



Physiochemical microstructure and properties of pancake supplemented with some novel components and different levels of beetroot powder (Beta Vulgaris).

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ABSTRACT

The global demand for healthier functional foods, particularly cereal-based products, is rising. Consumers seek options low in sugar and carbohydrates while rich in protein, minerals, and dietary fiber. This study aimed to develop nutrient-dense pancakes with enhanced fiber and antioxidant content by incorporating novel functional ingredients. Beetroot powder (BT) was added at varying levels (0, 5, 10, 15, and 20%) as a partial flour replacement. Samples underwent physical, chemical, sensory, and microstructural evaluations using SEM.

Physically, increasing BT levels decreased diameter and whiteness, while thickness and volume increased. Chemical analysis showed significant ($P < 0.05$) increases in protein (11.0% to 16.25%), moisture (45.7% to 49.0%), ash (1.3% to 1.7%), fat (10.3% to 13.4%), and dietary fiber (2.6% to 4.7%). Carbohydrate content decreased by nearly 50% at 20% BT substitution. Sensory evaluation indicated that all formulations were acceptable (scores > 5), with 20% BT being the most preferred. SEM analysis revealed that BT addition reduced starch gelatinization, strengthened the gluten-starch matrix, and increased micro-holes, enhancing structural integrity.

In conclusion, the results confirm possibility of developing healthier pancake using novel ingredients and BT with acceptable physical and sensorial attributes in order to replace conventional pancake that would be acceptable by consumers.

Keywords: functional food; beetroot powder; microstructure; physiochemical properties; sensory evaluation, pancak.

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Introduction

The growing consumer interest in health-promoting foods, particularly those rich in antioxidants and low in carbohydrates, has driven an increased demand for innovative functional foods.[1]. Various functional food products have been developed, ranging from beverages to dressings, with particular emphasis on bakery products. This focus is attributed to the widespread global consumption of bakery products, which are favored for their convenience, extended shelf life, and broad availability.[2].

Common bakery products such as biscuits, muffins, cakes, bread, pastries, and pies are widely consumed across different cultures [3]. Common bakery products such as biscuits, muffins, cakes, bread, pastries, and pies are widely consumed across different cultures [4]. Pancakes are known by various names and are incorporated into diverse culinary traditions worldwide [5]. Incorporating fruit and vegetable powders into food formulations has gained increasing attention due to their significant health benefits. Beetroot powder, in particular, has been utilized in numerous food products to enhance nutritional value and confer health-promoting effects. Its functional and nutritional composition includes carbohydrates (10 g), proteins (1.68 g), fats (0.18 g), dietary fiber (2 g), and minerals (0.483 g) per 100 g of wet weight[6]. Moreover, beetroot is a rich source of bioactive compounds with potential health benefits, including the prevention of cardiovascular diseases and diabetes. Beetroot and its derivatives have been incorporated into a variety of food products, including dairy products [7], sausages [8], legume bakery products [9] and legumes [10]. Moreover, beetroot is a rich source of bioactive compounds with potential health benefits, including the prevention of cardiovascular diseases and diabetes. Beetroot and its derivatives have been incorporated into a variety of food products, including dairy products. However, despite its extensive application, there remains a gap in the literature regarding its utilization in common bakery items such as low-carbohydrate pancakes, as well as its impact on

their physical, chemical, and microstructural properties. This study aims to address this gap by investigating the effects of beetroot powder incorporation on low-carbohydrate pancakes' physicochemical, structural, and sensory attributes, thereby contributing to the development of healthier functional bakery products.

Material and methodology

Material

All the materials used in this study such as Wheat flour, coconut oil, skimmed powdered milk, iodized salt; Vanilla, Eggs, and Stevia were purchased freshly in the local markets in Erbil city.

Methodology

1- Beetroot powder preparation:

The locally sourced beetroot variety was thoroughly washed and peeled using a peeler to remove the outer skin. It was then sliced into uniform pieces with a thickness of 1 mm. The sliced beetroot was arranged on specialized trays and dehydrated at $50 \pm 2^\circ\text{C}$ for 24 hours until a constant weight was achieved. Subsequently, the dehydrated beetroot was finely ground using a laboratory grinder (Gourmet Maxx 4201, Nutrition Mixer Deluxe, Germany). The resulting beetroot powder was stored in a specialized airtight container and kept in a dark environment to preserve its quality for future use [9].

2- The pancake preparation

The pancake samples were prepared by mixing 24 g of skimmed powdered milk, 30 ml of coconut oil, 250 ml of water, 1 g of salt, 3 g of vanilla, 3 g of baking powder, 61.57 g of eggs, 12 g of stevia, and 200 g of flour. For pancake samples, the flour was replaced with 5%, 10%, 15%, and 20% beetroot powder.

Table 1. ingredients percentage of pancake based on wheat flour with beetroot powder.

Component	Control	%5	%10	%15	%20
Wheat flour	200g	190g	180g	170g	160g
Beetroot powder	0g	10g	20g	30g	40g
milk	24g	24g	24g	24g	24g
Coconut Oil	30ml	30ml	30ml	30ml	30ml
Water	250ml	250ml	250ml	250ml	250ml
Salt	1g	1g	1g	1g	1g
Vanilla	3g	3g	3g	3g	3g
Baking powder	3g	3g	3g	3g	3g
Egg	61.57g	61.57g	61.57g	61.57g	61.57g
Stevia	12g	12g	12g	12g	12g

Control (100% wheat flour + %0 Beetroot), %5 (95% wheat flour + 5% Beetroot), %10 (90% wheat flour + 10% Beetroot), %15 (85% wheat flour + 15% Beetroot), %20 (80% wheat flour + 20% Beetroot)

3- Physical analysis

A- Color assessment

The color of the pancake samples with and without novel ingredients was determined using a colorimeter (Hunter Lab Colour Flex, Model No. 45/0, USA). The color determination included a^* (+: red; -: green), L^* (100=white; 0=black), and b^* (+: yellow; -: blue) using illuminate D65/10 as reference.

B- Volume

The volume of the pancake was determined using a standard seed displacement method. The process involved filling a known volume with seed and then emptying it. The samples were placed in, the seed was added, and the remaining volume was measured in a cylinder [11].

C- Thickness

After cooling down the samples to ambient temperature, thickness of the pancake were measured using lab ruler, for accuracy, the cake turned around and another measurement were taken [1].

D- Texture analyzer

The texture of the pancake samples were measure using texture analyzer (Brookfield CT3 Texture Analyzer). The pancake texture were measured for hardness [1].

Diameter

Prior to cooling down the samples, Pancake diameter was measured using the a ruler [12]

Chemical analysis of Pancakes

The chemical composition of the pancakes was determined by following the standard procedure as laid down in the literature of AOAC.

A-Crude fat determination

The fat content was determined by using Soxhlet extraction method (AOAC, 2012). In this method moisture free 5g sample was taken in a ready-made thimble and oil was extracted in pre-weighed round bottom flask (cleaned, dried and weighed) using petroleum ether is SOCS plus for 2.5 to 3 hours. The flask was then dried in a hot air oven to evaporate petroleum ether and allowed to cool, after cooling the final weight of the flask was taken and used for the estimation of crude fat content of sample.

The following equation was used for estimation of crude fat content (%) in the sample:

$$\text{Fat content: } (w1-w2/w) \times 100$$

Where,

W = Weight of sample taken (g)

W1= Weight of empty round bottom flask (g)

W2= Wight of the flask with fat (g)

B- Crude Protein determination

The protein content was determined using standard method of AACC46-10.01. The samples were first digested with H2So4. It was then distilled with ammonia and then titrated with NaOH. The crude protein was calculated based on the dry matter using the factor 6.25/ gN/100 g sample [13].

C-Determination of ash

The standard method of (AACC, 2009) was used to determine Ash content. An amount of 3 gm of the sample was placed in a crucible and then placed in muffle furnace at 550°C. The content of the Ash was calculated based on the % dry. The ash contents were expressed as ash in dry basis.[13].

D-Moisture content determination

The gravimetric method was used to quantify moisture content. An amount of 5 gm of the sample in a Petri dish was placed in the electric oven at 70°C for 2 hours and then cooled down and weighed. The process was continued until the weight stayed stable. The equation below was used to calculate moisture content.[15].

$$\text{Moisture content: } (w1-w2/w) \times 100$$

Were,

W = Weight in g of sample taken.

W1 = Weight in g of the dish with the material before drying, W2 = Weight in g of the dish with the material after drying.

E-Carbohydrate content

The total carbohydrate content was calculated using the difference method. The amount of carbohydrate was taken out from, protein, fat and ash using the following equation

$$\text{Total Carbohydrate (\%)} = [100 - (\% \text{ moisture} + \% \text{ ash} + \% \text{ protein} + \% \text{ fat})]$$

F-Energy value

The sample's energy value was calculated using the following mathematical equation:

$$\text{Energy} \left(\frac{\text{kcal}}{100\text{g}} \right) = [(\% \text{ carbohydrate} * 4) + (\% \text{ protein} * 4) + (\% \text{ fat} * 9)]$$

4- Sensory Evaluation

The sensory evaluation of the pancake with and without the novel ingredients by semi-trained students was done by students and staff of the food technology department of Salahaddin University-Erbil under normal daylight. The pancakes were assessed for appearance, color, texture, flavor, and overall acceptability on a nine-hedonic scale (1, extremely disliked, to 9, extremely liked).

5- Microstructure determination (Scanning Electron Microscopy)

The microstructure of the pancake samples was studied using scanning electron microscopy (FEI Quanta 450, Oregon, United States). After drying the samples, they were placed on the holder coated with gold and imaged at a magnification of 500.

Results

Table (2) proximate analysis of chemical composition of the pancake samples

Samples	%Protein	%Moisture	%Ash	%Fat	%Carbohydrate	%Fiber	Energy value(kcal/100g)
Control	11.02±1.2 ^c	45.78±0.6 ^{bc}	1.3±0.2 ^{cde}	10.30±0.9 ^b	31.56±0.8 ^a	2.60±0.1 ^c	492.7±6.6 ^a
5% Beetroot	14.14±0.6 ^{cd}	46.25±0.5 ^{ab}	1.4±0.09 ^{dc}	12.35±1.0 ^a	25.83±1.9 ^{cd}	2.90±0.1 ^d	511.1±7.7 ^b
10% Beetroot	15.16±1.0 ^{abc}	42.17±1.8 ^e	1.5±0.04 ^{abc}	12.60±0.8 ^a	28.53±2.7 ^{ab}	3.60±0.1 ^c	513.4±5.8 ^b
15% Beetroot	15.72±1.0 ^{ab}	44.18±1.5 ^{cd}	1.6±0.02 ^{ab}	12.62±0.7 ^a	25.83±2.8 ^{bc}	4.20±0.1 ^b	513.6±5.6 ^b
20% Beetroot	16.25±0.9 ^a	49.07±2.4 ^a	1.7±0.03 ^a	13.40±1.0 ^a	19.53±1.3 ^e	4.70±0.1 ^a	520.6±7.3 ^b

Control (100% wheat flour +%0 Beetroot), %5 (95% wheat flour+5% Beetroot), %10 (90% wheat flour+10% Beetroot), %15 (85% wheat flour+15% Beetroot), %20 (80% wheat flour+20% Beetroot)

The results of the study showed that the protein content increased significantly ($p>0.05$) from 11g (control) to 16g (20% beetroot) (Table 2). Similarly, the addition of BT increased the moisture content from 45% to 49%. Moreover, ash content, fat content, and crude fiber increased from 1.3 (control) to 1.7 (20% BT). 10.3 (control) to 13.4 (20% BT) and 2.6 g/100 g (control) to 4.7 g/100 g (20% BT), respectively. On the other hand, carbohydrate content reduced from 31.5 (control) to 19.5 (20% BT). The addition of BT significantly increased the energy value of the products from 492 kcal to 520 kcal. Generally, all the food nutrients increased with BT except carbohydrates, which decreased.

Table (3) Physical Properties of Pancake samples

Samples	Diameter (mm)	Thickness (mm)	Texture mg	Volume (ml)	Whiteness	Color		
						a	L	b
Control	122.5±2 ^a	5.7±0.2 ^e	332.0±2.6 ^a	47.0±6 ^c	49.7±5.9 ^a	14.61±3.4	68.29±5.7	36.02±2.4
5% Beetroot	115.0±3 ^b	7.2±0.2 ^c	332.6±2.5 ^a	75.3±3 ^{ab}	30.9±2.1 ^b	24.34±1.6	41.16±2.7	26.61±1.2
10% Beetroot	108.0±2 ^c	7.7±0.0 ^c	325.6±2.8 ^a	79.0±5 ^a	33.5±1.8 ^b	23.07±3.0	42.29±2.9	23.27±1.1
15% Beetroot	103.5±1 ^{cd}	8.5±0.2 ^b	336.0±4.0 ^a	64.6±6 ^{cd}	30.4±1.6 ^b	27.02±1.2	40.32±2.2	23.31±0.5
20% Beetroot	95.9±2 ^e	9.6±0.09 ^a	332.3±1.5 ^a	69.6±3 ^{bc}	25.3±1.6 ^c	23.68±3.5	32.06±1.1	19.72±1.2

Control (100% wheat flour +%0 Beetroot), %5 (95% wheat flour+5% Beetroot), %10 (90% wheat flour+10% Beetroot), %15 (85% wheat flour+15% Beetroot), %20 (80% wheat flour+20% Beetroot)

The results of the physical analysis showed that the diameters of the samples were significantly ($P<0.05$) decreased with the increasing BT dose (Table 3). The control sample recorded the highest at 122 mm to the lowest 95 mm with the addition of 20% BT. In contrast, thickness (control (5.7 mm) and 20%BT (9.6)) and volume (control (49 mm) and 20%BT (69)) respectively, were significantly different. Furthermore, the whiteness of the samples was decreased with the addition of the beetroot. The whiteness of the control was recorded to be 49, and the lowest whiteness recorded was 25 for the 20% BT sample. Similarly, this is more obviously visualized in the pancake pictures (figure 2). It is clearly seen that the darkness of the color is increasing in parallel with increasing.

Regarding the sensory attributes of samples with and without the BT, the benchmark and passing scale was five. From the results of Figure 1, it can be seen that the control, only appearance, and overall acceptability recorded seven; the rest recorded six out of nine. Regarding samples with 5%, 10%, and 15%, the majority of the parameters got six out of nine. However, surprisingly, the sensory characteristics of the pancake with 20% BT scored seven out of nine. This could mean that all the samples were accepted by the panelists and passed the benchmark (5).

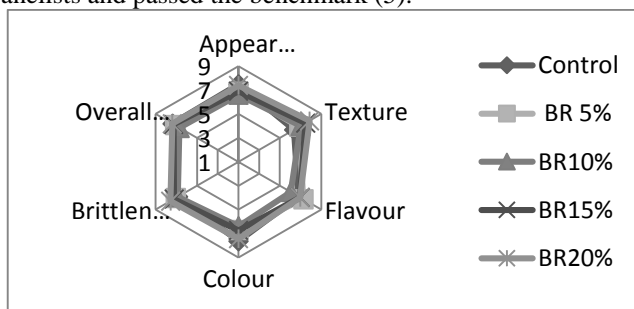


Figure (1) Sensory attributes of the pancake samples with and without beetroot

Control (100% wheat flour +%0 Beetroot), %5 (95% wheat flour+5% Beetroot), %10 (90% wheat flour+10% Beetroot), %15 (85% wheat flour+15% Beetroot), %20 (80% wheat flour+20% Beetroot)

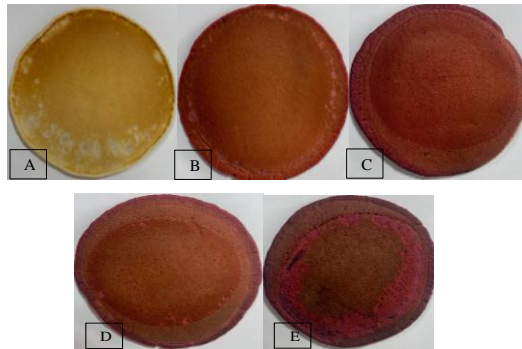


Figure (2) Appearance of pancake samples

(A) Control (100% wheat flour + %0 Beetroot), (B) %5 (95% wheat flour+5% Beetroot), (C)%10 (90% wheat flour+10% Beetroot), (D)%15 (85% wheat flour+15% Beetroot), (E)%20 (80% wheat flour+20% Beetroot)

The SEM analysis of the samples helped visualize the impact of novel ingredients on the microstructure of pancakes, particularly the protein and starch matrix. The control sample (A) seems to be comprehensively gelatinized, and the starch outline cannot be determined and is covered with protein. However, in samples with the BT added, the starches are less gelatinized. The hole size is 600 μm to a maximum of 940 μm . On the other hand, the hole of other samples seems to be larger and mostly more than 1 mm.

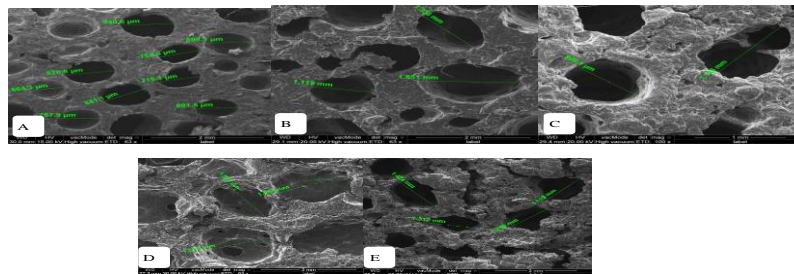


Figure (3) The microstructure of SEM of Pancake with and without beetroot powder

(A) Control (100% wheat flour + %0 Beetroot), (B) %5 (95% wheat flour+5% Beetroot), (C)%10 (90% wheat flour+10% Beetroot), (D)%15 (85% wheat flour+15% Beetroot), (E)%20 (80% wheat flour+20% Beetroot)

Discussion

The results of the physical properties analysis showed that the samples with BT is smaller in diameter but thicker in thickness, similar in texture and larger in volume. Previous result showed that addition of BT to cookies [16] reduced diameter and increased thickness. The results of earlier study showed that addition of BT 15-20% improved physical properties [17]. This might be due to the fact that addition of BT make is stronger because of having soluble dietary fibre. This fibre has a greater affinity toward water and retains more water. This was also confirmed as moisture content of the samples with BT was proportionally increased with increase in BT content. Increase In the moisture content improves the texture and shelf life of the products [1].

The results of the chemical analysis showed that majority of the components like protein, fat mineral and dietary fibre increased. That could mean that the samples are improved nutritionally. This could be attributed to the addition of the BT. This results is in congruent with previous who stated that supplementation of BT into bakery products improved nutritional value [9], [17]. earlier study confirmed increasing BT percentage to a sample proportionally increases important nutrients like Ash and dietary fibre [18]. Increasing fibre consumption might reduce the risks of metabolic diseases [19], [20]. On the other hand carbohydrate content decreased due to the replacement of flour with BT. This is also a positive indication on the development of products since many researchers connect sugar and carbohydrate with many metabolic diseases.

Sensory evaluation by the panellist showed the acceptance level of sensory attributes. It was not expected that adding 20% of BT would gain highest consumer acceptance. Previous results showed that adding 15 and 20% of BT showed better sensory attributes [17]. This is a positive indication that the addition of the BT not just did not compromise the quality, but it rather improved the sensory attributes and increased acceptability by the consumers.

The microstructure of the pancake showed that the starches are less gelatinized in the BT samples comparing to the control (0% BT). Previous researches also showed that dietary fibre to bakery products absorb more water and reduces starch gelatinization [1]. This can be due to great affinity of dietary fibre to moisture comparing to flour protein and polysaccharides.

Conclusion

In this study, the addition of beetroot powder significantly enhanced both the physical and sensory attributes of the pancake samples. Furthermore, the chemical composition and nutritional profile exhibited proportional improvements with increasing levels of beetroot powder. The findings indicate that it is feasible to develop pancakes with up to 20% beetroot powder substitution while maintaining acceptable physical and sensory characteristics, along with enhanced nutritional value.

Conflict of interest: None

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الخصائص الفيزيائية والكيميائية والبنية الدقيقة للفظائر المضاف إليها بعض المكونات الجديدة ومستويات مختلفة من مسحوق الشمندر (*Beta vulgaris*).

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الخلاصة

يتزايد الاهتمام العالمي بالأغذية الوظيفية الصحية، لا سيما المنتجات القائمة على الحبوب التي تتميز بانخفاض محتواها من السكر وارتفاع قيمتها الغذائية من حيث البروتين والمعادن والألياف الغذائية. تهدف هذه الدراسة إلى تطوير فطائر غنية بالعناصر الغذائية من خلال استبدال الدقيق جزئيًا بمستويات متفاوتة من مسحوق الشمندر (*BT*) بنسبة 0، 5، 10، 15، و20%. خضعت العينات لتقييمات متعددة شملت التحليل الفيزيائي والكيميائي، والتقييم الحسي، وتحليل البنية المجهرية باستخدام المجهر الإلكتروني الماسح. أظهرت النتائج أن إضافة *BT* أدت إلى انخفاض القطر ومستوى البياض، في حين زاد كل من السمك والحجم. من الناحية الكيميائية، لوحظت زيادة معنوية ($P < 0.05$) في محتوى البروتين (من 11% إلى 16.25%)، الرطوبة (من 45.7% إلى 49.0%)، الرماد (من 1.3% إلى 1.7%)، الدهون (من 10.3% إلى 13.4%)، والألياف الغذائية (من 2.6% إلى 4.7%). في المقابل، انخفضت نسبة الكربوهيدرات بنحو 50% عند استبدال 20% من الدقيق بـ *BT*. أظهرت نتائج التقييم الحسي تقبل جميع العينات، مع تحقيق عينة *BT* 20% لأعلى درجات القبول. كما كشفت صور البنية المجهرية أن إضافة *BT* قللت من جلته النشا، لكنها عززت تكوين مصفوفة الجلوتين والنشا، وزادت من عدد الثقوب المجهرية. وفي الختام، تؤكد النتائج إمكانية تطوير فطائر أكثر صحة باستخدام مكونات جديدة و*BT* بخصائص فيزيائية وحسية مقبولة لتحل محل الفطائر التقليدية.

الكلمات المفتاحية: أغذية وظيفية؛ مسحوق البنجر؛ التركيب الدقيق؛ الخصائص الفيزيائية والكيميائية؛ التقييم الحسي فطيرة.