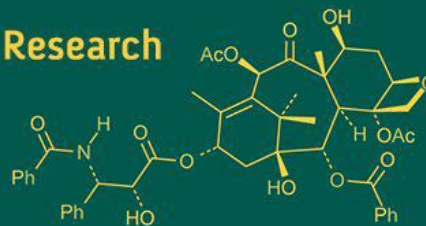
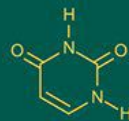


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Studies on preparation of brownie by using *Moringa* leaf powder with little millet

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Abstract

This research enhanced the healthiness of brownies by including *Moringa* leaf powder and fine millet flour, both of which are easily accessible and nutrient-dense. Millet is a fantastic source of fibre and other important nutrients. Many people call *Moringa* a "miracle food" since it has many vitamins, minerals, and antioxidants. There were four different formulations tested in all: a control (T₀) and three variations (T₁, T₂, and T₃), each with more *Moringa* and millet. T₁, which was made out of 20% millet and 1% *Moringa*, tasted better, felt better, looked almost as healthy as the control, and was better for your health. T₂ and T₃ had a stronger herbal flavour because they had more *Moringa* in them. The results for taste and sour flavour, on the other hand, were a little lower than expected. The microbiological tests indicated that all of the samples were safe, didn't degrade after being outside for seven days, and didn't have any harmful germs in them. The results indicate that T₁ is the best choice for flavour, health, and safety overall. The conclusion that can be derived from this data is that it is a fantastic way to generate baked goods that are healthier without making them less tempting to people. The overall plate count results demonstrated that the brownies maintained their microbiological stability throughout the entire week of storage. On the day of preparation, there was no visible indicator that germs had grown. Even on the third and seventh days, the number of bacteria stayed below 10⁴ CFU/g. The number of bacteria is much lower than what is safe to consume. These values that stay low all the time suggest that the food was manufactured in a clean place, baked at a temperature that killed harmful germs, and packaged in a way that kept it clean. The results indicate that the brownies were safe and tasted delicious the whole time they were in the fridge.

Keywords: *Moringa* leaf powder, nutrient enrichment, functional product

Introduction

For thousands of years, people have grown millets, a group of small-seeded grains, in various parts of the world. Millet is a cereal in the grass family (*Poaceae*). Millets are the sixth most important cereal grain in the world. They give energy and food to millions of people in India, Africa, and China, especially in dry and semi-arid areas. People often call them "Nutri-cereals" since they have more nutrients than most major cereals that are made in factories (Diksha Bhatt *et al.*, 2022) [2]. There are several kinds of millet and they all have different colours, textures, shapes, sizes, and species. There are two varieties of these based on the size of the grain: People also produce large or major millets and little or minor millets in areas with irrigation. (Paschapur *et al.*, 2021) [16]. Millets are little, round-seeded grains that are excellent at surviving droughts. They are part of the *Poaceae* family (Dey *et al.*, 2022) [5]. Millets also contain micronutrients such as iron, calcium, phosphorus, and magnesium. Minor millets are rich in macronutrients like proteins (7-13%), carbohydrates (60-70%), lipids (1.5-5%), and fibre (2-7%). Bioactive compounds, including polyphenols and antioxidants, also provide them the ability to heal and enhance the immune system (Kaur *et al.*, 2023) [8].

Sorghum millet (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), and finger millet or ragi (Eleusine coracana) are some of the most important types of millet. Foxtail millet (*Setaria italica*), kodo millet (*Paspalum scrobiculatum*), small millet (*Panicum sumatrense*), barnyard millet (*Echinochloa frumentacea*) and proso millet (*Panicum miliaceum*) are all examples of minor millets. These millets are not as well-known as fundamental cereal crops like wheat, rice and maize, but they have some distinct advantages, such as being able to

grow in dry, hot, and poor soil. The topography and the types of minor millets (Maharajan *et al.*, 2022) ^[12] determine how they grow and how much they produce. Minor millets are a good alternative to major grains because they are better for the RTE and RTS foods. They offer many health benefits because they are full of bioactive components and antioxidants. For example, they can help stabilise blood sugar, decrease cholesterol and fight malnutrition (Dekka *et al.*, 2023) ^[6].

As more study is done on their potential, it will be highly vital to develop and deploy processing methods that make little millets more appealing to consumers and more cost-effective (Kalsi *et al.*, 2023) ^[9]. Millets are gaining popularity now because they are healthy, grow in many climates and may contribute to food security. The United Nations declared 2023 the International Year of Millets to show how important they are all around the world. Millets have several benefits, but their cultivation areas have shrunk over the past 70 years. The total output has remained about the same, even while production has gone up by 200% (Yadav *et al.*, 2024) ^[29]. This trend can be explained by insufficient knowledge, a lack of willingness to change eating habits and the inability to find food in stores (Das *et al.*, 2023) ^[4]. Government programs that help rice and wheat have also made people less likely to eat millets. People are starting to realise that millets can help with problems related to nutrition, food security around the world and climate change. You can take advantage of this trend by investing more in millet research, genetic development and agronomic management. The future of the agricultural sector will depend on factors such as increased consumption of millet, improved value chains and the use of millets in sustainable farming systems. Millets are an old crop that will be around for a long time. They can grow well in dry and semi-arid areas and places with little rain. These grains use 70% less water than rice and can handle temperatures up to 42°C. Millets are an excellent choice for tropical countries looking for drought-resistant food because they can handle high temperatures. The International Crops Research Institute for the Semi-Arid Tropics says that millets are "usually the last crops standing in droughts" (Saxena *et al.*, 2018) ^[18].

The little millets hydrate the human colon, preventing constipation. Minor millet contains a high amount of tryptophan, which is converted into serotonin, ultimately helping us feel better. Niacin, or vitamin B3, in millet can help lower cholesterol. All varieties of millet are effective at combating free radicals. Millet is gluten-free and does not cause allergies. Millets are low-output crops that grow best in marginal locations. They assist in sustaining food security by being eaten often and keeping the environment safe (Singh *et al.*, 2020) ^[24]. The state-average yield and outputs from frontline demonstrations set up by the Department of Agriculture and Cooperation demonstrate significant productivity improvements. However, when you compare the minor millets, there are still significant differences in productivity. Yield gaps apply to both "large" and "small" millets, although they are different for each state and crop. Germplasm resources that are rich in key genes have been used successfully in traditional breeding operations to improve several crop plants. We need to develop gene-based, trait-specific molecular indicators that are linked to nutritional qualities to modulate these features. Next-generation sequencing techniques make it possible to quickly sequence the millet genome and provide features

that help you do this (Tiwari *et al.*, 2018) ^[26]. Millets have garnered significant interest as a possible ingredient in ready-to-eat foods since they are healthy and can be used in many different ways. These ancient grains are an excellent choice for healthy, ready-to-eat snacks because they are high in protein, fibre, vitamins, and minerals (Kumar *et al.*, 2024) ^[10].

Little millet (*Panicum sumatrense* Roth ex Roem. and Schult.) is a minor millet that is native to India and grows in temperate and subtropical areas of Southeast Asia and Africa. It is better for you and you can handle stress better than other millets. Little millet does well in marginal places and can survive drought and flooding (Vetriventhan *et al.*, 2021) ^[28], but it does not live very long. Little millet is a beneficial functional food ingredient since it is high in minerals, proteins and phytochemicals. It helps maintain your health in various ways, such as preventing diabetes, obesity, and heart disease. Small millet is more nutritious than other cereals, yet it is still not used enough (Panda *et al.*, 2024) ^[17].

Oxalate, trypsin inhibitors, tannins, and phytates are all examples of antinutrients that can attach to vital nutrients and make them more difficult for the body to use. However, various methods have been proposed to eliminate these antinutrient components, paving the way for the creation of innovative and valuable meals and products. Finally, it has many minerals, mainly zinc and iron (Nagaraja *et al.*). Little millet has much promise to help with "hidden hunger" and food security. Breeders and researchers now have a lot of new genomic and transcriptome research tools to help them improve this crop (Johnson *et al.*, 2019) ^[7].

Little millets are becoming increasingly important in the Ready-To-Eat food industry because of their nutritional value and valuable qualities. Little millets are crucial in the Ready-To-Eat food sector since they are healthy and have valuable properties. These small-seeded grains are beneficial for making goods. Little millets are also a fantastic choice for Ready-to-eat foods because they are high in proteins, dietary fibres, vitamins, minerals, and antioxidants. This prolonged shelf life is important for ready-to-eat items to ensure they stay stable and reduce food waste. Overall, tiny millets are a viable alternative for making quick and cheap RTE products. Minor millets are popular in the food industry because they have distinctive physical properties, are nutritious and have a long shelf life. This characteristic makes them a beneficial choice for meeting the growing need for quick and healthy foods. More research is still needed to determine the best ways to prepare minor millets and to identify additional applications for them in the RTE sector. Little millet has many health benefits. It has a lot of fibre, which helps digestion and keeps you from getting constipated. It also stimulates the healthy bacteria in your stomach. Little millet has a low glycaemic index, which makes it a beneficial choice for people who are trying to lose weight or who have diabetes. Little millet has antioxidants that help protect against oxidative stress and inflammation, which are two things that can lead to numerous long-term health problems. It may help prevent and treat chronic diseases, including diabetes and heart issues, because it has a low glycaemic index and is gluten-free (Maurya *et al.*, 2023) ^[13].

Saamai or Kutiki are little millets that can survive both drought and flooding. Little millet is also an annual plant. It has a hollow, jointed stem that is 30 to 90 cm long and has a

thin, robust base. The leaves are linear and can be 15 to 50 cm long and 12 to 25 cm wide. The nodes are smooth. Between February and March, the seeds grow. It has a creamy, shiny colour and a grain size of about 2.5×1.5 mm. Little millet is also rich in nutraceuticals, including resistant starch, phytates, phenolics, sterols, lignans, and gamma-aminobutyric acid. It is claimed that phytate retention is beneficial for healthy people since it helps prevent diabetes and cancer and is also an antioxidant. It has a lot of fibre, which helps food and waste move through the digestive system and reduces fat in the body. The main reasons people do not want to grow and use it are that it is difficult to process and tastes unpleasant.

Little millet has more dietary fibre than grains (37–38%) and is high in polyunsaturated fatty acids (PUFA). This discovery shows that we need to rekindle interest in millets because they may offer health and nutritional benefits. It is found that tiny millet has between 51 and 104 $\mu\text{g}/100$ g of carotenoids in total. Some types of small millet seem slightly yellow, which could mean they have carotenoids. There has been much interest lately in making extruded meals such as snacks, pastas, breakfast cereals, infant food, pet food and more. Snacks are a blend of cereals that have been pushed through a machine with a certain amount of water. Little millet is also known as 'kutki' in Hindi, 'samai' in Tamil, and 'saame' in Kannada. Little millets taste somewhat sweet and nutty, and they are full of nutrients. Minor millets are good sources of dietary fibre. They are made up of 70–80% carbohydrates and 9–14% protein. People in tribal groups have known for a long time that little millets are excellent for you, but they do not eat them very often because they cannot acquire ready-to-eat foods like rice and wheat that are easy for consumers to obtain. Minor millets have become popular lately, mainly because they are high in fibre and because people are working on ways to make them easier to eat. Research into milling and popping little millets has shown promise. Minor millets, which are also called small millets, receive a lot less attention when it comes to growing and using them (Saini *et al.*, 2018) [19].

Moringa oleifera Lam is also known as the "Miracle Tree" or "Drumstick." It is a plant that is wonderful for your health and food. This plant comes from northern India and Pakistan and belongs to the *Moringaceae* family. It now grows in tropical and subtropical areas of the world (Bibi *et al.*). It has vitamins, minerals, proteins, amino acids, and bioactive substances such as flavonoids and phenolic acids. You can eat any part of the *Moringa oleifera* plant, even the flowers. The roots and bark may contain dangerous chemicals; thus, the leaves are thought to be the safest component to eat. The number of bioactive compounds and antioxidants in *Moringa* leaves can vary depending on the weather, the kind of soil and the age of the tree (Vazquez Leon *et al.*). Researchers have studied *Moringa oleifera*'s health benefits in considerable depth. They lower blood sugar, fight free radicals, protect the liver and fight bacteria. Many items, like meats, baked goods and drinks, use it to make them healthier because it includes many nutrients and may offer health benefits. Both standard and alternative medicine agree that the plant can adapt and that it may be suitable for your health in treating hunger and other ailments (Anzano *et al.*, 2021) [1].

You may use *Moringa oleifera* leaf powder in a lot of different foods because it is both a functional component and a nutritional supplement. Eating the right amount of it

has been shown to make food healthier. Powdered *Moringa* leaf seems like an excellent method to add nutrients to a variety of different diets. However, you need to know how much to absorb to have the right balance of taste and health benefits. We need to do more research on its bioavailability and long-term effects to fully comprehend its potential as a natural preservative and food fortifier (Mashau *et al.*, 2021) [14]. *Moringa* leaf powder can be utilised in a lot of different ways because it has a lot of minerals and bioactive substances. *Moringa* leaf powder is an excellent natural coagulant for cleaning up wastewater since it may lower turbidity, pH, electrical conductivity and several pollutants, such as heavy metals, including arsenic, cadmium and lead. Researchers have discovered that *Moringa* leaf charcoal adsorbs better than neem and alum leaf powders (Sharif *et al.*, 2020) [23].

Research on animal nutrition shows that fish can benefit from supplements like powdered *Moringa* leaves. Adding 15% *Moringa* leaf powder to the guppy fish's food made their skin mucus immunity substantially stronger (Bisht). Some foods, including cookies and noodles, have *Moringa* leaf powder added to them to make them even healthier. However, using too much can change the way it feels and looks (Mpalanzi *et al.*, 2023) [15]. Researchers have shown that powdered *Moringa* leaves may help people with diabetes control their blood sugar levels. It is observed that people with diabetes who ate a meal containing 20 grams of powdered *Moringa* leaf showed a reduced glucose response after eating. You may use *Moringa* leaf powder for many things, like cleaning up the environment, adding nutrients to meals, and making food healthier. It is suitable for you and has antioxidants since it has a lot of bioactive compounds, such as flavonoids, phenols and saponins (Khalid *et al.*, 2023) [11].

People have also employed powdered *Moringa* leaves to improve the taste of other dishes. For example, yoghurt with 1% *Moringa* leaf powder added earned the best scores for body, texture, flavour, taste, and overall acceptance. Store-bought soup powders had fewer vitamins, minerals, protein, and fibre than those made from soy, mushrooms, and *Moringa* leaves. Adding *Moringa* leaf powder to food can make it taste better by adding more protein, minerals and fibre. However, you need to be careful when you choose the concentration because using too much could make the sensory parts worse. It looks like the optimal amount of concentration is between 1% and approximately 10%, depending on the dish (Saeed *et al.*, 2021) [20].

Moringa oleifera powdered leaves have shown promise for several uses, but the most important one is to make food and animal feed more nutritious. Guppy fish and Nile tilapia fingerlings with stronger immune systems had more phagocytic and lysozyme activity and superior antioxidant responses. The powder might help fish stay healthy by keeping their inflammatory response in check. People have used *Moringa oleifera* leaf powder to make a lot of different dishes stronger. At higher levels, it changed the way bread felt, but it also made gluten-free bread have more antioxidants and phenolic compounds (Bourekoua *et al.*, 2017) [3]. It can also affect the intestinal microbiota of hens when they are fed it, which may make them healthier overall (Soundararajan *et al.*, 2023) [25].

Materials and Methods

Development of Brownie

The development of a brownie begins with selecting high-quality ingredients. To get fudgy or cakey textures, the crucial ingredients, such as millet flour, sugar, cocoa powder, or melted chocolate, baking powder, butter or oil, and vanilla essence, are weighed precisely

Table 1: Development of Brownie

Ingredients used (%)	Control	T ₁	T ₂	T ₃
Refined wheat flour	32	15	15	15
Little millet flour	0	12	10	8
<i>Moringa</i> leaf flour	0	5	7	9
Dark chocolate	15	15	15	15
Cocoa powder	10	10	10	10
Sugar	20	20	20	20
Butter	11	11	11	11
Vanilla essence	1	1	1	1
Baking powder	1	1	1	1
Water	10	10	10	10

Methodology of Preparation of Brownie

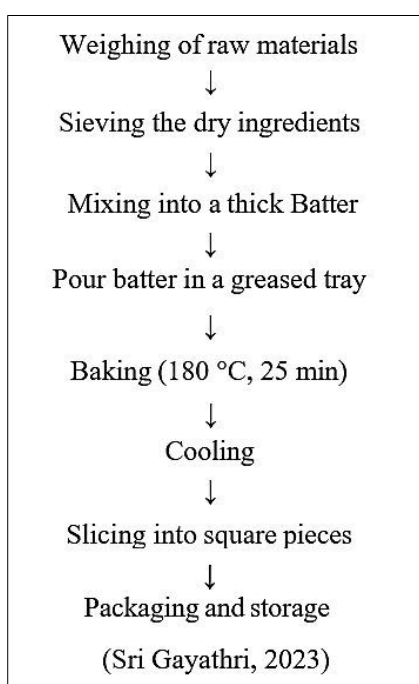


Fig 1: Mixing and Baking



Fig 2: Brownie after baking

Sensory evaluation of developed brownie

A sensory evaluation of the developed little millet and *Moringa* brownie was conducted using a 9-point hedonic scale to assess their appearance, flavour, taste, texture, chewiness and overall acceptability. On a numerical scale, 1 represents dislike extremely and 9 represents like extremely, with intermediate values varying degrees of liking/disliking. The sensory evaluation was carried out by the Head of the Department, along with Assistant Professors and 25 untrained panellists from the Department of Food Science and Technology, School of Agricultural Sciences, Malla Reddy University. The evaluation was conducted in isolated rooms under white light, ensuring a controlled environment. Panellists were provided with an adequate supply of bowls, spoons, and water bottles to facilitate an accurate assessment of the sensory attributes of the brownies.



Fig 3: Sensory evaluation of brownie



Fig 4: Sensory evaluation of brownie

Table of Sensory Analysis

Table 2: Table of Sensory Analysis

Variables	Control	T ₁	T ₂	T ₃
Appearance	8.14 ±0.66	8.19±0.77	7.71±0.76	7.9±0.86
Flavour	8.01±0.66	7.71±0.88	7.33±1.08	7.23±1.26
Taste	7.91±0.92	7.88±0.66	7.09±1.01	7.19±0.1.21
Texture	7.90±0.68	8.04±0.78	7.57±0.72	7.52±1.0
Chewiness	7.90±0.68	7.96±0.73	7.2±1.10	7.33±1.0
Overall acceptability	8.14±0.63	7.98±0.75	7.46±0.95	7.47±1.27

The above values are expressed as mean±SD (n =50).

Sensory evaluation data of brownies are presented in Table 2.4. The T_1 sample received the highest score for appearance (8.14 ± 0.77) compared to T_3 (7.9 ± 0.86) and T_2 (8.14 ± 0.66). Notably, the appearance of T_2 is lower than that of the control sample (8.19 ± 0.66). The T_1 sample received the highest texture score (8.04 ± 0.78), compared to T_2 (7.57 ± 0.72) and T_3 (7.88 ± 0.66). Both T_2 and T_3 received identical scores. The T_1 sample received the highest appearance score (8.14 ± 0.77) compared to T_2 (7.71 ± 0.76) and T_3 (7.9 ± 0.86). Sample T_1 received higher ratings compared to T_2 and T_3 . Sample T_1 received the highest texture score (8.04 ± 0.78) compared to T_3 (7.52 ± 1.0) and T_2 (7.57 ± 0.72). Sample T_3 received the lowest score compared to T_1 and T_2 . The T_1 sample received the highest score in

overall acceptability (7.98 ± 0.75) compared to T_3 (7.47 ± 1.27) and T_2 (7.46 ± 0.95). The overall acceptability of brownies appears to be influenced by various characteristics such as the appearance, taste, chewiness, flavour, and texture of the end product. T_1 demonstrates superior sensorial properties compared to the other experimental products and closely resembles the control sample. This may be attributed to the formulation of experimental product T_2 . In sample T_1 , little millet flour is used, which is rich in fibre. The *Moringa* powder was rich in calcium, iron, and micronutrients, which scored the highest in the product's appearance. The addition of sugar sweeteners resulted in the highest score for all taste, texture, chewiness, and flavour received the highest scores.

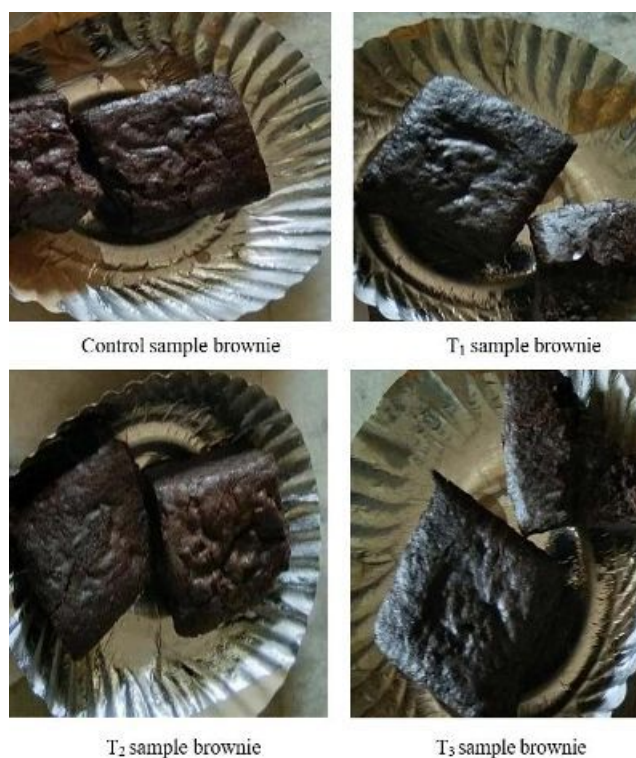


Fig 5: Different samples of brownie

Physical properties of brownie

Table 3: Physical properties of brownie

Parameters %	Control	T_1	T_2	T_3
Length	5.2 ± 0.16	5.2 ± 0.04	5.2 ± 0.08	5.2 ± 0.08
Breadth	6.2 ± 0.08	6.9 ± 0.08	6.7 ± 0.04	6.8 ± 0.04
Thickness	3.2 ± 0.08	3.3 ± 0.08	3.2 ± 0.08	3.2 ± 0.01

The results indicated that the samples were still the same length in all of the treatments, with mean lengths of about 5.2 mm and extremely negligible differences. This means that the treatment didn't change this trait. The breadth, on the other hand, showed big alterations. The average width of

the control was (6.2 ± 0.08). The T_1 area was the widest, measuring (6.9 ± 0.08), followed by T_3 at (6.8 ± 0.04) and T_2 at (6.7 ± 0.04). This result suggests that the treatments may have made the samples slightly wider than the control. The thickness numbers did not alter much; they stayed between 3.2 and 3.3 mm. T_1 was slightly thicker (3.3 ± 0.08), but this difference was too modest to matter. These results suggest that the treatment did not significantly alter the length and thickness of the samples. However, they still appeared like they could make the width somewhat better, with T_1 being the most obvious.

Functional properties of brownie

Table 4: Functional properties of brownie

Parameters %	Control	T_1	T_2	T_3
Water absorption capacity (%)	2.03 ± 0.16	2.04 ± 1.18	2.13 ± 0.04	2.16 ± 0.14
Swelling capacity (%)	1.02 ± 0.01	2.3 ± 0.08	2.4 ± 0.16	2.53 ± 0.94

The above values are expressed as mean $\pm$ SD (n = 3).

The samples could take up water slightly better with some treatments than others. The control result was (2.03 ± 0.16),

which is quite close to the T_1 value of (2.04 ± 1.18). T_2 took in the most water, at (2.26 ± 0.04) and T_3 took in the second

most, at (2.13 ± 0.14) . This conclusion means that some treatments may have made the material hold onto water better, even if only a little. The swelling capacity, on the other hand, changed significantly. The control exhibited a swelling capacity of only (1.02 ± 0.01) , but all of the treated samples had far larger increases. T_1 might swell by (2.3 ± 0.08) , T_2 could swell by (2.4 ± 0.16) and T_3 could swell by (2.53 ± 0.94) . The significant difference between the

control and the treatments suggests that changing how the material was produced or processed had a big effect on its structure, making it far better at swelling when it comes into contact with water. In general, the ability to soak in water only became slightly better, while the ability to swell showed a lot better in all of the treated groups, notably T_3 .

Chemical properties

Table 5: Chemical properties

Parameters %	Control	T_1	T_2	T_3
Energy (Kcal)	369.08 ± 0.09	370.1 ± 0.12	365.6 ± 0.06	362.7 ± 0.20
Protein (g/100g)	7.03 ± 0.08	7.8 ± 0.04	8.01 ± 0.12	8.23 ± 0.08
Carbohydrate (g/100g)	53.39 ± 0.28	53.95 ± 0.21	52.85 ± 1.24	52 ± 0.08
Fat (g/100g)	6.5 ± 0.24	6.81 ± 0.10	6.3 ± 0.46	6.1 ± 0.10
Vitamin A (mg/100g)	29.49 ± 1.6	36.8 ± 0.42	39.2 ± 0.81	40.6 ± 0.47
Vitamin E (mg/100g)	0.39 ± 0.94	0.76 ± 0.13	0.78 ± 0.08	0.80 ± 0.12
Vitamin B1 (mg/100g)	0.34 ± 0.08	0.42 ± 0.12	0.41 ± 0.01	0.40 ± 0.01
Vitamin B9 (mg/100g)	13.01 ± 0.08	23.04 ± 0.2	22.06 ± 0.01	21.02 ± 0.01
Iron (mg/100g)	3.82 ± 0.04	5.18 ± 1.16	5.67 ± 0.12	6.61 ± 0.08
Calcium (mg/100g)	58.4 ± 0.04	74.3 ± 0.08	77.3 ± 0.08	79.3 ± 1.24
Fibre (g/100g)	6.2 ± 0.08	7.26 ± 0.21	7.31 ± 0.13	7.33 ± 0.04
Moisture (%)	14.54 ± 0.20	14.27 ± 0.16	14.34 ± 0.21	14.46 ± 0.26
Ash (g/%)	1.57 ± 0.12	1.37 ± 0.21	1.25 ± 0.02	1.21 ± 0.01

The above table is expressed as mean $\pm$ SD

The treatments and the control didn't modify the samples' energy levels very significantly. The control sample had the most energy, with (370.08 ± 0.09) . T_3 was not far behind, with (369.08 ± 0.09) . The value of T_2 was (365.6 ± 0.06) , which was slightly less than the value of T_1 , which was (362.7 ± 0.20) . The samples contained similar levels of protein. The control had the protein, which was (7.03 ± 0.08) . The next one was T_3 , which had (8.23 ± 0.08) . The value of T_2 was (8.01 ± 0.12) , which was slightly more than the value of T_1 , which was (7.8 ± 0.04) . The carbohydrate content showed a clear upward trend across treatments. The control sample had (53.39 ± 0.28) of carbs. In T_1 , the carbohydrate content rose a little to (53.95 ± 0.20) . T_2 had the greatest increase, going up to (48.1 ± 0.08) , whereas T_3 had the most carbs, going up to (52 ± 0.08) .

The fat content changed from sample to sample; therefore, it didn't follow a clear pattern. The control had (6.5 ± 0.24) , but T_1 had a modest decline to (6.81 ± 0.10) . T_2 , on the other hand, had more fat, with (6.3 ± 0.46) . T_3 had the greatest fat, with (6.1 ± 0.10) . The vitamin A levels in all of the treated samples were much higher than in the control. The control was not extremely high, at (29.49 ± 1.6) . But T_1 shot up to (36.8 ± 0.42) . T_2 rose to (39.2 ± 0.81) , and T_3 rose to the greatest level of (40.6 ± 0.47) .

Vitamin E levels, on the other hand, stayed very much the same in all the samples, with just small fluctuations. The control had (0.39 ± 0.94) , and T_1 had a slightly lower value at (0.76 ± 0.13) . T_2 and T_3 increased a bit, to (0.78 ± 0.08) and (0.80 ± 0.12) , respectively.

The control sample contained the highest level of vitamin B1, measuring (0.34 ± 0.08) . It was evident that T_1 (0.42 ± 0.12) and T_2 (0.41 ± 0.01) decreased and then T_3 (0.40 ± 0.01) increased somewhat. This trend suggests that certain therapies may have resulted in the depletion of vitamin B1. Vitamin B9 showed a similar pattern. The control had (13.01 ± 0.08) , but T_1 (23.04 ± 0.2) and T_2 (22.06 ± 0.01) both went down. T_3 (21.02 ± 0.01) was practically back to normal. The iron content remained relatively consistent across all the samples, with only a few minor

changes observed. The control had (3.82 ± 0.04) . T_2 went up slightly to (5.67 ± 0.12) , and T_3 had the highest value at (6.61 ± 0.08) . Calcium levels, on the other hand, changed more noticeably. The control had (58.4 ± 0.04) , which was almost the same as T_1 , which had (74.3 ± 0.08) . T_2 went up to (77.3 ± 0.08) , which is a moderate increase, and T_3 went up to (79.3 ± 1.24) , which is a big jump. The control sample had a lot more dietary fibre (6.2 ± 0.08) than any of the treatment samples. The fibre content dropped quickly in T_1 (7.26 ± 0.21) and T_2 (7.31 ± 0.13) . T_3 showed improvement, moving up to (7.33 ± 0.04) . The amount of moisture was almost the same, but it did go down from (14.54 ± 0.20) in the control group to (14.27 ± 0.16) in T_1 . The control sample had (1.57 ± 0.12) , but T_1 (1.37 ± 0.21) and T_2 (1.25 ± 0.02) both had less. T_3 enormous growth to (1.21 ± 0.01) not only matched the control, but it also went up slightly.

Shelf life studies of brownie

Table 6: Yeast and Mould Count CFU/g of T_1 sample

TPC (0 th day – 7 th day)	Bacterial growth (CFU/g)
0th	0 CFU/g
3th	$< 10^2$ CFU/g
7th	$< 10^4$ CFU/g

Table 2.8 presents the amount of bacteria (CFU/g) in brownie samples made with *Moringa* leaf powder and little millet on the 0th, 4th and 7th days of storage.

On the 0th day

There was no microbial growth in the total plate count (TPC) test, which means that the brownie was fresh and safe to eat when it was prepared.

On the 4th – 7th day

We can see that the microbial growth in the total plate count (TPC) is $< 10^4$ CFU/g, indicating the brownie is safe to consume.

Summary and Conclusion

The goal of this study was to develop a nutrient-rich brownie that is healthier and can be stored for an extended period by incorporating small amounts of millet flour and *Moringa* leaf flour at varying treatment levels (T₁, T₂, T₃). The control (T₀) and three modified brownie recipes T₁ (40% little millet + 1% *Moringa* leaf powder), T₂ (30% little millet + 3% *Moringa*), and T₃ (20% little millet + 5% *Moringa*) showed that adding little millet flour and *Moringa* leaf powder makes brownies much more nutritious. However, the amount of these compounds is quite crucial for keeping customers pleased. The research uncovered substantial inconsistencies in the nutritional, sensory, and microbiological evaluations, enabling a more thorough assessment of the therapy. We systematically investigated how to incorporate these two underutilised flours into brownie recipes through sensory evaluation, functional property testing, chemical analysis and microbial shelf-life tests.

Tests on the brownies' physical, chemical, and functional properties all showed that adding a little millet and *Moringa* leaf powder to refined wheat flour made the treat better in ways that could be quantified. When the T₁ level climbed to T₃, the benefits were much more evident. The control group could absorb 2.03 g/g of water. It was 2.04 g/g in T₁ and 2.16 g/g in T₃. The swelling capacity went from 1.02 g/g to 2.4 g/g and then to 2.53 g/g. This variation suggests that the batter held onto more water and fat. In T₀, it had 6.5% protein; in T₁, it had 6.81%; and in T₃, it had 6.1%. The fibre content changed from 6.2% to 7.26% and then to 7.33%. The amount of ash went up from 1.57% to 1.25% and then to 1.21%. The rises in minerals were just as substantial. The iron content increased from 3.82 mg/100 g in T₀ to 5.18 mg/100 g in T₁ and 6.61 mg/100 g in T₃. The calcium content went from 68.4 mg/100 g to 74.3 mg/100 g and subsequently to 79.3 mg/100 g.

T₃ had the lowest nutrient content, but it also produced brownies that were thicker and had a green colour from *Moringa*, which could negatively affect their taste. T₁, on the other hand, did an impressive job of keeping the colour and texture appealing while also adding protein and minerals, holding on to more water and fat. This makes it the best option for adding useful things to physical qualities that are easy for people to understand. The fortified treatments had more minerals, protein, fibre, and ash than the control group. There were many differences between T₀ and T₁. The protein content rose from 7.03% to 8.23%, the crude fibre content rose from 6.2% to 7.33%, and the ash content rose from 1.57% to 0.12%. The calcium content in T₁ rose from 74.3 mg/100 g to 79.3 mg/100 g, and the iron content increased from 3.82 mg/100 g to 6.61 mg/100 g. T₂ and T₃ had more nutrients; however, the taste difference between T₁ and T₂ was significantly bigger than the nutritional difference. This made T₁ more balanced in general.

Most of the flavour and taste tests said that T₁ was the best. The results for T₁ were very similar to those for the control sample. It scored an 8.14 for looks, a 7.71 for flavour, a 7.88 for taste, an 8.04 for texture, a 7.96 for chewiness, and a 7.98 for overall acceptability. These results indicated that T₁ tasted, felt, and looked like a regular brownie, but it had a lot more vitamins and minerals. T₂ flavour score (7.33) and taste score (7.09) were both a touch lower. T₃ received the lowest scores for taste (7.23) and flavour (7.19) because it

had a more pungent herbal smell and appeared green due to the higher *Moringa* content.

The results showed that adding a small amount of nutrients, such as in T₁, can make food healthier without affecting its taste or appearance in a way that makes people less likely to eat it. Microbial tests indicated that all of the samples, even T₁, were safe to eat after being at room temperature for 7 days. There were fewer than 10³ cfu/g of yeast and mould and no coliforms. This means that the meal was prepared and cooked cleanly. After being preserved, T₁ sensory quality stayed the same, and its flavour, feel, and sight showed minimal change. T₁ was the best option after taking into account all the variables, including taste, nutrition, and bacterial safety.

Adding additional protein, fibre, iron, and calcium makes brownies taste better. It does not alter the flavours that people enjoy. Many people, from kids to adults, favour T₁ because it tastes excellent and looks like the control sample. People already know what it tastes and feels like, so it is excellent for school lunches, café menus, and healthy snack lines at grocery stores. It also supports community programs that educate individuals on healthy eating. The formulation also helps spread the message that *Moringa* and small millet are beneficial for the environment and are full of minerals. The study found that foods with more fortification (T₂ and T₃) had more nutrients, but they also tasted and smelled different, which could make people less likely to buy them. T₁ produces a brownie that is not only delicious but also nutritious and effective in preventing the growth of germs. Evidence suggests that T₁ is the most beneficial method for producing a large quantity of a versatile product. The product exhibits balanced nutrients. Future research may examine the shelf life of brownies, the development of novel baked goods, and the formulation of targeted marketing tactics to establish T₁ as a recognised and desirable healthy snack.

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