Original Research Article

Standardization and Evaluation of Techno Functional and Physicochemical Properties of Foxtail Millet Cookies Processed with Spice Incorporation

ABSTRACT:

Background: Foxtail millet is a rich source of vitamins, minerals and contain high fiber content which helps in improving resistance to disease, lowers cholesterol and blood sugar, and helps people with diabetes and gastrointestinal problems. Millets are gluten free making it an excellent alternative for individuals with celiac disease or gluten intolerance. Spices are widely used in food processing for their flavour, aroma, and potential health benefits. Incorporating spices into food products like cookies and bakery products not only enhances the sensory profile but can also contribute to the nutritional and functional quality of the product. Especially cumin (or) jeera used in ayurvedic system of medicine in India, cumin seeds have immense medicinal value, particularly for digestive disorders. They are used in chronic diarrhoea and dyspepsia.

Aim: To standardize the jeera incorporated foxtail millet cookies (FMC) by replacing wheat flour with different proportions of foxtail millet flour and evaluating their physico functional and bioactive compounds.

Study design: Experimental design

Place and Duration of Study: Post Graduate and research Centre (PGRC) and Millet Processing and Incubation Centre (MPIC) PJTSAU, Rajendranagar, during 2023 and 2024.

Methodology: Standardized the jeera incorporated foxtail millet cookies (FMC) by replacing wheat flour with different proportions of foxtail millet flour (20%, 40%, 50%, 80% and 100%)**.** Based on the sensory scores the best accepted formulation of foxtail millet cookies was further analyzed for physical parameters like diameter, thickness, bulk density and color (*h*, C*, L*, a** and *b**) values. Functional parameters which include oil absorption capacity (OAC) and water absorption capacity (WAC). Proximate and antioxidant compounds namely TPC (Total phenolic content), TFC (Total flavonoid content) and DPPH (Diphenyl-2-picrylhydrazyl radical scavenging assay) were analysed. Statistical tools such as ANOVA and t-test was used for analysis of data and drawing of conclusions.

Results: No difference was observed between the control cookies and the FMC_{80} for taste and consistency ($P > 0.05$). Significant difference was identified between the samples among various parameters like physical, functional, proximate and bioactive compounds. FMC_{80} cookies have a significantly larger diameter (35.16±1.526 mm) than control cookies (CC) (33.48±1.051 mm). Thickness of CC co are thicker (11.32±0.170 mm) compared to FMC_{80} (10.78±0.617 mm). In Color parameters FMC_{80} cookies exhibit higher hue and yellowness, lower redness, and slight increases in lightness and chroma compared to CC. Proximate and minerals composition analysis shows that the ash content was higher in FMC_{80} (1.15±0.12) compared to CC (0.75±0.13). Fat content of FMC_{80} was more (23.88±0.51) than CC (22.19±0.79). Crude fibre was significantly higher in FMC_{80} (1.41±0.22) compared to CC (0.33±0.04). Protein content of FMC_{80} (11.10±0.14) was more when compared to CC (4.75±0.45). Carbohydrate and energy in control cookies was (69.79±0.866) but lower energy (497.8±3.48) compared to FMC_{80} cookies (carbohydrate-61.42±8.70 and energy - 505±1.00). Minerals analysis of FMC_{80} shows higher levels of iron, zinc, sodium, and potassium than control cookies. Phenols, flavonoids and DPPH exhibited higher values for foxtail cookies as compared to control cookies.

Key words: Foxtail millet cookies, Cumin seeds, Sensory evaluation, Physical, Functional, Nutritional, Bioactive compounds.

1 INTRODUCTION

To achieve a healthy life style consumers are having high expectations from the food industry to come up with the health promoting food products. For this purpose, functional foods play a specific role. Such foods not only satiate hunger and also provide essential nutrients, but also to prevent nutrition related diseases and increase physical and mental well-being of consumers [1]. Attentiveness in the bakery products is expanding day by day because of their nutritional properties and feasibility of their use in feeding programs and disaster situations such as earthquakes. Among the bakery products, biscuit is a versatile snack of the food industry occupying a notable position due to its attractive features like longer shelf life, varied taste, and texture, including wider consumption [2]. The word biscuit derives from the Latin word '*panis biscoctus'* which meant for the twice-cooked bread usually made for mariners and named as ship biscuits. According to Johnson the primary definition to biscuit as 'hard dry bread, made to carry to sea'. According to Britain, 'biscuit' includes items like crackers, cookies, wafers. Britishers were the first to make the biscuit [3]. From a labour-intensive craft industry to a well-mechanized science-based industry, biscuit manufacturing has evolved over time. Nowadays, biscuits are used as a basic food item, a high-end present, a snack, baby food, nutritional supplements, dog and cat food, and decorative items that are flavoured with chocolate, cream, nuts, and other ingredients. Due to this, there is a great deal of room for improvement in the biscuit's nutritional quality in order to satisfy the enormous consumer demand for biscuits made with healthier ingredients and to make them taste better [2]. Bread, biscuits and cookies are the cereal based popular bakery products. worldwide both in urban and rural areas bakery products are consumed because of their affordable cost, stimulating taste, prolonged shelf life and convenience and handpicked by all age group population [4]. Wheat flour, sugar and fat these three major ingredients used to prepare bread, biscuits and cookies, which are low in moisture content high in fat and carbohydrates [5]. Around the world, biscuits are widely consumed as a snack food, particularly in developing nations where malnutrition due to inadequate protein and calories is common [6].

Millets are regarded as the "future crops" because they adapt well to the harsh conditions of Asia's and Africa's arid and semi-arid regions and are resistant to the majority of pests and diseases. Thrives in warm and harsh weather crop matures in 65–70 days, contributing significantly to its short growing season and successful output. Millets are referred to as "nutritious grains" because of their abundance in vitamins, minerals, sulphur-containing amino acids, and phytochemicals these are tag lined as "today's Nutri-cereals and yesterday's coarse grains" [7]. The nutrient-dense, easily digested foxtail millet boasts a nutty, sweet flavour. It improves resistance to disease, lowers cholesterol and blood sugar, and helps people with diabetes and gastrointestinal problems. Packed with vitamins, calcium, protein, and fibre, it is perfect for young kid's, expectant mothers and it promotes overall immune health of the individual [8].

In addition to its nutritional and medicinal properties, foxtail millet is becoming more appreciated for its versatility in the food production process, particularly in the bread industry. Emerging into Weaning foods, fermented goods, extruded snacks, and a variety of baked goods are all made with grain. It improves the nutritional profile of other products when added. Foxtail millet makes a stronger case to replace other staple crops that may be impacted by environmental stressors by enhancing the variety and creativity of baked goods. Because of its versatility and usefulness, foxtail millet is a valuable crop in both traditional and modern food systems [9]. Spices are an important component of the agricultural economy and valuable medicinal ingredients, particularly seed spices like fenugreek, coriander, cumin, and fennel [10]. In Ayurvedic medicine spices plays a significant role in treating digestive disorders such as dyspepsia and diarrhoea [11]. Known for its use in Indian cooking, cumin is an important ingredient in the seasonings, cumin contains important amino acids such as lysine and threonine [12]. Therefore, the primary goal of the current study was to develop cookies by substituting foxtail millet flour for wheat flour and adding jeera to increase the cookies' nutritional profile

2 MATERIALS AND METHODS

Millets and all needed raw materials, such as foxtail millet flour, refined wheat flour, sugar, spice, salt, ammonia, milk powder, and packaging materials, were sourced from Hyderabad's local markets and the Millet Processing & Incubation Centre (MPIC).

Procedure for making cookies:

Weighed all the mentioned raw materials. Powdered sugar, milk powder, and baking powder were sieved through the flour. Dry ingredients were sieved into the cream while the fat and sugar were being creamed. To make soft dough, ammonium was added and combined with kneading. Dough was sheeted with a roller pin, then moulded (sheets were cut with a desired shape cutter). The cookies that had been moulded were baked at 180°C for 20 to 25 minutes in a preheated oven at 170°C for 15 minutes. After being cooled for thirty minutes at room temperature (27° C), cookies were packaged and kept in polypropylene pouches. Figure 1 mentions the step-by-step process chart for making cookies.

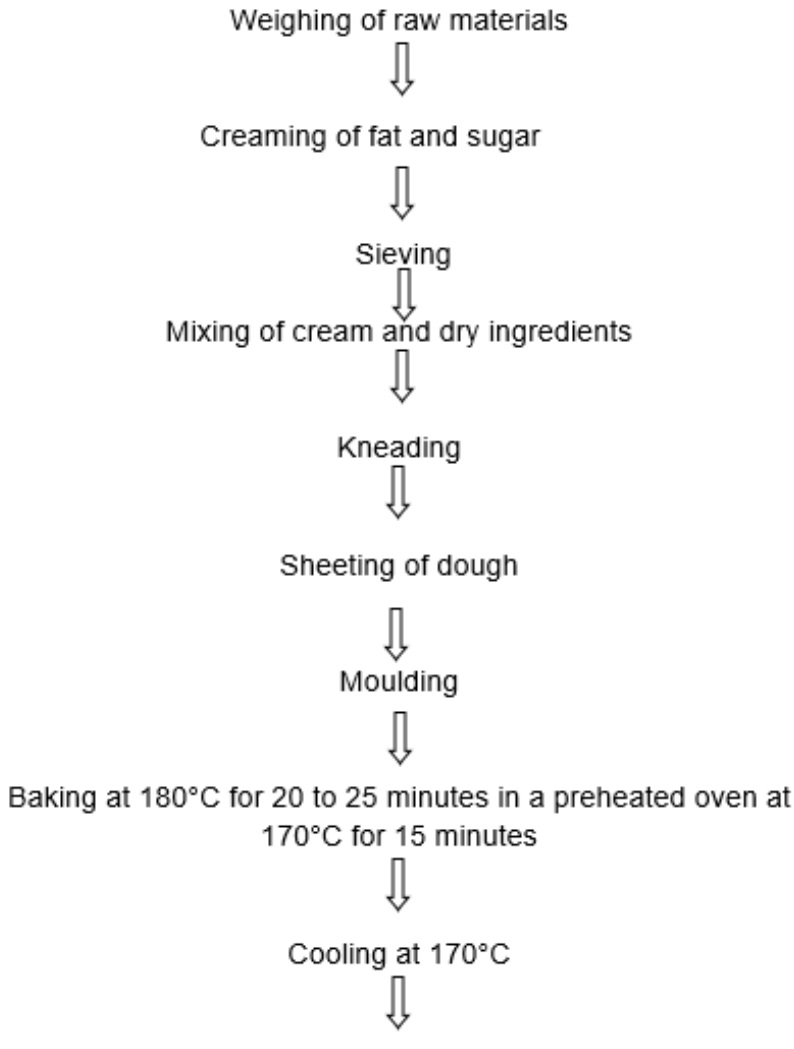

Fig.1.Flowchart for the preparation of cookies

Standardization of spice incorporated foxtail millet cookies:

All the mentioned ingredients were weighed separately (Table 1). In order to make biscuit dough, foxtail millet flour was substituted for refined wheat flour in different ratios (20%, 40%, 50%, 80%, and 100%)

Table 1: Standardization of the proportions of spice incorporated foxtail millet cookies.

Ingredients	CC	FMC_{20}	FMC_{40}	FMC_{50}	FMC_{80}	FMC_{100}
Refined wheat flour	100	80	60	50	20	-
Foxtail millet flour	-	20	40	50	80	100
Fat	36.5	36.5	36.5	36.5	36.5	36.5
Sugar powder	30	30	30	30	30	30
Baking powder	1.5	1.5	1.5	1.5	1.5	1.5
Salt	1	1	1	1	1	1
Ammonia	1.25	1.25	1.25	1.25	1.25	1.25
Milk powder	1.5	1.5	1.5	1.5	1.5	1.5
Jeera	1.5	1.5	1.5	1.5	1.5	1.5

CC: Cookies with 100%refined wheat flour
FMC_{20} : Cookies with 20% foxtail millet flour
FMC_{40} : Cookies with 40% foxtail millet flour
FMC_{50} : Cookies with 50% foxtail millet flour
FMC_{80} : Cookies with 80% foxtail millet flour
FMC_{100} : Cookies with 100% foxtail millet flour

Sensory evaluation of the developed cookies:

The developed jeera-incorporated foxtail millet biscuits were assessed for Appearance, Colour, Flavour, Taste, Mouth feel, Texture, Overall acceptability by a semi-trained panel of 15 members from PGRC (Post Graduate Research Centre), PJTSAU (Professor Jayashankar Telangana State Agricultural University) using a 9-point hedonic scale scores were determined using a hedonic scale of 1 to 9, with 1 denoting an extreme dislike (very bad) and 9 denoting an extreme like (excellent). Samples in the lab for sensory evaluation were coded, arranged on plates, and stored in separate booths.

Physical parameters: Cookies diameter, thickness, Bulk density and colour [13].

Functional parameters: Water absorption capacity, oil absorption capacity was determined according to the [14] and bulk density [15].

Nutritional parameters: Moisture and ash [16], carbohydrates [17], protein [16], fat and crude fibre [18], minerals like sodium and potassium [19], iron and zinc [20]. Bio active compounds like total phenolic content [21], total flavonoid content [22], antioxidant activity DPPH [23] were analysed for the best accepted samples.

Statistical analysis:

The investigation was conducted using an experimental design. Three replicates were analysed for each of the functional, physical, and nutritional assays conducted on each sample. Organoleptic scores were compared using analysis of variation (ANOVA) in order to determine which product variation was the most acceptable. The nutritional differences between the foxtail millet and refined wheat flour biscuits were compared using the student "t" test.

3 RESULTS AND DISCUSSION

Sensory evaluation of spice incorporated foxtail millet cookies:

The sensory scores of the samples were presented on Table 2, revealed that FMC80 (8.14) scored the highest score for appearance among all the spice incorporated foxtail millet cookie formulations. The color value ranging from 6.6 (FMC_{100}) to 7.87 (FMC_{80}). FMC_{80} (8.13) received the highest flavor scores, whereas FMC_{100} (6.80) had the lowest score. The taste attribute was observed to be highest in FMC_{80} (8.27) and lowest in FMC_{100} (6.67). The highest mouth feel was reported in FMC_{80} (8.33). FMC_{80} (8.20) had the highest mean texture scores, followed by FMC_{50}, FMC_{40}, FMC_{20}, and FMC_{100}. In FMC_{80} (8.60) and FMC_{100} (7.00), the mean sensory scores for overall acceptability were high and low, respectively. Up to 80% of biscuits incorporating foxtail millet flour obtained satisfactory ratings based on the sensory evaluation and it was accepted for further analysis.

Table 2: Sensory scores of foxtail millet cookies.

Samples	Appearance	Colour	Flavour	Taste	Mouth feel	Texture	Overall acceptability
WCC	7.14±1.07	7.07±0.69	7.00±0.58	6.80±0.66	6.80±0.77	6.80±0.86	7.20±0.67
FMC_{20}	7.36±0.96	7.13±0.99	7.13±0.95	7.13±1.07	7.20±0.95	7.27±0.80	7.60±0.63
FMC_{40}	7.71±0.83	7.53±1.04	7.67±0.87	7.53±0.85	7.27±0.97	7.47±0.85	7.60±0.63
FMC_{50}	7.93±0.76	7.53±0.66	7.27±0.83	7.13±0.73	7.20±0.80	7.80±0.95	7.80±0.77
FMC_{80}	8.14±0.81	7.87±0.60	8.13±0.80	8.27±0.43	8.33±0.61	8.20±0.53	8.60±0.63
FMC_{100}	6.79±0.72	6.60±0.66	6.80±0.44	6.67±0.74	6.53±0.65	6.87±0.53	7.00±0.53
Mean	7.48	7.28	7.33	7.25	7.22	7.40	7.63
S. E	0.990	0.897	0.880	0.968	1.009	0.945	0.858
C.D	0.6012	0.4896	0.4751	0.4787	0.5172	0.5270	0.4649
C.V%	11.024%	9.224	8.897	9.059	9.834	9.780	8.364

Note: values were expressed as mean ± standard deviation for 15 determinants
CC: Cookies with 100%refined wheat flour FMC_{80} : Cookies with 80% foxtail millet flour

3.1 Physical properties of spice incorporated foxtail cookies:

Physical attributes of the cookies like diameter, thickness and bulk density is presented in Table 3a. Significant differences were observed in terms of diameter (35.16 & 33.48), thickness (10.78 & 11.32) and bulk density (0.43 &0.53) between the FMC80 cookies and the control cookies.

Table: 3a Physical properties of foxtail cookies

Samples	Diameter	Thickness	Bulk density
CC	33.48±1.051	11.32±0.170	0.53±0.00
FMC_{80}	35.16±1.526	10.78±0.617	0.43±0.00
Mean	34.32	11.05	0.501
SD	0.336	0.316	0.004
CV%	1.71	0.20	2.17
P value	0.191	0.284	1.700

Note: values were expressed as mean ± standard deviation of three determinations
CC: Cookies with 100%refined wheat flour FMC_{80} : Cookies with 80% foxtail millet flour

3.2. Colour values of developed cookies

The spice-incorporated foxtail millet cookies colour score results were presented as L*, a*, b*, C*, and h* values (Table 3b). The cookies' L* values were 61.02 (CC) and 61.53 (FMC_{80}). The FMC_{80}'s a* and b* values were, respectively, 8.56 and 35.89. The control and the FMC_{80} were found to have c* values of 8.51 and 8.75, respectively. The h* values had a low score in CC (60.66) and a high score in FMC_{80} (63.95). The L*, a*, b*, C*, and h* values revealed a significant difference between the control and FMC_{80}. Hunter colour values L*, a*, and b* indicate that the colour green had been detected in FMC_{80}.

Table: 3b. Colour values of developed cookies

Samples	Colour L*	Colour a*	Colour b*	Colour C*	Colour h*
CC	61.02±1.00	9.70±0.255	30.71±0.34	8.51±0.01	60.66±0.212
FMC_{80}	61.53±0.27	8.56±0.118	35.89±0.18	8.75±0.00	63.95±0.125
Mean	61.28	9.13	33.30	8.63	62.31
SD	0.521	0.097	0.113	0.005	0.061
CV%	0.54	0.003	0.076	0.000	0.030
P value	0.484	0.006	0.0001	0.002	0.001

Note: values were expressed as mean ± standard deviation of three determinations
CC: Cookies with 100%refined wheat flour FMC_{80} : Cookies with 80% foxtail millet flour

3.3 Functional properties of spice incorporated foxtail cookies

The functional parameters of the cookies were analysed and are shown in Table 3c. The study found that the water absorption of the FMC_{80} was high (1.82) while that of the control cookies was low (1.76), indicating significant differences ($p \leq 0.05$) between the samples. A significant difference in oil absorption capacity was observed between the FMC_{80} (2.30) and Control cookies (2.20). There was variation in the water absorption capacity (WAC) of 1.55 g to 1.78 g water/g flour and the oil absorption capacity (OAC) of 1.43 to 1.65 g oil/g flour [24].

Table 3c Functional properties of cookies

Sample	WAC	OAC
CC	1.82±0.002	2.20 ± 0.01
FMC 80	1.76±0.03	2.30 ± 0.18
Mean	1.795	2.253
SD	0.026	0.119
CV%	0.001	0.016
P value	0.107	0.440

WAC: water absorption capacity OAC: Oil absorption capacity

3.4 Nutritional properties of cookies

The results of the nutritional composition of the developed products were reported in Table-3d. Moisture content was high in CC and low in FMC $_{80.}$ Ash, crude fiber, and protein content of CC and FMC 80 was 0.75% and 1.15%, 0.33% and 1.41%, 4.75% and 11.10% respectively. Previous studies also reported that foxtail millet and flying fish as potential functional food due to their rich nutrients. Proximate analysis of F3 cookies showed protein (11.89%), carbohydrates (45.19%), crude fibre (4.51%), fat (21.30%), moisture (5.94%) and ash (1.26%). Incorporation of foxtail millet flour and jeera significantly increased the protein and energy content by 11.10 % and 505 kcal/100g, decreased the carbohydrate content 61.42% [25].

Table 3d Nutritional composition of spice incorporated foxtail millet cookies

Samples	Moisture (%)	Fat (%)	Protein (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)	Energy (kcal/100g)
CC	2.52^{a}±0.42	22.19^{b}±0.79	4.75^{b}± 0.45	0.33^{b}±0.04	0.75^{b}±0.13	69.79±0.866	497.8±3.48
FMC $_{80}$	2.45^{b}± 0.48	23.88^{a}±0.51	11.10^{a}±0.14	1.41^{a}±0.22	1.15^{a}±0.12	61.42±8.70	505 ±1.00
Mean	2.48	23.03	7.930	0.89	0.96	65.355	500.9
SD	0.296	0.194	0.221	0.121	0.002	0.433	2.242
CV%	0.093	0.447	0.110	0.025	0.02	0.25	6.57
P value	0.812	0.053	0.001	0.015	0.017	0.001	0.039

Note: values were expressed as mean ± standard deviation of three determinations
CC: Cookies with 100%refined wheat flour $FMC_{80:}$ Cookies with 80% foxtail millet flour

3.5 Mineral composition for foxtail cookies

Mineral content of CC and FMC_{80} per 100g were resulted as iron-1.26mg and 1.37mg, zinc-1.3 mg and 2.06mg, sodium- 3.18mg and 4.76, potassium- 5.27mg and 8.66 mg respectively. There was significant difference found between the mineral content of CC and FMC_{80}.

The nutritional and phytochemical content of foxtail millet and the mineral contents was reported as iron 4.59 mg/100 g, potassium at 393, sodium 27.4, magnesium 45.40, manganese 0.71, copper 0.58 and zinc 2.30 mg/100 g [26].

Table 3e Mineral composition of foxtail cookies

Samples	Iron (mg)	Zinc (mg)	Sodium (mg)	Potassium (mg)
CC	1.26± 0.06	1.3±0.031	3.18±0.05	5.27±0.02
FMC $_{80}$	1.37±0.064	2.06±0.151	4.76±0.08	8.66±0.45
Mean	1.321	1.68	3.975	7.195
SD	0.041	0.085	0.020	0.164
CV%	0.002	0.0009	0.005	0.129
*P*value	0.09	0.076	0.001	0.002

Note: values were expressed as mean ± standard deviation of three determinations
CC: Cookies with 100%refined wheat flour FMC_{80} : Cookies with 80% foxtail millet flour

3.6. Bioactive compounds of spice incorporated foxtail millet cookies

Natural secondary metabolites found in plants, phytonutrients are beneficial to human health and wellness by preventing and defending against a variety of illnesses and infections [27]. These phytochemicals have health benefits that include preventing heart disease, preventing diabetes, lowering blood pressure, preventing cancer, enhancing gut health, and preventing anemia [28]. Fruits and vegetables' primary antioxidant components are phenolic compounds. Their antioxidant activity is directly correlated with the total amount of phenolic compounds [29].

In comparison to the CC (1.49 mg GAE/100 g), the total phenol content of the spice incorporated foxtail cookies increased by 2.12 mg GAE/100 g (FMC80). There was a significant difference ($p \leq 0.05$) noted between the samples. The significant difference was also evident in the DPPH and flavonoid values. The flavonoid content of CC was 6.57(µg RE/g), while the flavonoid content of FMC 80 was reported as 8.74(µg RE/g). The DPPH values are CC (52.82%) and FMC80 (57.62%). Bioactive compounds also yielded more or less similar values, with the TPC found to be 51.35 ±1.35 mg GAE/100 g [29].

Table 3f Bioactive compounds

Samples	Phenols (mg GAE/100 g)	Flavonoids (µg RE/g)	DPPH (%)
CC	1.49± 0.165	6.57±0.262	52.82±0.916
FMC $_{80}$	2.12 ±0.139	8.74±0.378	57.62±1.166
Mean	1.79	7.65	52.22
SD	0.018	0.081	0.176
CV%	0.023	0.105	1.100
P value	0.008	0.001	0.004

Note: values were expressed as mean ± standard deviation of three determinations
CC: Cookies with 100%refined wheat flour FMC_{80} : Cookies with 80% foxtail millet flour

4. CONCLUSION:

Among the bakery goods, biscuits possess desirable qualities such as increased consumption, extended shelf life, and availability in a variety of tastes and textures. The nutritional, textural, and physical characteristics of biscuits are significantly influenced by their ingredients. In comparison to the control cookies (CC), the developed jeera incorporated foxtail millet cookies showed significant differences in a number of physical and functional attributes. In terms of nutrient composition, control cookies had a higher carbohydrate content whereas FMC80 reported a significantly higher content of ash, fat, crude fiber, protein, and phenol. In comparison to control cookies, FMC80 demonstrated increased levels of antioxidant activity (DPPH value), phenol and flavonoid content, underscoring its superior nutritional profile and practical advantages. This study has shown that traditional high-fat, high-sugar biscuits, which most consumers do not associate with healthy diets, can be altered. This led to the creation of a wholesome substitute that is both consumer-acceptable and able to be produced under stringent commercial guidelines.

Limitations: In food processing industries spices can be used for various products like extruded snacks. These also can be used for ready to eat (RTE) and ready to cook foods (RTC) and ultra processed foods.

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ACKNOWLEDGEMENTS

The author wishes to express gratitude to the chairperson, committee members and the Department of Foods and Nutrition, family and friends for their invaluable support during the entire work.

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