-calorie, natural, nutritious, and healthier sweeteners because consumers want to eat healthier, natural products that will not harm their health.

Carob fruit (*Ceratonia silique* L.) are two different components. The first is a seed, while the second is a dark brown husk. The husk makes up 80–90% of the fruit, with the remaining 10–20% being seed. Because it contains a high amount of natural sugar, carob may be used as a natural sweetener in a variety of products, including beverages, ice cream, biscuits, cupcakes, and chocolates (Gökçe *et al*., 2023). Natural sugar makes up about 50–60% of the carob fruit, mostly sucrose, fructose, and glucose. Due to the sweetener ability of carob fruit, its low price, and similar flavor to chocolate and cacao, carob fruit can be used as a sugar and cocoa partial or total replacer in order to reduce the sugar and fat content in products or to provide different characteristics to the final product. Another advantage of substituting carob for cocoa: it is a substance devoid of theobromine and caffeine (Lupu *et al*., 2023).

On the other hand, carob has low levels of fat (0.2–2%), moderate quantities of protein (1–8%), and extremely high levels of crude fiber (9–18%) (Hafez and Mahgoub, 2023). Moreover, carob contains a significant amount of minerals (1–6%), mainly potassium, phosphorus, magnesium, and calcium. Additionally, carob flour has a high concentration of amino acids in different proportions and a significant proportion of unsaturated fatty acids as opposed to saturated fatty acids (Basharat *et al*., 2023). Carob flour also has a strong capacity to decrease cholesterol because of its high fiber content.

Moreover, the carob germ contains a high amount of phytochemicals such as polyphenols, gallotannins, and pro-anthocyanins. They stop too many reactive oxygen species and free radicals from forming (Elbouzidi *et al*., 2023; Nasr *et al*., 2024). Seed endosperm contains also polysaccharides (galactomannan), often known as carob gum. Locust bean gum is commonly used in the gluten-free products industry, as a thickening agent, a foaming agent, an emulsifier, dietary fiber, and a stabilizer for drug delivery (Nasrallah *et al*., 2024). Therefore, the aim of this study was to evaluate the influence of substitution of CP and sugar with CPP on the chemical composition and quality attributes of cupcakes.

MATERIAL AND METHODS

Materials:

Wheat flour (WF, 72% extraction) was obtained from the Middle Egypt Mills Company, Assiut Governorate, Egypt. Carob pods was obtained from the Ragab El-Attar market store located in Cairo Governorate, Egypt. Cupcake ingredients: cacao powder, sugar, eggs, skimmed powdered milk, corn oil, baking powder, vanilla, and salt were obtained from the local market in Assiut City, Egypt. All chemicals and reagents were of analytical grade and purchased from the Elgomhurya Company, Assiut Branch, Egypt. The table below displays the formulations of the cupcake (Table 1).

Table 1. Formulation of cupcake.

Ingredients (g)	Control	F_{25}	F_{50}	F_{75}	F_{100}
WF	200	200	200	200	200
CPP	-	50	100	150	200
CP	100	75	50	25	-
Sugar	100	75	50	25	-
Whole egg	100	100	100	100	100
Corn oil	50	50	50	50	50
Skimmed powdered milk	50	50	50	50	50
Baking powder	6	6	6	6	6
Vanilla	3	3	3	3	3
Salt	0.5	0.5	0.5	0.5	0.5
Water	**As required**				

WF: Wheat flour, CPP: Carob pulp powder, CP: Cocoa powder, Control: 0% carob pulp powder+100% cocoa powder+100% sugar, F_{25}: 25% carob pulp powder+75% cocoa powder+75% sugar, F_{50}: 50% carob pulp powder+50% cocoa powder+50% sugar, F_{75}: 75% carob pulp powder+25% cocoa powder+25% sugar, F_{100}: 100% carob pulp powder+0% cocoa powder+0% sugar.

Technological methods

Preparation of CPP:

To prepare CPP, steps presented in (Fig. 1) were used according to the method described by (Boublenza *et al*., 2017).

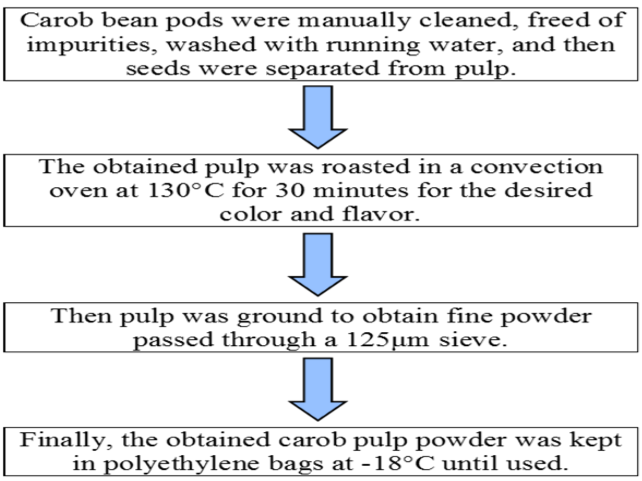

Fig. 1. Preparation of CPP.

Preparation and baking of cupcake:

To produce cupcakes, formulations presented in (Table 1) were used according to the method described by (Doweidar, 2001), with some modifications (Fig. 2).

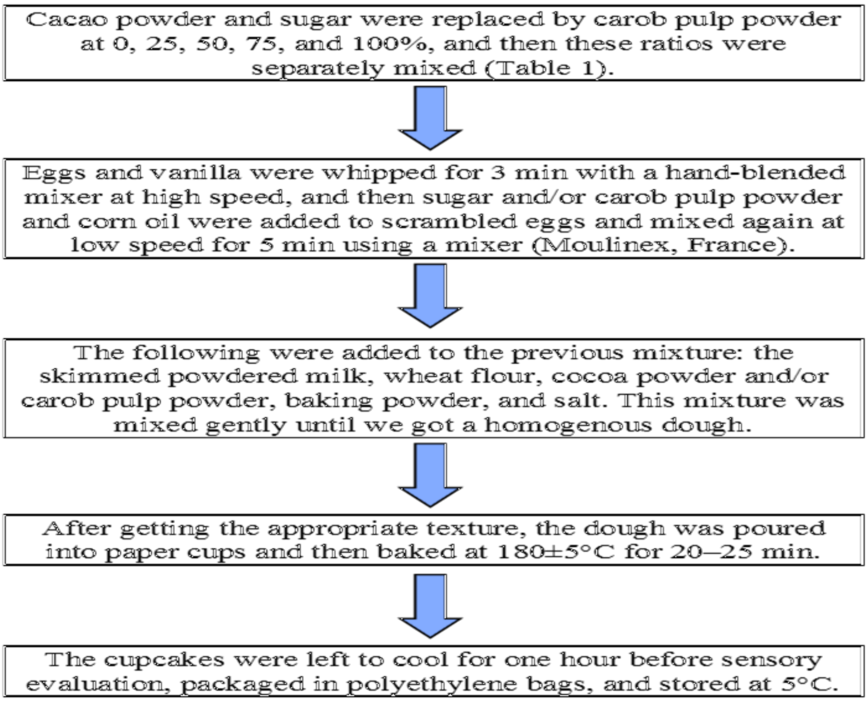

Fig. 2. Preparation and baking of cupcake.

Analytical methods:

Proximate chemical composition:

The moisture, protein, fat, ash, crude fibre, and sugar contents on dry weight basis (dwb, except moisture) of all the raw materials and the baked cupcake samples were determined according to (AOAC, 2019). All measurements were done in triplicate, and the means were noted. Carbohydrates were calculated by difference as follows:

% Carbohydrates = 100 – (% protein + % fat + % ash + % crude fibre).

The total calories were calculated by the formula of (Maclean *et al*., 2003) as follows:

The total calories (kcal) per 100g = 4 x (% carbohydrate + % protein) + 9 x (% fat).

Proximate minerals composition:

Calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) of all the raw materials and the baked cupcake samples were determined according to the method described in (AOAC, 2019) by using the atomic absorption spectroscopy technique. Potassium (K) and sodium (Na) were determined by using a flame photometer (Pye Unicom Sp. 1900 England). Phosphorus (P) content was determined calorimetrically by a spectrophotometer at 650 nm according to the methods described in (AOAC, 2019).

Proximate amino acids composition:

The amino acid content of the raw materials was determined according to the method described by (Pellet and Young, 1980) with some modifications and can be summarized as follows: 200 mg of dried sample was hydrolyzed with 5 mL of 6 N HCL in a sealed tube at 110 °C for 24 hours, after which the hydrolysate was filtered. The residue was washed with distilled water, and the filtrate was evaporated on water at 50 °C. The residue was dissolved in 5 mL of loading buffer (sodium citrate buffer, pH 2.2). Analysis was performed at the Central Service Unit, National Research Center, Egypt, using a Beckman Amino Acid Analyzer model 119 CL. Tryptophan was limited colorimetrically using the method described by (Sastry, 1985).

Physical properties of cupcakes:

The physical properties of the baked cupcake samples were determined after cooling for one hour; the weight of the cupcakes (grams) was recorded. The volume (cm³) was measured by seed displacement, and the specific volume (cm³/g) of the cupcake was then calculated by dividing the volume by the weight of the cupcake according to the methods described in (AACC, 2010). All measurements were conducted in triplicate.

Colour determinations of cupcakes:

The colour of the baked cupcake samples was measured in three replicates for each evaluated sample using a Minolta CR-400 (Minolta Camera, Co., Ltd., Osaka, Japan). The colour values were recorded as L^* = lightness (100: white; 0: black), a^* (+, redness; -, greenness), and b* (+, yellowness; -, blueness). The values of ΔE (total colour difference) were calculated according to (Marpalle *et al*., 2014) as follows:

Chroma = 1/2 square root of $[a^{*2} + b^{*2}]$

Hue = tan-1 $[b^*/a^*]$

$\Delta E = (L^{*2} + a^{*2} + b^{*2})^{1/2}$

Where $(a^* = a^* - a^*_0)$, $(b^* = b^* - b^*_0)$, and $(L^* = L^* - L^*_0)$. Subscript "o" indicates the colour of the control.

Texture profile analysis (TPA) of cupcakes:

The TPA was conducted for the baked cupcake samples as described by (Gómez *et al*., 2007) by a QC-Tech-B type texture analyzer (Taiwan) provided with the software "Texture Expert," using the cylindrical probe with a 25-mm diameter and a test speed of 2 mm/s for the double compression TPA tests. A number of textural parameters for cupcakes (hardness, cohesiveness, springiness, and resilience) were extracted. The experiment was performed in triplicate on three samples. The values of gumminess and chewiness were calculated according to (Soleimanifard *et al*., 2018) as follows:

Gumminess = hardness × cohesiveness

Chewiness = gumminess × springiness (that is, hardness × cohesiveness × springiness).

Sensory evaluation of cupcakes:

Following baking, the cupcake samples were cooled for 2 hours at room temperature (25±2°C) before being subjected to sensory evaluation. A cupcake samples were served to 10 staff from the Food Science and Technology Department, Faculty of Agriculture, Al-Azher University, on white, odorless, and disposable plates and was coded with three random digits for each cupcake sample, along with a glass of water to wash the taste buds. The staff were asked to rate the cupcake samples for colour, texture, appearance, odour, taste, and overall acceptability according to the method of (Bent *et al*., 2013).

Statistical analysis of data:

Data obtained from three replicates were analyzed by one-way analysis of variance (ANOVA) using the SPSS 20.0 software statistical package program, and differences among the means were compared using Duncan's multiple range test (SPSS, 2011). A significance level of 0.05 was chosen, and continuous variables were described by the mean and standard deviation.

RESULTS

Proximate chemical composition of raw materials:

Table (2) displays the proximate chemical composition (g/100 g sample on dwb, except moisture) of WF, CP, and CPP used in this study. From the results, it could be observed that WF of 72% extraction contained 11.28±0.11% moisture, 10.41±0.25% protein, 0.94±0.08% fat, 0.58±0.03% ash, 0.62±0.06% crude fibre, 1.13±0.14% sugars, 87.45±0.16% carbohydrates, and 399.90±1.10 kcal/100 g. On the other hand, the CP had a higher content of protein (9.03±0.21%), fat (16.57±0.41%), ash (4.36±0.05%), and total calories (458.57±1.12 kcal/100 g) when compared with the CPP which exhibited a higher content of moisture (8.77±0.14%), crude fibre (16.45±0.13%), sugars (54.46±0.34%), and available carbohydrates (70.49±0.13%).

Table 2. Proximate chemical composition of raw materials (g/100 g sample on dwb, except moisture).

Component (%)	WF	CP	CPP	P	$LSD_{0.05}$
Moisture	11.28±0.11[a]	5.03±0.17[c]	8.77±0.14[b]	0.000***	1.13
Protein	10.41±0.25[a]	9.03±0.21[b]	7.43±0.19[c]	0.000***	0.94
Fat	0.94±0.08[c]	16.57±0.41[a]	2.29±0.15[b]	0.000***	0.77
Ash	0.58±0.03[c]	4.36±0.05[a]	3.34±0.07[b]	0.000***	0.62
Crude fibre	0.62±0.06[c]	1.71±0.10[b]	16.45±0.13[a]	0.000***	0.73
Sugars	1.13± 0.14[c]	2.05±0.19[b]	54.46±0.34[a]	0.000***	0.91
Carbohydrate[a]	87.45±0.16[a]	68.33±0.11[c]	70.49±0.13[b]	0.000***	1.17
Total calories (kcal/100 g)	399.90±1.10[b]	458.57±1.12[a]	332.29± 1.18[c]	0.000***	2.21

[a] Carbohydrates calculated by difference. Values are the means of determination conducted in triplicate using standard division.

Different letters adjacent to values in the row indicate significant differences at p≤0.05 between samples, and the same letters indicate no significant differences.

Proximate mineral composition of raw materials:

Table (3) presents the proximate mineral composition (mg/100 g sample on dwb) of WF, CP, and CPP. The data revealed that CP was relatively higher in potassium (1029.31±2.62 mg/100 g), magnesium (294.67±1.91 mg/100 g), zinc (4.37±0.26 mg/100 g), and copper (2.18±0.12 mg/100 g). While CPP had the highest content in phosphorus (491.73±1.71 mg/100 g), calcium (311.45±1.93 mg/100 g), iron (5.87±0.31 mg/100 g), and manganese (2.73±0.22 mg/100 g).

Table 3. Proximate mineral composition of raw materials (mg/100 g sample on dwb).

Mineral	WF	CP	CPP	P	$LSD_{0.05}$
K	115.94±1.76[c]	1029.31±2.62[a]	968.54±2.56[b]	0.000***	5.79
P	164.04±1.37[c]	360.64±1.53[b]	491.73±1.71[a]	0.000***	4.91
Mg	112.63±1.15[c]	294.67±1.91[a]	217.95±1.47[b]	0.000***	3.82
Ca	23.74±0.73[c]	126.28±1.05[b]	311.45±1.93[a]	0.000***	3.54
Na	4.12±0.26[c]	14.19±0.41[b]	18.52±0.36[a]	0.000***	1.93
Fe	1.21±0.11[c]	2.74±0.20[b]	5.87±0.31[a]	0.000***	1.43
Zn	1.03±0.07[c]	4.37±0.26[a]	3.51±0.29[b]	0.000***	1.29
Mn	2.19±0.14[b]	2.46±0.13[ab]	2.73±0.22[a]	0.022*	0.51
Cu	0.82±0.05[c]	2.18±0.12[a]	1.26±0.15[b]	0.000***	0.36

Values are the means of determination conducted in triplicate using standard division. Different letters adjacent to values in the column indicate significant differences at p≤0.05 between samples, and the same letters indicate no significant differences.

Proximate essential and non-essential amino acid composition of raw materials:

Data in (Table 4) included the proximate essential and non-essential amino acid composition (g amino acid/100 g protein) of WF, CP, and CPP. The obtained results revealed that CPP showed higher amounts of the essential amino acids leucine (9.25±0.15), valine (9.08±0.28), threonine (5.08±0.17), lysine (4.25±0.10), and methionine (1.41±0.09 g amino acid/100 g protein) compared with WF and CP. In addition, non-essential amino acids were recorded in higher quantities: aspartic (18.23±0.17), alanine (10.57±0.11), and serine (6.81±0.19 g amino acid/100 g protein) compared with WF and CP.

On the other hand, isoleucine (4.16±0.19), phenylalanine (4.03±0.20), tryptophan (1.02±0.08), glutamic acid (28.80±0.20), proline (9.44±0.16), glycine (4.87±0.14), arginine (4.84±0.11), histidine (2.85±0.05), tyrosine (2.45±0.06), and cysteine (2.70±0.10 g amino acid/100 g protein) essential and non-essential amino acids were recorded in higher quantity in WF compared with CP and CPP.

Table 4. Proximate essential and non-essential amino acid composition of raw materials (g amino acid/ 100 g protein).

Amino acid	WF	CP	CPP	P	$LSD_{0.05}$
Essential amino acids					
Leucine	5.15±0.18[c]	7.20±0.21[b]	9.25±0.15[a]	0.000***	0.77
Valine	2.77±0.14[C]	3.19±0.13[b]	9.08±0.28[a]	0.000***	0.41
Threonine	3.15±0.11[b]	3.05±0.12[b]	5.08±0.17[a]	0.000***	0.60
Lysine	2.05±0.09[b]	4.22±0.16[a]	4.25±0.10[a]	0.000***	0.54
Isoleucine	4.16±0.19[a]	2.12±0.08[c]	3.77±0.22[b]	0.000***	0.36
Phenylalanine	4.03±0.20[a]	2.87±0.13[b]	3.09±0.11[b]	0.000***	0.45
Methionine	1.35±0.05[a]	0.98±0.07[b]	1.41±0.09[a]	0.001**	0.32
Tryptophan	1.02±0.08[a]	0.65±0.05[b]	0.97±0.03[a]	0.000***	0.26
Non-essential amino acids					
Aspartic	10.62±0.28[b]	10.01±0.19[c]	18.23±0.17[a]	0.000***	0.60
Alanine	4.98±0.12[b]	2.97±0.13[c]	10.57±0.11[a]	0.000***	0.63
Glutamic	28.80±0.20[a]	12.83±0.15[b]	9.67±0.18[c]	0.000***	0.77
Serine	4.77±0.13[b]	2.34±0.06[c]	6.81±0.19[a]	0.000***	0.81
Proline	9.44±0.16[a]	1.24±0.12[c]	5.79±0.17[b]	0.000***	0.89
Glycine	4.87±0.14[a]	2.02±0.07[c]	3.53±0.10[b]	0.000***	0.79
Arginine	4.84±0.11[a]	4.35±0.15[b]	3.18±0.12[c]	0.000***	0.45
Histidine	2.85±0.05[a]	2.02±0.08[b]	2.83±0.07[a]	0.000***	0.51
Tyrosine	2.45±0.06[a]	1.88±0.04[b]	1.67±0.03[c]	0.000***	0.20
Cysteine	2.70±0.10[a]	0.79±0.02[b]	0.82±0.05[b]	0.000***	0.26

Values are the means of determination conducted in triplicate using standard division.

Different letters adjacent to values in the row indicate significant differences at p≤0.05 between samples, and the same letters indicate no significant differences.

Proximate chemical composition of cupcake:

The proximate chemical composition (g/100 g sample on dwb, except moisture) of the cupcake is shown in (Table 5). The cupcakes with the replacement of CP and sugar by CPP had higher moisture when compared to the control sample, ranging between 33.26±0.15 to 39.79±0.16% (by rate increase 6.19 to 27.04%), while it was 31.32±0.11% in the control cupcake sample. The protein content in cupcake samples ranged between 13.74±0.24 to 18.09±0.12%; it was the highest value in the F_{100} cupcake sample, with a rate increase of 31.66% compared with the control cupcake sample. Furthermore, the control cupcake sample showed a higher lipid content (20.08±0.32%). Regarding the ash content, the ash content of the cupcakes increased by increasing the addition of CPP, with the F_{100} cupcake sample recording the highest ash content at 4.08±0.02% (by rate increase 72.88%), compared to 2.36±0.02% for the control cupcake sample.

On the other hand, the addition of 25% from CPP increased crude fibre from 1.04±0.06 (for the control cupcake sample) to 2.82±0.08 (by rate increase 171.15%) until it got to 8.23±0.05% (by rate increase 691.35%) in the cupcake sample containing 100% from CPP. Statistical analysis showed significant differences (p≤0.05) in crude fibre between cupcake samples. Otherwise, available carbohydrates of cupcake samples ranged between 57.45±0.21 to 62.78±0.23%; it was the highest in the control cupcake sample, while it was the lowest in the F_{100} cupcake sample. Finally, as the level of replacement of CP and sugar by CPP increased, the calorific value of the cupcakes decreased; a reduction in calorific value from 486.80±0.58 kcal/100g for the control cupcake sample to 411.51±0.37 kcal/100g for the cupcake made by 100% CPP (by rate decrease 15.47%).

Table 5. Proximate chemical composition of cupcakes containing different proportions of CPP replacing CP and sugar (g/100 g sample on dwb, except moisture)

Formula	Moisture	Protein	Lipids	Ash	Crude fiber	Carbohydrate[a]	Calorific value (kcal/100 g)
Control	31.32±0.11[e]	13.74±0.24[e]	20.08±0.32[a]	2.36±0.02[e]	1.04±0.06[e]	62.78±0.23[a]	486.80±0.58[a]
F_{25}	33.26±0.15[d]	15.20±0.17[d]	17.52±0.21[b]	2.79±0.05[d]	2.82±0.08[d]	61.67±0.17[b]	465.16±0.63[b]
F_{50}	34.89±0.13[c]	16.56±0.13[c]	15.41±0.15[c]	3.22±0.03[c]	4.67±0.05[c]	60.14±0.15[c]	445.49±0.45[c]
F_{75}	36.05±0.17[b]	17.27±0.29[b]	13.84±0.19[d]	3.65±0.01[b]	6.49±0.07[b]	58.75±0.19[d]	428.64±0.71[d]
F_{100}	39.79±0.16[a]	18.09±0.12[a]	12.15± 0.14[e]	4.08±0.02[a]	8.23±0.05[a]	57.45±0.21[e]	411.51±0.37[e]
P	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
$LSD_{0.05}$	1.12	0.98	1.03	0.65	0.78	1.36	1.57

[a] Carbohydrates calculated by difference. Values are the means of determination conducted in triplicate using standard division. Different letters adjacent to values in the column indicate significant differences at p≤0.05 between samples, and the same letters indicate no significant differences.

Proximate mineral composition of cupcakes:

The proximate mineral composition (mg/100 g sample on dwb) of cupcakes prepared with the replacement of CP and sugar by CPP is presented in (Table 6). All minerals were increased by a gradual and significant increase by the replacement of CP and sugar by CPP in all produced cupcakes samples compared to the control cupcake sample. The results showed that the minerals in the F_{100} cupcake sample by rate increased 55.31% for K, 172.29% for P, 44.59% for Mg, 347.66% for Ca, 149.43% for Na, 346.39% for Fe, 116.13% for Zn, 71.72% for Mn, and 87.65% for Cu compared with the control cupcake sample. On the other hand, sodium content (Na) ranged from 14.85±0.41 to 37.04±0.46 mg/100 g in all cupcake samples. The American Heart Association reported that the amount of sodium in the diet should be limited since sodium helps to increase blood pressure and the tendency to retain fluid. Foods that contain 140 mg of sodium or less are considered low-sodium foods. The required daily intake for sodium is 1000 to 1500 mg per day.

Physical properties of cupcakes:

The figure below displays the results of the replacement of CP and sugar by CPP on the weight (g), volume (ml), and specific volume (ml/g) of cupcake samples (Fig. 3). The findings indicate that with increasing levels of CPP, the weight of the cupcakes gradually increased, while the volume and specific volume decreased significantly when compared to the control cupcake. Cupcake weight ranged from 29.36±0.14 to 33.12±0.11 g. Statistical analysis showed non-significant differences in weight between the control and F_{25} two sample, while samples F_{50} to F_{100} were significantly higher.

Table 6. Proximate mineral composition of cupcakes containing different proportions of CPP replacing CP and sugar (mg/100 g sample on dwb)

Formula	K	P	Mg	Ca	Na	Fe	Zn	Mn	Cu
Control	1117.15±2.25[e]	361.21±1.47[e]	301.48±1.63[e]	139.37±1.13[e]	14.85±0.41[e]	2.63±0.17[e]	1.86±0.11[d]	1.45±0.05[e]	0.81±0.03[c]
F_{25}	1206.25±2.41[d]	516.35±1.53[d]	329.98±1.48[d]	252.44±1.22[d]	19.83±0.38[d]	4.95±0.25[d]	2.03±0.17[d]	1.71±0.10[d]	1.18±0.06[b]
F_{50}	1383.20±2.30[c]	672.05±1.61[c]	365.29±1.35[c]	374.59±1.19[c]	25.62±0.43[c]	7.24±0.16[c]	2.73±0.15[c]	1.96±0.08[c]	1.27±0.09[b]
F_{75}	1560.12±2.80[b]	827.76±1.74[b]	400.59±1.40[b]	498.75±1.27[b]	31.33±0.35[b]	9.49±0.21[b]	3.36±0.14[b]	2.21±0.13[b]	1.35±0.12[ab]
F_{100}	1735.08±3.05[a]	983.46±1.82[a]	435.90±1.57[a]	623.90±1.32[a]	37.04±0.46[a]	11.74±0.28[a]	4.02±0.18[a]	2.49±0.19[a]	1.52±0.15[a]
P	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
$LSD_{0.05}$	12.36	9.71	7.42	7.08	4.79	2.24	0.62	0.23	0.18
Children RDA[a] (mg/day)	3000	460-500	80-170	500-800	1000	7-10	3-5	1.2-1.5	0.50
Adults RDA[a] (mg/day)	3800	700-1250	350-420	800-1200	1500	10-15	8-12	1.6-2.3	0.7-0.9

[a] Recommended Dietary Allowances (2004). Values are the means of determination conducted in triplicate using standard division. Different letters adjacent to values in the column indicate significant differences at p≤0.05 between samples, and the same letters indicate no significant differences.

On the other hand, incorporating CPP into cupcakes had a negative effect on volume and specific volume. The cupcakes volume ranged from 72.27±0.23 to 81.50±0.20 ml; there was no significant difference in volume observed between the control and F_{25} sample, while the F_{50}, F_{75}, and F_{100} samples were significantly different from the control sample. The highest volume was observed in the control (81.50±0.20 ml) and F_{25} (80.00±0.25 ml) samples, respectively, while the volume significantly decreased in the F_{50} (78.65±0.35 ml), F_{75} (75.50±0.30 ml), and F_{100} (72.27±0.23 ml) samples. In addition, the specific volume of the cupcake ranged from 2.18±0.03 to 2.78±0.06 ml/g. Statistical analysis showed non-significant differences in specific volume between the control and F_{25} sample.

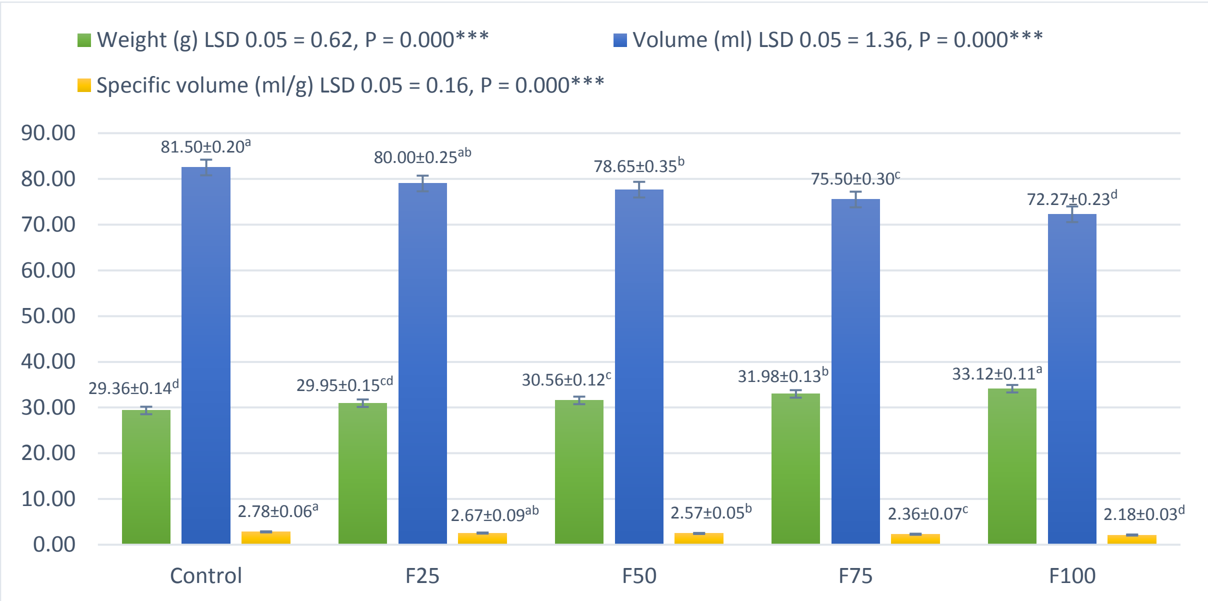

Fig. 3. Physical properties of cupcakes containing different proportions of CPP replacing CP and sugar.

Colour parameters of cupcake:

The colour parameters of the cupcakes are shown in (Table 7). It can be seen that as the CP and sugar were replaced by CPP, the cupcakes became darker in colour, and the sample formulation F_{100} was the darkest. From the results of all the cupcake samples, they can be classified as dark in colour in that they all had L^* values of less than 50 ($L^* < 50$).

Regarding the parameters of chromaticity (a^* and b^*), the chromaticity coordinate a^* increased in line with the increased substitution of CP and sugar were replaced by CPP, and the chromaticity coordinate b^* decreased in the same manner. From the results, it can be seen that the samples with lower levels of substitution of CP and sugar by CPP showed higher b^* values. Observing the results, it can be seen that as the replacement of CP and sugar by CPP increased, the a^* increased, and hence the darkening of the cupcakes occurred. Chroma values indicate that the colour of CPP-contented samples is also lower than the control in all samples, and a decrease in the values of Chroma was noticed as the CP and sugar were replacing increased by CPP.

As regards the Hue values, values close to 90 correspond to yellowish colours, while values close to 45 indicate reddish tones, when these values are reduced to zero, more violet tones are perceived. The control cupcake sample displayed hue values close to the yellow tones, while the products with CPP had hues between red and violet, which are closer to red.

Table 7. The colour parameters of cupcakes containing different proportions of CPP replacing CP and sugar

Formula	L^*	a^*	b^*	Chroma	Hue	ΔE
Control	49.83±0.12^a	10.12±0.08^e	17.19±0.14^a	19.95±0.11^a	59.51±0.07^a	-
F_{25}	47.26±0.14^b	11.28±0.07^d	14.93±0.15^b	18.71±0.08^b	52.93±0.10^b	3.61±0.05^d
F_{50}	45.92±0.13^c	12.66±0.04^c	11.13±0.12^c	16.86±0.06^c	41.32±0.12^c	7.65±0.04^c
F_{75}	42.17±0.13^d	13.12±0.03^b	09.71±0.09^d	16.32±0.05^d	36.50±0.08^d	11.12±0.03^b
F_{100}	40.15±0.15^e	13.75±0.05^a	08.04±0.06^e	15.93±0.09^e	30.32±0.13^e	13.81±0.02^a
P	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
$LSD_{0.05}$	2.59	0.61	1.41	0.37	3.29	2.61

Values are the means of determination conducted in triplicate using standard division.
Different letters adjacent to values in the column indicate significant differences at p≤0.05 between samples, and the same letters indicate no significant differences.

Texture profile analysis (TPA) of cupcakes:

The results for the texture analysis parameters of cupcakes are shown in (Table 8). The hardness, cohesiveness, springiness, and resilience values of cupcakes were determined. The standard cupcake showed the lowest hardness (3.65±0.04 N) compared with 4.37±0.06, 4.83±0.03, 5.54±0.05, and 6.82±0.02 N for F_{25}, F_{50}, F_{75}, and F_{100}, respectively. The results also showed that cohesiveness for the control sample was 0.71±0.02, which decreased in the F_{25} sample to 0.65±0.05, followed by the F_{50} sample (0.61±0.04), reaching 0.52±0.03 for the F_{100} cupcake sample.

In the same way, the springiness was highest in the control cupcake sample (0.87±0.03) and decreased with increasing level replacement of CP and sugar by CPP, reaching a low of 0.69±0.01 in the F_{100} cupcake sample. Springiness can be physically defined as the rate at which a cupcake returns to its original condition after being pressed. As with springiness, the standard cupcake formulation showed the best resilience (0.28±0.02). Resilience is given by the symmetry of a cupcake in the first compression, which relates to the degree that a sample recovers after compression when taking into account the distance to which the sample was compressed and the speed at which this compression occurred.

On the other hand, two other parameters were derived (gumminess and chewiness) by calculation from the measured parameters: Firstly, gumminess was defined as the multiple of hardness and cohesiveness, which reflects the energy needed to chew and swallow the cupcake, increasing along with hardness. Higher levels of replacement of CP and sugar by CPP resulted in both harder and gummier cupcakes. Secondly, chewiness, defined as the multiple of gumminess and springiness (which is hardness × cohesiveness × springiness), which reflects the effort required to chew the cupcake before swallowing, followed the opposite trend. The control cupcakes had the lowest chewiness (2.25±0.03), while the sample with the higher CPP level exhibited the highest chewiness (2.45±0.01 for the F_{100} cupcake sample). This indicates that CPP contributes to a chewier texture.

Table 8. The texture profile analysis of fresh cupcakes containing different proportions of CPP replacing CP and sugar

Formula	Hardness (N)	Cohesiveness (mm^3)	Springiness (mm)	Resilience (N)	Gumminess (N)	Chewiness (mJ)
Control	3.65±0.04^e	0.71±0.02^a	0.87±0.03^a	0.28±0.02^a	2.59±0.05^e	2.25±0.03^d
F_{25}	4.37±0.06^d	0.65±0.05^{ab}	0.81±0.04^b	0.26±0.01^{ab}	2.84±0.03^d	2.30±0.02^c
F_{50}	4.83±0.03^c	0.61±0.04^{bc}	0.79±0.02^{bc}	0.25±0.02^{ab}	2.95±0.01^c	2.33±0.01^c
F_{75}	5.54±0.05^b	0.57±0.03^{cd}	0.75±0.02^c	0.23±0.03^b	3.16±0.03^b	2.37±0.02^b
F_{100}	6.82±0.02^a	0.52±0.03^d	0.69±0.01^d	0.19±0.01^c	3.55±0.02^a	2.45±0.01^a
P	0.000***	0.001**	0.000***	0.002**	0.000***	0.000***
$LSD_{0.05}$	0.45	0.07	0.05	0.03	0.41	0.03

Values are the means of determination conducted in triplicate using standard division.
Different letters adjacent to values in the column indicate significant differences at p≤0.05 between samples, and the same letters indicate no significant differences.

Sensory evaluation of cupcakes:

Table (9) presents the sensory evaluation of cupcakes regarding colour, texture, appearance, odour, taste, and overall acceptability. In terms of colour, the control cupcake sample and the samples F_{25} and F_{50} had the highest average scores (8.10±0.10, 8.07±0.14, and 8.02±0.15, respectively), with no statistically significant difference ($p>0.05$) between them. While the sample F_{100} had the lowest acceptability of colour (7.00±0.11), a factor that may have been associated with the dark colour caused by replacing more of the CP and sugar with CPP. Regarding texture, the cupcake samples received scores from 6.00±0.09 (for the F_{100} cupcake sample) to 7.84±0.06 (for the control cupcake sample). As for appearance, we found that the F_{25} and F_{50} cupcake samples showed no significant differences compared to the control cupcake sample, while all other cupcake samples had lower but good scores.

On the other hand, the results obtained for the odour showed that all the cupcake samples received scores between 7.70±0.11 and 8.15±0.10 and did not differ significantly from each other. In terms of taste, all cupcake samples showed no significant differences compared to the control cupcake sample, with the exception of the F_{100} sample, which received a score of 7.05±0.10. As for the overall acceptability, the F_{75} and F_{100} cupcake samples differed from the others, being two of the least preferred, but they two still had good overall acceptability. All the cupcake samples containing up to 50% CPP showed no significant difference between each other compared to the control cupcake sample (with scores between 7.95±0.15 and 8.04±0.06), indicating the possibility of substituting CP and sugar with CPP up to this level.

Table 9. Sensory evaluation of cupcakes containing different proportions of CPP replacing CP and sugar

Formula	Colour	Texture	Appearance	Odour	Taste	Overall acceptability
Control	$8.10±0.10^{a}$	$7.84±0.06^{a}$	$7.60±0.13^{a}$	$8.15±0.10^{a}$	$7.71±0.08^{a}$	$8.04±0.06^{a}$
F_{25}	$8.07±0.14^{a}$	$7.65±0.15^{ab}$	$7.43±0.19^{a}$	$8.05±0.12^{ab}$	$7.63±0.13^{a}$	$8.00±0.14^{a}$
F_{50}	$8.02±0.15^{a}$	$7.43±0.12^{b}$	$7.35±0.15^{a}$	$8.10±0.14^{ab}$	$7.51±0.11^{ab}$	$7.95±0.15^{ab}$
F_{75}	$7.50±0.07^{b}$	$7.00±0.17^{c}$	$7.05±0.10^{b}$	$7.85±0.18^{bc}$	$7.40±0.15^{b}$	$7.70±0.20^{b}$
F_{100}	$7.00±0.11^{c}$	$6.00±0.09^{d}$	$6.50±0.12^{c}$	$7.70±0.11^{c}$	$7.05±0.10^{c}$	$7.35±0.17^{c}$
P	0.000***	0.000***	0.000***	0.010*	0.000***	0.001**
$LSD_{0.05}$	0.21	0.23	0.25	0.28	0.21	0.28

Different letters adjacent to values in the column indicate significant differences at $p≤0.05$ between samples, and the same letters indicate no significant differences.

DISCUSSION

Proximate chemical composition of cupcake:

Cupcakes are a popular food product known for their high calorie value, fat, and sugar content, and due to the high rate of diabetes and obesity, consumers are demanding healthier pastries that are low in calories, fat, cholesterol, and sugar. They also want pastries that contain health-promoting ingredients like fibre, protein, and minerals (Abdelmegiud *et al*., 2024b).

Higher moisture contents were found in the cupcakes with higher levels of fibre with increasing levels of replacement of CP and sugar by CPP. According to (Abdelmegiud *et al*., 2024a), products with high fibre content have high absorbency of water, and which is explained by the ability of fibres to retain and maintain water in their structure during the cooking process. El-Naggar and Hassan (2018) reported that carob caused an increase in protein in bakery products. Attributed the higher lipid content of the control cupcake sample to a higher lipid content in the CP, because the cupcakes substituted by CPP showed a lower lipid content. Medeiros and Lannes (2009) found that CP contains approximately 14.21% of lipids, while CPP has only 2.54%. Regarding the ash content, the ash content of the cupcakes increased by increasing the addition of CPP.

On the other hand, the crude fibre content of the cupcake samples varied significantly; the increased inclusion of the CPP in the cupcake formulation increased the crude fibre content. As the level of replacement of CP and sugar by CPP increased, the carbohydrates and calorific value of the cupcakes decreased; it was the highest in the control cupcake sample, while it was the lowest in the F_{100} cupcake sample. Rosa *et al*. (2015) formulated CP cupcake and CPP cupcake, and they found that the CPP cupcake contained fewer carbohydrates and calories than the CP cupcake because the CP has a high fat content and low fibre content, while the CPP contains little fat and a high fibre content.

Proximate mineral composition of cupcakes:

All minerals were increased by a gradual and significant increase by the replacement of CP and sugar by CPP in all produced cupcakes samples compared to the control cupcake sample. According to (Abdelmegiud, 2024), the human body requires minerals for a variety of metabolic and physiological functions, including immune function, blood acid-base balance, muscle contraction, enzyme activation, normal heart rhythm, bone health, nerve impulse conduction, oxygen transport, and oxidative phosphorylation. An adult requires around 350 mg of magnesium, 1000 mg of calcium, and 3000 mg of potassium each day.

Physical properties of cupcakes:

The increase in cupcake weight with increasing levels of CPP may be due to the high fibre content in the cupcake samples, which causes a high amount of water absorption by the fibre, leading to an increase in weight. In addition, the incorporation of CPP into cupcakes had a negative effect on volume and specific volume. El-Waseif *et al*., (2023) found that cupcakes made with flour with high fibre levels reduced in volume. These results may be associated with the hydrophilic characteristics of insoluble fibres retaining water in their structures. Raouf *et al*., (2022) reported that fibres adsorb intramolecular water, increasing their weight but not their height to any great degree. The baked cupcakes specific volume articulates the amount of air that can be keep in the final product. A higher gas keeping and higher extension of cupcakes leads to a higher specific volume (Elraqubay *et al*., 2024).

Colour parameters of cupcake:

The colour is one of the most important quality indicators that people consider when choosing food products. The cupcakes became a darker colour with an increase as the CP and sugar were replaced by CPP. According to (Esteller *et al*., 2006), cupcakes that have low L^* values are darker in colour because they have lower rates of reflectance for light. On the other hand, the chromaticity coordinate a* increased and b^* decreased in line with the increased substitution of CP and sugar were replaced by CPP. According to (Esteller *et al*., 2006), high values for the b^* parameter translate into samples with strong yellow/gold staining, which are characteristic of products that have been baked. In addition, high values for the a^* indicate cupcakes with a dark colour. In general, the colour changes observed in cupcakes are due to the influence of incorporating CPP. Esteller and Lannes (2008) stated that the colour of baked products depends on several factors, including water content, pH, reducing sugars, amino acid content, baking time, and temperature. While (Djordjević *et al*., 2019) stated that Maillard and caramelization reactions that occur during baking at high temperatures are mainly associated with crust colour, the crumb colour depends on the ingredients' colours.

Texture profile analysis (TPA) of cupcakes:

Hardness can be physically defined as the force that is required to achieve a given deformation of a certain product (Prasad *et al*., 2024). The cupcakes showed an increase in hardness with increasing CPP levels. The high hardness could be attributed for cupcakes to lower specific volume and high fibre content. Due to the lower specific volume, the cupcakes were denser, had a packed crumb structure, and had higher hardness. In addition, the fibre-protein complex at high baking temperatures of cupcakes can cause the hardening of the final product (Jan *et al*., 2018; Kadry *et al*., 2021). Jeddou *et al*., (2017) also reported that high fibre content absorbs more water, which can lead to a reduction in the quality of some of the technological characteristics of products, such as hardness, springiness, cohesiveness, and conformation.

In terms of cohesiveness, it describes the ability of food structure to resist compression, and it is an important factor in producing a high-quality product to meet consumer and packaging standards (Bozdogan *et al*., 2019). The results showed that the standard cupcake differed statistically from the others in that it had greater cohesiveness, which was related to its lower fibre content compared to the other formulations because it did not contain CPP. This decrease in cohesiveness of cupcake samples may be due to the increased fibre content that interferes with the development of the gluten network and leads to weak adhesion between the fibres and gluten starch matrix. In addition, the CPP makes the cupcakes less elastic and springiness, which was associated with the fibre content of the cupcakes. The greater the percentage of fibre, the lower the resilience (Rosa *et al*., 2015).

Sensory evaluation of cupcakes:

In general, the control cupcake sample and the samples F_{25} and F_{50} had the highest average scores of sensory evaluation regarding colour, texture, appearance, odour, taste, and overall acceptability. On the other hand, the F_{75} and F_{100} cupcake samples differed from the others, being two of the least preferred, but they two still had good acceptability. The results indicate that it is possible to prepare cupcakes using the CPP, the natural sweetener, to replace the sugar and CP up to 50% with pleasant sensory attributes.

CONCLUSION

The results showed that it is possible to produce new, healthy, and low-sugar cupcakes. This cupcake has a high content of protein, dietary fibre, and mineral composition and low lipid content, carbohydrates, and calories by replacing CP and sugar with CPP. The cupcakes with up to 50% replacement of CP and sugar by CPP showed no significant difference in terms of appearance, odour, taste, and overall acceptability compared to the standard cupcake, demonstrating that replacement up to this level did not influence sensory attributes.

However, more studies should be conducted to investigate the possibility of using CPP as an ingredient in other food products in order to increase the application of such a valuable food ingredient.

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تأثير إستبدال مسحوق الكاكاو والسكر بمسحوق لب الخروب على التركيب الكيميائي وخصائص الجودة للكب كيك

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هدفت هذه الدراسة إلى إنتاج كب كيك صحي ومنخفض السعرات الحرارية والدهون والسكر عن طريق إستبدال مسحوق الكاكاو (CP، عالي الدهون) والسكر (أحد المكونات الرئيسية للكب كيك) بمسحوق لب الخروب (CPP). كانت مستويات إستبدال مسحوق لب الخروب المستخدم في تركيبة الكب كيك صفر، ٢٥، ٥٠، ٧٥ و ١٠٠٪ من مسحوق الكاكاو والسكر. أظهرت النتائج أن الألياف والسكريات الطبيعية والكربوهيدرات في مسحوق لب الخروب كانت أعلى من تلك الموجودة في مسحوق الكاكاو. بينما أظهر مسحوق الكاكاو محتوى أعلى من الدهون والسعرات الحرارية الكلية. بالإضافة إلى ذلك، كان مسحوق لب الخروب أعلى في الفوسفور والكالسيوم والحديد والمنجنيز مقارنة بمسحوق الكاكاو الذي كان أعلى في البوتاسيوم والمغنيسيوم والزنك والنحاس. يعتبر مسحوق لب الخروب مصدرًا مهمًا لمعظم الأحماض الأمينية الأساسية وغير الأساسية مقارنة بمسحوق الكاكاو. من ناحية أخرى، أدى إستبدال مسحوق الكاكاو والسكر بمسحوق لب الخروب إلى زيادة محتوى البروتين والألياف والمعادن، وانخفاض محتوى الدهون والكربوهيدرات والسعرات الحرارية في عينات الكب كيك مقارنةً بعينة التحكم وذلك بالتوازي مع زيادة مستوى الاستبدال. كما زاد وزن الكب كيك ولونه الداكن مع زيادة مستوى الاستبدال، بينما انخفض حجمه وحجمه النوعي. أدى ارتفاع مستوى استبدال مسحوق الكاكاو والسكر بمسحوق لب الخروب (من صفر إلى ١٠٠٪) إلى زيادة صلابة الكب كيك (من ٣,٦٥±٠,٠٤ إلى ٦,٨٢±٠,٠٢ نيوتن) وإنخفاض تماسكه (من ٠,٧١±٠,٠٢ إلى ٠,٥٢±٠,٠٣ مم³). وبشكل عام، لم يظهر التقييم الحسي للكب كيك اختلافًا معنوياً ($p > 0.05$) مع استبدال ما يصل إلى ٥٠٪ من مسحوق الكاكاو والسكر بمسحوق لب الخروب في اللون والمظهر والرائحة والطعم والقبول العام.

الكلمات المفتاحية: الكب كيك، مسحوق لب الخروب، مسحوق الكاكاو، السكر، الخصائص الحسية.