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# Production and Quality Evaluation of Cupcakes Enriched with Prebiotics

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## ABSTRACT

This study aimed to assess the physicochemical and sensory properties of cupcakes enriched with sugar beet pulp powder and potato peel powder. Potato peels had the highest protein (12.20%) and fat (2.25%), followed by wheat flour at 11.73 and 1.08% and sugar beet pulp at 10.50 and 0.35%. Crude fiber but soluble dietary fiber were highest in sugar beet pulp powder, while total dietary fiber and insoluble dietary fiber were the highest in potato peel powder, while wheat flour (72% extraction) had the lowest values. The substitution in cupcakes resulted in a decrease in fat content, an increase in ash content, and a significant increase in crude fiber and total dietary fiber contents, as well as soluble and insoluble fiber contents, compared with the control. The physical properties showed an increase in the hardness of cupcakes, and a negative correlation was found between specific volume and hardness. The findings suggest that the crust and crumb color of the produced cupcakes varied with the quantity of fiber used. The sensory evaluation showed that the addition of sugar beet pulp and potato peel powder up to 15% resulted in expectable cupcakes.

## 1.Introduction

Functional foods are now focused on promoting gastrointestinal health, owing to the high incidence and proven severity of gastrointestinal disorders. Prebiotics and probiotics can be included in food products as functional ingredients to obtain functional foods, which have revolutionized and augmented the role of food in health (Ahire et al., 2022). Prebiotics are defined by (Hawrelak 2020) as compounds that are used specifically by certain bacteria in the host, leading to advantageous health outcomes. Prebiotics are utilized to promote the survival of probiotics. These non-digestible carbohydrates promote the growth of specific advantageous microbiota (probiotics) in the intestine by supplying food and energy (Sánchez-Zapata et al., 2013). On the other hand, (Mollakhalili-Meybodi et al., 2021) described prebiotics as non-digestible food components that enhance human health by selectively promoting the growth and/or activity of probiotic bacteria in the gastrointestinal tract. Incorporating prebiotics into one's diet on a regular basis may lower the risk of developing various diseases, including colorectal cancer, type 2 diabetes, metabolic syndrome, osteoporosis, inflammatory bowel diseases, irritable bowel syndrome (IBS), obesity, and infectious diarrhea. (Mohebbi et al., 2018) noted that these benefits are primarily attributed to prebiotics' capacity to promote beneficial microbiota, inhibit the growth of pathogenic microorganisms, boost immune function, slow stomach emptying, increase viscosity, and reduce the availability of polysaccharides. Prebiotics can be found in natural sources; in addition, many foods are fortified with prebiotics (such as inulin or fructo-oligosaccharides) that are either directly extracted from plants or synthesized through chemical methods.



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The sugar beet (Beta vulgaris L.) belongs to the family Chenopodiaceae and is mainly used for sugar production in different parts of the world. Sugar beet pulp is obtained after the water extraction of sugar from the sliced beet tuber as a by-product of the sugar refining industry. The isolated fiber is about 73% of the total dietary fiber (Cappa et al., 2013).

The fiber is reported by (Huang et al., 2020) to be a source of 25–30% pectin, 22–24% cellulose, and 26–32% hemicellulose. (Minarovicova et al., 2018) found that sugar beet is a good source of total dietary fiber, most of which is insoluble, as they studied the effects of wheat flour replacement with different levels of sugar beet pulp powder on the properties of pasta. The study by (Saeidy et al., 2022) showed that depectinized sugar beet fiber, a by-product of sugar factories, has the potential to be used in the formulation of gluten-free muffins with no adverse effects on their quality.

The potato *(Solanum tuberosum L.)* is a highly significant vegetable crop. During the processing of raw tubers, peeling is typically necessary, which generates a substantial amount of bulky waste. This waste is usually disposed of or used as animal feed. However, potato peel, as a by-product, contains a wide array of nutritional and pharmacologically active components, including phenolic compounds, polysaccharides, and glycoalkaloids (Nazir et al., 2022).

These components offer dietary fiber and natural antioxidant properties (Jeddou et al., 2017). In a recent review by (Sampaio et al., 2020) on the nutritional value, chemical composition, bioactivity, and technological properties of potato peels and their extracts, it was discovered that there is significant interest in the sustainable utilization of potato processing by-products by the food and pharmaceutical industries.

These endeavors have the potential to enhance the overall value of the crop while simultaneously reducing its environmental impact. From the above reports, it could be noticed that the utilization of potato and sugar beet by-products in prepared products can provide a dual benefit of producing healthy phytonutrient-rich cupcakes along with solving the problem of solid waste dispersal of potato and sugar beet industry processing by-products. Accordingly, this study aimed to assess the physical and chemical properties of cupcakes that were enriched with sugar beet pulp powder and potato peel powder. Additionally, a sensory evaluation was conducted to gather feedback on the cupcakes.

## 2. Materials and Methods

### Materials

Potato peel was obtained from Tiba Trading Company (Kom Hamada, El-Bihira, Egypt). Sugar beet pulp was obtained from Delta Sugar Co. (6 October, Giza, Egypt). A wheat flour extraction rate of 72% was obtained from the South Cairo Company of Milling. Sugar, baking powder, palm shortening (food grade: CM Amalina), table salt, fresh eggs, skimmed dry milk and vanilla extract were purchased from the local market in Giza, Egypt. All chemicals were of analytical reagent grade.

### Methods

### Preparation of Potato Peel Powder

The potato peel was manually washed and cleaned. The peels were then rinsed several times with distilled water, and the excess water was drained. The peels were subsequently dried in a hot air oven at 45±2˚C for 24 hours. After drying, the peels were finely ground to pass through a 100-mesh sieve and stored in sealed plastic containers at room temperature (28 to 30°C) for further use.

### Preparation of sugar beet pulp powder

Sugar beet pulp was dried at room temperature, milled, sieved through a 100-mesh sieve, and packed in polyethylene bags. According to the method described by (Minarovicova et al., 2018).

### Determination of Water Holding Capacity (WHC)

The water holding capacity (WHC) of the wheat flour, potato peel powder, and sugar beet pulp powder used in the preparation of the cake samples was determined using the methods outlined by (Alkarkhi et al., 2010).

## Preparation of cupcake samples

The cake was prepared following the procedure outlined in (AACC 2002), and the ingredients used are listed in Table 1. After baking, the cake was allowed to cool for an hour and then packaged in plastic bags for subsequent analysis.

**Table 1. Formula for Control and Produced Cupcakes**

| Ingredient | Control | Cupcake with Sugar Beet Pulp | | | | Cupcake with Potato Peel Powder | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 15% | 20% | 5% | 10% | 15% | 20% |
| Wheat Flour Extraction Rate of 72% | 100 | 95 | 90 | 85 | 80 | 95 | 90 | 85 | 80 |
| Sugar Beet Pulp Powder | - | - | - | - | - | 5 | 10 | 15 | 20 |
| Potato Peel Powder | - | 5 | 10 | 15 | 20 | - | - | - | - |
| Shortening | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Fresh Egg | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 |
| Sugar | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| Dry Skim Milk | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Baking Powder | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Vanilla Extract | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Table Salt | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

## Chemical Analysis

The moisture, protein, fat, ash, total dietary fiber, soluble, and insoluble dietary fibers were determined using the methods described in AOAC (2010). Approved Methods 44-16, 46-30, 30-10, 08 -01, and 32-45.01. The total carbohydrate content was calculated by dividing the difference. The elemental analysis of sodium, potassium, magnesium, calcium, zinc, and iron was conducted using a microwave digestor (Multiwave GO Plus 50 HZ) prior to spectrophotometric analysis of the samples by MPAES (Microwave Plasma-Atomic Emission Spectroscopy) (Agilent, Mulgrave, Victoria, Australia) as described by Helal and Nassef, 2021. Three replicates were measured for each sample.

## Physical Properties for Cupcakes

After cooling for one hour, the weight (in grams) of the cupcakes was recorded, and their height was measured to the nearest millimeter using a micrometer. The weight (in grams) and volume (in cubic centimeters) were determined using seed displacement, as outlined in (AACC 2002) Method 10-91. The specific volume (in cubic centimeters per gram) of the cupcakes was calculated by dividing the volume by the weight. Three replicates were measured for each sample. The water activity (aw) was measured using a rotronic Hygro Lab EA10-SCS (Switzerland) aw meter. All measurements were conducted in triplicate.

### Determination the Color Attributes

A Hunter Lab Color QUEST II Minolta CR-400 (Minolta Camera, Co., Ltd., Osaka, Japan) was used to determine the color parameter L* (100: white; 0: black), a* (+, red; -, green), and b* (+, yellow; -, blue) values of wheat flour, sugar beet pulp, potato peel powder, and prepared cupcake samples. The procedure was outlined in (Francis 1983). For every sample, three replicates were measured. In accordance with (Saricoban and Yilmaz 2010), the overall change in color (Δ E) was computed using the following relationship:

$$\Delta E = \sqrt{} (L_0 - L^*)^2 + (a_0 - a^*)^2 + (b_0 - b^*)^2$$

## Sensory Evaluation of Cupcakes

After baking, the cupcake samples were allowed to cool at room temperature (25°C±2) for four hours before being subjected to organoleptic evaluation. four hours before being subjected to organoleptic evaluation. A slice of each cupcake sample was served to 10 well-trained panelists (five males and five females) from the Food Technology Research

Institute staff on white, odorless, and disposable plates. The samples were scored based on appearance, texture, odor, taste, and overall acceptability according to the method described in Bennion and Bamford (1997).

## Statistical Analysis

The analytical data were analyzed using SPSS 20.0 software. Means and standard deviations were determined using descriptive statistics. Comparisons between samples were determined using one-way variance (ANOVA) and multiple range tests. Statistical significance was defined at $P \leq 0.05$ (Steel and Torrie, 1986).

## Results and Discussion

## Chemical, mineral content and functional properties of raw materials

Table 2. displays the chemical and physical properties of the raw materials. In terms of moisture content, wheat flour had the highest level, followed by sugar beet pulp, whereas potato peel powder had the lowest level. The protein and fat content of the potato peel were the highest (12.20% and 2.25%, respectively), followed by (11.73% and 1.08%) for wheat flour and (10.50% and 0.35%) for sugar beet pulp, respectively. Ash was highest in potato peel (6.89%), followed by sugar beet pulp (3.62%), and the lowest was wheat flour. Crude fiber and soluble dietary fiber were highest in sugar beet pulp, while total dietary fiber and insoluble dietary fiber were the highest in potato peel powder, while wheat flour had the lowest values (72% extraction). These findings are consistent with the results obtained by (Sharoba et al., 2013; Dhingra et al. 2012 and Jeddou et al., 2017). The analysis indicated that calcium, magnesium, and sodium were highest in potato peel powder, while sugar beet pulp was highest in iron and zinc. Findings are consistent with work by (Sharoba et al., 2013 and El-Ayek et al., 2009).

**Table 2. Chemical Composition and Functional Properties of Ingredients**

| | Wheat Flour | Potato Peel Powder | Sugar Beet Pulp |
|---|---|---|---|
| Moisture (g/100g) | 11.44±0.02 | 4.78±0.05 | 6.40±0.06 |
| Protein (g/100g) | 11.73±0.04 | 12.20±0.03 | 10.50±0.02 |
| Fat (g/100g) | 1.09±0.09 | 2.25±0.06 | 0.35±0.09 |
| Ash (g/100g) | 0.58±0.03 | 6.89±0.02 | 3.62±0.04 |
| Crude Fiber (g/100g) | 0.58±0.07 | 12.06±0.05 | 17.00±0.07 |
| Total Dietary Fiber (g/100g) | 2.65±0.06 | 73.25±0.08 | 69.00±0.03 |
| Soluble Dietary Fiber (g/100g) | 1.06±0.05 | 19.86±0.04 | 21.50±0.08 |
| Insoluble Dietary Fiber (g/100g) | 1.59±0.02 | 53.39±0.07 | 47.50±0.05 |
| Ca (mg/100gm) | 20.00±0.03 | 245.00±0.18 | 61.5±0.18 |
| Mg (mg/100gm) | 112.36±0.08 | 155.00±0.05 | 29.8±0.07 |
| Fe (mg/100gm) | 1.13±0.04 | 1.85±0.09 | 3.92±0.05 |
| Zn (mg/100gm) | 1.07±0.05 | 1.65±0.07 | 2.52±0.04 |
| Na (mg/100gm) | 4.13±0.07 | 59.92±0.04 | 20.6±0.03 |
| K (mg/100gm) | 116.76±0.18 | 88.25±0.09 | 48.4±0.07 |
| Water Holding Capacity (g/g) | 1.50±0.05 | 3.45±0.03 | 20.00±0.03 |

Data are presented as means ± SDM (n=3)

## Nutritional Composition of Cupcake

Table 3. presents the proximate composition of cupcakes supplemented with sugar beet pulp and potato peel powder. The protein content of all cake samples ranged from 8.00% to 8.34%, with the 20% potato peel powder samples having the highest protein content at 8.34%. The addition of sugar beet pulp led to a decrease in protein content, which is likely due to the low protein content of the pulp. This finding is consistent with previous research by (Simić et al., 2021). In contrast, the addition of potato peel powder resulted in an increase

in protein content, as the powder contains a considerable amount of protein (12.20%). The results also showed that increasing the concentration of potato peel powder led to a higher protein content in the cupcakes, which agrees with the findings of (Jeddou et al., 2017).

**Table 3. Chemical Composition of Cupcake**

| Formula | Protein % | Fat % | Ash % | Crud Fiber % | Total Dietary Fiber % | Soluble Dietary Fiber % | Insoluble Dietary Fiber % | Carbohy-drate % |
|---|---|---|---|---|---|---|---|---|
| Control | | | | | | | | |
| | 8.28 ±0.04[a] | 22.35 ±0.02[a] | 1.76 ±0.11[e] | 1.02 ±0.08[e] | 1.88 ±0.05[e] | 0.73 ±0.06[e] | 1.13 ±0.04[e] | 66.59 ±0.18[b] |
| Sugar Beet Pulp | | | | | | | | |
| 5% Sugar Beet Pulp Powder | 8.18 ±0.06[b] | 22.05 ±0.03[b] | 1.89 ±0.04[d] | 2.56 ±0.06[d] | 5.97 ±0.04[d] | 2.08 ±0.06[d] | 3.89 ±0.08[d] | 66.72 ±0.16[a] |
| 10% Sugar Beet Pulp Powder | 8.14 ±0.04[c] | 21.89 ±0.06[c] | 2.04 ±0.09[c] | 3.96 ±0.03[c] | 9.29 ±0.05[c] | 3.10 ±0.04[c] | 6.18 ±0.04[c] | 66.62 ±0.10 [b] |
| 15% Sugar Beet Pulp Powder | 8.09 ±0.07[d] | 21.71 ±0.04[d] | 2.28 ±0.03[b] | 5.19 ±0.05[b] | 12.60 ±0.03[b] | 4.13 ±0.07[b] | 8.48 ±0.07[b] | 66.43± 0.15[c] |
| 20% Sugar Beet Pulp Powder | 8.00 ±0.05[e] | 21.45 ±0.05[e] | 2.57 ±0.02[a] | 6.38 ±0.08[a] | 15.92 ±0.06[a] | 5.15 ±0.05[a] | 10.77 ±0.02[a] | 66.35± 0.02[c] |
| Potato Peel Powder | | | | | | | | |
| 5% Potato Peel Powder | 8.31 ±0.05[d] | 22.30 ±0.05[b] | 2.02 ±0.04 [d] | 2.33 ±0.06 [d] | 6.33 ±0.08 [d] | 1.14 ±0.04 [d] | 5.18 ±0.07 [d] | 65.04 ±0.15 [b] |
| 10% Potato Peel Powder | 8.32 ±0.03[c] | 22.25 ±0.04[c] | 2.27 ±0.09 [c] | 3.64 ±0.03 [c] | 10.02 ±0.06 [c] | 1.21 ±0.09 [c] | 8.76 ±0.03 [c] | 63.06 ±0.12 [c] |
| 15% Potato Peel Powder | 8.33 ±0.06 [b] | 22.10 ±0.06[d] | 2.53 ±0.03 [b] | 4.92 ±0.05 [b] | 13.91 ±0.03 [b] | 1.29 ±0.07 [b] | 12.35 ±0.04 [b] | 62.12 ±0.14 [d] |
| 20% Potato Peel Powder | 8.34 ±0.04[a] | 21.95 ±0.01[e] | 2.79 ±0.06 [a] | 6.18 ±0.08 [a] | 17.40 ±0.02 [a] | 1.34 ±0.05 [a] | 15.94 ±0.06 [a] | 60.75 ±0.17 [e] |

*Data was calculated as percentages (%). All of data were calculated on dry weight basis. Means with the same letter in the same column are not significantly different ($p > 0.05$).

The addition of both sugar beet pulp and potato peel powder caused a slight but significant decrease in fat content. The ash content of the cupcakes increased with the addition of both ingredients, with the 20% potato peel powder cupcakes recording the highest ash content at 2.78% and 2.57% for sugar beet pulp, compared to 1.76% for the control. These findings are consistent with those reported by (Gadhe et al., 2017), though the values obtained were slightly higher. The crude fiber content of the control cupcakes was low at only 1.02%, while the cupcakes with both sugar beet pulp and potato peel powder had higher crude fiber contents at 6.37% and 6.18%, respectively. The addition of both ingredients, especially at high levels, resulted in an increase in crude fiber content, which is in agreement with the research of (Amin and Zubair in 2020 and Singh et al., 2022). Furthermore, the inclusion of different levels of sugar beet pulp and potato peel powder in the cupcake formulation increased the total dietary fiber content, as well as the soluble and insoluble fiber contents. With the addition of 20% potato peel powder, the total dietary fiber content increased from 1.88% in the control cupcakes to 10.56% in the cupcakes containing 10% potato peel fiber and 17.4% in the cupcakes containing 20% potato peel powder. Additionally, the insoluble fiber content of the cupcakes increased significantly from 1.133% in the control to 9.34% in the cakes containing 10% potato peel fiber and 15.94% in the cakes containing 20% potato peel powder. These results are consistent with the findings of (Jeddou et al., 2017). (Ali et al., 2018) reported that rat groups fed with biscuits prepared with replacement of wheat flour by 30% prebiotics resulted in a considerable increase in the colon content of *Lactobacillus sp.*, *Bifidobacteria sp.* compared with control group.

In summary, the addition of both sugar beet pulp and potato peel powder to the cupcakes resulted in a decrease in fat and ash content. A significant increase in crude fiber and total dietary fiber contents, as well as soluble and insoluble fiber contents.

**Table 4. Element Contents of Cupcakes (mg/100g dry weight)**

| Formula | Calcium | Magnesium | Iron | Zinc | Sodium | Potassium |
|---|---|---|---|---|---|---|
| Control | | | | | | |
| | 123.928 ±0.003 [a] | 13.106 ±0.005 [a] | 1.082 ±0.004 [e] | 0.667 ±0.003 [e] | 206.460 ±0.006 [a] | 99.783 ±0.002 [a] |
| Sugar Beet Pulp Powder | | | | | | |
| 5% Sugar Beet Pulp Powder | 123.780 ±0.002 [a] | 12.538 ±0.005 [b] | 1.119 ±0.001 [d] | 0.692 ±0.003 [d] | 204.738 ±0.002 [b] | 97.480 ±0.007 [b] |
| 10% Sugar Beet Pulp Powder | 123.227 ±0.006 [b] | 12.050 ±0.002 [c] | 1.162 ±0.003 [c] | 0.721 ±0.006 [c] | 203.354 ±0.002 [c] | 95.879 ±0.006 [c] |
| 15% Sugar Beet Pulp Powder | 122.923 ±0.003 [c] | 11.707 ±0.001 [d] | 1.219 ±0.002 [b] | 0.758 ±0.005 [b] | 202.364 ±0.007 [d] | 94.904 ±0.005 [d] |
| 20% Sugar Beet Pulp Powder | 122.205 ±0.003 [d] | 11.053 ±0.004 [e] | 1.239 ±0.002 [a] | 0.774 ±0.004 [a] | 201.515 ±0.005 [e] | 93.271 ±0.003 [e] |
| Potato Peel Powder | | | | | | |
| 5% Potato Peel Powder | 128.270 ±0.003 [d] | 15.677 ±0.005 [b] | 1.092 ±0.002 [b] | 0.680 ±0.001 [d] | 206.980 ±0.004 [a] | 99.079 ±0.002 [b] |
| 10% Potato Peel Powder | 132.974 ±0.006 [c] | 18.235 ±0.002 [c] | 1.105 ±0.002 [b] | 0.698 ±0.002 [c] | 207.635 ±0.005 [a] | 98.392 ±0.002 [c] |
| 15% Potato Peel Powder | 135.645 ±0.005 [b] | 20.475 ±0.005 [d] | 1.109 ±0.003 [c] | 0.710 ±0.002 [b] | 206.564 ±0.003 [a] | 97.450 ±0.002 [d] |
| 20% Potato Peel Powder | 138.873 ±0.118 [a] | 23.026 ±0.003 [e] | 1.113 ±0.005 [c] | 0.722 ±0.003 [a] | 206.246 ±0.004 [a] | 96.167 ±0.003 [e] |

Data are presented as means ± SDM (n=3) & Means within a column with different letters are significantly different at $P \leq 0.05$.

Table 4. displays a significant increase in both iron and zinc but a decrease in all other minerals with the use of sugar beet pulp. This could be attributed to the low content of minerals in sugar beet pulp.

Conversely, the data in the same table indicate that using potato peel powder results in an increase in mineral content, with the exception of potassium. These findings are consistent with the research of (Singh et al., 2022), who reported a 21% increase in minerals with the addition of potato peel powder.

## Physical Properties of Cupcakes

Table 5. displays the results of the effect of incorporating sugar beet pulp and potato peel powder on the weight, volume, and specific volume of cupcakes. The findings indicate that with increasing levels of both ingredients, the weight of the cupcakes gradually increased, while the volume and specific volume decreased significantly when compared to the control cupcake. The cupcake samples with 20% sugar beet pulp had the highest weight at 37.81g, compared to 35.42g for the control cupcake. Also, cupcakes with 20% potato peel had a weight of 37.78g. This increase in weight may be due to the high fiber content in the cupcake samples, which causes high water absorption by the fiber, leading to an increase in weight. These results are consistent with previous research by (Sharoba et al., 2013).

**Table 5. Physical Properties of Cupcake**

| Formula | Weight (g) | Volume ($cm^3$) | Specific Volume ($cm^3/g$) | Density (gm/ $cm^3$) | Water Activity |
|---|---|---|---|---|---|
| **Control** | | | | | |
| | 35.42 ±0.03[d] | 53.82 ±0.05 [b] | 1.52 ±0.02[a] | 0.66 ±0.06[d] | 0.781 ±0.001 [e] |
| **Cupcake with Sugar Beet Pulp Powder** | | | | | |
| 5% Sugar Beet Pulp Powder | 36.15 ±0.03[d] | 54.10 ±0.07 [a] | 1.49 ±0.05[b] | 0.67 ±0.03[d] | 0.787 ±0.004[d] |
| 10% Sugar Beet Pulp Powder | 37.00 ±0.07[c] | 52.55 ±0.03 [c] | 1.42±0.04[c] | 0.70 ±0.07[c] | 0.792 ±0.001[c] |
| 15% Sugar Beet Pulp Powder | 37.87 ±0.05[b] | 51.64 ±0.06[d] | 1.36±0.03[d] | 0.73 ±0.05[b] | 0.795 ±0.003[b] |
| 20% Sugar Beet Pulp Powder | 38.24 ±0.02[a] | 51.00 ±0.03[d] | 1.33 ±0.03[e] | 0.75 ±0.02[a] | 0.801 ±0.005[a] |
| **Cupcake with Potato Peel Powder** | | | | | |
| 5% Potato Peel Powder | 35.95 ±0.06[b] | 54.40 ±0.03[a] | 1.51 ±0.03[a] | 0.66 ± 0.07[d] | 0.789 ±0.002[d] |
| 10% Potato Peel Powder | 36.53 ±0.04[b] | 52.82 ±0.03[c] | 1.44 ±0.01[b] | 0.69 ± 0.03[c] | 0.794 ±0.002[c] |
| 15% Potato Peel Powder | 37.13 ±0.03[b] | 52.22 ±0.01[c] | 1.41 ±0.04[c] | 0.71 ± 0.05[b] | 0.799 ±0.003[b] |
| 20% Potato Peel Powder | 37.78 ±0.02[a] | 51.10 ±0.03[b] | 1.35 ±0.05[d] | 0.74 ± 0.02[a] | 0.803 ±0.005[a] |

Data are presented as means ± SDM (n=3) & Means within a column with different letters are significantly different at $P \leq 0.05$.

Incorporating both sugar beet pulp and potato peel in cupcakes had a negative effect on volume and specific volume. The highest volume of 54.10 $cm^3$ and 54.40 cm3 was recorded by cupcakes with 5% sugar beet pulp and 5% potato peel powder. The increase in volume of cupcakes with the addition of 5% sugar beet pulp and potato peel was explained by (Majzoobi et al., 2018) as the fact that fibers can support the air bubble cell walls inside the cake and prevent them from rapid collapse after removing the cakes from the oven and during storage. These findings agreed with those obtained by (Ayadi et al., 2009). However, with an increase in substitution level up to 10%, a decrease in volume was observed. (Akubor and Ishiwu 2013) explained this decrease as the dilution of gluten levels by the added fiber. Since gas retention in dough during baking is a property of gluten, which traps carbon dioxide and contributes to the rise in volume and spongy texture, a decrease in gluten levels can lead to a decrease in volume and texture. Overall, the results suggest that while incorporating sugar beet pulp or potato peel powder into cupcakes can increase their weight and density, it may also lead to a decrease in volume and specific volume, especially at higher levels of addition. The results agree with the findings of (Sudha 2011), who reported that the density of the cakes increased due to the strong water-binding properties of apple fiber. The cupcakes prepared with different levels of substitution exhibited statistically significant variations in their moisture content. A higher moisture content was found in cakes prepared after 20% substitution compared to the control. (Rossel et al., 2001) reported that the hydroxyl group of the fiber structure allows more water interaction through bonding, which could explain the higher moisture content. The results also indicate that the water activity differed significantly among the different treatments. The water activity of the cupcakes ranged from 0.781 for the control to 0.803 for samples with 20% potato peel. The findings suggest that there was a gradual increase in water activity with increasing levels of sugar beet pulp and potato peel powder. (Qureshi et al., 2017) reported that water activity is directly related to moisture content, which could explain the observed variations in water activity. According to results, it was observed that as the fiber content increased, the hardness of cupcakes increased. In (Aydogdu, 2018) study, a negative correlation was found between specific volume and hardness. (Simić et al., 2021) reported that fiber content would have a greater influence on cookie hardness as sugar beet pulp contains a significant fiber proportion that absorbs water and can cause a more intense increase in cookie hardness. In summary, the incorporation of sugar beet pulp or potato peel powder in cupcakes resulted in significant variations in water activity. The cupcakes with higher levels of substitution exhibited higher water activity, likely due to the hydroxyl group of the fiber structure allowing for increased water interaction. The cupcakes with higher levels of substitution exhibited higher water activity, likely due to the hydroxyl group of the fiber structure allowing for increased water interaction.

The results suggest that careful consideration of the moisture content and water activity is important when formulating baked goods with sugar beet pulp or potato peel.

## Color Attributes of Cupcakes

Color is a critical factor that influences the acceptability of baked goods by consumers. For the color of the interior of the cupcake (crumb), a desirable characteristic would be a light-colored cake, as dark-colored cupcakes may not be accepted by many consumers. Table 6. displays the effect of substituting wheat flour with different levels of sugar beet pulp and potato peel powder on the color characteristics of the produced cupcakes. The addition of sugar beet pulp and potato peel powder resulted in significant changes in all studied color indicators compared to the control sample. The findings suggest that the crust and crumb color of the produced cupcakes varied with the quantity of fiber used. The "L" and "b" values decreased, while the "a" and ΔE values rose with an increase in the proportion of wheat flour replaced with potato peel powder, resulting in darker cupcakes compared to the control. The incorporation of sugar beet pulp or potato peel powder resulted in a greater decrease in lightness (L value), which is consistent with the findings of (Bchir et al., 2014; Simić et al., 2021 and Tlay et al., 2023) reported that the yellowness and brightness of the cupcakes decreased due to enzymatic browning, where brown pigments form during the browning and caramelization reaction. (Esteller and Lannes, 2008) stated that the color 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 color while the crumb color depends on ingredients' colors. Accordingly, crumb color was significantly affected by the color of added fibers.

## Sensory Acceptability of Cupcakes

Table 7. presents the sensory evaluation scores of the produced cupcake samples. The evaluated sensory parameters, including appearance, texture, taste, flavor, color, and overall acceptability, showed no significant differences between the control and tested cupcake samples made with fiber up to 5% of both sugar beet pulp and potato peel powder cupcake. However, increasing the level of substitution resulted in a decrease in the score of all parameters. These findings are consistent with the research of (Iskander et al., 2021). These findings are consistent with the research of (Iskander et al., 2021). The findings further revealed that the cupcake samples made with both sugar beet pulp and potato peel powder did not exhibit significant differences from the control samples at 5% replacement in all evaluated parameters. However, it was observed that the texture scores significantly decreased with the addition of both sugar beet pulp and potato peel powder above 5% due to an increase in hardness, which is not desirable to consumers. Increasing the level of substitution also resulted in a decrease in the score of all parameters for both sugar beet pulp and potato peel powder. These results align with the research conducted by (Zoair et al., 2016).

**Table 6. Color Values of Raw Materials and Cupcakes**

| | L | a | b | E |
|---|---|---|---|---|
| Wheat Flour | 87.95± 0.03 | -0.34 ± 0.02 | 9.31± 0.05 | - |
| Sugar Beet Pulp Powder | 78.80±0.02 | 2.11±0.06 | 14.33±0.03 | - |
| Potato Peel Powder | 58.00± 0.05 | 3.52 ±0.03 | 16.38 ±0.02 | - |

| Formula | Crumb | | | | Crust | | | |
|---|---|---|---|---|---|---|---|---|
| | L | a | b | ΔE | L | a | b | ΔE |
| | Control | | | | | | | |
| | 62.93 ±0.02$^{a}$ | 1.66 ±0.02$^{e}$ | 30.82 ±0.04$^{a}$ | - | 41.16 ±0.11$^{a}$ | 13.36 ±0.13$^{a}$ | 26.47 ±0.09$^{e}$ | - |
| | Sugar Beet Pulp Powder | | | | | | | |
| 5% Sugar Beet Pulp Powder | 60.43 ±0.01$^{b}$ | 2.10 ±0.05$^{d}$ | 25.00 ±0.01$^{b}$ | 6.36 ±0.05$^{d}$ | 39.90 ±0.01$^{b}$ | 12.25 ±0.09$^{b}$ | 27.73 ±0.03$^{d}$ | 2.10 ±0.05$^{d}$ |
| 10% Sugar Beet Pulp Powder | 56.57 ±0.03$^{c}$ | 2.25 ±0.01$^{c}$ | 23.70 ±0.05$^{c}$ | 9.57 ±0.04$^{c}$ | 37.11 ±0.02$^{c}$ | 11.39 ±0.03$^{c}$ | 28.11 ±0.05$^{c}$ | 4.79 ±0.01$^{c}$ |
| 15% Sugar Beet Pulp Powder | 52.73 ±0.09$^{d}$ | 2.71 ±0.05$^{b}$ | 22.30 ±0.03$^{d}$ | 13.33 ±0.01$^{b}$ | 35.87 ±0.05$^{d}$ | 10.61 ±0.07$^{d}$ | 29.79 ±0.01$^{b}$ | 6.82 ±0.07$^{b}$ |
| 20% Sugar Beet Pulp Powder | 50.11 ±0.02$^{e}$ | 2.97 ±0.07$^{a}$ | 21.12 ±0.02$^{e}$ | 16.13 ±0.07$^{a}$ | 32.12 ±0.02$^{e}$ | 9.11 ±0.05$^{e}$ | 30.50 ±0.06$^{a}$ | 10.77 ±0.05$^{a}$ |
| | Potato Peel Powder | | | | | | | |
| 5% Potato Peel Powder | 57.30 ±0.03$^{b}$ | 2.00 ±0.05$^{d}$ | 21.24 ±0.01$^{b}$ | 11.12 ±0.06$^{d}$ | 39.51 ±0.05$^{b}$ | 12.18 ±0.08$^{b}$ | 27.57 ±0.04$^{d}$ | 2.31 ±0.05$^{d}$ |
| 10% Potato Peel Powder | 52.58 ±0.02$^{c}$ | 2.17 ±0.01$^{c}$ | 19.53 ±0.03$^{c}$ | 15.3 ±20.04$^{c}$ | 36.78 ±0.10$^{c}$ | 11.28 ±0.03$^{c}$ | 28.03 ±0.06$^{c}$ | 5.09 ±0.03$^{c}$ |
| 15% Potato Peel Powder | 48.48 ±0.03$^{d}$ | 2.68 ±0.02$^{b}$ | 18.37 ±0.04$^{d}$ | 19.10 ±0.01$^{b}$ | 32.37 ±0.04$^{d}$ | 10.35 ±0.09$^{d}$ | 29.68 ±0.05$^{b}$ | 9.83 ±0.01$^{b}$ |
| 20% Potato Peel Powder | 48.23 ±0.02$^{e}$ | 2.85 ±0.01$^{a}$ | 17.08 ±0.03$^{e}$ | 20.16 ±0.05$^{a}$ | 31.77 ±0.08$^{e}$ | 9.01 ±0.07$^{e}$ | 30.17 ±0.04$^{a}$ | 10.99 ±0.07$^{a}$ |

Three values of L, a, and b were measured where L = 100 (white), L = 0 (black); +a = red, -a = green; and +b = yellow, -b = blue, ΔE= total change in color. Data are presented as means ± SDM (n=3) & Means within a column with different letters are significantly different at $P \leq 0.05$.

**Table 7. Acceptability Score of Cupcakes**

| Formula | Appearance | Texture | Taste | Flavor | Color | Overall Acceptability |
|---|---|---|---|---|---|---|
| Control | | | | | | |
| | 19.89 ±0.03 [a] | 19.22 ±0.04 [a] | 19.17 ±0.06 [a] | 19.88 ±0.02 [a] | 19.97 ±0.06 [a] | 98.10 ±0.05[a] |
| Sugar Beet Pulp Powder | | | | | | |
| 5% Sugar Beet Pulp Powder | 19.70 ±0.03[a] | 19.15 ±0.06 [a] | 19.11 ±0.02[a] | 19.80 ±0.03 [a] | 19.90 ±0.08[a] | 97.66 ±0.15[a] |
| 10% Sugar Beet Pulp Powder | 19.61 ±0.03[b] | 18.09 ±0.02[b] | 18.52 ±0.03[b] | 18.45 ±0.03[b] | 18.51 ±0.08[b] | 93.18 ±0.19[b] |
| 15% Sugar Beet Pulp Powder | 19.17 ±0.03[c] | 18.00 ±0.03[c] | 18.17 ±0.12[c] | 18.10 ±0.03[c] | 17.95 ±0.05[c] | 91.39 ±0.16[c] |
| 20% Sugar Beet Pulp Powder | 18.82 ±0.04[d] | 17.44 ±0.03[d] | 17.67 ±0.03[d] | 17.85 ±0.03[d] | 17.81 ±0.06[d] | 89.59 ±0.09[d] |
| Potato Peel Powder | | | | | | |
| 5% Potato Peel Powder | 19.78 ±0.03[a] | 19.17 ±0.06[a] | 19.03 ±0.02[a] | 19.83 ±0.03[a] | 19.96 ±0.08[a] | 97.85 ±0.14[a] |
| 10% Potato Peel Powder | 19.68 ±0.03[b] | 18.12 ±0.02[b] | 18.48 ±0.03[b] | 18.48 ±0.03[b] | 18.58 ±0.08[b] | 93.35 ±0.09[b] |
| 15% Potato Peel Powder | 19.23 ±0.03[c] | 18.02 ±0.03[c] | 18.07 ±0.12[c] | 18.12 ±0.03[c] | 18.05 ±0.05[c] | 91.48 ±0.19[c] |
| 20% Potato Peel Powder | 18.95 ±0.04[d] | 17.48 ±0.03[d] | 17.38 ±0.03[d] | 17.88 ±0.03[d] | 17.93 ±0.06[d] | 89.64 ±0.16[d] |

Data are presented as means ± SDM (n = 10) & Means within a column with different letters are significantly different at $P \leq 0.05$.

## Conclusion

In this study, there were significant differences between the control and samples containing different sources and concentrations of fiber. From the sensory evaluation test, it could be observed that the addition of sugar beet pulp and potato peel powder up to 15% resulted in expectable cupcakes. The substitution resulted in a decrease in fat content, an increase in ash content, and a significant increase in crude fiber and total dietary fiber contents, as well as soluble and insoluble fiber contents. These findings suggest that incorporating sugar beet pulp and potato peel powder in baked goods can increase their nutritional value and fiber content.

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