

DEVELOPMENT OF LOTUS SEED AND SORGHUM CUPCAKES FOR DIABETES MELLITUS

Attia Mazhar¹, Nighat Bhatti², Nida Iqbal³, Saadia Manzoor⁴, Samavia Rashid Saleem⁵, Nosheen Naz⁶, Fakiha Mehak⁷

^{1,2,*3,4,5,6,7}Department of Human Nutrition and Dietetics, Riphah International University, Faisalabad Campus

¹attiamazhar309@gmail.com, ²dr.nighat@riphahfsd.edu.pk, ³dr.nida@riphahfsd.edu.pk, ⁴saadia.manzoor@riphahfsd.edu.pk, ⁵samavia.rashid@riphahfsd.edu.pk, ⁶nosheen.Naz@riphahfsd.edu.pk, ⁷fakiha.mehak@riphahfsd.edu.pk

DOI: <https://doi.org/10.5281/zenodo.17015694>

Keywords

Anti-oxidant, blood sugar, diabetes, lotus Seed, sorghum, storage study

Article History

Received on 29 May 2025

Accepted on 04 August 2025

Published on 30 August 2025

Copyright @Author

Corresponding Author: *

Nida Iqbal

Abstract

High blood sugar levels are a hallmark of diabetes, a group of metabolic diseases that can cause a number of consequences. This condition is linked to an increased risk of heart attack, stroke, and renal failure, among other health issues. To overcome this issue, the present research conducted focused on the development of nutrient rich cupcakes. Cupcakes were prepared in various formulations: TOa (control - sorghum-only cupcakes), T1 (50% sorghum flour and 25% lotus seed powder), T2 (25% sorghum flour and 50% lotus seed powder), and T3 (25% sorghum flour and 25% lotus seed powder). The antioxidant potential and physicochemical characteristics of these treatments were examined. Total sugars, energy calculations, and sensory evaluation were examples of physicochemical parameters. Total phenolic content (TPC) and DPPH radical scavenging activity were used to measure antioxidant activity. Analyses were carried out at 15-day intervals during a one-month storage study. The findings showed that whereas sugar concentrations dramatically rose over time, antioxidant activity decreased. Every therapy had a sensory evaluation at 0, 15, and 30 days. The sensory panel gave T1, which contains 50% sorghum flour and 25% lotus seed powder, the highest acceptance ratings of any formulation, indicating that it may be used as a functional food product to treat diabetes mellitus.

INTRODUCTION

Because diabetes mellitus is causing excessive stress to individuals, their carers, healthcare institutions, and society at large and a grave public health issue. The most recent projections say that 425 million people around the world had diabetes in 2017. It is anticipated the number will increase to 629 million by 2045 (Forouhi et al., 2019). This is because more people throughout the world are becoming overweight and engaging in harmful behaviours like not exercising and eating poorly. Because there are no

systems in place to register and track people with type 1 and type 2 diabetes, estimates of their numbers in low- and middle-income countries are not very reliable. According to the most recent IDF Atlas, Pakistan has the 3rd highest rate of diabetes in the world. It is estimated that 33 million individuals in Pakistan have type 2 diabetes. In Pakistan, an estimated 8.9 million people lacks to confirm diagnosis of Diabetes, and an additional 11 million adults have impaired glucose tolerance (Bhutta et al.,

2022). The prevalence of type 2 diabetes in 2019 in Pakistan was 16.98% and prediabetes was 10.91%. The average HbA1c level was 5.62% overall, and 8.56% among those who had just received a diagnosis (Aamir et al., 2019).

For most of human history, including the 20th century, the largest nutritional challenge was not having enough food. The government wanted to solve this problem by encouraging the production and distribution of as much cheap food as possible, especially starchy basic foods and their processed, shelf-stable versions. People couldn't have imagined that the widespread availability of inexpensive, unhealthy food would lead to a worldwide epidemic of obesity and long-term illnesses. These old ways of doing things, as well as how businesses and consumers reacted, are at least partly to blame for the rise of health problems associated with eating habits, including cardiovascular disease, type 2 diabetes, obesity, and numerous cancers in recent decades. Government policies have maintained to put a lot of emphasis on farming basic goods and helping the food sector, even though there have been a lot of chronic diseases associated to nutrition in the past. This is because of traditional ideas on food security, economy, and trade. The government has mostly focused on educational policies aimed at individuals because of the rise in chronic diseases. However, undernutrition has gotten better thanks to government-supported changes to the system, such as agricultural development and fortification programs. These initiatives, which include clinical counselling, food labelling, menu labelling, and dietary guidelines, all focus on personal responsibility and choice in manner to enhance your product's nutrition. Increasing amounts of proof shows that a multitude of complicated factors, not just personal tastes, have a big effect on what people eat and how they eat it. Food preferences are affected by several things, including personal choice, age, gender, culture, education, wealth, health, and cooking and nutrition skills. Some psychological elements are values, motivation, rewards, and how you feel about food and health. Food preferences can also be affected by things that happen early in life, like the mother's diet during pregnancy, the baby's feeding patterns, and the foods the baby eats when they are very young. Some of the broader sociocultural factors that affect personal

decisions are social class, race/ethnicity, family and community norms, social networks, and household habits like watching TV and sleeping. Also, the local environment is important (Mozaffarian et al., 2018). When the pancreatic-beta cells stop producing insulin, typically due to autoimmune damage, type 1 diabetes mellitus (T1DM) happens. To control the hyperglycemia and ketosis that follow, insulin replacement treatment is essential. Although onset can happen at any age, the highest incidence occurs around puberty and the early years of adulthood. Some of the symptoms include a reduced appetite, increased thirst, and decreased weight. Medical intervention is required without delay in the case of diabetic ketoacidosis and other serious complications. People who have type 1 diabetes are at increased risk for psychosocial issues and other autoimmune diseases. In order to lessen the likelihood of both short-term and long-term complications, care should prioritise better glucose control (Syed, 2022).

Insulin resistance is a condition in which people with type 2 diabetes have a decreased ability to respond to insulin. In this situation, insulin doesn't work well, so the body makes more of it at first to keep glucose levels stable. But with time, insulin production goes down, which leads to T2DM. People over the age of 45 have a higher likelihood of being diagnosed with type 2 diabetes. But type 2 diabetes is on the rise among kids, teens, and young adults due to sedentary lifestyles, excessive calorie intake, and obesity (Goyal et al., 2023).

Studies have shown that the risk of developing type 2 diabetes is reduced in people who eat a diet rich in fresh vegetables, whole grains, lean dairy, seafood, nuts, and other healthy foods. Research has linked consuming red and processed meat, refined carbs, and sugary drinks to an increased risk of developing type 2 diabetes. Keeping in mind that there is no magic diet that can stave off type 2 diabetes or guarantee your health is vital. Instead, adopting a varied diet that includes items from each food category in the right amounts may help lower your chance of developing type 2 diabetes (Basiak et al., 2019).

For 7,000 years, people have utilised lotus seeds (phool makhana), also known as *Nelumbo Nucifera* Gaertn, as a vegetable, functional food, and medicine. Its low calorie content, high nutrient content, and

bioactive components make it a special therapeutic food (Arooj et al., 2021).

China is the world's greatest producer and consumer of lotus seeds, an aquatic vegetable of economic importance in Asian countries, with 45,000 tonnes of dry seeds produced annually on an area of 0.5 to 0.7 million hectares of land. The three components of a lotus seed are the cotyledons, embryo, and seed epicarp. Because of its excellent nutritional and non-nutritive qualities as well as its wonderful flavour, lotus seeds are a popular functional food. Lotus seeds can be consumed raw, roasted, or crushed and cooked into a paste or syrup after being peeled and cored. Traditional medicine has a long history of using lotus seed for a wide range of medical conditions, including cancer, heart palpitations, fever, indigestion, persistent diarrhoea, enteritis, inflammation of tissues, and sleeplessness. The seed embryo, which is the excised core of the seed, is bitter and aromatic and is mostly used as a functional food or in medicine. Because it may calm the blood and cleanse heat, people have long employed the lotus seed embryo to treat neurological issues, insomnia, high fevers with restlessness, and heart disorders like hypertension and arrhythmias (Zhu et al., 2016).

The seed contains 2.40 to 3% crude fat, 16% to 21% total protein, 61% to 62% carbs, and 5% to 9% moisture. One of the primary forms of carbohydrates present in lotus seeds is starch. The lotus seed's retrograded starch, also known as resistant starch 3, showed potent prebiotic effects by promoting the growth of *Lactobacillus* and *Bifidobacteria*, two helpful bacteria, in the stomach. Recently, lotus seed protein hydrolysate made with Flavourzyme shown outstanding antioxidant qualities, indicating their potential application as a nutraceutical and health-promoting supplement. With 20–24 milligrammes per 100 grammes, vitamin C is the most concentrated vitamin available. In addition to its high iron content (13–18 mg/100 g), lotus seed is rich in calcium (30–31 mg/100 g), sodium (30–35 mg/100 g), and potassium (16–20 mg/100 g). The main phenolic chemicals detected in lotus seeds are secondary metabolites. All of the following compounds are alkaloids: neferine, isoliensinine, liensinine, lotusine, arnepavine, dauricine, pronuciferine, nuciferine, and roemerine. Several flavonols, such as procyanidin, epicatechin, hyperoside, isoquercitrin, gallic acid, and

myricetin 3-O-galactoside are examples of phenolic compounds and terpenoids. Neferine is one of these chemicals that has been demonstrated to have a lot of different biological effects. Numerous secondary metabolites, including nuciferine, dauricine, liensinine, lotusine, pronuciferine, roemerine, arnepavine, and neferine, are found in lotus seeds. It has been demonstrated that these substances have anti-inflammatory, anti-diabetic, neuroprotective, anti-cancer, and immunomodulatory properties.. Lotus seed is a functional food since it has a lot of bioactive compounds that are good for your health. Researchers also confirmed that lotus seed may be used to manufacture new food products. Lotus seed flour was used to replace up to 10% of the wheat in the bread recipe. This made the product better and more appealing to customers (Banger et al., 2022).

Numerous naturally occurring substances, including polyphenols, protein, and polysaccharides, that have been separated from lotus seeds have been verified to constitute multiple useful molecules. The primary nutrients found in lotus seeds are proteins and carbs. Lotus seeds are getting more and more attention across the world because of its unique nutritional benefits, such as being low in fat and having a good amount of amino acids. Many research have looked at the functional parts of lotus seeds. Lotus seed components include bioactive qualities that can help with things like lowering blood sugar, boosting the immune system, fighting bacteria, reducing inflammation, relieving pain, and controlling the digestive system. Lotus seeds could be useful in both traditional medicine and functional meals. People in China have traditionally thought of lotus seeds as a high-quality tonic that everyone likes. Recent research have shown that lotus seeds are full of nutrients and bioactive chemicals and are important for human health in a unique way. The Chinese Ministry of Health has given the green light for their use "as both food and medicine." Lotus seeds are utilised as medicine once the skin and core have been removed. In Chinese, this medicine is called "flesh of lotus." The core of the lotus seed that was taken out also contains healing properties. Lotus seeds were said to be good for the spleen, kidneys, heart, and eyes in ancient Chinese medical books. They were also said to be good for diarrhoea and to give you energy. Recent study in pharmacology has shown that lotus seeds

have calming, heart-protecting, anti-aging, and other effects (Zhang et al., 2015).

Researchers have carefully looked at the medicinal properties and health benefits of plant tissues and their extracts. These include antioxidant, anti-obesity, anti-diabetic, anti-inflammatory, antifungal, antidiarrheal, anti-carcinogenic, anti-proliferation, anti-neurodegenerative, anti-amnesic, and anti-thrombotic effects, as well as effects on immunomodulatory, hepato-protective, photo-protective, psycho-pharmacological, cardiovascular, and arrhythmia treatment (Showkat et al., 2021).

Nutrient-dense lotus (*Nelumbo nucifera* G.) seeds are mostly used for culinary and therapeutic purposes. The seeds are often regarded as a low-glycemic index food and are a staple in many nations. Lotus seeds have a significant amount of starch, which can make up more than half of their dry weight. Gelatinisation and retrogradation are two of the starch qualities that primarily define the quality of lotus seed products. This paper provides a thorough summary of current advancements in lotus seed starch (LS) isolation, modification, and application. High peak gelatinisation temperatures ($>70^{\circ}\text{C}$), high pasting temperatures ($>75^{\circ}\text{C}$), and a high amylose content (20–35%) have all been seen in native LS. Faster LS retrogradation and reduced swelling power have been attributed to the increased amylose concentration. LS has been altered through a range of methods, including chemical, enzymatic, high pressure, microwave, and thermal processing, to enhance its functionality. Native and modified LS both exhibit potential as practical functional components for a range of culinary and other uses (Dhull et al., 2022). Lotus seeds are routinely prescribed in Chinese traditional medicine as a treatment for hyperlipidaemia. According to recent findings, lotus seeds contain important phytoconstituents. Its special bioactive ingredients, which include flavonoids, alkaloids, phenolic compounds, and essential oils, have demonstrated effectiveness in enhancing health. It may offer a good opportunity for future valorisation and usage as a functional component and addition in the food industry due to the high content of dietary fibre, starch, vitamins, and minerals (Showkat et al., 2021).

Sorghum (*Sorghum bicolor*) is a significant grain crop grown in arid and semi-arid countries. It is the sixth

most significant grain crop in the world. Small holder farmers produce the majority of Kenya's sorghum, a vital food and income crop. Between 800 and 2,000 meters above sea level, the majority of the nation's food production occurs in dry and semi-arid regions. The average sorghum yield in the nation is between 0.7 and 1 ton, whereas the average yield for a particular variety is greater than 2 tons (Kazungu et al., 2023).

Sorghum grain (*Sorghum bicolor* L. Moench) is a staple grain that is farmed all over the world, but mostly in semi-arid areas of Asia and Africa. Sorghum grain is becoming more and more popular for people to eat because it doesn't contain gluten and phenolics may be good for your health. Numerous bioactive phenolic compounds, including luteolin, luteolinic acid, gallic acid, apigenin, and 3-deoxyanthocyanidins (3-DXA), are found in sorghum grain. Numerous health advantages of these compounds, including their anti-inflammatory, anti-proliferative, anti-diabetic, and anti-atherogenic properties, have been established (Xu et al., 2021).

Sorghum is one of the most significant but underutilised staple crops in the world. The grain sorghum is a great source of minerals and phenolic compounds that are good for your health. Sorghum has a phenolic profile that is remarkably distinct, abundant, and varied in comparison to other popular cereal grains. Sorghum has phenolic acids, 3-deoxyanthocyanidins, and concentrated tannins in most of its phenolic components. Sorghum phenolic compounds have better antioxidant properties, according to in vitro research. This means they may improve gut health and lower the risk of chronic diseases. In addition to its many other uses, sorghum grain has recently found its way into a number of functional food and drink products. Natural multipurpose additives such as concentrated tannins, 3-deoxyanthocyanidins, and phenolic compounds can be isolated and utilised in a range of culinary products (Xiong et al., 2019).

Sorghum is most abundant in six western states in the United States, which contributes 90% of global production. Food production is the primary application of sorghum globally. Although sorghum is now used more for animal feed and biofuel in the US than for human consumption, this number is rapidly increasing due to growing interest in sorghum as a

gluten-free wheat substitute. Rich in soluble fibre and antioxidants, this grain is nutrient-dense and may lower the incidence of conditions like type 2 diabetes (McGinnis et al., 2020).

Numerous secondary metabolites found in sorghum bicolor (SB) have been shown to be useful in reducing many metabolic disorders, such as obesity, cancer, hyperglycemia, and type 2 diabetes. According to a recent study, taking sorghum bicolor orally at doses of 0.5% and 1% significantly decreased low density lipoprotein cholesterol, triglycerides, and glucose levels (Ki Kawang et al., 2020).

Sorghum known for its resilience and versatility, has a dynamic nutritional profile that includes high levels of protein, dietary fibre, and vital minerals. Sorghum contains essential oleic and linoleic acids, even though it contains just around 3% lipids. Among its nutrients include vitamin E and the B-complex vitamins (thiamin, riboflavin, and niacin). Iron, zinc, magnesium, and phosphorus are all considered essential minerals. Its high dietary fibre content (6%) facilitates digestion and may help prevent cardiovascular disease and weight loss. Sorghum is a critical dietary resource for growth, maintenance, and metabolic processes because it contains important proteins (9–13%) and necessary minerals such as phosphorus (16%), magnesium (0.1%), iron, and zinc (0.002%). The antioxidant properties of certain phytochemicals including polyphenols, tannins, sterols, and phytic acid have been connected to a decreased risk of chronic illnesses and an expanded function beyond simple nutritional support. Because of their strong antioxidant capabilities, polyphenols aid in lowering oxidative stress in the body and may have anticancer effects. Pathogens are deterred by tannins (up to 6%). Sterols are recognised to have the ability to cut cholesterol levels, whereas phytotic acids (1–3%) are linked to reducing risks of a number of chronic diseases (Tanwar et al., 2023)

Different cultures have long utilised sorghum grain for a variety of purposes. In place of maize, sorghum grain is frequently ground and used to prepare traditional foods like ugali. To make wholesome meals, it is frequently combined with other grains including green gram, cowpeas, and amaranthus. Nonalcoholic drinks made from sorghum millet are well-liked worldwide. Sorghum is not yet a typical part of everyday diets, despite their nutritional

advantages. One way to make sorghum more usable and use it in mainstream food manufacturing is to mix refined sorghum flours with commercial wheat flour. This method combines the health benefits of sorghum with the well-known properties and flexibility of wheat flour. The purpose of blending sorghum flour with wheat flour is to find the right amount of sorghum flour to add without ruining the quality of the baked items. The study says that you can use sorghum flour instead of 10% to 20% of wheat flour. So, you can use a lot of sorghum flour instead of wheat flour. This adjustment can make baked goods healthier without changing their taste or texture (Tanwar et al., 2023). Sorghum-based baked goods are a tasty and healthier substitute for conventional baked goods prepared with wheat. These goods meet the market's increasing need for nutrient-dense and gluten-free solutions. Adding sorghum to baked goods boosts their nutritious content and expands the selection of gluten-free goods on the market. It can be used to make a variety of baked products, such as loaf, breakfast pancakes, oatmeal, and fermented beverages. Because of their affordable prices, vast range of flavours, and enticing texture characteristics, bakery goods have become very popular. They are easily marketable to consumers because of their appealing packaging and long shelf life. Because these products are so easy to carry and store, the baking business has experienced exponential rise in production. Numerous research have examined the glucosidase and amylase, and sorghum extracts or products have demonstrated efficacy in the treatment of diabetes. Based on these studies, sorghum extracts considerably suppress these enzymes. Sorghum extracts and other products have decreased glucose absorption and hyperglycemia risk by changing the body's sugar metabolism. Sorghum helps keep blood sugar levels stable, which is an important part of treating diabetes well. Compared to a drink that didn't have sorghum, drinking a sorghum drink with proanthocyanidins and deoxyanthocyanins lowered high blood sugar levels significantly. Consequently, whole-grain sorghum's functional starch, proanthocyanidins, and deoxyanthocyanins have been recognised as possible functional dietary components that enhance human glucose metabolism (Tanwar et al., 2023).

1.1 Research Objectives:

- To develop anti-diabetic and nutrient rich lotus seed powder cupcakes.

RESEARCH METHODOLOGY

Area of Research

The current study was conducted at Riphah International University Faisalabad. In present study the cupcakes for diabetes mellitus were made by using varying amounts of Lotus seeds, Sorghum flour, Almond milk and Stevia. Cupcakes were examined for proximate, antioxidant, mineral and sensory evaluation. The steps and techniques that were used are listed below.

Procurement of Raw Materials:

Faisalabad's local market was the source of raw materials i.e Lotus seeds, Sorghum flour, Almond milk and Stevia.

- To analyse the nutritional composition of the cupcakes.
- To check the overall acceptability of product through sensory evaluation .

Cupcakes preparation

The cupcakes were formulated according to the respective protocol mentioned in (Caims et al., 2023). Different concentrations of lotus seed powder were used for the formation of cupcakes. In accordance with the formulation of the different treatments as shown in Table 1, cupcakes were made using the following concentrations: Sorghum (100%, 50%, 25% and 25%) and LS (25%, 50%, and 25%). Sorghum flour, stevia, almond milk, vegetable oil, and eggs were the main components. All the Ingredients were measured and thoroughly mixed in a mixing bowl for three to five minutes. After that, the ingredients were thoroughly combined in the mixture for five minutes before the eggs were added. The cupcakes were then baked in silicon cupcake moulds in a baking oven for 15 minutes at 160°C. The baked cupcakes were allowed to cool at room temperature of 28°C and then sealed in polythene bags.

Treatment Plan

Table 3.1: Treatment Plan

Treatments	Sorghum flour %	Lotus Seed powder%
T _{0a}	100	-
T ₁	50	25
T ₂	25	50
T ₃	25	75

T_{0a}= 100% sorghum flour cupcakes

T₁=50% sorghum flour , 25% lotus seed powder cupcakes

T₂= 25% sorghum flour , 50% lotus seed powder cupcakes

T₃=25% sorghum flour , 75% lotus seed powder cupcakes

Product development

Cupcakes were made using various lotus seed and sorghum flour treatments by modifying the recipe as directed by (Caims et al., 2023).

Analysis of Lotus Seed and Sorghum cupcakes

Prepared cupcakes will be subjected to the following analysis for quality evaluation.

Proximate analysis

The cupcakes' and the control's approximate composition (ash, moisture, crude protein, crude fibre, and crude fat) will be evaluated using the AACC's standard procedures (2016).

Moisture

The AACC (2016) methodology was employed to determine the total moisture content of the sample. The moisture content examination was conducted as follows: the sample was accurately weighed and positioned in the aluminium moisture dish, with a mass of approximately 10 grammes. After placing the wet plates inside, close the door of the convection oven. After turning on the heater, the temperature was raised to between 131 and 135°C. For eighteen hours, the samples were in the oven. The sample was then placed inside a desiccator and allowed to come

to room temperature. The sample was carefully weighed after cooling, and the findings were recorded. To ascertain the moisture content, the sample's weight was recorded both before and after it was heated in a hot air oven. The sample's overall moisture content was shown by the weights' decline. The following formula was used to determine a sample's percentage moisture content:

$$\text{Moisture (\%)} = \frac{\text{Weight of the original sample (g)} - \text{Weight of dried sample (g)}}{\text{Weight of the original sample (g)}} \times 100$$

Ash

The total ash content of the sample was determined using AACC (2016). Ten grammes of the material were placed in a dry, clean crucible to continue the procedure. After burning it all up in the muffle furnace, we measured the total amount of ash at high temperatures. The samples were heated to 585 °C for

24 hours in a muffle furnace. After that, the leftover mixture was left to cool to room temperature. By dividing the original weight of the sample by 100, we were able to determine the total ash content. We used the following formula to determine the amount of ash in a sample:

$$\text{Ash (\%)} = \frac{\text{Weight of ash sample (g)}}{\text{Weight of the sample (g)}} \times 100$$

Crude fat

To determine the amount of fat in the sample, the AACC (2016) method employed the Soxhlet apparatus and n-hexane as the organic solvent. Hexane was used as the solvent to extract the fat from two grammes of material. To remove fat from the

sample, seven continuous syphons were employed. The solvent was then removed using a rotary evaporator. To determine the amount of crude fat present, we applied the following formula:

$$\text{Crude Fat (\%)} = \frac{\text{Wt. of fat} \times 100}{\text{Wt. of sample}}$$

Crude fiber

We used the methodology in AACC (2016) to figure out how much crude fibre was in the sample. A fat and moisture free 1g sample was taken into porous fibre crucible. We added 150 ml of H₂SO₄ and let it boil for 30 minutes. Then, after 3 to 4 washings with distilled water, the acid was allowed to run out to make sure that all of it was gone. The mixture was

baked in the oven for an hour and a half at 150 °C, then cooled down and weighed (W₁). Finally, the sample was put in a muffle furnace for three hours at 65 °C and then weighed after it had cooled down in a desiccator.

We found the proportion of crude fibre by doing the following:

$$\text{Crude fiber (\%)} = \frac{\text{Weight loss during ignition} \times 100}{\text{Wt. of sample}}$$

Crude protein

Using Kjeldahl's equipment, the protein content of a sample was determined in accordance with the AACC (2016) technique. A Kjeldahl flask was filled with two

grammes of the dried material, which had been precisely measured. In addition to digesting tablets, 30 millilitres of powerful sulphuric acid were used to treat it. For the first step, the entire mixture was

heated to 400°C, and for the second phase, it was heated to 600°C. The colour of the combination was altered to give it a greenish appearance. The digested samples were then made less concentrated by adding around 250 mL of distilled water. We made 4% boric

acid from the preceding combination by distilling 10 mL of the diluted sample with 40% NaOH. 0.1N H₂SO₄ was utilised in the titration, and the end point was light pink in hue.

$$N (\%) = \frac{\text{Vol. of H}_2\text{SO}_4 \text{ used} \times \text{Vol. of dilution} \times 0.0014 \times 100}{\text{Wt. of sample} \times \text{Vol. of sample taken}}$$

The protein content was projected by multiplying the nitrogen content with factor 6.25

Nitrogen free extract

The nitrogen-free extract was determined using the approach outlined by AACC (2016). Following the evaluation of all parameters in the proximate analysis, the nitrogen content was ascertained by calculating the difference from all values. The following equation was employed to compute NFE.

$$\text{NFE}\% = 100 - (\% \text{ moisture} + \% \text{ crude protein} + \% \text{ crude fat} + \% \text{ crude fiber} + \% \text{ crude ash})$$

Total Sugar Content (Reducing and Non-Reducing)

Preparation of reagents:

Fehling's solution;

The preparation involves combining equal amounts of reagent 2 (copper sulphate solution) and reagent 3 (alkaline tartrate solution) immediately prior to use.

Alkaline tartrate solution;

Dissolve 346g of Rochelle salt (potassium sodium tartrate, KNaC₄H₄O₆·4H₂O) and 120g of NaOH in water to achieve a final volume of 1000 mL.

Methylene blue indicator;

Dissolve 1g methylene blue in 100 mL water.

Neutral lead acetate, 45% solution;

Dissolve 112.5g neutral lead acetate, Pb(C₂H₃O₂)₂·3H₂O, in water and dilute to 250 mL.

Potassium osalate, 22 % solution;

Solubilise 55g of potassium oxalate in water and dilute to a final volume of 250mL. Calculate the precise

Citric acid

Standard method of Titration:

Two 250 mL Erlenmeyer flasks were pipetted with 10 mL of mixed Fehling's solution. A 50 mL burette was filled with the titrated solution. Make use of almost the entire volume required to reduce Fehling's solution, making sure that a minimum of 0.5 mL and a maximum of 10 mL are needed to complete the titration. The contents of the flask were mixed

Copper sulphate solution;

69.2 grammes of CuSO₄·5H₂O were dissolved in water. Dilute to 1000 mL and, if required, filter using No. 4 Whatman paper.

volume of potassium oxalate solution required to precipitate lead from 2 mL of lead acetate solution.

Standard sugar solution;

In a 250 mL beaker, 9.5 g of pure sugar solution was combined with 100 mL of water and 5 mL of concentrated HCl. diluted with water at 20°C to 1000 mL. Use the following method to neutralise the sugar solution for titration: Using phenolphthalein as an indicator, pipette 50 mL of the standard inversion solution into a 200 mL volumetric flask, then add around 100 mL of water. 20% NaOH was then added until the solution turned pink. 1N HCl should be added to the solution drop by drop until the pink hue is gone. Water was used to make up the volume. As stated in the "Standard Method of Titration," titrate against 10 mL of Fehling's solution.

together, brought to a boil, and then kept there for two minutes. After that, 2 mL of methylene blue solution was added, being careful not to touch the flask's sides. By adding two to three drops of sugar solution at 5- to 10-second intervals until the indicator was completely decolorised, the titration was completed in less than a minute. At the endpoint, the boiling liquid turns brick-red, indicating precipitated cuprous oxide.

Procedure for sample preparation:

A 400 mL beaker was filled with 25 g of the filtered material after it had been weighed. Water (one hundred millilitres) was added. After applying 1N NaOH to get the pH down to 7-8, the mixture was moved to a 250 mL volumetric flask. Two millilitres of lead acetate solution and 100 to 200 millilitres of water were added, stirred, and left to stand for ten

minutes. After adding the necessary amount of potassium oxalate and diluting it with water to bring it up to volume, No. 5 Whatman filter paper was used for filtering. To determine whether lead was present, the filtrate was examined using a little amount of potassium oxalate. The filtrate was designated as (a).

Reducing sugar:

For most juices, reducing sugars are low and therefore filtrate "a" can be used directly in the "Standard Method of Titration".

$$\text{reducing sugar (\%)} = \frac{\text{factor}}{\text{titer}} \times \text{dilution} \times \frac{100}{1000}$$

Non-Reducing sugar:

The following equation was used to find the non-reducing sugars %non-reducing sugars= (%Total sugar- %Reducing sugar) ×0.9

Total sugar:

We used the AACC (2016) approach. A 250 mL flask was pipetted with 50 mL of the filtrate (a). After adding 50 mL of water and 5 g of citric acid solution, the mixture was gently heated for 10 minutes to convert sucrose to starch before being allowed to cool. Using phenolphthalein as an indicator, the solution was neutralised after being moved to a 250 mL volumetric flask or 250 mL beaker. The solution

turned pink once 20% NaOH was added. Drop by drop, 1N HCl was added until the pink hue vanished. To keep the finish, point from being obscured by the red hue, the pH was brought down to 8.1. It was titrated using the "Standard Method of Titration" and the volume was prepared in a 250 mL flask. Use the formula to determine the percentage of total sugar.

$$\text{total sugar (\%)} = \frac{\text{factor}}{\text{titer}} \times \text{dilution} \times \frac{100}{1000}$$

Antioxidant Potential of Lotus Seed and Sorghun Cupcakes

Assay of total antioxidant activity

The antioxidant profile of sorghun flour and lotus seed cupcakes from 0 to 28 days was analyzed by the procedure of Chiremba, C. (2008).

Total phenolic content

The following formula can be used to determine the total amount of phenolic compounds in plant extracts in gallic acid equivalents (GAE) using the Folin-Ciocalteu method: [(Absorbance of sample - Absorbance of blank) / slope of the calibration curve] = Total Phenolic Content (in mg GAE/g) × Dilution factor x (1 / Sample weight) Here's a detailed tutorial on figuring out the total phenolic content: Using various gallic acid concentrations (e.g., 0.01, 0.02,

0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, and 0.10 mg/mL), create a calibration curve. Combine 5 mL of diluted Folin-Ciocalteu reagent, 4 mL of sodium carbonate (20%), and 1 mL aliquots of each gallic acid concentration. Plot the calibration curve by calculating absorbance as a function of concentration after measuring each solution's absorbance at 765 nm after an hour. Calculate the calibration curve's slope. With the same reagents as previously mentioned, make a blank solution, omitting the sample extract. At 765 nm, measure the blank solution's absorbance. This number should be noted as "Absorbance of blank." Using the same reagents as in step 1, combine 1 mL of the sample extract (0.001 g/mL). Measure the blue colour complex's absorbance at 765 nm after an hour. This value should be noted as "Absorbance of sample." Find the reciprocal of the volume ratio of the

sample extract used to make the final solution, or the dilution factor. For instance, the dilution factor would be 10 if you utilised 1 mL of the sample extract and created a final solution with a volume of 10 mL. Calculate the weight of the sample that was used to make the extract, then record the result as "Weight of sample." Enter the slope of the calibration curve and the values derived from steps 2, 3, 4, and 5 into the

following formula: $[(\text{Absorbance of sample} - \text{Absorbance of blank}) / \text{slope of the calibration curve}] \times \text{Dilution factor} \times (1 / \text{Weight of sample}) = \text{Total Phenolic Content (in mg GAE/g)}$ Use this formula to get the total phenolic content. Milligrammes of gallic acid equivalents per gramme of sample (mg GAE/g) is the standard unit of measurement for total phenolic content.

$$T = C \times V / M$$

Where,

T = total contents of phenolic compound in mg GAE/g plant extract.

C = the concentration of gallic acid calculated from calibration curve in mg/mL.

V = the volume of extract in mL.

M = the weight of plants extracts in grams.

DPPH Scavenging Activity

The following formula can be used to determine the DPPH radical samples' % inhibition: $[(\text{Absorbance of control} - \text{Absorbance of sample}) / \text{Absorbance of control}] \times 100$ is the percentage inhibition. Here's a detailed tutorial on figuring out the percentage inhibition: Using a spectrophotometer, determine the absorbance of the control sample (which does not include plant extract) at 517 nm. This value should be noted as "Absorbance of control." Using a spectrophotometer, determine the sample's absorbance at 517 nm that contains plant extract.

This value should be noted as "Absorbance of sample." Utilise the following formula with the values acquired in stages 1 and 2: $[(\text{Absorbance of control} - \text{Absorbance of sample}) / \text{Absorbance of control}] \times 100$ is the percentage inhibition. Determine the % inhibition by changing the variables. It is important to note that the DPPH test is used in the aforementioned procedure to assess the sample's antioxidant capacity. The sample's ability to scavenge DPPH radicals is indicated by the percentage inhibition; a larger percentage denotes stronger antioxidant activity.

$$\text{DPPH Inhibition (\%)} = \frac{\text{Blank absorbance (A}_0\text{)} - \text{Sample absorbance (A}_1\text{)}}{\text{Blank absorbance (A}_0\text{)}} \times 100$$

Where,

A₁ = Absorbance of sample.

A₀ = Absorbance of blank.

Mineral Analysis of Sorghum floor and Lotus seed Cupcakes

Following an Atomic Absorption Spectrophotometer, cookies were evaluated for calcium and magnesium analysis following the AACC protocol (2016). (Rao et al., 2018).

Procedure for Sample Preparation

The wet digestion process involved dissolving 0.5g of the material in a solution of 3 mL perchloric acid and 7 mL HNO₃ in a digestion flask. The flask was then heated on a hot plate to temperatures ranging from 50°C to 250°C, releasing white vapours, a sign that digestion is finished. The mixture was chilled after that.

The liquid was allowed to cool before being diluted with 100 millilitres of distilled water.

Determination of Minerals by Atomic Absorption Spectrophotometer

Atomic absorption spectrophotometry was used to evaluate the minerals in cookies following the methods outlined in AACC (2016). First, 0.5 g of each sample was combined with 3 ml of perchloric acid and 7 ml of nitric acid to undergo wet digestion. The digestion process took place on a heated plate that was gradually heated to 300°C over the course

of 40 to 50 minutes. The conclusion of the digestion process was indicated by the appearance of white fumes. Ten millilitres of distilled water were then added. After processing, the samples were put in a beaker to be examined for minerals. To obtain

standardised values, the atomic absorption spectrometer used standard solutions. Each mineral's concentration was then measured in parts per million (ppm), which were then translated to milligrammes by dividing by 1000 and accounting for dilution effects.

$$MW = \frac{\text{Absorbancy (ppm)} \times \text{dry wt.} \times \text{Dilution}}{\text{Weight of sample}} \times 100$$

Physiochemical Analysis of Lotus Seed and Sorghum Cupcakes:

Weight of Cupcakes:

The mass of the cupcake sample was ascertained using a weighing balance immediately following cooling (Marie et al., 2024).

Dimensions of Cupcakes:

The dimensions of the cupcakes were ascertained in accordance with the AACC methodology. The dimensions included weight, diameter and thickness of cupcakes were measured using a ruler. The

cupcakes were rotated at 90-degree angles for duplicate measurements. The experiment was conducted twice, and the measurements were documented in millimetres (Johnson, 2012)

Energy Calculation of Cupcakes:

The calorie content of the cupcakes was determined using the following formula:

$$\text{Energy (Kcal/g)} = [(\text{protein} \times 4) + (\text{fat} \times 9) + (\text{carbohydrate} \times 4)]$$

(Shahzad et al., 2021)

Sensory evaluation

The cooked cupcakes with various formulations were subjected to sensory evaluation using the Hedonic Scale at various storage intervals, following the procedures described by Farooq et al. (2024). 30 inexperienced panellists chosen from the campus community conducted a sensory assessment of the cupcakes. The sensory qualities (flavour, aroma, colour, consistency, and general preference) were evaluated. The products were rated on a nine-point hedonic scale, where 9 meant "like extremely" and 1 meant "dislike extremely."

Statistical analysis

Upon conclusion of the research, the acquired data will undergo Statistical Analysis to assess the level of significance (Montgomery, 2008).

RESULTS AND DISCUSSION

The present study titled "Development of Lotus Seed and Sorghum Cupcakes for Diabetes Mellitus" was undertaken with the primary aim of formulating nutrient-rich and anti-diabetic cupcakes using lotus seed powder in combination with sorghum flour. The specific objectives included evaluating the nutritional composition of the developed products, enhancing their functional properties through the incorporation

of health-promoting ingredients, and assessing their overall acceptability through sensory evaluation. To comprehensively achieve these goals, a series of parameters were analyzed including proximate composition (moisture, ash, protein, fat, fiber sugar, and nitrogen-free extract), phytochemical properties (total phenolic content, total flavonoid content), antioxidative potential, sensory attributes (taste and texture) and physiochemical analysis (weight, dimension, energy calculation, and storage). The results presented below illustrate the impact of these formulations (T0 to T3) on the nutritional and functional quality of the cupcakes, and provide insights into their potential suitability for individuals managing diabetes mellitus.

Proximate analysis

Moisture content

The moisture content of cupcakes across different treatments (T0 to T3) is illustrated in Tabel 4.1 and Figure 4.1. The moisture content increased significantly from the control (T0: 19.24 ± 3.31%) to T2 (36.50 ± 1.19%), with the highest value observed in T2. Conversely, T3 exhibited the lowest moisture content (8.76 ± 0.99%). The results indicate that the inclusion of specific ingredients in T1 and T2 significantly (P < 0.05) enhanced moisture retention,

while the formulation of T3 led to a significantly drier product ($P < 0.05$) (Table 4.2). The variation across treatments was statistically significant as reflected in the standard deviations, particularly between T3 and T2 in comparison to T0. The incorporation of lotus seed flour enhances water retention because this ingredient contains protein and fiber components which exhibit strong water-absorbing characteristics. The components within the batter retain more water

because of their properties leading to enhanced moisture content in baked products. Bangar et al. (2022) and Dhull et al. (2022) proved that bakery products gain advantages from lotus seed flour because of its excellent moisture retention ability. During baking T3 experienced lowered moisture levels because its combination of high fibers with unrefined structure restricted the absorption of free water.

Table 4.1: Mean $\pm$ Standard Deviation of Total Moisture Content in Cupcakes

Treatment	Mean $\pm$ SD
T0	19.24 $\pm$ 3.31
T1	31.95 $\pm$ 5.09
T2	36.50 $\pm$ 1.19
T3	8.76 $\pm$ 0.99

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

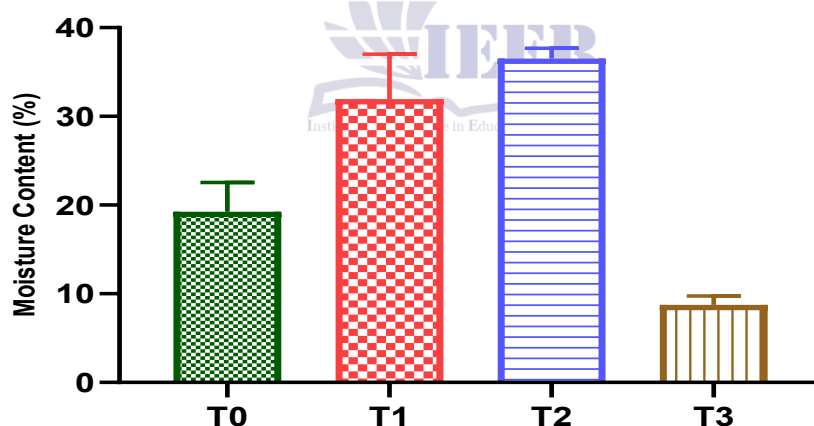


Figure 4.1: Moisture content of cupcakes of different compositions

Table 4.2: ANOVA Summary for Moisture Content

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
Treatments	2154.20	3	718.07	73.89**
Error	95.63	20	4.78	
Total	2249.83	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Ash content

The ash content varied among treatments, with T3 ($4.64 \pm 0.58\%$) and T2 ($4.08 \pm 0.49\%$) demonstrating significantly higher mineral content compared to the control (T0: $2.84 \pm 0.66\%$) and T1 ($1.78 \pm 0.71\%$) as shown in Table 4.3 and Figure 4.2. The increase in ash content in T2 and T3 may be attributed to the mineral-rich ingredients used in these formulations. Statistical analysis shows a clear differentiation ($P <$

0.05) between treatments, confirming the impact of composition on mineral content (Table 4.4). The mineral content in baked products rises substantially since lotus seeds contain abundant mineral components. Research by Dinkar et al. (2020) and Shahzad et al. (2021) proves that adding lotus seed flour increases ash content and results in improved nutritional value through enhanced micronutrient content.

Table 4.3: Mean $\pm$ Standard Deviation of Ash Content in Cupcakes with Significance

Treatment	Mean $\pm$ SD
T0	2.84 ± 0.66
T1	1.78 ± 0.71
T2	4.08 ± 0.49
T3	4.64 ± 0.58

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

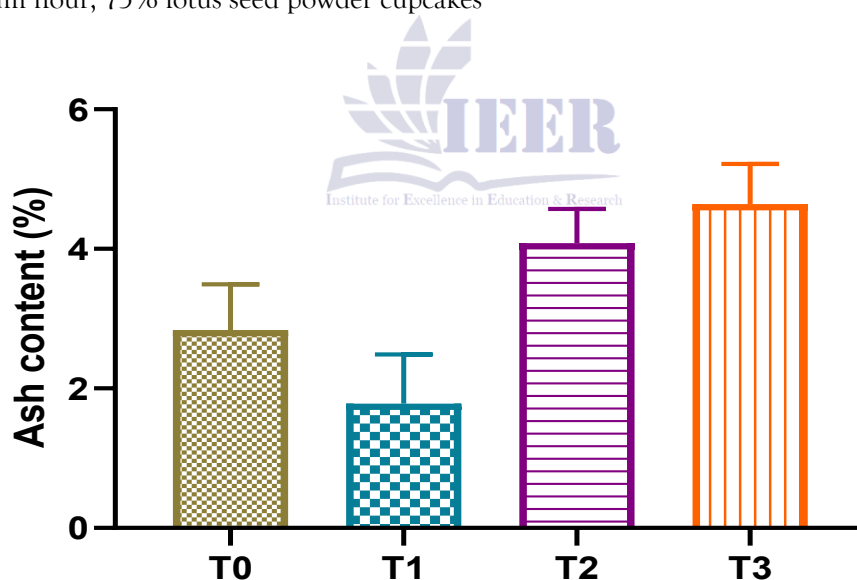


Figure 4.2: Ash content of cupcakes of different compositions

Table 4.4: ANOVA Summary for Ash Content of Cupcakes

Source of Variation	SS	df	MS	F
Treatments	20.75	3	6.92	21.35**
Errors	6.49	20	0.3245	
Total	27.24	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Protein content

The protein content of different cupcake treatments is presented in Table 4.5. A statistically significant increase in protein was observed from T0 ($5.77 \pm 0.55\%$) to T3 ($12.28 \pm 0.97\%$). T1 and T2 showed intermediate values ($7.14 \pm 0.63\%$ and $9.76 \pm 0.88\%$, respectively). These findings suggest that the substituted ingredients in the modified treatments contributed to a substantial improvement in protein content, with a noticeable progressive

increase from T0 to T3 ($P < 0.05$) (Table 4.6). The protein concentration in lotus seed flour elevates the protein levels of the final product since it replaces conventional flour. The research conducted by Dada et al. (2023) proves that lotus seed acts as an advantageous plant protein ingredient that boosts protein properties in food products. The protein levels in the products grew consistently from T0 to T3 because of continuous lotus seed flour incorporation

Table 4.5: Protein Content of Cupcakes (Mean $\pm$ SD)

Treatment	Mean $\pm$ SD
T0	5.77 ± 0.5470
T1	7.14 ± 0.6319
T2	9.76 ± 0.8840
T3	12.28 ± 0.9728

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

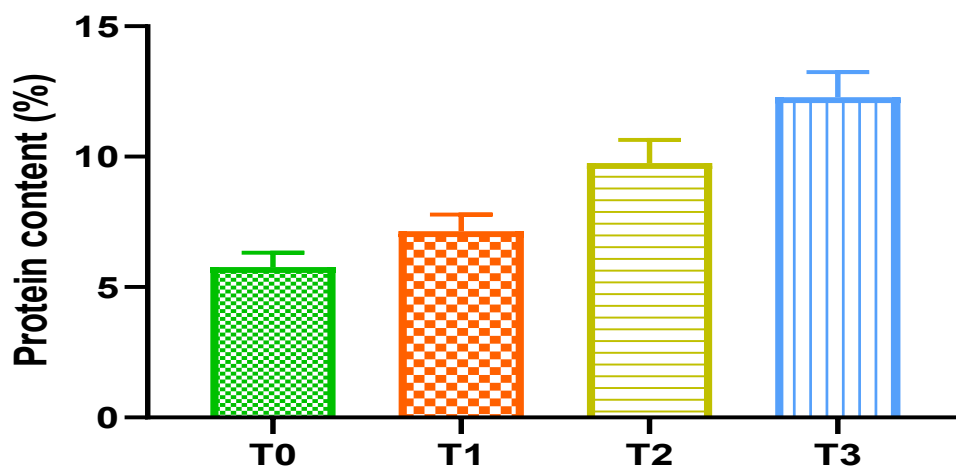


Figure 4.3: Protein content of cupcakes of different compositions

Table 4.6: ANOVA Summary for Protein Content of Cupcakes

Source of Variation	SS (Sum of Squares)	df	MS (Mean Square)	F
Treatments	143.48	3	47.83	80.29**
Errors	11.91	20	0.60	
Total	155.39	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Fat content

The fat content decreased across treatments as depicted in Table 4.7. The control (T₀) recorded the highest fat content ($5.51 \pm 0.90\%$), whereas T₃ exhibited the lowest ($2.00 \pm 0.59\%$). T₁ and T₂ contained intermediate fat levels of $4.47 \pm 0.89\%$ and $2.22 \pm 0.76\%$, respectively. The decreasing trend was statistically significant ($P < 0.05$) and reflects the efficacy of fat-reducing ingredients in T₂ and T₃ (Table 4.8). This decline may be due to the

replacement of high-fat ingredients such as butter or refined flour with lotus seed flour, which contains lower fat levels. Furthermore, formulations with lotus seed likely required less added fat due to improved water-binding and textural properties. Literature also supports this observation; sorghum flour, likely used in T₀ and T₁, generally has higher fat content, while lotus seed flour is comparatively lower in fat (Adeyeye, 2016; Aljobair, 2022).

Table 4.7: Fat Content of Cupcakes (Mean $\pm$ SD)

Treatment	Mean $\pm$ SD
T ₀	5.51 ± 0.9015
T ₁	4.47 ± 0.8900
T ₂	2.22 ± 0.7608
T ₃	2.01 ± 0.5894

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

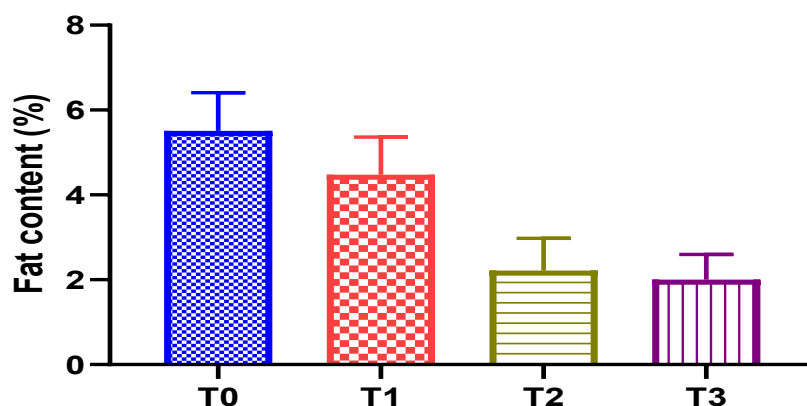


Figure 4.4: Fat content of cupcakes of different compositions

Table 4.8: ANOVA Summary for Fat Content

Source of Variation	SS	df	MS	F
Treatments	49.31	3	16.44	44.11**
Errors	7.45	20	0.3725	
Total	56.76	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Fiber content

The fiber content of the cupcakes significantly increased across treatments, with T3 showing the highest fiber content ($6.07 \pm 0.74\%$) and T0 the lowest ($2.35 \pm 0.32\%$). T1 and T2 exhibited intermediate fiber values of $3.98 \pm 0.60\%$ and $4.84 \pm 0.66\%$, respectively (Table 4.9). These results indicate that the incorporation of lotus seed flour, which is rich in dietary fiber, led to higher fiber content in the cupcakes, especially in T2 and T3 formulations ($P < 0.05$) (Table 4.10). The increase in fiber content is particularly beneficial for diabetic patients as dietary fiber plays a key role in regulating blood sugar levels by slowing down glucose

absorption. The elevated fiber content in T2 and T3 is particularly beneficial for diabetic patients, as dietary fiber slows down the absorption of glucose, helping in better glycemic control. This finding is consistent with previous studies where lotus seed flour has been shown to be rich in dietary fiber, providing potential benefits for metabolic health and digestive function (Bangar et al., 2022). The increased fiber content not only contributes to improved blood sugar regulation but also adds bulk to the diet, which can aid in weight management, making these cupcakes a healthier alternative for diabetic individuals (Zhang et al., 2024).

Table 4.9: Fiber Content of Cupcakes (Mean $\pm$ SD)

Treatment	Mean $\pm$ SD
T0	2.35 ± 0.320
T1	3.98 ± 0.600
T2	4.84 ± 0.657
T3	6.07 ± 0.741

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

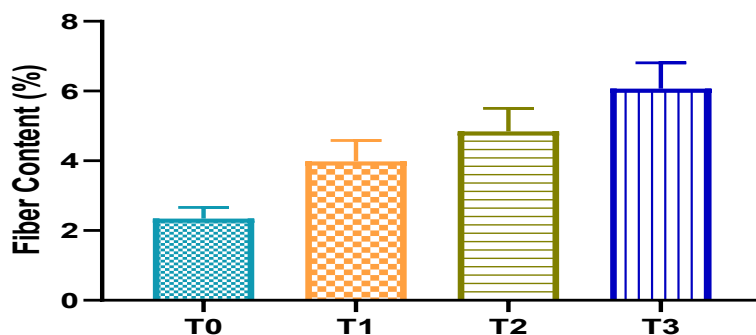


Figure 4.5: Fiber content of cupcakes of different compositions

Table 4.10: ANOVA Summary for Fiber Content

Source of Variation	SS	df	MS	F
Treatments	49.01	3	16.34	44.39**
Errors	7.36	20	0.368	
Total	56.37	23		

NS = Not Significant ($p > 0.05$)

*= Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Nitrogen free extract (NFE)

NFE, representing available carbohydrates, decreased significantly from T₀ ($61.02 \pm 5.05\%$) to T₃ ($16.61 \pm 2.86\%$) (Table 4.10). Intermediate values were recorded in T₁ ($50.02 \pm 2.32\%$) and T₂ ($28.77 \pm 3.77\%$). This trend suggests a decrease in digestible carbohydrates, likely due to increased fiber or protein content in the later treatments. The standard deviations confirm statistically meaningful

differences ($P < 0.05$) among treatments (Table 4.9).

The dietary transition indicates the replacement of high-carbohydrate foods by ingredients rich in protein alongside dietary fiber. The addition of lotus seed flour in the formulation decreases the content of rapidly digestible carbohydrates which matches the criteria for health-oriented product development. The research by Ajala et al. (2025) confirmed that baked products enriched with lotus seed demonstrated reduced total available carbohydrates.

Table 4.11: Nitrogen Free Extract (NFE) of Cupcakes (Mean $\pm$ SD)

Treatment	Mean $\pm$ SD
T ₀	61.02 $\pm$ 5.049
T ₁	50.02 $\pm$ 2.321
T ₂	28.77 $\pm$ 3.768
T ₃	16.62 $\pm$ 2.864

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

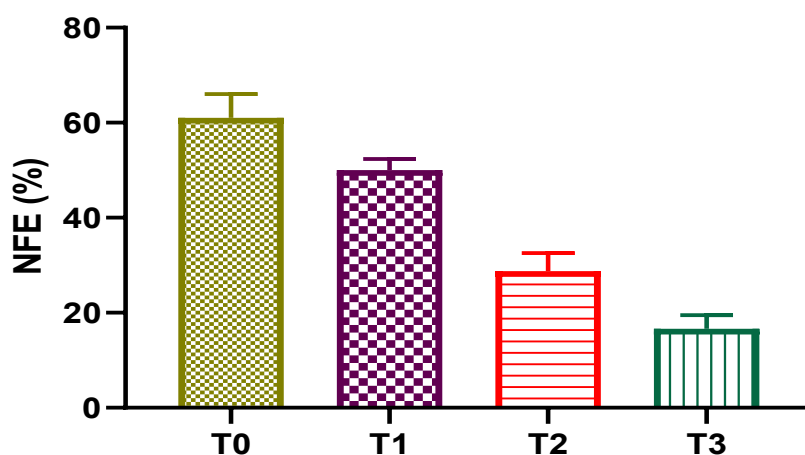


Figure 4.6: Nitrogen free extract of cupcakes of different compositions

Table 4.12: ANOVA Summary for Nitrogen Free Extract (NFE)

Source of Variation	SS	df	MS	F
Treatments	5557.23	3	1852.41	172.51**
Errors	214.74	20	10.74	
Total	5771.97	23		

NS = Not Significant ($p > 0.05$)* = Significant ($p < 0.05$)** = Highly Significant ($p < 0.01$)

Mineral analysis (Calcium and Magnesium) of Cupcakes

The mineral composition of cupcakes made with different amounts of sorghum flour and lotus seed powder. They focus on the calcium and magnesium levels. As the amount of lotus seed powder increases, both calcium and magnesium levels go up, as shown in Table 4.34. The treatment with 100% sorghum flour (T0) had the least minerals, with 45.30 ± 1.10 mg of calcium and 30.25 ± 0.90 mg of magnesium per 100 g. On the other hand, T3 (25% sorghum, 75% lotus seed powder) had the greatest levels, with calcium at 63.10 ± 1.55 mg/100g and magnesium at 41.35 ± 1.20 mg/100g. These results show that adding

lotus seed powder to the cupcakes greatly improves their mineral content. Table 4.35's statistical analysis backs up this finding. One-way ANOVA showed that there were very big differences ($p < 0.01$) between the treatments for both calcium and magnesium levels. The F-values for calcium (42.85) and magnesium (38.67) were quite high, which shows that the variations in mineral content were caused by the different ratios of lotus seed flour. Overall, the statistics show that adding lotus seed powder to cupcake recipes greatly increases the amount of important minerals, which might make the finished product more nutritious.

Table 4.13: Mineral Analysis (Calcium and Magnesium) of Cupcakes (Mean $\pm$ SE)

Treatment	Calcium (mg/100g) Mean $\pm$ SE	Magnesium (mg/100g) Mean $\pm$ SE
T0	45.30 ± 1.10	30.25 ± 0.90
T1	52.75 ± 1.25	34.50 ± 1.05
T2	59.80 ± 1.40	38.20 ± 1.10
T3	63.10 ± 1.55	41.35 ± 1.20

Table 4.14: ANOVA for Mineral Content in Cupcakes

Mineral	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
Calcium	Between Treatments	540.5	3	180.17	42.85**
	Within Treatments	25.2	8	3.15	
	Total	565.7	11		
Magnesium	Between Treatments	402.3	3	134.10	38.67**
	Within Treatments	27.7	8	3.46	
	Total	430.0	11		

Mineral	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
	Total	430.0	11		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Phytochemical analysis

Total phenolic content (TPC)

TPC increased significantly with the inclusion of functional ingredients as presented in Table 4.15. The control sample (T0) had the lowest phenolic content (20.89 ± 3.08 mg GAE/g), whereas T3 showed the highest (50.40 ± 4.30 mg GAE/g). T1 and T2 recorded mean values of 28.11 ± 2.23 mg and 40.47 ± 1.38 mg, respectively. These increases were

statistically significant ($P < 0.05$) and suggest improved antioxidant capacity (Table 4.16). The elevated phenolic compound content in lotus seed indicated that enriched treatments achieved better TPC values because lotus seeds are enriched with antioxidants. The research conducted by Bangar et al. (2022); Seferli et al. (2024) and Zhu et al. (2022) demonstrates that lotus seed possesses antioxidant properties in food applications.

Table 4.15: Total Phenolic Content (TPC) of Cupcakes (Mean $\pm$ SD)

Treatment	Mean (mg GAE/g) $\pm$ SD
T0	20.89 ± 3.081
T1	28.11 ± 2.235
T2	40.47 ± 1.383
T3	50.40 ± 4.297

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

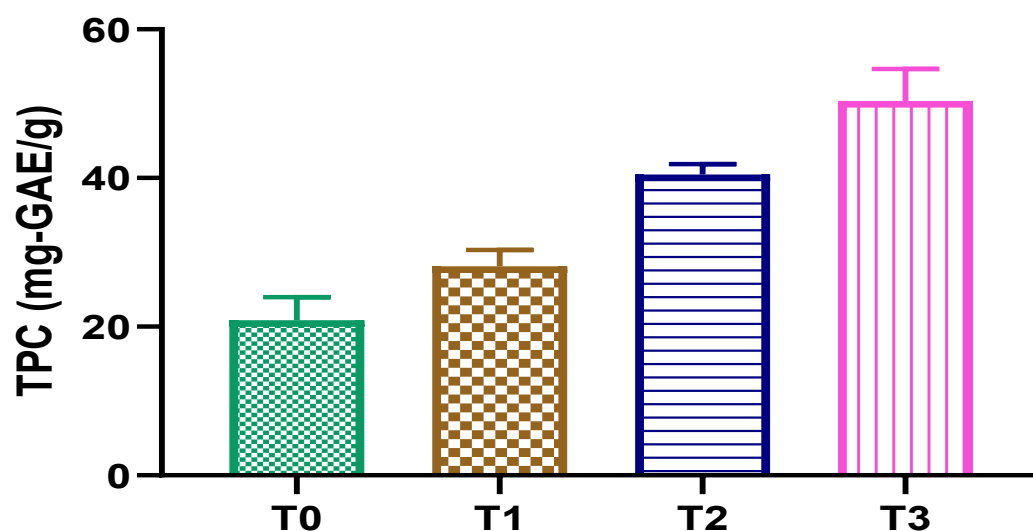


Figure 4.7: Total phenolic content of cupcakes of different compositions

Table 4.16: ANOVA Summary for Total Phenolic Content

Source of Variation	SS	df	MS	F
Treatments	2970.60	3	990.20	140.67**
Errors	140.78	20	7.04	
Total	3111.38	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Antioxidative potential

The antioxidative potential increased significantly across treatments as shown in Table 4.19. T3 demonstrated the highest activity ($59.10 \pm 5.29\%$), while the control (T0) showed the lowest ($23.82 \pm 2.96\%$). The enhanced antioxidative

potential ($P < 0.05$) in T2 and T3 aligns with their elevated TPC and TFC levels, reinforcing the functional benefits of the modified formulations (Table 4.20). The research demonstrates that lotus seed flour functions as an appropriate bakery material with antioxidant properties for product development (Li et al., 2019; Zhu et al., 2022)

Table 4.17: Antioxidative Potential of Cupcakes (Mean $\pm$ SD)

Treatment	Mean $\pm$ SD
T0	23.82 $\pm$ 2.96
T1	30.99 $\pm$ 4.20
T2	41.69 $\pm$ 3.17
T3	59.10 $\pm$ 5.29

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

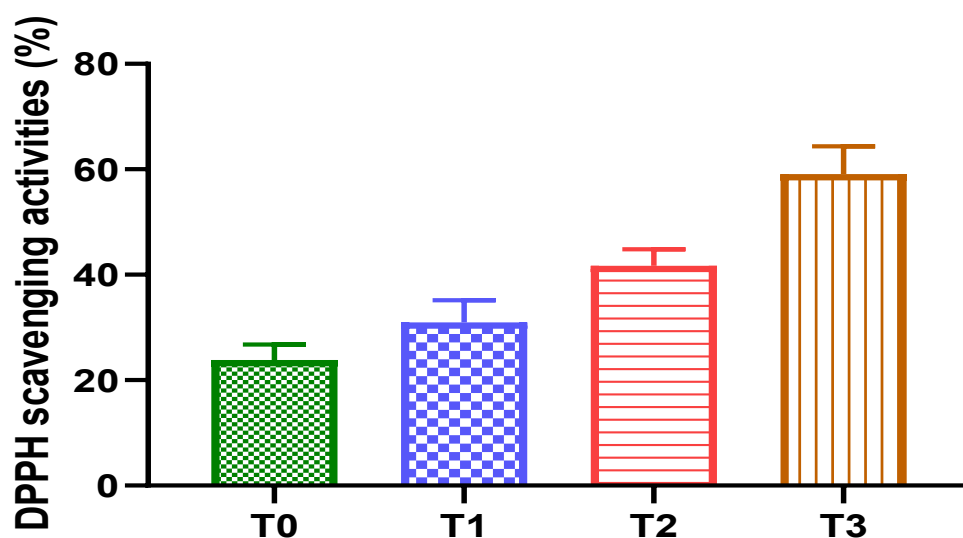


Figure 4.8: Antioxidative potential of cupcakes of different compositions

Table 4.18: ANOVA Summary for Antioxidative Potential

Source of Variation	SS	df	MS	F
Treatments	3639.63	3	1213.21	84.86**
Errors	285.83	20	14.29	
Total	3925.46	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Total Sugar content

A significant reduction in sugar content was observed from T₀ ($11.35 \pm 1.43\%$) to T₃ ($1.91 \pm 0.45\%$) as displayed in Table 4.11. T₁ and T₂ recorded values of $8.48 \pm 1.12\%$ and $3.68 \pm 0.82\%$, respectively. This marked reduction ($P < 0.05$) suggests that the alternative ingredients used in T₂ and T₃ effectively replaced sugars without compromising the structure of the product (Table 4.12). This reduction is likely a result of incorporating complex carbohydrates and

fibers from lotus seed flour, which dilute the concentration of simple sugars and reduce the overall sugar content. Additionally, dietary fibers in lotus seed may interfere with sugar solubilization during baking and analysis. Similar findings were reported by Dhull et al. (2022) and Sopawong et al. (2022), who emphasized that lotus seed flour contributes to lower glycemic indices and reduced sugar levels in functional baked products.

Table 4.19: Total Sugar Content of Cupcakes (Mean $\pm$ SD)

Treatment	Mean $\pm$ SD
T ₀	11.35 ± 1.426
T ₁	8.48 ± 1.120
T ₂	3.68 ± 0.820
T ₃	1.91 ± 0.452

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

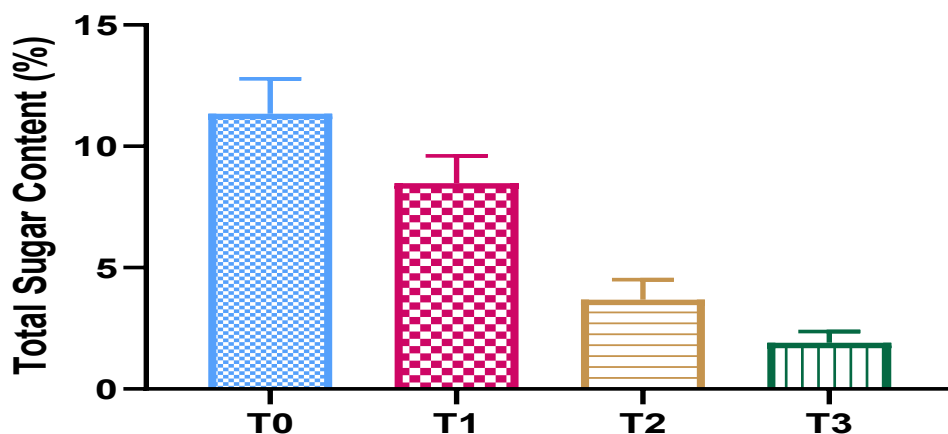


Figure 4.9: Total sugar content of cupcakes of different compositions

Table 4.20: ANOVA Summary for Total Sugar Content

Source of Variation	SS	df	MS	F
Treatmentss	270.74	3	90.25	132.70**
Errors	13.60	20	0.68	
Total	284.34	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Energy calculation

The energy content of the cupcakes decreased progressively from T₀ (118.06 ± 4.32 kcal) to T₃ (74.80 ± 7.31 kcal). T₁ and T₂ exhibited intermediate values (102.77 ± 10.18 kcal and 73.72 ± 9.20 kcal, respectively) (Table 4.27). The reduction ($P < 0.05$) in energy content in T₂ and T₃ (Table 4.23) can be attributed to the lower sugar and fat content in these formulations, coupled with the higher fiber and protein content from lotus seed flour. This energy reduction is particularly beneficial for diabetic patients, as it contributes to lower caloric intake,

which helps in managing weight and controlling blood sugar levels. A reduction in energy content provides significant advantages to diabetic patients by helping them control their blood glucose levels along with body weight management. These formulations contain reduced levels of fat and sugar which match the dietary recommendations for diabetic patients thus offering them as nutritious alternatives to typical baked products. Various studies demonstrate that functional bakery products retain their quality while lotus seed flour substitution leads to decreased energy content (Dhull et al., 2022; Adeyeye et al., 2016).

Table 4.21: Energy Calculations of Cupcakes (Mean $\pm$ SD)

Treatment	Mean $\pm$ SD
T ₀	118.06 ± 4.32
T ₁	102.77 ± 10.18
T ₂	73.72 ± 9.20
T ₃	74.80 ± 7.31

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

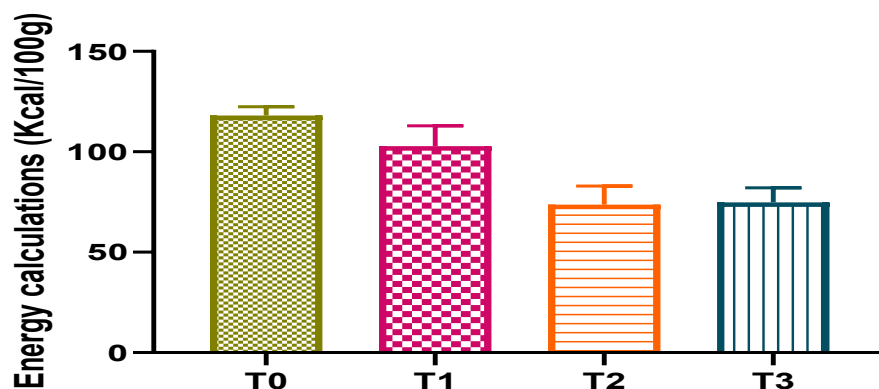


Figure 4.10: Energy calculations of cupcakes of different compositions

Table 4.22: ANOVA Summary for Energy Calculations of Cupcakes

Source of Variation	SS	df	MS	F
Treatments	6155.01	3	2051.67	26.71**
Errors	1537.68	20	76.88	
Total	7692.69	23		

NS = Not Significant ($p > 0.05$)

* = Significant ($p < 0.05$)

** = Highly Significant ($p < 0.01$)

Sensory evaluation

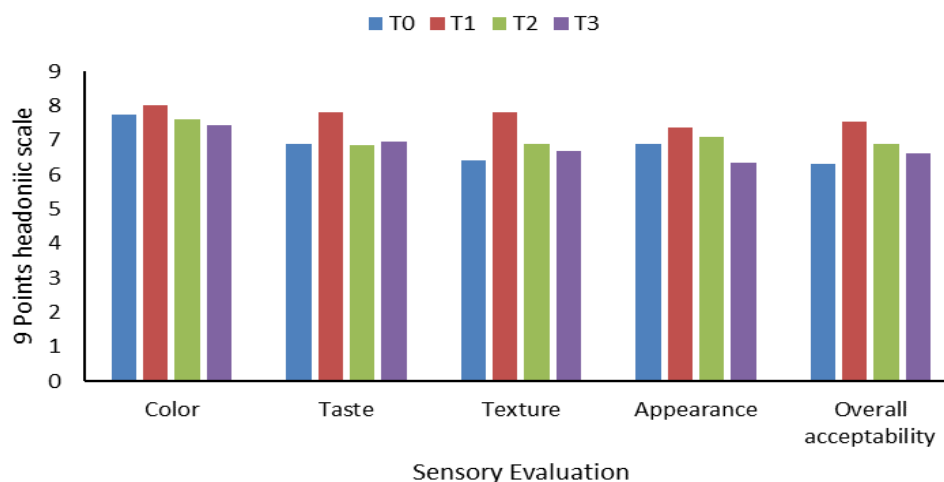


Figure 4.11: Sensory evaluation of cupcakes of different compositions

Effect of storage on appearance of cupcakes

The appearance of cupcakes made with different amounts of sorghum flour and lotus seed powder changes over time shown in table 4.24 and 4.24. Table 4.24 shows that when storage duration (0, 15, and 30 days) increases, the appearance ratings for all treatments go down. At all storage times, T1 (50% sorghum, 25% lotus seed) always got the best appearance scores. It started at 7.39 ± 0.08 at 0 days and went down to 6.89 ± 0.05 at 30 days. This means that lotus seed powder at reasonable levels may help make products seem better. On the other hand, T3

(25% sorghum, 75% lotus seed) had the lowest scores all the time, which suggests that increasing doses of lotus seed powder may make things seem worse over time. The two-way ANOVA results in Table 4.25 back up these findings even further. There was a very strong impact of treatment ($p = 0.0021$) and a strong effect of storage time ($p = 0.0104$). This means that both the formulation and the length of time it was stored had an effect on appearance. However, the interaction between treatment and duration was not statistically significant ($p = 0.133$), which means that the impact of storage was the same for all treatments.

Table 4.23 : Effect of Storage on Appearance of Cupcakes (Mean $\pm$ SE)

Treatment	0 Days (Mean $\pm$ SE)	15 Days (Mean $\pm$ SE)	30 Days (Mean $\pm$ SE)
T0	6.95 ± 0.05	6.72 ± 0.06	6.48 ± 0.07
T1	7.39 ± 0.08	7.22 ± 0.07	6.89 ± 0.05
T2	7.25 ± 0.06	7.08 ± 0.14	6.75 ± 0.09
T3	6.42 ± 0.06	6.28 ± 0.07	6.14 ± 0.05

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

Table 4.24 : Two-Way ANOVA – Effect of Treatment and Storage Duration on Appearance of Cupcakes

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
Treatment	2.481	3	0.827	48.64 **
Storage Duration	0.638	2	0.319	18.79*
Treatment × Duration	0.256	6	0.043	2.53NS
Error	0.102	6	0.017	
Total	3.477	17		

Legend:

- ** = Highly significant ($p < 0.01$)

- * = Significant ($p < 0.05$)

- NS = Not Significant ($p > 0.05$)

Effect of Storage on the color of cupcakes

The colour of cupcakes made with different amounts of sorghum flour and lotus seed powder changes over time. Table 4.26 shows that colour scores went down steadily for all treatments from 0 to 30 days. At first, T₁ (50% sorghum, 25% lotus seed) got the best colour score (7.98 ± 0.02), which meant it looked good on day 0. By day 30, the score had dropped to 7.43 ± 0.03 . This means that adding a small amount of lotus seed powder makes cupcakes look better. On the other hand, T₀ (100% sorghum flour) and T₃ (25% sorghum, 75% lotus seed) showed more colour

loss over time. T₃ had the lowest score (7.19 ± 0.04) after 30 days. The two-way ANOVA findings in Table 4.27 show that both treatment ($p = 0.0028$) and storage period ($p = 0.0061$) had effects on cupcake colour that were statistically significant. The interaction between treatment and storage length, on the other hand, was not significant ($p = 0.085$), which means that the effect of storage on colour was the same for all treatments. These results show how important it is to get the right balance of ingredients to keep the colour quality when storing.

Table 4.25: Effect of Storage on Color of Cupcakes (Mean ± SE)

Treatment	0 Days (Mean ± SE)	15 Days (Mean ± SE)	30 Days (Mean ± SE)
T ₀	7.79 ± 0.10	7.51 ± 0.09	7.21 ± 0.08
T ₁	7.98 ± 0.02	7.76 ± 0.04	7.43 ± 0.03
T ₂	7.65 ± 0.05	7.59 ± 0.02	7.34 ± 0.06
T ₃	7.61 ± 0.04	7.43 ± 0.03	7.19 ± 0.04

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

Table 4.26: Two-Way ANOVA Table – Effect of Treatment and Storage Duration on Color

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
Treatment	1.234	3	0.411	45.67**
Storage Duration	0.558	2	0.279	31.02 *
Treatment × Duration	0.171	6	0.0285	3.17NS
Error	0.054	6	0.009	
Total	2.017	17		

- ** = Highly significant ($p < 0.01$)

- * = Significant ($p < 0.05$)

- NS = Not Significant ($p > 0.05$)

Effect of storage on overall acceptability

The length of time cupcakes are stored and the type of flour used affect how well they are liked overall. Table 4.28 shows that acceptability scores go down steadily throughout the 0, 15, and 30 days of storage for all treatments. T1 (50% sorghum flour and 25% lotus seed powder) got the best scores for acceptability at all times, starting at 7.86 ± 0.30 and going down slightly to 7.22 ± 0.12 by day 30. This means that adding a small amount of lotus seed powder makes cupcakes taste and smell better, which makes people want to buy them more. T0 (100% sorghum flour), on

the other hand, received the lowest acceptance scores during the storage period. This shows that lotus seed powder improves flavour, texture, and appearance. Table 4.29 shows that both treatment ($p = 0.0031$) and storage time ($p = 0.0126$) had statistically significant influence on how acceptable the entire product was. The interaction between treatment and storage length, on the other hand, was not significant ($p = 0.303$). This means that the drop in acceptability caused by storage was the same for all formulations. These results show that lotus seed powder helps keep the quality of cupcakes while they are being stored.

Table 4.27: Effect of Storage on Overall Acceptability of Cupcakes (Mean $\pm$ SE)

Treatment	0 Days (Mean $\pm$ SE)	15 Days (Mean $\pm$ SE)	30 Days (Mean $\pm$ SE)
T0	6.41 ± 0.06	6.25 ± 0.05	6.07 ± 0.04
T1	7.86 ± 0.30	7.55 ± 0.18	7.22 ± 0.12
T2	6.99 ± 0.04	6.86 ± 0.01	6.64 ± 0.05
T3	6.71 ± 0.03	6.56 ± 0.02	6.33 ± 0.04

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

Table 4.28: Two-Way ANOVA Table – Effect of Treatment and Storage Duration on Overall Acceptability

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
Treatment	2.146	3	0.715	38.62 **
Storage Duration	0.402	2	0.201	10.85*
Treatment × Duration	0.157	6	0.026	1.41 NS
Error	0.111	6	0.0185	
Total	2.816	17		

- ** = Highly significant ($p < 0.01$)

- * = Significant ($p < 0.05$)

- NS = Not Significant ($p > 0.05$)

Effect of storage on the taste of cupcakes

Over a 30-day period, taste scores for all treatments steadily dropped, as shown in Table 4.30. This illustrates that the flavour gradually faded while it was being stored. T1 (50% sorghum flour and 25% lotus seed powder) always had the best taste ratings out of the four formulations. On day 0, it got a score of 7.87 ± 0.04 , and on day 30, it got a score of 7.42 ± 0.05 . This means that adding a moderate amount of lotus seed powder makes the taste much better and helps the flavour last longer. On the other hand, T0 (100% sorghum flour) had the lowest taste

scores for the whole storage time. This shows that lotus seed powder makes the product taste better. The two-way ANOVA findings in Table 4.31 show that both the treatment ($p = 0.0037$) and the amount of time the cupcakes were stored ($p = 0.0279$) had a big effect on how they tasted. But the interaction between treatment and duration was not statistically significant ($p = 0.280$), which means that the pace at which taste decreased with time was the same for all formulations. These results show that lotus seed powder is useful for keeping cupcakes fresh and increasing their taste while they are stored.

Table 4.29: Effect of Storage on Taste of Cupcakes (Mean $\pm$ SE)

Treatment	0 Days (Mean $\pm$ SE)	15 Days (Mean $\pm$ SE)	30 Days (Mean $\pm$ SE)
T0	6.97 ± 0.02	6.81 ± 0.04	6.65 ± 0.03
T1	7.87 ± 0.04	7.68 ± 0.06	7.42 ± 0.05
T2	6.86 ± 0.09	6.70 ± 0.06	6.53 ± 0.07
T3	6.88 ± 0.13	6.63 ± 0.08	6.39 ± 0.04

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

Table 4.30: Two-Way ANOVA Table – Effect of Treatment and Storage Duration on Taste

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
Treatment	2.389	3	0.796	34.61**
Storage Duration	0.338	2	0.169	7.35*
Treatment $\times$ Duration	0.204	6	0.034	1.49NS
Error	0.138	6	0.023	
Total	3.069	17		

- ** = Highly significant ($p < 0.01$)

- * = Significant ($p < 0.05$)

- NS = Not Significant ($p > 0.05$)

Effect of storage on texture of cupcakes

The texture of cupcakes changes depending on how long they are stored and how they are made. Table 4.32 shows that the texture ratings for all treatments dropped after 30 days. This means that the textural quality got worse while it was being stored. T1 (50%

sorghum flour and 25% lotus seed powder) always had the best texture ratings. They started at 7.82 ± 0.04 on day 0 and went down to 7.41 ± 0.06 on day 30. This means that using lotus seed powder instead of some of the sorghum flour makes the cupcakes stronger and softer, even when they are stored for a long time. On

the other hand, T0 (100% sorghum flour) received the lowest texture ratings for the whole storage time, which means it had worse textural qualities. Treatments T2 and T3, which had more lotus seed powder, also had better texture scores than T0 but not as good as T1. This suggests that the best texture comes from adding 25% lotus seed powder. Table

4.33 shows that the two-way ANOVA results back up these findings. They demonstrate that treatment had a very big influence on texture ($p = 0.0042$) and storage time had a big effect on texture ($p = 0.0267$). But the interaction between treatment and storage time wasn't significant ($p = 0.306$), which means that the texture of all treatments got worse at the same rate.

Table 4.31: Effect of Storage on Texture of Cupcakes (Mean $\pm$ SE)

Treatment	0 Days (Mean $\pm$ SE)	15 Days (Mean $\pm$ SE)	30 Days (Mean $\pm$ SE)
T0	6.47 $\pm$ 0.05	6.32 $\pm$ 0.04	6.18 $\pm$ 0.03
T1	7.82 $\pm$ 0.04	7.61 $\pm$ 0.05	7.41 $\pm$ 0.06
T2	6.87 $\pm$ 0.06	6.65 $\pm$ 0.07	6.47 $\pm$ 0.05
T3	6.72 $\pm$ 0.03	6.53 $\pm$ 0.04	6.35 $\pm$ 0.04

T₀ = 100% sorghum flour cupcakes

T₁ = 50% sorghum flour, 25% lotus seed powder cupcakes

T₂ = 25% sorghum flour, 50% lotus seed powder cupcakes

T₃ = 25% sorghum flour, 75% lotus seed powder cupcakes

Table 4.32: Two-Way ANOVA Table – Effect of Treatment and Storage Duration on Texture

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value
Treatment	2.011	3	0.670	31.86 **
Storage Duration	0.314	2	0.157	7.46*
Treatment $\times$ Duration	0.173	6	0.029	1.37NS
Error	0.126	6	0.021	
Total	2.624	17		

- ** = Highly significant ($p < 0.01$)

- * = Significant ($p < 0.05$)

- NS = Not Significant ($p > 0.05$)

CONCLUSION

The study's conclusion is that adding lotus seed flour to cupcake recipes makes them much healthier and more helpful.

This novel solution helps with a big public health problem by offering consumers an option other than regular baked products, which are high in calories and low in nutrients.

Treatments T2 and T3, which included 50% and 75% lotus seed flour, had a lot more protein, ash, and fibre. These changes were connected to increased levels of total phenolic and flavonoid content, which means they may be better at fighting free radicals. People with diabetes, obesity, and heart disease can

especially benefit from these sorts of improvements since dietary antioxidants can help lessen inflammation and oxidative damage. Cupcakes prepared with lotus seed flour are also perfect for diets that aid with weight reduction and low-glycemic meals since they have less sugar, fat, and digestible carbs. These changes assist enhance metabolic outcomes by keeping blood sugar levels from going up too high, which makes the products better for persons with diabetes. But the study also brought up a common difficulty in the field of functional food development: the sensory compromise. Even though the nutritional profiles got better, panellists in more replacement treatments didn't appreciate the taste and texture as

much. This agrees with what previous studies have shown concerning functional additives, which may change the taste, texture, and appearance of a product by modifying its chemical and physical properties.

The research demonstrated that therapy T1 might be a good balance between health benefits and consumer satisfaction. This means that it would be best to use lotus seed flour in small amounts. It highlights how vital it is to make product formulations that not only promote health but also keep consumers interested in buying them. The study was able to show that lotus seed flour may be a valuable functional ingredient, even if the sensory evaluations went down with more lotus treatments. Adding it adds compounds that could help avert long-term ailments from occurring. It proved that lotus seed flour can be utilised to produce healthier cupcakes that are high in nutrients and antioxidants. The information is very helpful for food scientists, dietitians, and product makers that wish to help individuals with their present dietary issues. The study adds to what we know about functional ingredients in baked goods and gives people who care about their health a new way to prepare healthful snacks and desserts. But there are certain sensory issues that demonstrate that more work has to be done before it can be fully commercialised. You need to correct any flaws with the flavour and texture of these functional cupcakes so that they are not only excellent for your health but also taste delicious and are pleasant to eat every day.

REFERENCES

- Adeyeye, S. A. O. J. C. F., & Agriculture. (2016). Assessment of quality and sensory properties of sorghum-wheat flour cookies. 2(1), 1245059.
- Ajala, A., Yolacanar, E. T., Colussi, R., Kaur, L., Singh, J. J. H. o. S. S., & Technology. (2025). Digestibility and Glycaemic. 317.
- Aljobair, M. O. J. F. S., & Nutrition. (2022). Physicochemical properties and sensory attributes of cookies prepared from sorghum and millet composite flour. 10(10), 3415-3423.
- Arooj, M., Imran, S., Inam-ur-Raheem, M., Rajoka, M. S. R., Sameen, A., Siddique, R. & Aadil, R. M. (2021). Lotus seeds (Nelumbinis semen) as an emerging therapeutic seed: A comprehensive review. *Food Science & Nutrition*, 9(7), 3971-3987.
- Aamir, A. H., Ul-Haq, Z., Mahar, S. A., Qureshi, F. M., Ahmad, I., Jawa, A., ... & Heald, A. H. (2019). Diabetes Prevalence Survey of Pakistan (DPS-PAK): prevalence of type 2 diabetes mellitus and prediabetes using HbA1c: a population-based survey from Pakistan. *BMJ open*, 9(2), e025300.
- Bangar, S. P., Dunno, K., Kumar, M., Mostafa, H., & Maqsood, S. (2022). A comprehensive review on lotus seeds (Nelumbo nucifera Gaertn.): Nutritional composition, health-related bioactive properties, and industrial applications. *Journal of Functional Foods*, 89, 104937.
- Basiak-Rasala, A., Rozanska, D., & Zatonska, K. (2019). Food groups in dietary prevention of type 2 diabetes. *Roczniki Państwowego Zakładu Higieny*, 70(4).
- Bhutta, Z. A., Haq, Z. U., & Basit, A. (2022). Diabetes in Pakistan: addressing the crisis. *The Lancet Diabetes & Endocrinology*, 10(5), 309-310.
- Bangar, S. P., Dunno, K., Kumar, M., Mostafa, H., & Maqsood, S. J. J. o. F. F. (2022). A comprehensive review on lotus seeds (Nelumbo nucifera Gaertn.): Nutritional composition, health-related bioactive properties, and industrial applications. 89, 104937.
- Bishayee, A., Patel, P. A., Sharma, P., Thoutireddy, S., & Das, N. (2022). Lotus (Nelumbo nucifera Gaertn.) and its bioactive phytochemicals: A tribute to cancer prevention and intervention. *Cancers*, 14(3), 529.

- Cairns, A., Brazington, S., Gragg, E., Holmes, A., Vavra, C., Whitehair, K., & Getty, K. (2023). Development and scale-up of gluten-free sorghum-based bakery goods for K-state Dining Services. *Journal of Agriculture and Food Research*, 14, 100840.
- Dhull, S. B., Chandak, A., Collins, M. N., Bangar, S. P., Chawla, P., & Singh, A. (2022). Lotus seed starch: a novel functional ingredient with promising properties and applications in food—a review. *Starch-Stärke*, 74(9-10), 2200064.
- Dada, M. A., Bello, F. A., Omobulejo, F. O., & Olukunle, F. E. J. H. (2023). Nutritional quality and physicochemical properties of biscuit from composite flour of wheat, African yam bean and tigernut. 9(11).
- Dhull, S. B., Chandak, A., Collins, M. N., Bangar, S. P., Chawla, P., & Singh, A. J. S. S. (2022). Lotus seed starch: A novel functional ingredient with promising properties and applications in food—A review. 74(9-10), 2200064.
- Dinkar, D. K., Mishra, S. J. I. J. o. R. i. E., Science, & Management. (2020). Preparation of biscuits by using lotus seed, pearl millets and multigrain wheat for elderly people. 3(7), 413-415.
- Forouhi, N. G., & Wareham, N. J. (2019). Epidemiology of diabetes. *Medicine*, 47(1), 22-27.
- Farooq, S. A., Imran, S., & Tanweer, A. (2024). Nutritional, functional and sensory evaluation of flaxseed-enriched cupcakes. *Nurture*, 18(2), 340-348.
- Goyal, R., Singhal, M., & Jialal, I. (2023). Type 2 diabetes. *StatPearls [Internet]*.
- JOHNSON, H. (2012). *DESCRIPTIVE, INSTRUMENTAL, AND ACCEPTABILITY ASSESSMENT OF REDUCED-CALORIE CUPCAKES PREPARED WITH ALTERNATIVE SWEETENERS* (Doctoral dissertation, Tese (Mestrado em Ciência)-University of Georgia, Georgia, 2007.
- KIM, MY. Comparison of the chemical compositions and nutritive values of various pumpkin (Cucurbitaceae) species and parts. *Nutricion Research and Practice*, Seoul).
- Kazungu, F. K., Muindi, E. M., & Mulinge, J. M. (2023). Overview of sorghum (Sorghum bicolor. L), its economic importance, ecological requirements and production constraints in Kenya. *International Journal of Plant & Soil Science*, 35(1), 62-71.
- Li, T., Li, Q., Wu, W., Li, Y., Hou, D.-x., Xu, H., . . . Lu, X. J. A. b. e. b. S. (2019). Lotus seed skin proanthocyanidin extract exhibits potent antioxidant property via activation of the Nrf2-ARE pathway. 51(1), 31-40.
- McGinnis, M. J., & Painter, J. E. (2020). Sorghum: History, use, and health benefits. *Nutrition Today*, 55(1), 38-44.
- Mozaffarian, D., Angell, S. Y., Lang, T., & Rivera, J. A. (2018). Role of government policy in nutrition—barriers to and opportunities for healthier eating. *Bmj*, 361.
- Montgomery, M. R. (2008). The urban transformation of the developing world. *Science*, 319(5864), 761-764.
- Marie, A. M., Elgazzar, M. M., & Abd El-Salam, R. S. (2024). Gluten-Free Cupcake Enriched with Black Quinoa Treated with Some Technological Methods. *Egyptian Journal of Food Science*, 52(2), 243-267.
- Seferli, M., Kotanidou, C., Lefkaki, M., Adamantidi, T., Panoutsopoulou, E., Finos, M. A., . . . Anastasiadou, C. J. A. S. (2024). Bioactives of the freshwater aquatic plants, *Nelumbo nucifera* and *Lemna minor*, for functional foods, cosmetics and pharmaceutical applications, with antioxidant, anti-inflammatory and antithrombotic health promoting properties. 14(15), 6634.

- Shahzad, M. A., Ahmad, N., Ismail, T., Manzoor, M. F., Ismail, A., Ahmed, N., Characterization. (2021). Nutritional composition and quality characterization of lotus (*Nelumbo nucifera* Gaertn.) seed flour supplemented cookies. *15*, 181-188.
- Sopawong, P., Warodomwichit, D., Srichamnong, W., Methacanon, P., & Tangsuphoom, N. J. F. (2022). Effect of physical and enzymatic modifications on composition, properties and in vitro starch digestibility of sacred lotus (*Nelumbo nucifera*) seed flour. *11*(16), 2473.
- Syed, F. Z. (2022). Type 1 diabetes mellitus. *Annals of internal medicine*, *175*(3), ITC33-ITC48.
- Tanwar, R., Panghal, A., Chaudhary, G., Kumari, A., & Chhikara, N. (2023). Nutritional, phytochemical and functional potential of sorghum: A review. *Food Chemistry Advances*, 100501.
- Xu, J., Wang, W., & Zhao, Y. (2021). Phenolic compounds in whole grain sorghum and their health benefits. *Foods*, *10*(8),1921.
- Xiong, Y., Zhang, P., Warner, R. D., & Fang, Z. (2019). Sorghum grain: From genotype, nutrition, and phenolic profile to its health benefits and food applications. *Comprehensive Reviews in Food Science and Food Safety*, *18*(6), 2025-2046.
- Xu, J., Wang, W., & Zhao, Y. (2021). Phenolic compounds in whole grain sorghum and their health benefits. *Foods*, *10*(8), 1921.
- Zhu, Z., Zhong, B., Yang, Z., Zhao, W., Shi, L., Aziz, A., . . . Suleria, H. A. R. J. A. o. (2022). LC-ESI-QTOF-MS/MS characterization and estimation of the antioxidant potential of phenolic compounds from different parts of the lotus (*Nelumbo nucifera*) seed and rhizome. *7*(17), 14630-14642.
- Zhang, Y., Lu, X., Zeng, S., Huang, X., Guo, Z., Zheng, Y., ... & Zheng, B. (2015). Nutritional composition, physiological functions and processing of lotus (*Nelumbo nucifera* Gaertn.) seeds: a review. *Phytochemistry Reviews*, *14*, 321-334.
- Zhu, M., Liu, T., & Guo, M. (2016). Current advances in the metabolomics study on lotus seeds. *Frontiers in plant science*, *7*, 891.

