DOI: 10.53992/njns.v9i4.229 NUST Journal of Natural Sciences, Vol. 9, Issue 4, 2024

Research Article

Development and quality assessment of oat flour incorporated sponge cake

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Abstract

The demand for healthy foods enhanced with different functional bioactive ingredients is rising in the modern day. Cakes are widely consumed, ready-to-eat baked goods that can be used to produce functional food products. The present study was conducted to utilize oat flour as a wheat flour replacer in sponge cake development. The developed treatments included: T_1 = Control (whole wheat flour cake), T_2 = 10% oat flour with 90% wheat flour, and T_3 = 30% oat flour with 70% wheat flour. The results showed that the cake treated with 30% oat flour and 70% wheat flour (T_3) resulted in 37.98% moisture, 0.65% ash, 11.47% protein, 9.25% fat, 11.14% fiber, 45.60% carbohydrate, 262.49 Kcal/100 g energy value, 860 cm^3 cake volume, 4.00 cm cake height, 283 g cake weight, 9.91% baking loss, 8.34 color, 8.23 texture, 7.90 taste, 8.46 aroma and 8.76 overall acceptability. Similarly, the cake with 10% oat flour and 90% wheat flour (T_2) resulted in 26.95% moisture, 0.62% ash, 10.21% protein, 8.48% fat, 9.05% fiber, 43.30% carbohydrate, 246.62 Kcal/100 g energy value, 640 cm^3 cake volume, 3.77 cm cake height, 273 g cake weight, 5.53% baking loss, 7.50 color, 7.43 texture, 7.63 taste, 7.70 aroma and 7.23 overall acceptability. The control (whole wheat flour cake) resulted in 25.77% moisture, 0.55% ash, 9.25% protein, 7.16% fat, 7.73% fiber, 34.58% carbohydrate, 219.43 Kcal/100 g energy value, 600 cm^3 cake volume, 3.00 cm cake height, 268 g cake weight, 3.70% baking loss, 6.95 color, 6.94 texture, 6.76 taste, 6.43 aroma and 6.63 overall acceptability. The findings of the study indicate that the cake treated with 30% oat flour and 70% wheat flour (T_3) showed a better effect on the proximate, baking, and sensorial qualities of the cake.

Keywords: Sponge cake development, Oat flour, Wheat flour replacer, Functional food, Bakery product, Cake quality

Article History: **Received:** 12 Jun 2024, **Revised:** 11 Sep 2024, **Accepted**: 4 Oct 2024, **Published:** 16 Dec 2024.

Introduction

Consumer demand for functional foods with higher concentrations of bioactive ingredients, such as antioxidants, fiber, and minerals, has increased recently.

Furthermore, the food sector must produce products to fulfill customer expectations because busy lives demand ready-to-eat meals and snacks with adequate nutritional content [1]. Nowadays, many consumers favor snacks that are both nutritious and convenient, with 40% specifically seeking functional, portable options that can be enjoyed on the go [2]. A variety of snack foods are developed and consumed globally. However, there is a tendency in the food industry towards developing new varieties of high-fiber, low-fat baked snacks [3].

Cakes as a bakery product are well-known as one of the most popular snack foods in different parts of the world due to convenience, high nutritional value, ideal organoleptic properties, and a shelf-life that ranges up to four weeks [4 - 5]. Cakes are widely enjoyed sweet baked desserts, popular across various social classes. Their popularity is mainly due to their convenience as ready-to-eat items, availability in multiple flavors, and affordable cost. Typically made from wheat flour, cakes are classified as cereal products and are characterized by their elastic and flexible crumb texture [6]. Cake is a baked good made by combining flour, sugar, salt, shortening, milk, eggs, and various necessary additives. Due to its wide range of ingredients, cakes can be a rich source of essential macronutrients. They contain macronutrients such as carbohydrates, proteins, and fats, as well as micronutrients including calcium, phosphorus, and vitamins A, B, and C. Sponge cake is a specific variety of cake characterized by its lighter batter compared to other cake types and typically consists of three primary ingredients: eggs, flour, sugar, along with other liquid components [7]. Additionally, sponge cakes are classified as intermediate moisture foods, having a water activity (a_w) ranging from 0.75 to 0.90. This makes them susceptible to microbial spoilage, particularly from molds, which consequently shortens their shelf life [8].

Cakes are often associated with high energy content and calorie counts. Their high levels of fat and sugar can contribute to various health concerns. However, this concern can be addressed through the fortification of cake formulations with health-promoting ingredients and the development of functional cakes. A strategy to enhance the nutritional value of cake involves partially substituting wheat flour with alternative flours derived from non-wheat grains, legumes, tubers, and pseudo-cereals [9].

Oats (*Avena sativa* L.) are an underappreciated grain rich in proteins, minerals, fats, β-glucan, which is a polysaccharide, and various other phytochemicals such as flavonoids, avenanthramides, flavonolignans, saponins, sterols, triterpenoids, and tocols. Due to its rich nutritional profile, it has significant potential for use in the development of a range of nutraceuticals and functional food products [10]. The natural substances present in oats possess a variety of beneficial properties, including antioxidant effects, anti-inflammatory benefits, promotion of wound healing, modulation of the immune response, anti-diabetic effects, and the ability to lower cholesterol levels. These biological activities highlight the therapeutic potential of oats [11]. Furthermore, because it lacks gluten, it is particularly significant for individuals with celiac disease. Incorporating oat bran and grains into food products not only enhances their nutritional value but also serves as a therapeutic measure for various lifestyle-related diseases [12]. Oats provide a valuable source of functional food ingredients, with numerous health benefits that are well-documented by scientific research. As such, oats can play a crucial role in functional foods that promote a healthy lifestyle within society [13].

Therefore, looking into the nutritional importance of oats, it is important to understand that oat incorporation into our daily consumed products might impart health benefits to the consumers, thereby justifying the efforts of many researchers to incorporate them into baked goods and other foodstuffs. With this aim in mind, the present study was conducted to incorporate oat flour into sponge cake development at different levels and to analyze its effect on the proximate, baking quality, and sensory attributes of the developed sponge cake.

Material and Methods

Sample collection

Ingredients such as wheat flour, oat flour, fine white sugar, fresh eggs, low-fat milk, sunflower oil, baking powder, and vanilla essence were sourced from a local market in Hyderabad, Sindh, Pakistan.

Preparation of sample

The method of Majzoobi et al. [14] was adopted to prepare sponge cake with slight modifications. The sugar, eggs, and vanilla were mixed together using a household mixer on medium speed for two minutes. Afterward, milk was added and mixed at the same speed for an additional two minutes until a thick cream was formed. The flour and baking powder, along with or without oat flour, were sifted three times. This mixture was then gradually added to the cream and gently mixed using a plastic spoon. Finally, sunflower oil was then incorporated into the mixture and stirred gently to create the cake batter. The cake batter was poured into greased cups and baked in an oven set to 150°C for 25 minutes. After baking, the cakes were allowed to cool at room temperature for 30 minutes before being packed in plastic bags for future analysis.

Treatment plan

T_1 = Control (Without oat flour)
T_2 = 10% oat flour with 90% of wheat flour
T_3 = 30% oat flour with 70% of wheat flour

Table 1: Treatments information/ list of ingredients used for making sponge cake samples

Ingredients	T_1 (Control)	T_2	T_3
Wheat flour	100 g	90 g	70 g
Oat flour	0	10 g	30 g
White fine sugar	75 g	75 g	75 g
Low-fat milk	50 g	50 g	50 g
Eggs	3	3	3
Sunflower oil	40 ml	40 ml	40 ml
Baking powder	3g	3g	3g
Vanilla essence	1 tsp	1 tsp	1 tsp

Proximate analysis

The moisture, ash, protein, fat, and fiber contents were analyzed using the standard methods outlined by AOAC [15]. The total carbohydrate content was calculated by the difference formula:

Carbohydrate % = 100 – (% Moisture + % Ash + % Fat + % Protein + % Fiber)

The energy value (kcal per 100g) of each sample was determined using the Asibey-Berko and Taiye [16] formula, which involves multiplying the fat, carbohydrate, and protein values by 8.37, 3.57, and 2.44, respectively.

Baking quality analysis

The volume of the cake samples was determined using the rapeseed displacement method, as described by Hallen et al. [17]. The height of cake samples (cm) was recorded using a digital caliper. The weight of the cake samples (g) was recorded by using a digital weight balance. Baking loss of samples was

determined by taking the initial weight of the sample, subtracting the final weight, and then multiplying the result by 100.

Sensory evaluation

Sensory analysis of sponge cake samples, i.e., color, texture, taste, aroma, and overall acceptability, was observed as per the method described by Iwe, [18]. The scorecards (based on nine-point hedonic scale) were presented to the panel of judges (academic staff and senior students at the institute) to observe the sensory properties of the sponge cake.

Statistical analysis

The study employed a Completely Randomized Design (CRD) for its research methodology. A total of three replications were studied during the study for all tests (proximate, baking quality, and sensorial properties). The data obtained from the present study was tabulated in Excel and analyzed using Statistical Package for the Social Sciences-20 for one-way ANOVA. The mean values ranges (maximum and minimum) at p-value < 0.05 were evaluated.

Results

Proximate composition of oat flour incorporated sponge cake

The study aimed to develop sponge cakes by incorporating oat flour and to assess its impact on various physico-chemical and sensorial characteristics. The results showed that the maximum moisture content was recorded in T_3 (37.98%), followed by T_2 (26.95%), with the minimum moisture (25.77%) in control (T_1). Similarly, T_3 had the highest ash content (0.65%), followed by T_2 (0.62%), and the lowest in T_1 (0.55%). Protein content was also highest in T_3 (11.47%), with T_2 at 10.21% and T_1 at 9.25%. Carbohydrate content was maximized in T_3 (45.60%), followed by T_2 (43.30%) and T_1 (34.58%). The fat content showed a similar trend, with T_3 at 9.25%, T_2 at 8.48%, and T_1 at 7.16%. Fiber content was highest in T_3 (11.14%), then T_2 (9.05%), and lowest in T_1 (7.73%). Lastly, the energy value was highest in T_3 (262.49 Kcal/100 g), followed by T_2 (246.62 Kcal/100 g), with the control (T_1) having the lowest energy value (219.43 Kcal/100 g).

Table 2: Proximate composition of oat flour incorporated sponge cake.

Treatments	Moisture %	Ash %	Protein %	Carbo-hydrate %	Fat %	Fiber %	Energy Value Kcal/100 g
T_1	25.77 b	0.55 c	9.25 b	34.58 b	7.16 c	7.73 c	219.43 c
T_2	26.95 b	0.62 b	10.21 ab	43.30 a	8.48 b	9.05 b	246.62 b
T_3	37.98 a	0.65 a	11.47 a	45.60 a	9.25 a	11.14 a	262.49 a
SE ±	0.8342	0.017	0.8292	1.4099	0.2319	0.2507	4.0075
LSD 0.05	2.0413	0.041	2.0289	3.4499	0.5674	0.6134	9.8061

T_1 (Control with 100% whole wheat flour), **T_2** (with 10% oat flour and 90% wheat flour), **T_3** (with 30% oat flour and 70% wheat flour), **SE** (Standard Error), **LSD** (Least Significant Difference)

Baking quality assessment of oat flour incorporated sponge cake

The baking quality assessment of oat flour incorporated sponge cake revealed that the maximum cake volume was recorded in T_3 (860 cm^3), followed by T_2 (640 cm^3), with the minimum volume observed in T_1 or control (600 cm^3).

Table 3: Baking quality assessment of oat flour incorporated sponge cake.

Treatments	Cake volume (cm^3)	Cake height (cm)	Cake weight (g)	Baking loss (%)
T_1	600 c	3.00 c	268 c	3.70 c
T_2	640 b	3.77 b	273 b	5.53 b
T_3	860 a	4.00 a	283 a	9.91 a
SE ±	0.0136	0.5086	1.633	0.663
LSD 0.05	0.0378	1.2446	3.9958	1.6223

T_1 (Control with 100% whole wheat flour), **T_2** (with 10% oat flour and 90% wheat flour), **T_3** (with 30% oat flour and 70% wheat flour), **SE** (Standard Error), **LSD** (Least Significant Difference).

Similarly, the maximum cake height was also found in T_3 (4.00 cm), with T_2 (3.77 cm) and T_1 (control) (3.00 cm). The weight analysis showed that T_3 had the highest cake weight (283 g), T_2 had 273 g, and the control had the lowest weight (268 g). Furthermore, the baking loss was highest in T_3 (9.91%), followed by T_2 (5.53%), and the lowest baking loss was observed in the control treatment (3.70%).

Sensory evaluation of oat flour incorporated sponge cake

The sensory evaluation of oat flour-incorporated sponge cake revealed that the maximum scores for color (8.34), texture (8.23), taste (7.90), aroma (8.46), and overall acceptability (8.76) were recorded in the T_3 treatment, which consisted of 30% oat flour and 70% wheat flour. T_2, with slightly lower but still favorable scores, followed by color (7.50), texture (7.43), taste (7.63), aroma (7.70), and overall acceptability (7.23). The control treatment, T_1, consistently showed the minimum scores for all parameters, with color (6.95), texture (6.94), taste (6.76), aroma (6.43), and overall acceptability (6.63). The LSD test confirmed that these differences were significant ($P<0.05$), indicating that incorporating 30% oat flour with 70% wheat flour is the optimal blend for enhancing the sensory qualities of sponge cake.

Discussion

Bakery products are widely consumed globally, with cakes being particularly favored for their delicious sponge texture and desired taste and quality attributes [19]. Oats, a type of cereal grain, have been widely acknowledged for their ability to lower cholesterol levels [20].

Table 4: Sensory characteristics of oat flour incorporated sponge cake

Treatments	Color	Texture	Taste	Aroma	Overall Acceptability
T_1	6.95 a	6.94 c	6.76 c	6.43 c	6.63 c
T_2	7.50 a	7.43 b	7.63 b	7.70 b	7.23 b
T_3	8.34 a	8.23 a	7.90 a	8.46 a	8.76 a
SE ±	0.6726	0.1308	0.0871	0.0709	0.0721
LSD 0.05	1.6458	0.3201	0.213	0.1734	0.1764

T_1 (Control with 100% whole wheat flour), **T_2** (with 10% oat flour and 90% wheat flour), **T_3** (with 30% oat flour and 70% wheat flour), **SE** (Standard Error), **LSD** (Least Significant Difference)

They also help in moderating the body's response to blood sugar and insulin after meals [21], thereby reducing the risk of diabetes and various long-term health conditions [22]. In the present study, significant ($P<0.05$) results were observed for the proximate, baking quality, and sensory properties of oat flour-incorporated sponge cakes.

The incorporation of oat flour significantly increased the moisture, ash, protein, carbohydrate, fat, fiber, and energy value contents of the sponge cakes (T_2 and T_3) compared to the control treatment (T_1). This aligns with previous research by Chauhan et al. [10], who reported increased protein, fiber, ash, and fat content but a significant decrease in carbohydrate content in bread and noodles with oat flour addition. The observed increase in nutritional profile, especially the fiber content of the oat flour incorporated sponge cake, is a significant finding, as oat flour is a well-known source of dietary fiber and other bioactive compounds. This could be beneficial for consumers seeking fiber-rich bakery products. Aydin and Gocmen [23] observed that adding oat flour significantly raised the ash content in noodles, particularly when incorporating 20%, 30%, and 40% of egg and oat flour. They also found that the sample with 40% oat flour had the highest levels of ash, protein, and crude fat, which they linked to the naturally higher ash, protein, and crude fat content in oat flour. Given the high protein content in oat flour-enriched bakery products, these could be beneficial in preventing and treating protein-energy malnutrition (PEM) conditions such as kwashiorkor and marasmus in children. Gambus et al. [24] discovered that residual oat flour, rich in proteins, can be effectively incorporated into white bread, comprising up to 20% of the total wheat flour mass. Oats also exhibit remarkable moisture retention capabilities, extending the freshness of bakery items. Incorporating oat lecithin or oat starch into wheat bread has been found to slow down the staling process.

The study revealed that incorporating oat flour (T_2 and T_3) resulted in increased cake volume, cake height, and cake weight compared to the control treatment (T_1). This could be due to the water-absorbing capacity of oat flour, leading to improved batter viscosity and gas retention during baking. However, T_3 also showed the highest baking loss, possibly due to the increased fiber content hindering gluten network formation and leading to crumblier cakes. This aligns with research by Kudake et al. [25] who found that oat flour addition up to a certain level (up to 40%) increased noodles volume due to the presence of beta-glucans, which can enhance gas retention during baking. However, our study suggests that exceeding this level (30% oat flour in T_3) might lead to a denser cake structure, as evidenced by the higher weight of T_3 compared to T_1 and T_2. The baking loss also followed a similar trend, with T_3 having the highest value (9.91%). This could be attributed to the higher moisture content and water-holding capacity of oat flour compared to wheat flour. Similarly, Aydin and Gocmen, [23] observed significantly higher cooking loss values in oat flour-incorporated noodles as compared to the control samples (without oat flour). Izydorczyk et al. [26] noted that cooking losses occur due to the breakdown or weakening of the protein-starch matrix.

The sensory evaluation highlighted the superiority of T_3 for all sensory attributes i.e., color, texture, taste, aroma, and overall acceptability. This suggests that the 30% oat flour incorporation offered a favorable balance between the familiar texture and flavor of wheat flour-based sponge cake with the added benefits and potentially more complex flavor profile of oat flour. Similar findings were also reported by Kudake et al. [25] who

observed that incorporating oat flour up to 30% improved the sensory characteristics of noodles. The lower scores for T_1 (control) could be due to the lack of the nutty and slightly sweet flavor associated with oat flour. Flander et al. [27] found that breads incorporated with oat flour have a mild, nutty, and pleasant flavor.

Conclusion

In conclusion, the partial replacement of wheat flour with oat flour in sponge cake development significantly improves the nutritional profile and sensory quality of the final product. The observed results of the study revealed that sponge cakes formulated with 30% oat flour and 70% wheat flour (T_3) showed superior proximate compositions, i.e., higher moisture, ash, protein, fat, and fiber contents compared to both the control (T_1) and the 10% oat flour variation (T_2). The T_3 formulation also displayed better baking characteristics, such as increased cake volume, height, and weight. The sensorial evaluation revealed that the T_3 cakes received higher scores in color, texture, taste, aroma, and overall acceptability. These findings indicate that substituting wheat flour with oat flour up to 30% not only meets the growing consumer demand for healthier and functional bakery products but also retains desirable organoleptic properties. Therefore, oat flour can be effectively utilized to develop sponge cakes with enhanced nutritional and sensory qualities, contributing to the diversification and improvement of functional food products in the bakery industry.

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