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Development of nutritional millet based biscuits incorporated with amaranth seeds

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Abstract

Millets are acknowledged as "coarse cereals" but considering its nutritional composition, they are now regarded as "nutricereals". In this present investigation, five different types of millet biscuits, *i.e.*, T_1, T_2, T_3, T_4 and T_5 were developed by using millet grains, *i.e.*, pearl millet, foxtail millet and finger millet along with incorporation of amaranth seeds. The developed biscuits were tested for sensory and physico-chemical evaluation. Furthermore, based on the score of sensory evaluation and nutritional composition, developed T_5 biscuit that comprised of 10:10:2.5:7.5:20 ratio of wheat flour, pearl millet flour, foxtail millet flour, finger millet flour, amaranth seed flour achieved highest values in terms of nutritional evaluation. The iron and zinc content of T_5 was 3.95 ± 0.03 mg and 1.44 ± 0.03 mg, respectively which would suffice nearly 1/8th of the daily dietary iron requirements.

1. Introduction

India represents itself as a "Golden land of agriculture," where our diligent farmers grow varieties of nutrient rich crops including millets. Millets are acknowledged as "coarse cereals" but considering their nutrient composition they are now regarded as "nutricereals" (Saini *et al*., 2021). They, are enriched with nutrients and serve as a good source of many health-promoting constituents like good quality proteins, carbohydrates, dietary fibres, unsaturated fatty acids, minerals, antioxidants and phytochemicals (Bhat *et al*., 2018).

In millets, pearl millet (*Pennisetum glaucum* (L.) R.Br.) is superior in protein (14.0%), fat (5.7%), fiber (2.0%) and ash (2.1%) content when compared to other major cultivated cereal crops such as wheat and rice (Kavitha and Parimalavalli, 2014). It is a good source of calcium, iron (8.8 mg/100 g) as well as zinc (Yadav *et al*., 2014). This iron-rich millet being packed with polyphenol which possesses antioxidant activity (AOA) and also contains phytate (647 mg/100 g), tannin (0.010%) as catechin equivalent (Osman, 2011). Likewise finger millet (*Eleusine coracana* (L.) Gaertn.) possesses carbohydrate (81.5%), starch (65% to 75%), protein (9.8%), fat (1% to 1.7%), mineral (2.7%) and fiber (4.3%), which is comparable with other millets and cereals like wheat and rice (Saleh *et al*., 2013). It is packed with rich sources of zinc (2.53 mg/100 g), iron (3.9 mg/100 g) and polyphenols. Certain antinutritional factors like tannins (0.04-3.47%) and phytates (0.48%) also adorn this millet (IFCT, 2017; Rathore *et al*., 2019). Similarly, the foxtail millet (*Setaria italica* (L.) P. Beauv.) is a good source of starch, protein, fiber, fats, vitamins and minerals. The moisture, ash, protein, fat, fiber and carbohydrate content of foxtail millet is 9.35 per cent, 3.10 per cent, 10.29 per cent, 3.06 per cent, 4.25 per cent and 69.95 per cent, respectively. Adequate amount of zinc (4.1 mg/100 g) is present in foxtail millet with fair source of iron (2.7 mg/100 g). This millet also contains significant amount of total phenolic content, *i.e.* (33.17 mg (GAE)/100 g) with tannin (2.80 mg/100 g) and phytate (0.341 mol/kg) (Sharma *et al*., 2015).

Along with millets, some pseudocereals also gain their nutritional importance in present scenario due to abundance of proteins, phenolic acids, minerals, vitamins, amino acids, dietary fibers and unsaturated fatty acids (Pirzadah and Malik, 2020) which are helpful to human health. One of the major pseudocereal, *i.e.*, amaranth seed contains largest amount of protein, twice as much as essential amino acids, lysine, more dietary fibre and 5 to 20 times the calcium and iron content with respect to other grains (Venskutonis and Kraujalis, 2013). This gluten-free amaranth seed (*Amaranthus viridis* L.) in comparison with other grains contains protein, *i.e.*, 13.27 g, 5.56 g (fat), 7.47 g (fibre), 3.05 g (ash), 61.46 g (carbohydrate), 8.02 mg (iron), 2.52 mg (zinc) per 100 g grains (IFCT, 2017). Bioactive compounds like total phenolic content (26.65 mg GAE/100 g), phytic acid (0.70 g/100 g), tannin (0.19 g catechin equivalent/100 g) are also present in amaranth seed (Perales Sanchez *et al*., 2014; Hezazi *et al*., 2016).

Food plays a key role in the effective development of body in order to maintain an individual's health (Gupta and Sarwat, 2022). The interactions among physiological function, illness and diet have continued to improve in current scenario (Pushpangadan *et al*., 2014). Hence, iron rich value-added millet-based products are useful to provide most of the daily dietary iron requirements which will be beneficial to control iron deficiency anemia. The findings of Chuwa and Dhiman (2022) indicated that iron rich instant muffin mix supplemented with amaranth grain flour utilized as a supportive

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food for alleviating iron deficiency anemia. Awareness among the people regarding positive impact of millets on their haematological health aids in creating an optimistic outlook towards millets. Millet crops are conventionally used as dumplings, porridge, roti and desserts (Mounika and Hymavathi, 2021). Very few millet-based convenience products like biscuits, muffins, cakes, *etc*., are available in the market but they are not so popular among people. Generally, food use of millets has been confined to only traditional consumers and very few Indians are acquiring the knowledge of their health benefits and nutritional value. Therefore, different processing of millets using contemporary as well as traditional methods for preparation of value-added products would diversify their food uses. Keeping all these point, the present study was taken into an objective of development of nutritional millet based biscuits incorporated with amaranth seeds.

2. Materials and Methods

2.1 Procurement of raw materials

The millet grains, *i.e*., pearl millet (Pusa hybrid 1202), foxtail millet (Rajendra kauni 1) and finger millet (RAV 8) along with amaranth seeds (GA-1) each of 1 kg were used to develop the products. All the raw materials were procured in a lot at a time in order to avoid any varietal differences during the entire investigation. Other required food ingredients for the development of products were brought from the local market of Pusa, Samastipur district of Bihar. After cleaning and washing, the entire millet grains were soaked for 12 h. After soaking, pearl millet was germinated for 72 h, finger millet and foxtail millet were germinated for 48 h. This was in line with Owheruo *et al.* (2018) study which revealed that germination of pearl millet for 72 h brought about an significant increase in protein, fibre, minerals and phytochemicals and able to meet the criteria for being served as a functional food.

Laxmi *et al.* (2015) suggested that processing technique like germination (48 h) was used to improve the nutritional or organoleptic characteristics of foxtail millet flour. Another study, Shingote *et al.* (2021) analyzed the effect of malting on nutritional composition of finger millet by soaking it in water for 12 h and allowed to germinate for two days. The result showed the positive impact. After germination, all the grains were sun-dried and grinded to fine flour through domestic chakki. Other than that, amaranth seeds were cleaned and grinded to fine flour. Then, the total amount of flour was sieved through 80 mesh size and kept in an air tight container separately at room temperature for future use. A flow sheet of development of flour is shown in Figure 1.

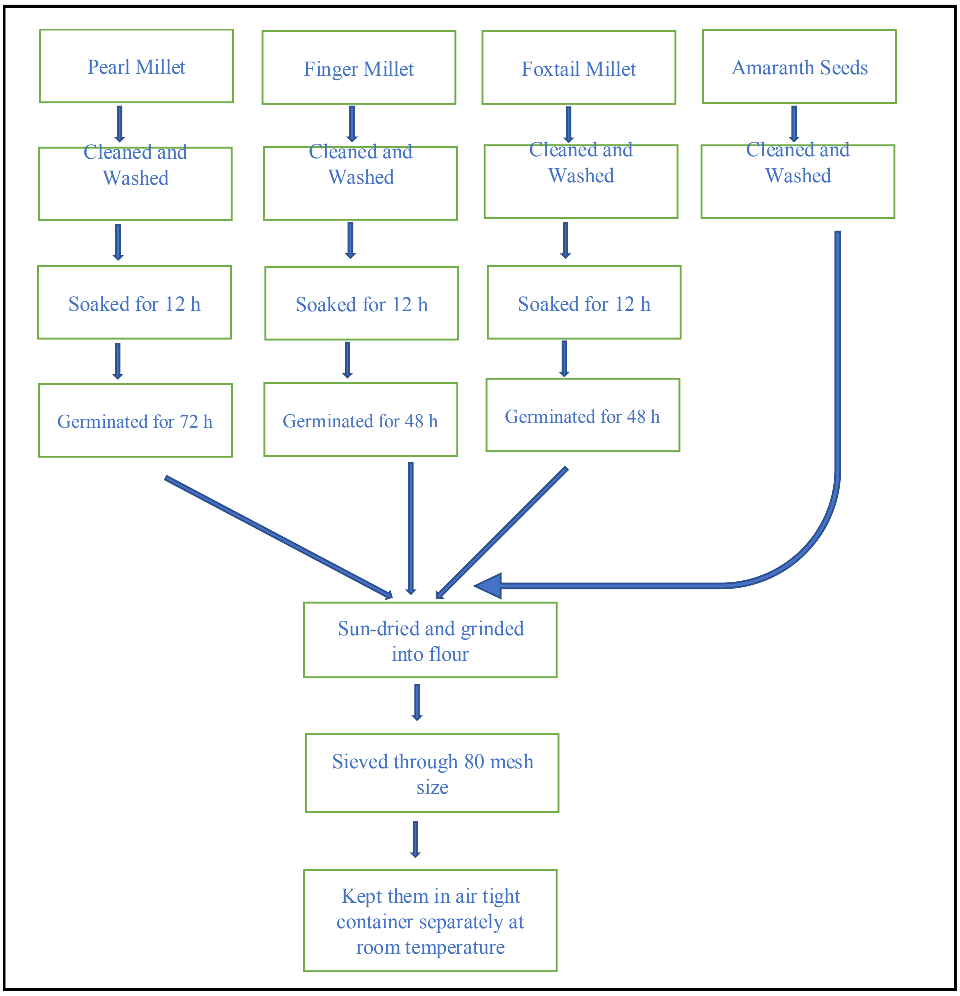

Figure 1: Flow sheet of development of flour.

2.2 Preparation of millet biscuits

Millet and amaranth seed flour were more beneficial with reference to micronutrients content when included in bakery products, so it was planned to incorporate both in development of biscuits in order to eliminate our complete reliance on wheat. In contrast to millet flour and amaranth flour; whole wheat flour, jaggery, powdered sugar, unsalted butter, cardamom powder, baking powder and baking soda were used for the development of biscuits. These ingredients were purposively selected because they were locally available and affordable whereas jaggery was preferred due to its high iron content. After this, considerable attempts were undertaken for standardization of biscuits. In this present investigation, five different types of millet biscuits, *i.e.*, T_1, T_2, T_3, T_4 and T_5 were developed and standardized by using different combinations of flour where whole wheat flour was used for control biscuit. The other raw ingredients, *i.e.*, unsalted butter, jaggery, powdered sugar, *etc*., were kept constant for all the combinations as present in Table 1. A flow sheet for preparation of millet biscuits was given in Figure 2. The formulated millet biscuits were presented in Plate 1.

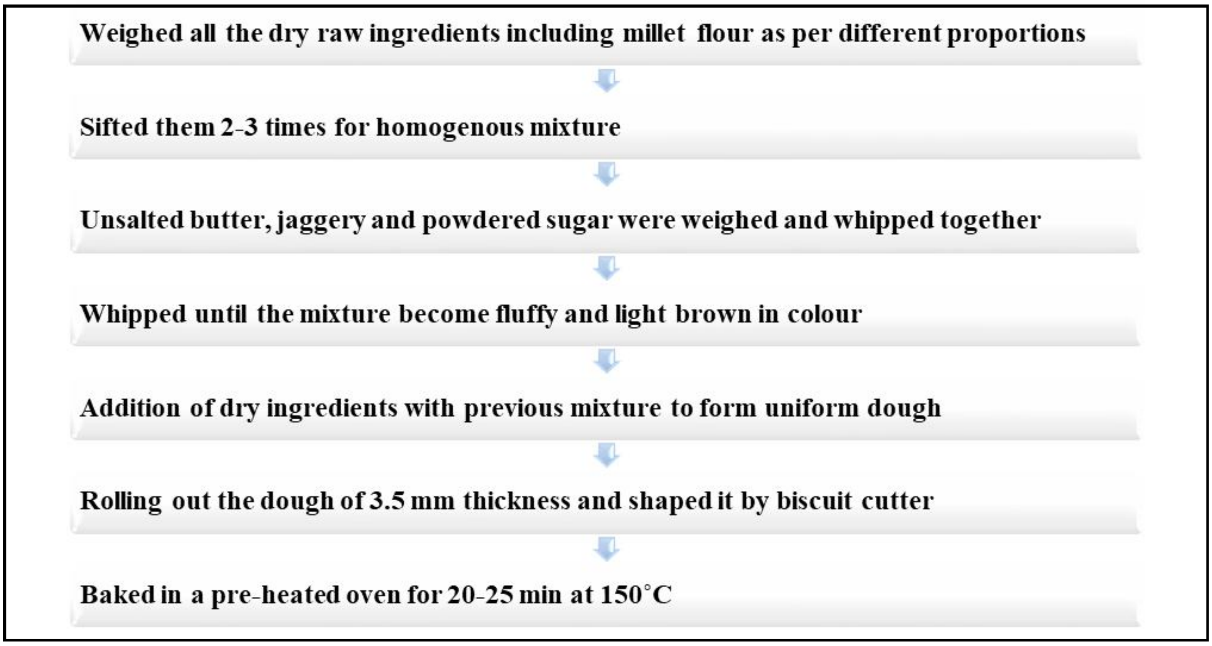

Figure 2: Flow sheet for preparation of millet biscuits.

Table 1: Formulation of millet biscuits

Treatments	Control	T_1	T_2	T_3	T_4	T_5
Whole wheat flour (g)	50.00	25.00	30.00	15.00	15.00	10.00
Pearl millet flour (g)	-	5.00	7.50	7.50	10.00	10.00
Foxtail millet flour (g)	-	5.00	2.50	2.50	-	2.50
Finger millet flour (g)	-	15.00	10.00	10.00	10.00	7.50
Amaranth seed flour (g)	-	-	-	15.00	15.00	20.00
Unsalted butter (g)	25.00	25.00	25.00	25.00	25.00	25.00
Jaggery (g)	12.50	12.50	12.50	12.50	12.50	12.50
Powdered sugar (g)	10.00	10.00	10.00	10.00	10.00	10.00
Cardamom powder (g)	2.50	2.50	2.50	2.50	2.50	2.50
Baking powder (g)	0.30	0.30	0.30	0.30	0.30	0.30
Baking soda (g)	0.30	0.30	0.30	0.30	0.30	0.30
Total (g)	100.60	100.60	100.60	100.60	100.60	100.60

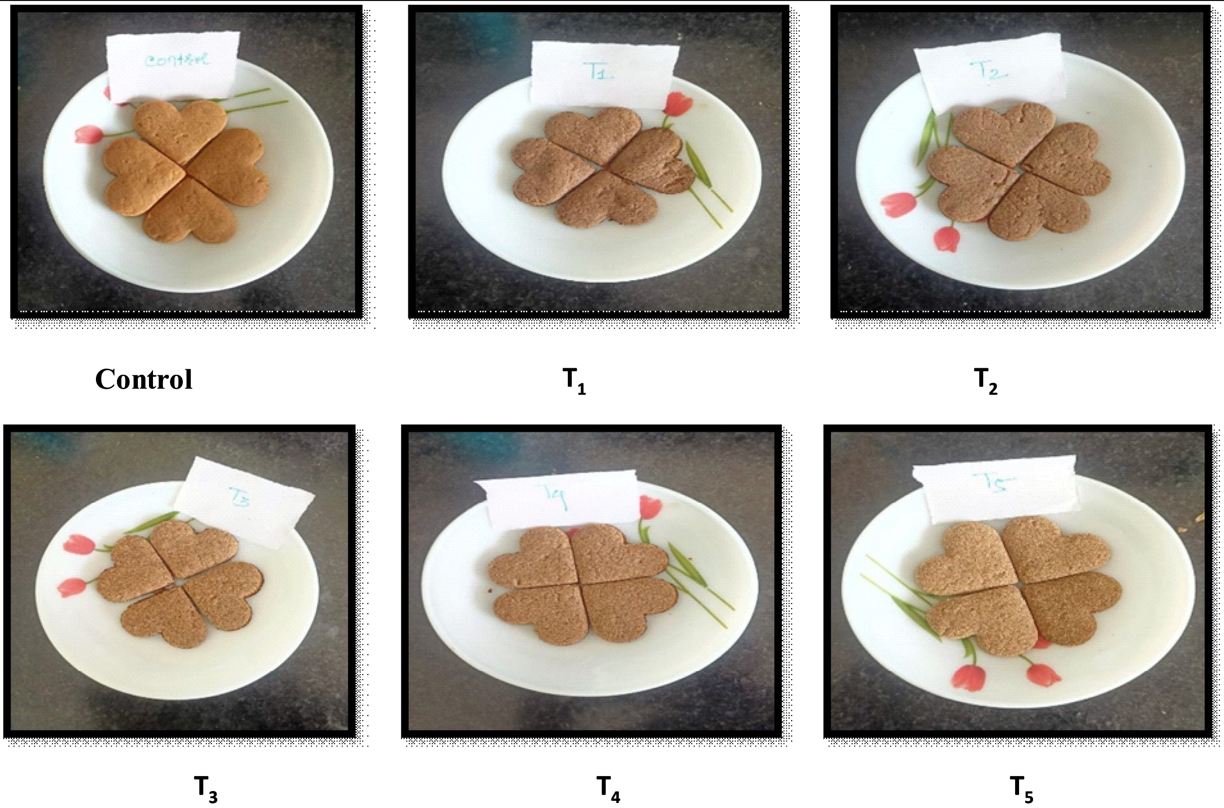

Plate 1: Formulated millet biscuits.

2.3 Organoleptic analysis of the millet-based biscuits

The developed millet biscuits were subjected to organoleptic analysis in a laboratory area by a panel of thirty semi-trained judges at mid-morning in an ambient condition. The nine-point hedonic score card was used for evaluation of sensory characteristics.

2.4 Physicochemical evaluation of the millet-based biscuits

2.4.1. Physical evaluation

Under physical evaluation, texture evaluation was a crucial phase for the development of millet-based products. The most important factor was hardness, which was analyzed with the help of a texture analyzer (TA-XT, Stable Micro Systems, U.K.). The flexure attachment was tightened properly into the load cell carrier. The instrument bed was attached by using fixing screws to locate the base into heavy duty platform. The two plate fastening screws was tightened to secure the base position to the heavy-duty platform. The two adjustable supports were set at a proper distance apart to support the developed biscuit and locked it in position. The heavy-duty platform was manoeuvred, then secured it firmly such that the upper blade was equidistant from the two bottom supports. Afterwards, the test was conducted.

2.4.2 Nutritional evaluation

The 100 g of developed biscuits were grinded into fine flour and kept it in air tight container for conducting nutritional evaluation.

2.4.2.1 Proximate composition

The moisture present in millet biscuits was evaluated by using hot air oven following standard procedure of AOAC (2005) method. The ash content of developed biscuits was analyzed by using muffle furnace following standard procedure of AOAC (2005). The crude fat and crude fibre content of millet biscuits was determined by AOAC (2000) method. The crude protein content of millet biscuits was estimated by AOAC (2005) method by using KEL PLUS-ELITE EX (VA). The carbohydrate content of developed biscuits was measured by subtracting total percentage of moisture, ash, crude protein, crude fat, crude fibre from 100. The energy value of millet biscuits was assessed by using physiological fuel value per gram of carbohydrate, protein and fat, respectively.

2.4.2.2 Iron and zinc

At first, minerals solution was prepared for analysis of iron and zinc content of developed biscuit. 0.5 g of millet biscuit sample was weighed and taken in 100.0 ml micro kjeldahl tube. 10 ml diacid (HNO_3: $HClO_4$ – 9:4 (1 litre)) was added and left overnight. Then, it was kept on a hot plate and heated gently. Then, it was heated vigorously till a colourless solution was obtained. The heating was discontinued when the volume was reduced to 1 ml (1 drop). Precaution was taken not to take up to dryness. Then, it was cooled and some distilled water was added. Then, it was transferred into a 100 ml volumetric flask. The volume was made by adding distilled water. The reading was taken by AAS. The iron and zinc content of developed biscuits were estimated by using THERMOSCIENTIFIC ICE 3000 SERIES Atomic Absorption Spectrophotometer (AAS) [Lindsay and Norvell (1978)].

2.4.2.3 Total phenolic content

The total phenolic content of millet biscuits was determined by using Folin-Ciocalteu reagent (Slinkard and Slingleton, 1997). In a shaking incubator, 1.0 g powdered millet biscuit sample was dissolved in 20.0 ml of methanol and incubated overnight. The content was centrifuged for 5-10 min at 3000 rpm, then the supernatant was collected. 100 µl of supernatant making volume balanced up to 1.0 ml with methanol were mixed with 0.5 ml diluted Folin-Ciocalteu's reagent in a tube and incubated at room temperature for 6 min. The solution was then treated with 1.5 ml of 7.5% Na_2CO_3. After adding 3.0 ml of distilled water, the reaction mixture was incubated for 30 min at 25°C. At 750 nm, the absorbance was measured using spectrophotometer. The findings were contrasted to a gallic acid calibration curve and the total phenolic content in the millet biscuit extraction was represented as mg of gallic acid equivalents per gram of extracts.

2.4.2.4 Tannin content

The tannin content was assessed by using Folin-Ciocalteu technique (Kavitha and Indira, 2016). A 5.0 g millet biscuit sample was boiling for 30 min in 100 ml distilled water. The content was centrifuged for 5-10 min at 3000 rpm, then the supernatant was collected. 100 µl of supernatant making volume balanced up to 1.0 ml with distilled water were mixed with 0.5 ml diluted Folin-Ciocalteu's reagent in a tube and incubated at room temperature for 6 min. The solution was then treated with 1.0 ml of 35% Na_2CO_3. 2.0 ml of distilled water was added in the reaction mixture and incubated at 25°C for 30 min. Tannic acid reference standard solutions (10, 20, 30, 40, 50, 60, 70, 80, 90, 100 µg/ ml) were developed in the same manner as previously reported. By using a UV/ Visible spectrophotometer, absorbance for test and standard solutions were determined against a blank at 700 nm. The tannin concentration was calculated in triplicate. The tannin concentration was measured in mg of tannic acid equivalents per g of dried sample.

2.4.2.5 Phytate content

Trichloroacetic acid is used to extract the phytate, which is then precipitated as ferric salt. The precipitate's iron content is quantified calorimetrically and the phytate phosphorus content is computed assuming a constant 4Fe:6P molecular ratio in the precipitate (Wheeler and Ferrel, 1971).

2.5 Statistical analysis

The organoleptic and physicochemical characteristics of the millet-biscuits were expressed as Mean ± SD and were analysed by using one-way ANOVA test at 5 per cent level of significance.

3. Results

3.1 Analysis of the organoleptic characteristics of the millet-based biscuits

The data represented in Table 2 revealed that the overall acceptability for all developed biscuits ranged from 8.26 ± 0.02 to 7.99 ± 0.02 which indicated that developed biscuits were liked very much to liked moderately. The score for overall acceptability was recorded highest for control which was 8.26 ± 0.02, followed by T_5 (8.23 ± 0.01), T_3 (8.13 ± 0.02), T_2 (8.06 ± 0.03), T_4 (8.00 ± 0.00), T_1 (7.99 ± 0.02).

Table 2: Analysis of the organoleptic characteristics of the millet-based biscuits

Treatments	Colour	Appearance	Taste	Flavour	Texture	Overall acceptability
Control	8.22 ± 0.01	8.29 ± 0.01	8.35 ± 0.06	8.31 ± 0.03	8.21 ± 0.01	8.26 ± 0.02
T_1	7.86 ± 0.01	7.94 ± 0.03	8.07 ± 0.05	8.03 ± 0.04	8.11 ± 0.01	7.99 ± 0.02
T_2	7.97 ± 0.02	8.10 ± 0.03	8.13 ± 0.02	8.10 ± 0.01	8.12 ± 0.01	8.06 ± 0.03
T_3	8.02 ± 0.03	8.13 ± 0.02	8.21 ± 0.03	8.17 ± 0.01	8.15 ± 0.00	8.13 ± 0.02
T_4	7.91 ± 0.01	8.01 ± 0.05	7.98 ± 0.04	7.93 ± 0.03	8.13 ± 0.00	8.00 ± 0.00
T_5	8.16 ± 0.02	8.22 ± 0.02	8.31 ± 0.02	8.26 ± 0.01	8.16 ± 0.00	8.23 ± 0.01
CD	0.06	0.08	0.18	0.09	0.03	0.07
CV	0.47	0.55	1.27	0.62	0.23	0.48

Values expressed as Mean ± SD and analysed by using one-way Anova.

LSD ($p<0.05$)

3.2 Evaluation of the physicochemical characteristics of the millet-based biscuits

3.2.1 Physical evaluation

The developed millet biscuits were evaluated for hardness/crispiness in order to know consumers prospective. The data presented in Figure 3 showed that there was non-significant difference ($p<0.05$) of hardness present among all the millet treatments. Control had significantly the lowest hardness ($p<0.05$) among all the treatments.

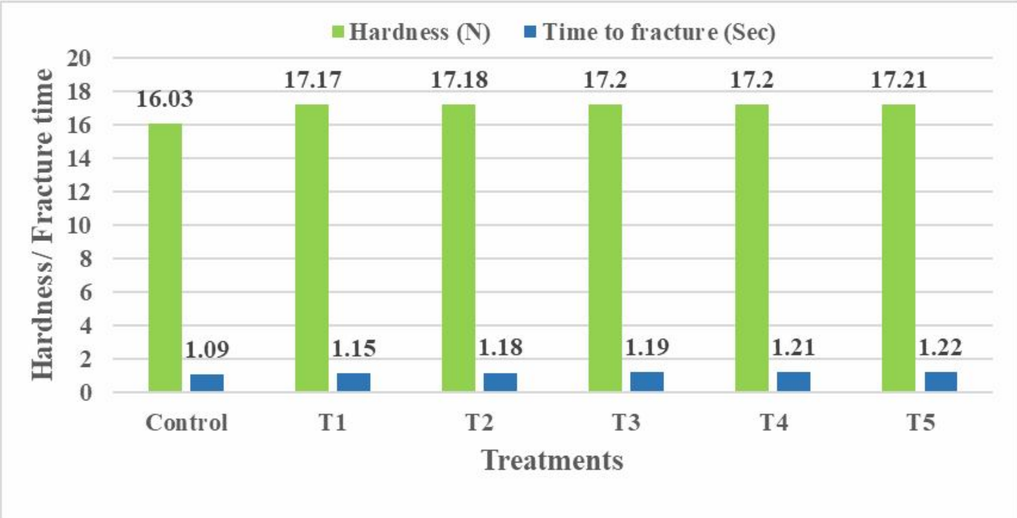

Figure 3: Hardness/crispiness of millet-based biscuits.

3.2.2 Nutritional evaluation

3.2.2.1 Proximate composition of millet-based biscuits

Persual of the data presented in Table 3 clearly indicated that the moisture content of millet biscuits was ranging from 4.00 ± 0.01 g to 4.30 ± 0.02 g. Statistical data revealed that there were no significant differences ($p<0.05$) observed for moisture content among all the treatments with respect to their control counterpart. There was a significant increase ($p<0.05$) in ash content recorded for all the millet treatments than their control counterpart. Highest ash content was observed in T_5 which was significantly increased ($p<0.05$) from all the treatments including control. A significant decrease ($p<0.05$) in fat content was observed in control compared to other millet treatments. T_5 was found to possess the highest fat content. The crude protein and crude fibre content of T_5 significantly increased ($p<0.05$) from all the other treatments including control, whereas in control it was found to be significantly decrease ($p<0.05$) from the other treatments. The carbohydrate content of control was recorded highest, *i.e.*, 65.61 ± 0.01g. It was significantly increased ($p<0.05$) from all the other millet treatments. The difference of energy content among control and T_5 was statistically non-significant ($p<0.05$).

Table 3: Proximate composition of millet-based biscuits (g/100g dry weight basis)

Treatments	Moisture (g)	Ash (g)	Fat (g)	Crude protein (g)	Crude fibre (g)	Carbohydrate (g)	Energy (kcal)
Control	4.30 ± 0.02	1.79 ± 0.02	21.15 ± 0.02	5.62 ± 0.05	1.53 ± 0.05	65.61 ± 0.01	475.26 ± 0.23
T_1	4.23 ± 0.04	2.07 ± 0.03	21.44 ± 0.06	5.77 ± 0.03	2.16 ± 0.05	64.33 ± 0.12	473.33 ± 0.51
T_2	4.15 ± 0.11	1.98 ± 0.05	21.38 ± 0.03	5.81 ± 0.04	1.94 ± 0.05	64.74 ± 0.13	474.56 ± 1.04
T_3	4.20 ± 0.05	2.14 ± 0.01	21.95 ± 0.02	6.12 ± 0.05	2.17 ± 0.05	63.42 ± 0.04	475.70 ± 0.28
T_4	4.00 ± 0.13	2.11 ± 0.04	21.96 ± 0.06	6.10 ± 0.06	2.08 ± 0.04	63.75 ± 0.28	477.04 ± 0.51
T_5	4.00 ± 0.01	2.29 ± 0.02	22.14 ± 0.01	6.38 ± 0.02	2.39 ± 0.05	62.80 ± 0.04	475.96 ± 0.26
CD	NS	0.10	0.13	0.14	0.16	0.44	1.71
CV	3.32	2.89	0.35	1.36	4.53	0.38	0.20

Values expressed as Mean ± SD and analysed by using one-way Anova.

LSD ($p<0.05$)

NS: Non-significant

3.2.2.2 Iron and zinc content of millet-based biscuits

It was depicted (Table 4) that T_5 had shown significant increase (p<0.05) in iron content among all other treatments which was contradicted with the value obtained for control that had shown significant decrease (p<0.05) in iron content comparing with all other treatments. With respect to zinc content, there were absence of significant differences (p<0.05) among all the millet treatments, but difference of zinc content between control and T_5 was statistically at par.

3.2.2.3 Total phenolic content of millet-based biscuits

A close persual on the data presented in the Figure 4 clearly indicated that total phenolic content of control was significantly decreased (p<0.05) from all the millet treatments. A non-significant difference (p<0.05) was observed among T_1, T_2 as well as T_5 regarding total phenolic content. Total phenolic content of T_1 was significantly increased (p<0.05) from T_3 and T_4.

Table 4: Iron and zinc content of millet-based biscuits

Treatments	Iron (mg/100 g)	Zinc (mg/100 g)
Control	2.89 ± 0.02	1.56 ± 0.03
T_1	3.07 ± 0.03	1.36 ± 0.03
T_2	3.10 ± 0.07	1.45 ± 0.03
T_3	3.72 ± 0.04	1.38 ± 0.03
T_4	3.74 ± 0.04	1.39 ± 0.06
T_5	3.95 ± 0.03	1.44 ± 0.03
CD	0.14	0.12
CV	2.32	4.79

Values expressed as Mean ± SD and analysed by using one-way Anova.

LSD (p<0.05)

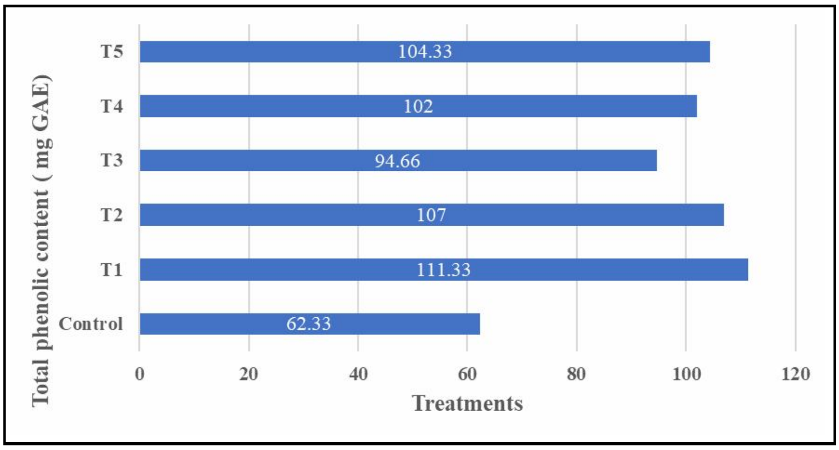

Figure 4: Total phenolic content of millet-based biscuits.

3.2.2.4 Tannin and phytate content of millet-based biscuits

The estimation of tannin content from Figure 5 revealed that T_5 recorded the highest tannin content while control had the lowest tannin content. The phytate content of control was higher while that of T_1 was lower. A significant difference (p<0.05) was observed in phytate content among all the treatments except between T_4 and T_5 and between control and T_5 which was shown non-significant differences (p<0.05).

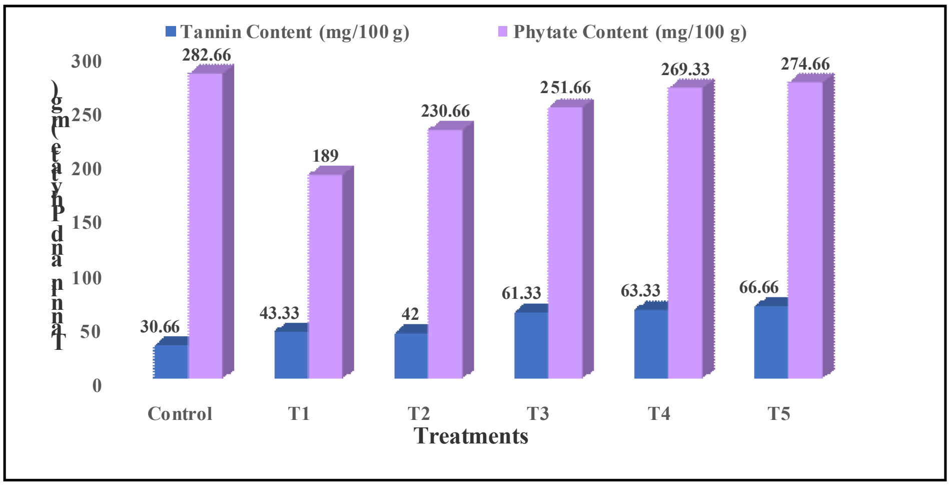

Figure 5: Tannin and phytate content of millet-based biscuits.

4. Discussion

After standardization of biscuits, the organoleptic and physicochemical analysis were carried out because the ultimate criteria of acceptance of any food product is its quality. With respect to colour, the difference of score between control and T_5 was statistically at par, but in case of appearance, a non-significant difference (p<0.05) was observed between control and T_5. After that T_1 was recorded lowest score regarding colour and appearance. The reason for less acceptability of T_1 might be due to the presence of high proportion of finger millet flour in comparison with other millet treatments which brought dark brown appearance to this particular treatment. In terms of taste and flavour, non-significant difference (p<0.05) was observed between control and T_5. The data also suggested that significant increase (p<0.05) score of texture was seen in case of control when it compared with other millet treatments. There might be difference of value due to the coarseness of millets and amaranth grains present in the millet treatments. At last, statistical data revealed that control and T_5 was differed non-significantly (p<0.05) with respect to overall acceptability. Moreover, it was concluded that the T_5 millet biscuit recorded highest organoleptic score next to control. Some references suggested that inclusion of millets in our diet was a better choice to lead a healthy life-style. Pandit *et al*. (2021) developed crackers and revealed that pearl millet crackers (Pearl millet flour: Sorghum flour: Soybean flour in the ratio of 60:30:10) were highly accepted by the consumers and helpful to provide potential health benefits.

The increased hardness in millet biscuits might be due to the processing of millet flour for the development of biscuits. Similar results had been reported by Agrahar-Murugkar *et al.* (2014) who revealed that sprouted flour biscuits were found to be higher hardness as compared to unsprouted flour due to the presence of free sugars available on sprouting. After that, it was concluded that there was a positive relationship present between hardness and time to break the biscuit.

The nutritional composition of different treatments disclosed that among all the treatments including control, T_5 was nutritionally superior and significant (p<0.05) pertaining to ash, fat, crude protein, crude fiber and iron. On the other hand, control was nutritionally less superior and significant (p<0.05) in terms of ash, fat, crude protein, crude fiber and iron content when compared with all other treatments. The germination of millet and presence of amaranth seed might be the reason which aid in elevating the nutritional content of T_5 millet biscuit. This value was supported by several findings. A study conducted by Sharma *et al*. (2015) indicated that optimized germinated foxtail millet flour contained higher dietary fiber, protein, magnesium, calcium, iron, sodium and lower antinutritional factors like phytate. Some investigators like Owheruo *et al.* (2018) revealed that protein and crude fiber content of pearl millet and finger millet flour was increased upon germination for 72 h. The findings of Iswarya and Narayanan (2017) revealed that germination of biofortified pearl millet significantly enhanced fat, ash, protein, calcium, iron and zinc content. Shukla *et al*. (2020) also suggested that amaranth flour possessed significant level of ash, fat, protein, crude fiber than cereals. Skwarylo-Bednarz *et al*. (2020) further revealed that amaranth seed comprised five times higher iron than wheat and, therefore it was found to be the favourable component of diets and nutritional products for anemic individuals.

In overall treatments, significantly lowest carbohydrate content (p<0.05) was noticed in T_5 (62.80 ± 0.04 g) with respect to other treatments; the reason for decreasing the value of carbohydrate content in this millet treatments might be due to the presence of increased crude protein, ash and crude fiber content. The findings of Chuwa *et al.* (2022) stated that wheat had significant amount of carbohydrates. Thus, control scored the highest zinc content because wheat might be considered as a good source of zinc. This study was in line with Hussain *et al*. (2018) who developed healthy multi-grain biscuit combining buckwheat flour, barley flour and wheat flour. From this study, it was revealed that wheat flour contained good amount of zinc, *i.e.*, 2.71 mg/100 g.

Presence of high proportion of finger millet flour might be the reason for increased total phenolic content in T_1 as compared to other treatments. This study was in line with Dhan and Ganga (2012) who revealed that total phenolic content was increased during 48 h germination in finger millet varieties.

Control possessed the lowest tannin content whereas T_5 possessed the highest tannin content among all the treatments. The combination of unprocessed amaranth seed flour with germinated millet flour might be responsible for the higher tannin content in T_5. Another assumption could be taken that wheat flour might have less tannin. Wang *et al*. (2015) revealed in their study that wheat flour contained less tannin so they improved the mixing properties of dough by addition of tannin. Another study of Nazni and Shobana (2016) concluded that germination reduced the anti-nutritional factors and improved the nutrient content and digestibility of the foxtail millet.

Regarding phytate content, control had the highest phytate content might be due to the presence of wheat flour. This was in line with the study conducted by Azeke *et al*. (2011) which indicated that wheat contained about 5.6 mg phytate per g which further decreased during germination for 10 days. Kulthe *et al*. (2018) also reported similar value of phytate content in their cookies which was prepared by substituting maida with pearl millet flour.

Even though T_5 possessed higher tannin and phytate content than other treatments, its level was lower than the maximum acceptable daily intake of tannic acid and phytate for human being. This was supported by Akin-idowu *et al*. (2017) who observed that tannin content and phytate content of five grain amaranth species was ranging from 0.10-0.14 g and 1.16-1.58 g per 100 g which was lower than the maximum acceptable tannic acid and phytate daily consumption for humans.

5. Conclusion

The developed millet-based biscuits are enriched with many health-promoting constituents like proteins, carbohydrates, fibers, iron, zinc and total phenolic content. The overall acceptability for all the developed biscuits ranged from 8.26 ± 0.02 to 7.99 ± 0.02 which indicated that developed biscuits were liked very much to liked moderately. The nutritional composition of different treatments disclosed that T_5 was nutritionally superior and control was nutritionally less superior pertaining to ash, fat, crude protein, crude fiber and iron content when compared with all other treatments. Furthermore, based on the data, T_5 was selected as desirable treatment combination for development of nutritionally superior and acceptable millet based biscuits.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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