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Study of Sensory and Qualitative Characteristics of Cake Manufactured from Composite Flour

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ABSTRACT

This study wheat flour was partially replaced at ratio of (25, 50, and 75 %) by with local millet flour in purpose of preparing composite flour. The percentages of moisture, fat, protein, ash, fiber and carbohydrates in millet flour were (9.30, 4.30, 9.80, 1.62, 1.81, 73.17%) and in wheat flour (12.00, 2.00, 10.50, 0.55, 0.48, 74.47%) respectively. Increasing the substitution ratios led to a significant increase (P≤0.05) in the experimental cupcake pieces as compared to the control treatment. Transactions with substitution ratios of (25%) and (75%) recorded the highest values in terms of volume. The weights of the cupcake pieces, the specific volume, and the density of the cake after baking did not differ significantly with control treatment. The treatment with 25% substitution treatment recorded the highest values of the specific volume, the lowest density, and the highest percentage of weight loss after baking. The sensory attributes values for the cupcake treatment under study showed no significant differences among the values of the specific volume, regularity of the external shape, softness, and color of the crumb. The values of freshness, aroma, taste, and total scores decreased with increasing substitution ratios. The treatment with 25% substitution did not record a significant difference as compared to control, while the rest of the treatments achieved high acceptance scores at the same time. The production cost for cupcakes from wheat flour and composite flour was the same, with a total profit of 200%.

Key words: cost, Cupcakes, flour,proso millet, sensory evaluation, spelled.

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INTRODUCTION

Composite flour is flour made by mixing flour with starches or other plant food ingredients, which aims to replace wheat flour completely or partially. It has some advantages, in terms of saving hard currency, reducing the food gap resulting from low self-sufficiency in locally grown wheat, and encouraging local cultivation of high-yielding crops (Hymavathi et al., 2020; Tharifkhan et al., 2021). Recently, there has been an increase in the consumption of baked goods, especially in countries located under tropical conditions that do not favor wheat production. Also, the continuous import of basic materials, especially food, imposes dependence on producing countries. Therefore, in 1964, the Food and Agriculture Organization encouraged these countries to grow and use local crops such as cassava, maize and potatoes in order to reduce the burden of supporting these countries (Thilagavathi et al., 2015). Wheat flour is an essential component of composite flour needed to produce baked goods similar in quality to those produced from wheat flour alone. The flour mixing process also compensates for the deficiency of essential amino acids in wheat such as lysine and threonine and contributes to improving nutritional quality (Kazim et al., 2012). Millet has been used for centuries to fortify wheat flour because it is rich in proteins, phenolic compounds and minerals. Compared to wheat, millet is four times richer in fats and three times richer in minerals.

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Compared to rice, it has twice the calcium content and seven times the mineral content (Zheng et al., 2020; Wang et al., 2022). To improve the use of millet in the bakery industry, appropriate processing techniques should be developed. In addition, vital gluten can be added to the compound flour to improve the quality of its product. Because millet has a low glycemic index, it is beneficial for those suffering from hypertension, diabetes and heart disease **.** In 1964, the Food and Agriculture Organization encouraged these non-wheat-producing countries to cultivate and use local crops such as cassava, maize and potatoes in order to reduce the burden of subsidies for these countries (Ohimain, 2014). Bakery products constitute one of the most consumed foods in the world. Cakes are one of the most important of these products and are considered by customers as a delicious commodity with specific sensory qualities. Fat, sugar, eggs, and flour are the main ingredients used in making cakes, each of which plays an important functional role in the structure and quality of the product. More specifically, cake butter represents a complex emulsion and foaming system that is processed by heating. Baking cakes result in a light and airy structure as well as the production of a large number of volatile compounds, which play a major role in the development of their typical flavor. The choice of raw materials as well as changing the manufacturing process can modify the cake structure and the produced volatile flavor compounds (Klivans, 2005 ; Matsakidou et al.,2010). The applications of composite flours are diverse in the production of various bakery and pastry products. This study aimed to produce low glycemic index cakes from composite flours (wheat and local millet) and to study the effect of substitution ratios on the physical, chemical, and functional properties of the flour and the product and its consumer acceptance.

MATERIALS AND METHODS

Iraqi millet, proso (*Panicum miliaceum*) type, wheat flour and cupcake ingredients were obtained from Iraqi local markets - Baghdad.. All foreign materials, broken and immature grains were removed. The grains were washed after soaking for 15 minutes and dried in the shade (hot air 40 - 45°C) for 24 hours

=**Preparation of crush millet**: The proso millet grains were crushed using an electric grinder (Cia tronic). The powder passed through a 250 micron sieve, and stored in plastic bags at 5±1°C until use**.**

Preparation of millet flour

The purified millet grains were conditioned before performing the milling process, , by raising the moisture of the grain sample to 10% using filtered water in two batches for 18 hours at room temperature. The technical grinding process was carried out for hydrated millet grain samples to produce flour with an extraction rate of 70% using a laboratory mill equipped from the German Brabender Mill Company. The resulting powder passed through a 250 micron sieve and stored in plastic bags in the freezer at a temperature of (-18 °C).

Chemical composition analyses of wheat and millet flour :The chemical composition, including moisture, ash, protein, and fat, were analyzed using the established procedures outlined in the AACC, (2010) with the symbols (19-44), (30-25), (46-11), and (01-8). The total carbohydrate content was calculated, by subtracting the sum of these approximated elements from 100**.**

Amylose estimation: The amylose content was measured using the colorimetric method of blue amylose-iodine complex**.**

Scanning electron microscopy (SEM) examination: The samples preparation and SEM examination were done due to the method described in (36). A scanning electron microscope from the Dutch company Thermos Scientific (Axia Chiemi SEM) was used**.**

Estimation of total carbohydrates in millet flour: The method followed by Hammoud et al., (2024) was adopted.

Cupcakes preparation: Cupcakes were prepared. The basic ingredients included the following **:**

Al-fakher wheat flour 150 g, sugar 75 g, dry milk powder 15 g, margarine butter 15 g, vegetable oil 15 g, eggs (190 g), vanilla 10 g, salt 1 g, vinegar 1 ml, cake improver 10 g, baking powder 10 g. Meanwhile the wheat flour partially replace by millet flour at ratios

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of 25%, 50%, and 75%. The treatments labeled as following **:**

C0: (Control) consisting of the basic ingredients. C1, C2 and C3 consist of basic ingredients with 25%, 50% and 75% substitution of wheat flour by millet flour. The cake mix was divided into 12 portions, 40 gm each, and the remaining mixture was neglected. Weight before baking= 480 g (40 g x 12 pieces).

Physical characteristics of the cupcake

Specific volume measurement: was followed to estimate the volume of the cupcakes pieces based on the method of displacing the rape seeds, and then the cake pieces were weighed. The specific volume (permeability) was calculated by applying the following equation**:**

Specific volume (cm^3/g) = Volume of displaced rape seeds (cm^3) / Weight of cupcake (g)

The cake pieces with the highest specific volume were given a score of 30 on the grading scale of the sensory evaluation table, and the remaining pieces were scored on the basis of this piece**.**

Measuring the density of the cupcakes pieces: The density of the cake pieces was estimated by dividing the weight of the cake (g) by the volume of the cake (cm^3), according to the following equation**: Cake density (g/cm^3) = weight / volume**

Measurement of weight loss percentage after

baking: The percentage of weight loss after baking was determined by using the following equation **:**

W. L. % = (W.Cp.B.B.-W.Cp.A.B)/(W.Cp.B.B.) x 100

W.L.=weight loss, W.Cp.B.B.= weight of the experimental cupcakes pieces before baking, W.Cp.A.B= weight of the same cupcakes pieces after baking .

Measurement of color degree of cupcakes: The color degree of the experimental cupcakes pieces were measured using a Lab colorimeters (The Lab colorimeter utilizes the International Commission on Illumination) according to the method described by Al-Masri and Abdel Hamid, (2016). (CIE) color scales, expressing color values as luminance (L*) , red-green axis (a*), and yellow-blue axis (b*), recorded directly from the color measurement device at a calibrated rate **.**

Sensory evaluation of cake: The sensory evaluation for the experimental cake was done using the evaluation form **.**

Cupcakes Pricing Calculation: The method described by Śmiałek, (2024) was followed to calculate the costs of producing cupcakes based on the prices of all components involved in manufacturing and the manufacturing costs (expenses for electricity, labor, and tools)**.**

Statistical analysis: The Statistical Analysis System (2018) was applied for data analysis to point out the impact of different factors on the evaluated characteristics using a Completely Randomized Design (CRD). The significant differences among means were compared using the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

Chemical composition: Table (1) shows the chemical composition of white wheat flour and proso millet flour (70% extraction rate) represented by moisture, protein, fat, ash, fiber and carbohydrates. According to the results, the moisture content of the two types of flour was 12.0 and 9.30%, respectively. The moisture content of flour plays a crucial role in determining its quality and water absorption rate. Bakers prefer a moisture content ranging from 11.50 - 15.20%, as this range ensures that the flour is safe against microbial and enzyme spoilage and reduces the risk of insect infestation (Hammoud et al., 2024). While the results indicate that the protein content of the flour under study was 10.50 and 9.80%, respectively. Protein is the decisive factor in determining the suitability of flour for bread making in addition to its nutritional value. The same table shows that the fat content was 2.00 and 4.30%, respectively. Although the fat content in wheat flour is low, it gives the gluten network the required flexibility to be flexible enough to enable it to expand and retain the gases produced during the fermentation process. Therefore, the high fat content in millet flour will help to give the gluten network the required elasticity. As for the fiber content, as indicated in the table above, it were 0.48 and 1.81%, respectively, in the flour under study. While the ash content in

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the two types of flour were 0.55 and 1.62%, respectively. The results indicate a higher percentage of fiber and ash in millet flour compared to wheat flour, which may be due to the thickness of the fruit and seed coat in millet compared to its counterparts in wheat. As for the carbohydrate content, it reached 74.47 and 73.17%, respectively. The high percentage of ash, fiber and fat in millet flour contributes to its high nutritional value and enhances the nutritional properties of the products derived from it, but the low moisture content in it helps to extend its storage period **.**Protein plays an important role in determining the quality of the final product, but the protein content in flour is not the only factor affecting its strength. On the other hand, protein quality remains the primary factor determining the properties of flour and the volume of the final bread. In contrast to other flour components, this genetic trait is rarely affected by external factors**.** Flour properties are affected by extraction rates from the milled grains, the nature of the mixture components used, and their intended purpose. In general, a high extraction rate during milling is usually the reason for the high percentage of ash and fiber in flour. Whereas some researcher (Hymavathi et al.,2020) found that the percentage of chemical components of millet in the same order above were (8.12, 14, 4.9, 0.7, 71 %) and (10.29, 11, 3.3, 3.91, 63%), respectively. While for wheat flour those values were (11.62, 10.8, 2, 0.45, 0.48, 74.47%) and (12.5, 10.64, 2.45, 0.55, 0.75, 74.89%) (Klivans, 2005).

Table 1 . The chemical composition and calories of wheat flour and Iraqi proso millet flour

The chemical composition	Iraqi proso millet flour (%)	Calories	wheat flour (%)	Calories
Moisture	9.30	---	12.00	---
Fat	4.30	38.70	2.00	18.00
Protein	9.80	39.20	10.50	42.00
Ash	1.62	---	0.55	---
Fiber	1.81	---	0.48	---
Carbs	73.17	292.68	74.47	297.88

Estimation of total carbohydrates in the treatments : Table (2) shows the concentrations of total carbohydrates in wheat flour and whole grain proso millet flour for the treatments under study (W, P0, P1, P2) as they were (72.50, 48.05, 32.90, 34.20%) respectively. The highest value of total carbohydrate content was recorded in the wheat flour treatment (W) with a significant difference from the rest of the treatments. The treatments of millet flour soaked in water (P1, P2) for 24 and 48 hours achieved the highest decrement in total sugar content, as the percentages of sugar reduction (P0, P1, P2) were (33.72, 54.62, 52.83%) respectively, which gives a clear idea about the importance of using millet in the production of low-sugar baked goods compared to wheat flour and its effect in preventing the elevator in blood sugar levels. The decrease in total sugar content after soaking is due to the activity of amylolytic enzymes (α- and β-amylase) and the leaching of soluble sugars with the soaking water. Soaking of millet grains was carried out in an attempt to increase the availability of total sugars in millet flour (to be used in cake manufacturing). The results shown in the table above were the opposite of what was expected, as this process reduced the concentrations of total sugars. Since cake is a sweet baking product, it was made from untreated millet flour. Soaking is recommended when making special (low energy) cakes for people on a diet or consuming low-calorie foods. that the water binding capacity of flour (WBC), which is one of the important functional properties to achieve the required consistency and give a high-quality final product, depends on the amount of sugars available, amylose leaching (high percentage of amylopectin), loss of starch crystal structure, and solubility. that wheat flour contains the highest percentage of total sugars and its decrease in proso millet flour as well as millet flour soaked in water. They attributed the reason for the sugar decrease after the soaking treatment to the occurrence of self-fermentation by natural flora and enzymes present with the grains

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(contaminated with them), which caused the consumption of sugars and a decrease in their concentration during the soaking period. The results of total sugars under study were consistent with what was indicated by Thilagavathi et al., (2015) in proso and small millet grains as well as wheat flour, as they were 1.83, 2.67, 3.16 %, respectively.

Amylose content in wheat flour and millet flour: Table (2) shows the concentration of amylose in the treatments of wheat flour and whole grain proso millet flour under study for treatments (W, P0, P1, P2) as they were (33.30, 30.19, 26.08, 37.97%) respectively. It is noted that the highest value was in the treatment of millet flour soaked in water for 48 hours (P2) with a significant difference (P≤0.05), while the lowest value was in treatment (P1). The reason for the decrease in amylose in treatment (P1) may be due to this treatment recording the highest decrease in total sugars, while the long soaking time in treatment (P2) of 48 hours led to the breakdown of the complex and homogeneous multiple chains of sugars, which increased the surface area for binding to iodine. This gives a clear idea about the role of the soaking process in analyzing polysaccharides into smaller units and raising the amylose content, which may improve the specifications of the products manufactured from them (while they are fresh) later . The high percentage of amylose in the flour used for making baked goods improves the properties of the gas-retaining membrane, giving it a higher expansion rate. The negative side of increasing it is that it leads to slow digestion, beside it is the main reason for the mechanism of spoilage of baked goods, as they become hard and highly susceptible to rebound over storage period. Alzubaidy,(2009) pointed out the reason for the low digestibility of starch with high amylose content, that the very long amylose chains are arranged in double helices to form type B crystallization. These long straight chains limit the access of β-amylases in the small intestine to the terminal units of glucose in the chain, which may be difficult to access originally due to the folding of the polymer. On the contrary, the highly branched amylopectin provides multiple terminal units of glucose that are easily accessible; in addition to that amylose works to form a helical complex with fats (such as fatty acids, mono glycerides and phospholipids). This complex protects the starch from enzymatic degradation and prevents the swelling of the starch granule during heat treatment. The results of this study as they were (28.90, 42.40%). Singh et al.,(2012) divided nine varieties of proso millet according to their amylose content into three categories, very low amylose (waxy) at 3.10%, medium amylose 18.15%, and high amylose, as it reached 21.40 - 34.60%. It can be concluded from this classification that the proso millet under study belongs to the high-amylose varieties. Accordingly, its components will be suitable for manufacturing high-quality products, whether used in manufacturing gluten-free products or in fortifying wheat products, as in manufacturing the compound flour under study.

Physical properties of cake: Table (3) presents the variations in the volume, weight, and density of cupcakes prepared using compound flour (replacing wheat flour with 25, 50, and 75% ratios of millet flour) and the control sample (using wheat flour), designated by treatments C0, C1, C2, and C3.

Table 2. Total Carbohydrates (%) in wheat and proso flour under study

Treatments	Total Carbohydrates (%)	Reduction in sugars compared to wheat flour (%)	Reduction in sugars compared between the millet treatments (%)	Amylose (%)
White wheat flour (W)	72.50 a	0.00	0.00	33.30 b
Millet flour (Unsoaked) (PO)	48.05 b	33.72 b	0.00	30.19 c
Millet flour (Soaked 24 h.) (P2)	32.90 c	54.62 a	31.53 a	26.08 d
Millet flour (Soaked 48 h.) (P2)	34.20 c	52.83 a	28.82 b	37.97 a
L.S.D.	2.463*	*2.105	*0.834	*1.384

*(*P≤0.05).*

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Table 3. Physical properties of cupcakes models manufactured from compound flour and wheat flour

Treatments	Volume (cm3)	Weight after baking (g)	Specific volume (cm^3/g)	Cupcakes density (g/cm^3)
C0	1980 ab	400	4.95	0.20
C1	2040a	395	5.16	0.19
C2	1920 b	405	4.74	0.21
C3	2010 a	400	5.03	0.20
L.S.D.	84.251*	20.01NS	0.471 NS	0.042 NS

*(*P≤0.05).*

C0: (Control) consisting of the basic ingredients. C1, C2 and C3 consist of basic ingredients with substituting 25%,50 % and 75% of wheat flour by millet flour

The table clearly shows that the volumes of the obtained cupcake pieces increased significantly as the replacement ratios were increased. The highest increases were seen in treatments C1 and C3, where the difference was not statistically significant (P≤0.05), and the values were 1980, 2040, 1920, and 2010 cm^3, respectively. Treatment C2 achieved the lowest volume without significantly differences as compared to control treatment. After baking process, the weight of C0, C1, C2, C3 cake samples were 400, 395, 405, and 400 g, respectively. The results of both volume and weight were reflected in the characteristics of specific volume and density without recording significant differences. Treatment C1 was the best than the rest of the treatments by recording the highest specific volume and lowest density, and the highest percentage of weight loss after baking, with a significant difference (P≤0.05). Lu et al., (2010) and Hafez et al., (2012) pointed out that good cake buttercream should maintain sufficient viscosity to prevent embedded air bubbles from rising to the surface and being lost during initial heating, so cake preparation timing should be adjusted so that air bubbles can expand adequately. This is done by carbon dioxide gas and water vapor before the cake is cooked and therefore, the resulting cake structure is fluffier and has a more defined structure. The reason for the decrease in volume and specific volume for treatment C2 may be due to the gluten matrix, which is responsible for retaining gases in baked foods being greatly weakened. A new protein reconstitution resulting from the union of millet proteins with the gluten proteins led to the formation of a network capable of trapping gases and increasing the size of the cupcake pieces. This is what Hammoud et al.,(2024) found, in manufacturing bread from compound flour after raising the replacement ratio.

Colorimetric examination of cupcake pieces: Table 4. Demonstrates the color attributes of the crust and crumb of cupcakes manufactured from wheat flour with millet flour . An increase in the percentage of local millet flour had an impact on the treatments' crust and crumb color. In comparison to the control treatment (C0), the treatments' color values all became grew darker. According to Nada et al., (2016), the color change of the cake could be attributed to the oxidation of millet flour pigment or phenolic compounds, in addition to the occurrence of caramelization process during baking. Except for treatment C2, all color characteristics of the cupcake treatments decreased as compared to the control treatment, however, the final value of the desired golden color (L*/b*) did not differ significantly.

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Table 4. Crust and crumb color characteristics of experimental cake manufactured from wheat flour and compound flour prepared from replacing wheat flour by different ratio of millet flour based on the laboratory color scale

Treatments	Crust color				Crumb color			
	L*	a*	b*	L*\b*	L*	a*	b*	L*\b*
C0	57.39[a]	14.39 [b]	33.31 [a]	1.72 [a]	63.71[a]	7.41 [a]	25.71	2.48
C1	47.30[b]	15.97 [a]	29.47 [b]	1.61 [ab]	52.53[c]	4.35 [b]	23.12	2.27
C2	47.51[b]	14.99 [b]	29.93 [b]	1.58 [b]	58.46[b]	6.19[a]	23.79	2.46
C3	51.15[b]	15.26 [ab]	29.83 [b]	1.71[a]	58.89[b]	6.08[a]	23.34	2.52
L.S.D	3.861*	0.855*	1.843*	0.124*	4.074*	1.524*	3.031NS	0.311NS

(P≤0.05).

C0: (Control) consisting of the basic ingredients. C1, C2 and C3 consist of basic ingredients with 25%,50% and 75% substitution of wheat flour by millet flour

The results of this investigation were consistent with those reported by Gulati et al., (2018), who suggested that the high concentration of minerals (Ash) in the millet flour , along with the high concentration of phenols and flavonoids that impart a dark color to the baked good, contributed to the bread's dark color (dark brown color in comparison to wheat flour). A higher replacement rate may have an impact on the color of the crust and crumb because of the large proportion of ash and colored chemical compounds. Sucrose contributes to caramelization and Maillard reactions during baking, together with the other ingredients used in production, giving the baked good its intended flavor .

Sensory evaluation of cupcakes: Table (5) displays the sensory evaluation of the experimental cupcakes treatments. The results show that there were no significant differences among the specific volume values of the treatments under study. Increasing the replacement ratios had a negative impact on the values given to the regularity of the external shape, softness and uniformity of the crumb texture, as well as tenderness, which decreased with increasing the replacement ratios and increasing the fragmentation of the edges of the cupcakes pieces (reduced consistency and partial dryness), but without significant differences. This may be due to the low percentage of gluten and its effects on the appearance and sensory characteristics of baked goods, as well as its effect on the aroma and taste of baked goods. The quality and crumb color were not significantly affected by increasing replacement rates, with the exception of treatments C2 and C3, which recorded the lowest values. This may be due to the low percentage of total sugars, which interfere in the color reactions, in addition to the effect of the light brown color of millet flour on the color of crust. The values of the aroma and taste indicate that the control treatment C0 gained the highest scores, in addition to the general acceptance. Then the values given to the same two criteria (extent of acceptance by residents) decreased as the replacement rate increased. No significant differences (P≤0.05) were recorded between treatments C0 and C1, and the rest of the values did not differ significantly from these two treatments and achieved high degrees of acceptability.

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Table 5. Sensory evaluation of cupcakes samples manufactured from the wheat flour with different replacing ratio of millet flour

Parameters	Score	C0	C1	C2	C3	L.S.D.
Specific volume	20	19.9	20.0	18.4	19.5	2.250 NS
Symmetry of form	10	9.5	9.0	8.5	8.5	1.031 NS
Crust color	10	10.0^{a}	9.4^{ab}	9.2^{b}	9.9^{a}	0.692*
0 954 20Softness	10	9.3^{a}	8.8^{ab}	8.6^{ab}	8.1^{b}	0.978*
Moistness	10	9.6	9.5	9.3	9.0	0.613 NS
Crumb Texture (Porosity)	10	9.3	9.3	8.6	8.5	0.872 NS
Crumb color	10	9.3	8.5	9.2	9.4	0.973 NS
Aroma and taste	20	19.5^{a}	18.4^{ab}	16.9^{bc}	15.1^{a}	2.465 *
Total	100	96.4^{a}	92.9^{ab}	88.7^{b}	88.0^{b}	5.281 *
		(P≤0.05*)				

C0: (Control) consisting of the basic ingredients. C1, C2 and C3 consist of basic ingredients with 25%,50% and 75% substitution of wheat flour by millet flour.

Aroma and taste are the most important criterion in determining the acceptability of products, resulting from reflecting the interaction of ingredients inside a piece of baked product. The reason for the low acceptance of the taste may be due to its taste not being similar to the taste of wheat baked goods, relative dryness, low sweetness, increased percentage of resistant starch in millet with increased substitution rates, and the emergence of a new taste that was not known before. In addition, many people are not aware of the idea of introducing millet as a food product to the Eastern table. All the previous explanations are due to the lack of nutritional studies on this crop and societal development that has made many people accept more luxurious products. Additionally, cupcakes was done without adding any colloids or materials that improve the texture , flavor and the quality of the cupcake. Mageed and Al-Abdullah (2020) and Abdalla and Saeed, (2023) found a decrease in the rate of water absorption of compound flour with higher substitution rates compared to wheat flour. The reason may be due to the quality of millet proteins, the nature of the (resistant) starch, grinding methods, the degree of fineness of the flour, and the inverse effect of the decrease in the percentage of gluten. This confirmed the validity of the results of this study. Emmanuel and Sackle, (2013) reported that all sensory evaluation attributes for cupcakes made from compound flour with millet were gained more than 6 (scores out of 10), which is a good indicator, showing that all sensory attributes were at least acceptable by the taste panel. They also mentioned that product preference increased with increasing the replacement rates up to 40%, accordingly the possibility of offering it on a commercial scale is very welcomed. The studs corroborated Lu et al.,(2010) and Santos et al., (2013) findings, who suggested that cake pieces became hard as the powder content of dry materials substituted increased. This is because the volume of the cakes and the density of the materials tested directly affect the hardness of cake pieces. It determines the consistency of the cake butter components (or the viscosity resulted because the effect of the ingredients) and the amount of resistance to internal aeration of the food structure, the effect of which appears in increased viscosity, decreased elasticity, and difficulty in chewing cake pieces as the level of substitution increases.

The economic cost of producing cake: Table (6) display the cost values of producing cakes pieces manufactured from wheat flour and compound flour (wheat and local millet). Gluten-free baked goods are usually prepared specifically for a segment of society due to the lack of the necessary accessories to prepare gluten-free flour and the lack of knowledge about the type of grains suitable for this type of manufacturing. Monopolizing preparation techniques and exploiting the health status of this group, in addition to the low demand for it, works to raise the prices of gluten-free flour

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and products manufactured from it. Most of the flour mixes available in local markets reach a price of $ 10 per kg. They are made from a mixture of rice and cornstarch with some glue, and have low nutritional value and quality. This study aimed to attempt to overcome many of these difficulties by using the millet crop and its nutritional advantages, while using the technical mill designated for grinding wheat grains and equipped by the laboratory company Brabender, after performing the initial operations as described in the materials and methods.

Table 6. Production costs for the gluten-free cupcakes make from wheat flour and proso millet flour

Ingredient	Coast ($/KG)	Weight	Total material cost ($)
Wheat – Millet flour (1Kg)	0.83	150 g	0.125
Eggs (1Kg)	3.34	190 g	0.63
Baking powder (400 g)	2.67	10 g	0.02
Salt (1Kg)	1.34	1g	0.001
Sugar (1Kg)	0.67	75 g	0.05
Fat (1Kg)	1.67	15 g	0.03
Oil (1 liter)	1.67	15 g	0.03
vanillin (500 g)	10.00	10 g	0.10
Full fat milk	4.00	15 g	0.06
Water	0.00	40 ml	0.00
Cake Improver (Gel) (500g)	3.34	10 g	0.03
White vinegar (1 liter)	0.67	1 ml	0.001
Cupcake paper (100 pieces)	0.84	12 pieces	0.001
Total price	---	532	1.078
Number of resulting pieces	---	12	---
Manufacturing cost (works, cleaning, and baking) 25% ($)		12 pieces	0.27
Final production cost (total) ($)		12 pieces	1.35
Manufacturing cost per piece ($)		1 pieces	0.11
Sales price per piece/total ($)		0.33	3.96
Total profits per piece/total ($)		0.22	2.61

Morphological structure of proso millet grains using scanning electron microscop :

Scanning electron images showed the external shape of the millet grains at 65 and 100X magnification (Figure 1), from which it is clear that they were smooth, elliptical to oval in shape and contained two grooves along the length of the grain. Elliptical is defined as (swollen in the middle and semi-pointed at the upper end).

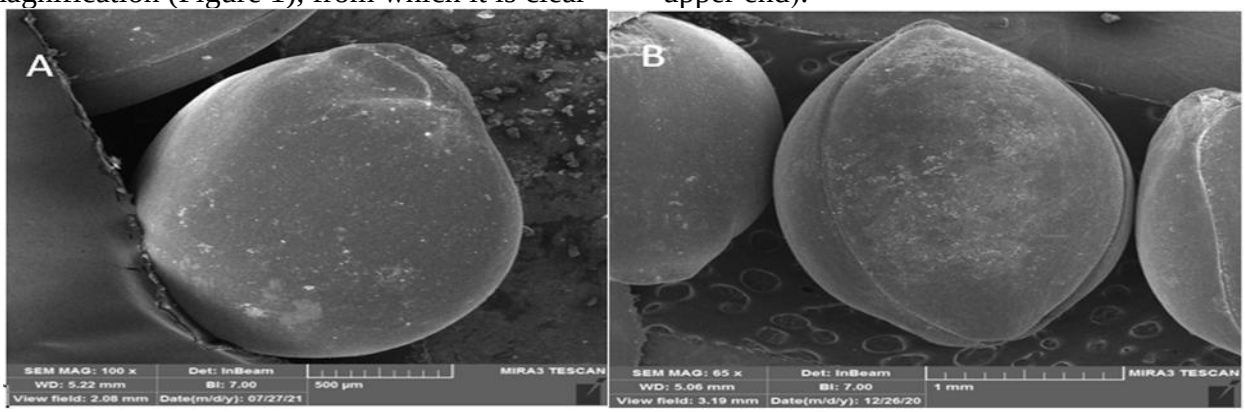

Figure 1. The cross-sectional images marked with symbols (A – B) represent complete grains of proso millet photographed using the scanning electron microscope (SEM) technique

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Morphological and anatomical structure of proso millet flour using scanning electron microscopy : The images of proso millet powder granules shown in Figure (2) bearing the symbols (C-D-E-F-I) and taken by scanning at a magnification of 1, 5, 10, 25, 200 KX respectively, showed that the starch granules were buried and covered with protein matrix tissue and that they had different shapes, sizes and diameters. Some of the large spherical granules showed relatively smooth surfaces with gaps (pores) and some of them showed irregularities (visible masses) due to the presence of protein bodies. Other areas showed the presence of small polygonal, rhombic and multi-shaped granules. It is also clear from these images that the larger granules were present in greater numbers, and the size range of the granules ranged from (17.72 - 78.06 nm).The results of this study, which showed that the starch granules were large polygonal with spherical granules of different sizes, were consistent with what was found by Verma et al.(2018) and Bangar et al., (2021). The morphological characteristics of starch granules vary depending on their biological origin, the biochemistry of chloroplasts or amyloplasts (the time of their formation during grain growth and the position of starch granules within the endosperm matrix), as well as plant physiology, environmental conditions and the type of treatment or processing.

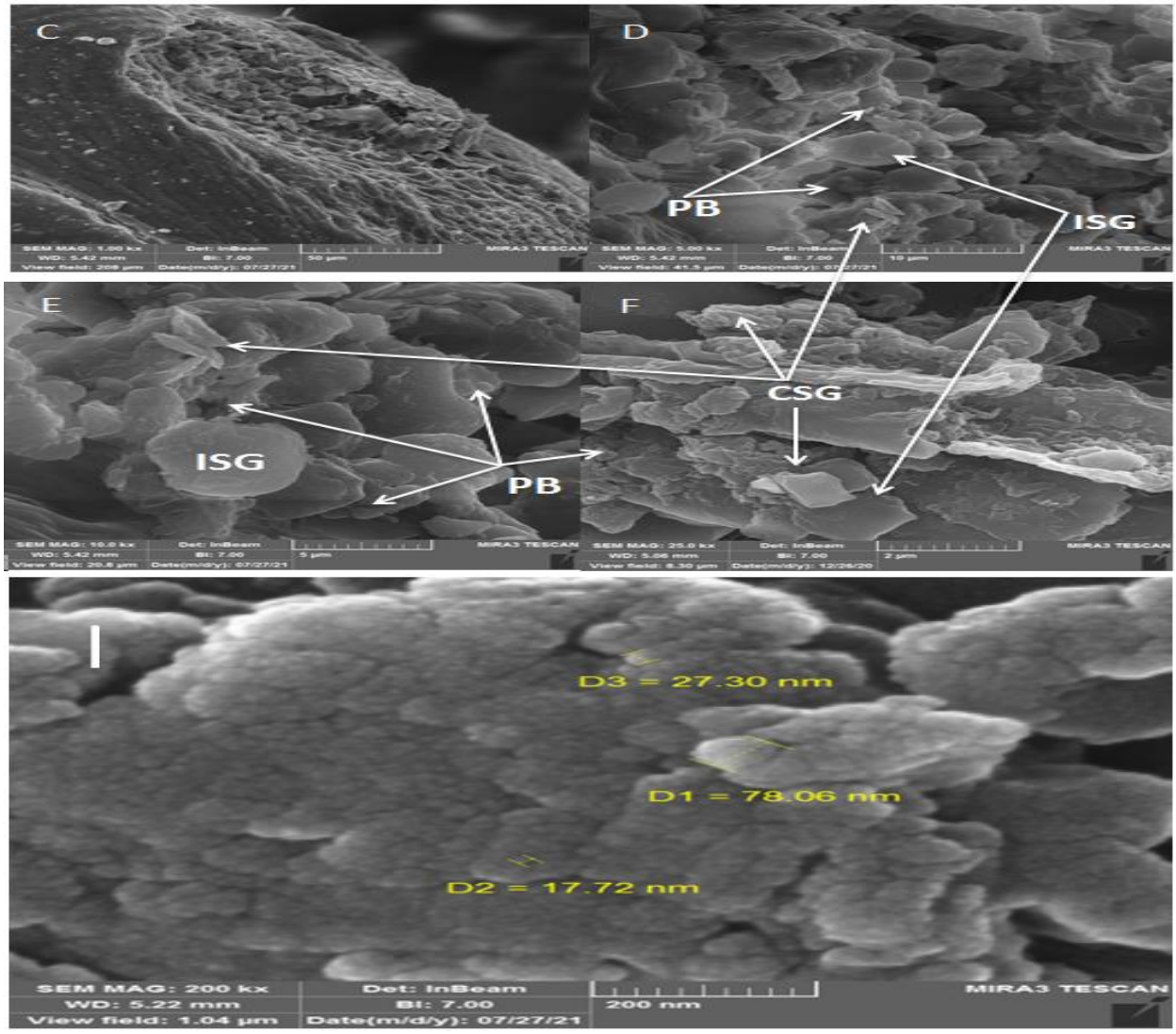

Figure 2-A. Cross-sectional images marked with symbols (C-D-E-F-I) of the grains of proso millet powder according to the scanning electron microscope technique. Where each of the following represents; ISG = individual starch granules (separated), DSG = complex starch granules (bound together), PB = protein bodies

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Proso millet starch granules are relatively small in size compared to wheat, rice and corn starch granules. Bangar et al., (2021) reported that the smallest size of proso millet starch granules was 0.3 µm and the largest was 17 µm, while in this study, the smallest granule size was 17.72 nm and the largest was 78.06 nm. Surface pores (holes) were also observed in some granules, which is contrary to what the researcher found above, who indicated that they are not common in proso millet starch granules as they are in other starch granules such as maize, sorghum and large millet grains. Figure (2-B) bearing the symbols (K – L – M – N) at magnification power (2, 5, 10KX) shows the effect of the regular milling process mechanism in the Brabender quadruple mill on the properties of the resulting particles. The starch grains were more regular and intact, and this is due to the role of the milling machine and the prior conditioning of the grains by the moisturizing process before the milling process. The over-grinding process (grinding) using a household grain mill in the first case, accompanied by high temperatures, led to the formation of heterogeneous masses in addition to the crushing of most of the granules (high damaged starch), which prevented the regularity of the shape. This is contrary to what was observed during regular grinding (using a laboratory quadruple Brabender mill in the current study), as it was found that the original individual starches had a shiny, well-defined surface and there may be pores on some parts of the granules, but due to excessive crushing of some of them, the granules appeared with a very rough and unclear surface (DSG). The roughness or crushing of some granules during the grinding process may be due to the effect of the amount of protein bonding with the starch granules, and this was confirmed by Al-Zubaidi, (2009) and Verma et al., (2018), who showed that low-protein wheat starch granules had smooth walls with fine pores, while wheat rich in protein led to the appearance of the walls of the starch granules with rough and torn porosity as a result of Increase bond strength. The results of this study were close to those of Gulati et al., (2018) as individual starch granules ISG, individual protein bodies PB and complex starch masses were the main visible components when examining proso millet under the electron microscope. The interconnection of polygonal starch granules led to the formation of complex starch granules DSG similar to those found in oats and rice. They also observed two main sizes of starch granules A-type (>9.9 mm) and B-type (<9.9 mm). In addition, they observed the presence of spherical protein bodies with a diameter of <2.5 mm and a diameter of 2.5-5 mm in the cracks of complex starch granules which were mainly observed after high magnification. They also noted that the starch granules were of a distinctive hexagonal shape and large size compared to the small protein bodies and that the starch granules were complex and individual and some of the larger starch granules contained surface depressions and that this feature is a characteristic of starch belonging to the Panicoideae subfamily to which proso millet belongs.

The presence of individual starch granules led to improved water binding properties during the manufacture of cake batter and this was reflected in improving the properties of the cake product and making it somewhat more fragile.

CONCLUSION

The present study demonstrated the successful utilization of local proso millet flour as a partial substitute for wheat flour in cupcake production. Incorporation of millet flour improved the nutritional value of the composite flour through increasing fat, fiber, and ash contents, while also contributing to lower total carbohydrate levels and a potentially lower glycemic response. The physical properties of cupcakes were not adversely affected by millet substitution, particularly at the 25% replacement level, which achieved the highest specific volume and lowest density among treatments**.** Sensory evaluation indicated that increasing millet flour substitution levels slightly reduced aroma, taste, softness, and overall acceptability; however, cupcakes containing 25% millet flour showed no significant differences compared with the control treatment and maintained high consumer

acceptance. In addition, color characteristics became darker with higher substitution levels due to the natural pigments and phenolic compounds present in millet flour**.** The study also confirmed the economic feasibility of producing cupcakes from composite flour with a high profit margin, highlighting the potential of millet as a locally available and nutritionally valuable ingredient for bakery applications. Therefore, incorporation of proso millet flour, particularly at moderate substitution levels, can be recommended for the development of functional bakery products with acceptable sensory quality and enhanced nutritional properties.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this research.

AUTHOR/S DECLARATION

We confirm that all Figures and Tables in the manuscript are original to us.

Author/s signature on Ethical Approval Statement.

Ethical Clearance and Animal welfare

Funds

AUTHOR'S CONTRIBUTION STATEMENT

Ezuldeen K. Hammood contributed to the study design, laboratory experiments, data analysis, interpretation of results, and manuscript preparation. Balasim T. Ali participated in sensory evaluation, statistical analysis, and manuscript revision. Ezuldeen K. Hammood supervised the research work, contributed to methodology development, and critically revised the manuscript. All authors read and approved the final version of the manuscript.

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دراسة الخصائص الحسية والنوعية لكيك الأقداح المصنع من الدقيق المركب

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المستخلص

تم إنتاج الدقيق المركب عن طريق استبدال دقيق الحنطة جزئياً بدقيق الدخن المحلي بنسبة 25 و 50 و 75٪. أظهرت نتائج التركيب الكيميائي نسب أعلى لجميع مكونات دقيق الدخن مقارنة بدقيق الحنطة باستثناء الرطوبة والكربوهيدرات. كانت نسب الرطوبة والدهون والبروتين والرماد والألياف والكربوهيدرات في دقيق الدخن (9.30، 4.30، 9.80، 1.62، 1.81، 73.17٪) وفي دقيق الحنطة (12.00، 2.00، 10.50، 0.55، 0.48، 74.47٪) على التوالي. أدت زيادة نسب الاستبدال إلى زيادة معنوية ($P \leq 0.05$) في حجم قطع كيك الاقداح مقارنة بمعاملة السيطرة. سجلت المعاملات (ذات نسب الاستبدال 25٪ و 75٪) أعلى القيم. لم تختلف أوزان قطع الكيك والحجم النوعي وكثافة الكيك بعد الخبز بشكل كبير. سجلت معاملة الإستبدال 25% أعلى قيم للحجم النوعي وأقل كثافة وأعلى نسبة فقدان للوزن بعد الشواء، وأظهرت قيم المعايير الحسية لمعايير كيك الاقداح قيد الدراسة عدم وجود فروق معنوية بين قيم الحجم النوعي وانتظام الشكل الخارجي ونعومة وانتظام ولون اللب، وانخفضت قيم النضارة والرائحة والطعم والدرجات الكلية بزيادة نسب الإحلال، ولم تسجل معاملة الإحلال 25% فرقاً معنوياً عن السيطرة، في حين حققت بقية المعاملات درجات قبول عالية في الوقت ذاته، وأظهرت حسابات تكاليف الإنتاج أن تكلفة تصنيع كيك الاقداح من دقيق الحنطة والدقيق المركب متساوية، مع ربح إجمالي قدره 200%.

الكلمات المفتاحية: الكلف، كيك الاقداح، الدقيق،دخن البروسو، التقييم الحسي، الحنطة