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Formulation and Functional Characterization of Gluten-Free Crackers with Foxtail Millet, Chia Seeds, and Veldt Grape (*Cissus quadrangularis*) for Enhanced Nutritional Benefits

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Abstract

The aim of the study is to develop a healthy cracker enriched with nutrients from foxtail millet, chia seeds, and veldt grape. The effect of the inclusion of foxtail millet, chia seed, and veldt grape at different ratios of 95:0:5, 90:5:5, and 85:10:5 was studied. The crackers were evaluated in terms of nutritional, functional, and sensory attributes. The nutritional value of the optimized crackers contains protein (8.93 g/100g), fat (17.02 g/100g), carbohydrate (65.83 g/100g), ash (2.55 g/100g), and calorific value (451.07 kcal/100g). The water activity of crackers ranges from 0.257 to 0.312. The physical parameters are almost equivalent to control crackers. Incorporating chia seeds has significantly improved the texture profile of the crackers. The study showed significant retention of total phenolics, flavonoids, and antioxidant activity (3.94 mg/g, 3.07 mg/g, and 43.38 %) in the selected crackers. A low level of anti-nutritional factors such as oxalate, phytate, and tannin content was determined. No visible total plate count, yeast, mold, and coliform growth were observed in the crackers. The sensory score revealed that crackers with a 90:5:5 ratio had the highest score and overall acceptability. The storage study performed at ambient temperature exhibited that the optimized crackers are shelf stable for up to 60 days. As a novelty, preparing a healthy snack as an alternative to millet and chia seed flour with the incorporation of underutilized herbs helps in potential health-promoting effects and nutritional enhancement.

Keywords: Nutritious crackers, foxtail millet, chia seeds, veldt grape, quality evaluation

INTRODUCTION

Bakery products are fetching more popular in our modern life due to their easy accessibility, and ready-to-eat suitability with longer storage stability. Maida acts as the main ingredient in many fast foods and bakery products (Awika and Rooney, 2004). Maida contains gluten, a protein responsible for the elastic characteristics of the dough which might exhibit immune sensitivity to the gluten proteins in some individuals. Millions of individuals around the world suffer from gluten-related disorders, like celiac disease, wheat allergy, and non-celiac gluten sensitivity (Pareyt *et al., 2008*). Celiac disease is triggered by the intake of gluten products, leading to an immune response that attacks the small intestine, and prevents the assimilation of nutrients in the food. A gluten-free diet can address the need of celiac patients to prevent the symptoms of this disorder (Rai *et al.,* 2014).

Nowadays, consumers' interests are shifting towards gluten-free food with functional and nutritional properties in order to meet the nutritional benefits as well as to prevent celiac disease (Xu *et al.,* 2020) The rising demand for gluten-free diets is caused due to increasing of diagnosed celiac patients and allergenic proteins from the diet (Hansel *et al.,* 2007). Bakery acts as a blooming sector for gluten-free products, due to the increasing availability of gluten-free flour alternatives. Among gluten-free products, crackers with universal appeal are important cereal products (Turk Aslan and Isik, 2022). Crackers are thin, crispy baked product that serves as a quick snack with less sugar, moderate fat, and low salt, can be used as a medium for the enrichment of nutrients by replacing wheat flour with nutrient-rich millet flour, pulses, fruits, and vegetables to meet the consumer demands (Rendon *et al.,* 2017). An effective strategy to encourage the consumption of millet and underutilized herbs could involve incorporating them into snack products. Therefore this research is based on the preparation of gluten-free crackers from millets, chia seeds, and underutilized herbs which imposes high nutritional value and health benefits.

Recently, millet are identified as a nutritional foodstuff to be combined with other nutritious ingredients and aids in the formation of gluten-free products with high nutritional content Foxtail millet is an important crop that provides a high amount of minerals, vitamins, fiber, proteins, and amino acids. Foxtail millet with high polyphenolics boosts the immune system and is cardio-protective (Sonel *et al.,* 2017). The rich source of fiber content is beneficial for a healthy digestive system and has a low glycemic index.

Chia seeds are considered to be a popular food ingredient and possess functional and bioactive compounds which provide beneficial effects on cardiovascular diseases, obesity, and diabetes. Besides, Chia is a reliable source of polyphenolics, proteins, vitamins, and minerals (Goyat *et al.*, 2018). The incorporation of chia seeds in bakery products improves their physicochemical properties and nutritional characteristics.

Veldt grape commonly called "Pirandai" (*Cissus quadrangularis*) is an ancient medicinal plant, rich in flavonoids, minerals, and phenolic compounds with pharmacological activities such as analgesic, anti–inflammatory, and free radical scavenging activity, which is effective against bone demineralization due to high amount of calcium and phosphorous (Joseph *et al.,* 2013) The presence of a high amount of oxalate acts as a hurdle in the consumption of fresh plants. Even though the plant is rich in medicinal value it remains underutilized due to lack of awareness and unavailability in easy consumable forms (Yoganarisimhan, 2000).

In the present study, crackers are prepared by substituting wheat flour with different flour blends of foxtail millet and chia seed flour with the incorporation of the underutilized herb was optimized and further analyzed for their physicochemical properties, nutritional status, anti-nutritional factors, sensory attributes, and product stability.

MATERIAL AND METHODS

Procurement of raw materials

For the preparation of crackers, Foxtail millet, Chia seeds, butter, sugar, salt, sodium bicarbonate, and baking powder were purchased from the supermarket in Chennai. Veldt grape is procured from the garden. All the chemicals and reagents used in this study were of analytical grade.

Sample preparation

Preparation of foxtail millet and chia seed flour

The procured foxtail millets and chia seeds were roasted individually at 90°C for 10 mins followed by cooling and milled according to the method described by (Bookwalter *et al.,* 1987). Further, the flours were sieved with a mesh size No. 30 and stored in airtight bags.

Preparation of veldt grape powder

The procured veldt grape was washed, chopped, and soaked in 0.5 % citric acid for 30 mins. After that, the outer skin of the veldt grape is peeled and dried in a tray drier followed by roasting for 10 mins at 90°C, further ground, sieved, and stored in airtight bags as described by (Karadbhajne *et al.*, 2014) with slight modifications.

Ingredients	**Formulations**			
	Control	**Veldt grape sweet crackers**		
	C	**T 1**	**T 2**	**T 3**
Refined wheat flour	100	0	0	0
Foxtail millet flour	0	95	90	85
Chia seed flour	0	0	5	10
Veldt grape powder	0	5	5	5

Formulation of Crackers

The suitability of foxtail millet and chia seed in the development of crackers was studied. The crackers were formulated using the method of (Ahmed and Abozed, 2015) with different proportions as enumerated in Table 1. Apart from this, raw materials such as butter, sugar, baking powder, baking soda, salt, water, and vanilla essence were added. The process flow involves mixing ingredients into a smooth dough and allowing for 30 mins of conditioning. Further sheeted, cut into desirable shapes, and baked at 150°C for 10 mins, cooled and packed.

Table 1 Formulation of crackers with different flour blends.

Determination of proximate composition

Moisture, protein, fat, crude fiber, and ash content of the samples were determined according to the (AOAC, 2010) method, while total carbohydrate was calculated by difference. The calorific value of the samples was calculated according to the WHO/FAO formula as follows in formula (1).

$$Total\ calorie = Fat \times 9 + Protein \times 4 + Carbohydrate \times 4 \tag{1}$$

Physicochemical analysis

Physical characteristics of crackers

The crackers samples are evaluated for physical parameters such as diameter, thickness, weight, and spread ratio. The thickness and diameter of crackers samples are measured in triplicates with a Vernier caliper and the spread ratio was calculated as diameter/thickness. The water activity of the crackers was analyzed with a water activity analyzer.

Colour Analysis

The color intensity of the crackers samples was evaluated with the parameters such as lightness, redness, and yellowness by Hunter color lab, USA.

Texture analysis of crackers

Textural characteristics of crackers samples were determined using a texture analyzer with a 2 mm probe and a distance of 3 mm was applied.

Determination of total phenolic content, flavonoids, and antioxidant activity

Preparation of aqueous extract

The methanolic extracts were prepared by refluxing 2 g of crackers sample with 20 mL of acidified methanol containing 1% HCL for 2 hrs at 60 ± 5°C. After centrifugation at 5000 rpm for 20 mins, the extracted supernatants were separated and analyzed for their antioxidant activity, total phenolic, and flavonoids.

Total phenolic and flavonoid compounds

The phenolic content of the crackers samples was analyzed using the spectrophotometric method of (Singleton and Rossi, 1965). The amount of phenolics in the sample is calculated based on the gallic acid standard curve and expressed as mg of gallic acid equivalent per g of crackers sample. The total flavonoids of crackers were estimated with the method described by (Mahloko *et al.*, 2019) with quercetin as a standard and results were exhibited as mg of quercetin per g of sample.

DPPH Radical scavenging

The DPPH activity of the crackers was analyzed as described by (De Ancos *et al.*, 2002). To 0.1 mL crackers extract, 3.9 mL of DPPH was added and allowed for 30 mins of reaction at dark. After this, the absorbance was analyzed using a spectrophotometer at 517 nm.

Determination of anti-nutritional factors

Oxalate content in the samples was analyzed by using (AOAC, 1990). The tannin content of the samples was measured by the Folin-Denis method, as described by (Kirk and Sawyer, 1998). Phytate content was estimated by using the spectrophotometric method of (Darambazar, 2018).

Sensory evaluation

Sensory evaluation was carried out for the prepared crackers using a 9-point hedonic scale ranging from 1 (extremely dislike) to 9 (extremely like), as described by (Ihekoronye and Ngoddy, 1985). The attributes such as color, texture, appearance, taste, and overall acceptability were evaluated by 20 panelists.

Microbial evaluation of crackers

Microbial populations such as total plate count, yeast, mold, and coliform growth of the crackers samples were estimated and the results are expressed as colony-forming units per gram (CFU/g).

Storage stability of crackers

The shelf life of the crackers sample is evaluated in terms of moisture content, free fatty acid value, peroxide value, total plate count, and water activity at regular intervals of 0, 30, and 60 days under ambient storage conditions. Moisture content was estimated by hot air oven and water activity by water activity meter. Auto oxidation of fat results in the development of rancidity and acts as an important parameter in the storage study of food products. Peroxide value was estimated by (IS 548-1, 1964) and free fatty acid % was determined by the method of (AOCS, 1997).

Statistical analysis

All the analyses were conducted in triplicates and the experimental values were subjected to statistical analysis using one-way ANOVA with SPSS Version 27 software. To determine the significant differences between the means, Duncan's multiple range test was utilized, with a significance of $p<0.05$.

RESULT AND DISCUSSION

Proximate analysis of crackers

The proximate content of the crackers samples was analyzed and the results were presented in Table 2. The moisture content of the crackers (B to D) ranged from 5.43% - 5.74% compared to control sample A with 5.02%. The significant increase in moisture level could be attributed due to the increase in the addition of chia seeds in the crackers samples. However, it is very much lower than the moisture of amaranth crackers varied from 5.80 % to 10.36 % reported by (Gebreil *et al.*, 2020). The Ash content of the crackers has significantly increased compared to the control crackers. Ash content increased in sample D (2.67g/100g) followed by sample C (2.55g/100g) relative to control crackers (1.23 g/100g). The increase in ash content might be due to the incorporation of veldt grape and the replacement of wheat flour with millet and chia seed flour. The Ash content of the samples was higher than the defatted coconut flour snack crackers which varied from 1.28 to 2.34 g/100g (Mihiranie *et al.,* 2017).

The fat content has significantly increased due to the incorporation of chia seeds. The fat content ranges between 16.6 and 17.26 compared to control sample A with 15.89 g/100g but there is no significant difference between samples B, C, and D. It is however lower than the fat level of teff crackers which ranged from 13.4 to 14.65 % (Rico *et al.*, 2019). The incorporation of flour blends with millet, chia seeds, and veldt grape has significantly increased the protein content in samples from 8.14 to 9.06, while the highest value in sample D and the lowest in sample A. The protein content of optimized crackers exceeds that of pseudo cereal crackers (Aslan and Isik, 2022) which had 3.22 to 6.57 % of protein.

The results showed a slight decrease in carbohydrates of blended crackers compared to control crackers which might be due to an increase in protein, fat, moisture, and ash content of blended crackers. It is lower than the level in the amaranth snack bar found to be 69.09 % of carbohydrates (Guzman and Sebastian, 2019). Total fiber has increased significantly as an increase in substitution of chia seed flour and the highest value was found in sample D and the lowest value in Control sample A. Further, a slight reduction of calorific value was observed compared to control crackers which range from 451.72 to 454.49 Kcal/100g. These results state that the incorporation of foxtail millet, chia seed, and veldt grape in the preparation of crackers has increased the protein, fat, moisture, fiber, and ash content, however, decreased the carbohydrate content and calorific value. This is found to be higher than gluten-free crackers (Jothi *et al.*, 2014) which varied between 361.32 and 389.54 kcal/100g.

Table 2 Proximate composition of crackers.

Samples	**Moisture%**	**Ash (g/100 g)**	**Fat (g/100 g)**	**Protein (g/100 g)**	**Carbohydrate (g/100 g)**	**Fiber (g/100 g)**	**Calorific value (Kcal/100 g)**
A	5.02±0.03^{d}	1.23 ±0.06^{d}	15.89±0.17^{c}	8.14±0.44^{d}	69.73±0.06^{a}	1.27±0.04^{c}	454.49±0.09^{a}
B	5.43±0.09^{c}	2.39±0.05^{c}	16.6±0.26^{b}	8.76±0.08^{c}	66.82±0.05^{b}	1.52±0.06^{b}	451.72±0.07^{d}
C	5.67±0.02^{b}	2.55±0.02^{b}	17.02±0.21^{ab}	8.93±0.04^{b}	65.83±0.04^{c}	1.59±0.08^{a}	452.22±0.13^{c}
D	5.74±0.06^{a}	2.67±0.03^{a}	17.26±0.63^{a}	9.06±0.07^{a}	65.38±0.01^{c}	1.63±0.05^{a}	453.1±0.04^{b}

A - Control, Sample B to D contains 0, 5, and 10% chia seeds. Values are average±standard deviation of triplet samples. Different superscripts in a column indicate significant differences between the values (p<0.05).

Physicochemical analysis of crackers

Physical characteristics

The physical properties of crackers are shown in Table 3. Although, Gluten influences the diameter and spread ratio of the crackers. There is no significant difference between the diameter, weight, and thickness of the blended crackers and control crackers. The diameter of crackers ranges from 4.03 to 4.04 cm. The thickness of blended crackers was slightly similar to control crackers ranging from 0.23 – 0.28 mm. Even though the spread ratio has decreased due to the incorporation

Parameters	**A**	**B**	**C**	**D**
Weight (g)	1.42±0.05[a]	1.44±0.05[a]	1.45±0.09[a]	1.43 ±0.09[a]
Thickness (mm)	0.23±0.02[a]	0.25±0.018[a]	0.26±0.02[a]	0.28±0.02[a]
Diameter(mm)	4.043±0.01 [a]	4.039±0.02[ab]	4.037±0.01[b]	4.033±0.02[c]
Spread ratio	17.57±1.62 [a]	16.15±0.81 [b]	15.52±0.76 [c]	14.4±1.48 [d]
Water activity	0.257±0.01 [a]	0.284±0.03 [a]	0.297±0.06 [a]	0.312±0.02 [a]

of millet flour compared to control crackers. The spread ratio is decreased in blended samples from 14.4–16.15 comparable with control crackers (17.57). Water activity has increased in blended samples compared to control samples which might be due to an increase in the addition of chia seeds. The water activity of crackers was found to be high in sample D (0.312), followed by sample C (0.297), and lowest in sample A (0.257). However, the physical parameters such as weight, thickness, and diameter of the developed samples were almost equivalent to the control sample.

Table 3 Physical parameters of crackers.

A – Control, Sample B to D contain 0, 5, and 10% chia seeds. Values are mean±standard deviation of triplicate samples. Different superscripts in a column indicate significant differences between the values ($p<0.05$).

Color analysis

Color is an important factor in determining the preference of food consumers. The color of the crackers was represented by lightness, redness, and yellowness are shown in Table 4. The control samples had the highest L value compared to other samples. Replacement of wheat flour with different proportions of foxtail millet, chia seeds, and veldt grape resulted in a decrease in the lightness of the blended samples which varied from 43.77 to 51.13. Redness values were increased with an increase in substitution of chia seed flour while the highest value (5.48) is found in sample D and the control sample recorded the lowest value (2.097). Finally, the yellowness of the crackers was high in the control sample compared to other blended samples.

Table 4 Color analysis of crackers.

Samples	L*	a*	b*
A	64.44 ± 0.97^{a}	2.09 ± 0.02^{d}	23.56 ± 0.24^{a}
B	51.13 ± 0.18^{b}	3.08 ± 0.05^{c}	19.61 ± 0.07^{b}
C	47.74 ± 0.58^{c}	4.55 ± 0.045^{b}	17.50 ± 0.13^{c}
D	43.77 ± 0.13^{d}	5.48 ± 0.10^{a}	14.32 ± 0.25^{d}

Values are average±standard deviation of triplet samples. Different superscripts within a column indicate significant differences between the values (p<0.05).

Textural analysis of crackers

The textural characteristics of the crackers was presented in Table 5. The hardness of the crackers ranged from 27.98 to 33.05 N, where the highest value is found in control crackers compared to other blended samples. Fracturability of the crackers increases with an increase in hardness of the crackers as a result tractability is increased in control crackers in comparison with other crackers samples ranging from 0.498 to 0.543 mm. Springiness, chewiness, and gumminess of the blended crackers are significantly increased which could be due to an increase in the incorporation of chia seeds where the highest value is found to be 0.486 mm, 16.94 N, and 21.19 N in sample D, followed by sample C with 0.302 mm, 15.71 N and 18.85 N. Resilience of the crackers ranges from 0.103 to 0.147. There is no significant difference between the samples at p< 0.05. A Decrease in hardness and increase in other parameters such as springiness, chewiness, and gumminess of the blended crackers samples results in the softness of the crackers which might be attributed due to the incorporation of foxtail millet, chia seed, and veldt grape.

Table 5 Texture profile analysis of crackers.

Parameters	A	B	C	D

Hardness (N)	33.05±0.69 ^{a}	31.61±0.76^{b}	29.67± 0.61^{c}	27.98±0.63^{d}
Fracturability (mm)	0.54±0.56 ^{a}	0.51±0.86^{a}	0.50±0.79^{a}	0.49±0.78^{a}
Springiness(mm)	0.19±0.03^{d}	0.25±0.18^{c}	0.30 ±0.04^{b}	0.48 ±0.05^{a}
Cohesiveness	0.50 ±0.11^{a}	0.14 ±0.02^{d}	0.24±0.06^{c}	0.30 ±0.10^{d}
Gumminess(N)	11.03±0.23^{d}	15.09±0.11^{c}	18.85±0.37^{b}	21.19±0.56^{a}
Chewiness(N)	10.06±0.43^{d}	13.31±0.60^{c}	15.71±0.97^{b}	16.94±0.18^{a}
Resilience	0.10±0.05^{a}	0.13±0.02^{a}	0.13±0.074^{a}	0.14±0.19^{a}

A - Control, Sample B to D contains 0, 5, and 10% chia seeds. Values are mean±standard deviation of triplicate samples. Mean values with different superscripts in the same row are significantly different ($p<0.05$).

Sensory evaluation

The sensory quality of crackers was evaluated in terms of appearance, taste, color, and odor. The obtained results were shown in Figure 1. Control crackers A have the highest score for all the characteristics, however, scores of sample C with 5% chia seeds were found to be on par with the control sample. There is a significant decrease in color and appearance of the crackers with an increase in chia seeds. Sample B has a high acceptance of color and appearance while sample D has the least acceptance. The taste, texture, and overall acceptability of the crackers samples have the highest score in sample C. The sensory score revealed that crackers sample C containing 5% chia seeds secured the highest score among other crackers, though all samples were acceptable.

Considering the physical parameters, textural characteristics, nutritional composition, and sensory evaluation results, the crackers sample with 5% chia seeds was selected as the best crackers shown in Figure 2.

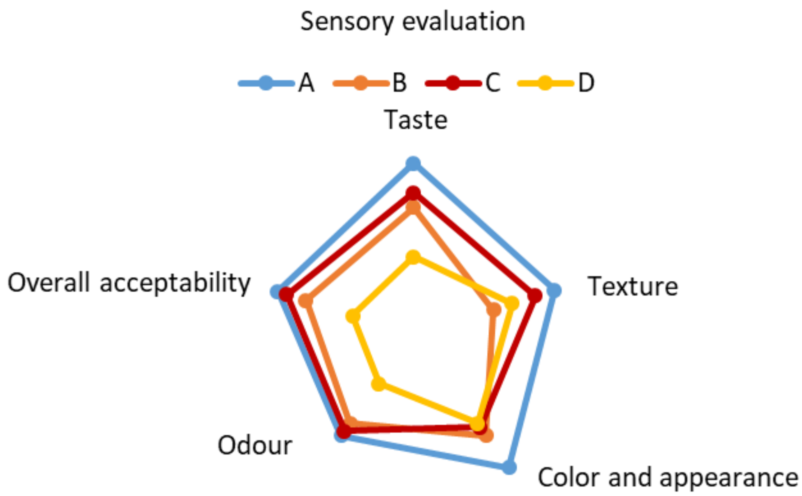

Figure 1. Sensory evaluation of crackers; A - Control, Sample B to D contains 0, 5, and 10% chia seeds. Values are mean±standard deviation (n = 20).

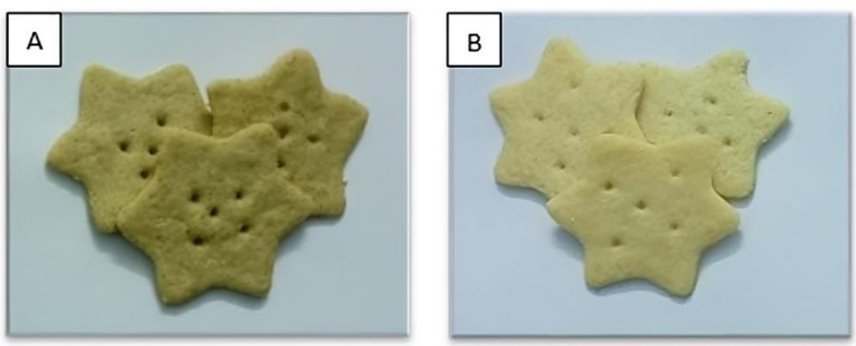

Figure 2. Control samples with 100% wheat flour (A) and optimized sample with 90% foxtail millet, 5% chia seed, and 5% veldt grape (B).

Total phenolic content, flavonoids, and antioxidant activity

Antioxidants act as promising compounds that help in delaying or inhibiting oxidation. The antioxidant activity of crackers were given in Table 6. Total phenolic content was increased from 2.218 to 3.942 mg Gallic acid equivalent because of the substitution of millet, chia seeds, and veldt grape. A significant difference exists between the control (30.77%) and optimized sample (43.38%) which indicates the good scavenging activity of veldt grape-incorporated millet crackers. There was a significant retention of flavonoids in optimized crackers (3.031 mg QE/g) compared to control crackers (1.456 mg QE/g) which might be due to the replacement of wheat flour with millet flour incorporated with veldt grape. The results show the enhanced antioxidant activity, and phenolic and flavonoid content of the crackers prepared with the flour blends of millet, chia, and veldt grape.

Table 6 Bioactive compounds of crackers.

Parameters	% DPPH Inhibition	Total phenolic compounds (mg GAE /g)	Total flavonoids (mg QE/g)
Control crackers A	30.77±0.74^{b}	2.21±0.47^{b}	1.45±0.35^{b}
Optimized Veldt grape crackers C	43.38±0.28^{a}	3.94±0.95^{a}	3.03±0.64^{a}

Values are average±standard deviation of triplet samples. Different superscripts within a column indicate significant differences between the values ($p < 0.05$).

Anti-nutritional factors

The amount of anti-nutritional factors found in the crackers were shown in Table 7. Nutrient inhibitors are present in many species and millets which renders the bioavailability of minerals. The oxalate content of the samples varies from 0.327 to 0.653 %. A significant difference in the oxalate content of the control crackers was observed when compared to optimized crackers and the highest value is observed in optimized veldt grape crackers. The phytate content of the crackers

Samples	Oxalate (%)	Phytate (%)	Tannin (%)
Control crackers	0.327±0.02^{a}	0.137±0.01^{a}	0.213±0.00^{a}
Optimized veldt grape crackers	0.653±0.01^{b}	1.73±0.02^{b}	0.469±0.00^{b}

samples varies from 0.137 to 1.73 % and was found to be significantly different. The highest value is observed in optimized crackers and the lowest value is observed in control crackers. The samples showed a significant difference in their tannin contents. The optimized crackers had the highest tannin content of 0.469 % and the control sample had the lowest tannin content of 0.213 mg/100g. The study reveals that, the increase in the anti-nutrient level of the blended sample when compared to the control cracker might be attributed due to the incorporation of foxtail millet, chia seeds, and veldt grape addition to the samples (Okoye *et al.*, 2020). However, the anti-nutritional content of the crackers samples is still lower than that of cassava crackers, which had higher tannin content (0.27%) but lower oxalate (0.84%) and phytate (2.95%) levels.

Table 7 Anti-nutritional factors of crackers.

Values are average±standard deviation of triplet samples. Different superscripts within a column indicate significant differences between the values ($p < 0.05$).

Microbial safety of crackers

Table 8 shows the microbial load of the optimized crackers and control crackers. The total plate count ranged from 1.8×10^4 to 2.3×10^4 CFU/g, while optimized veldt grape crackers had the lowest plate count compared to the control crackers. There is no visible yeast, mold, or coliform growth observed in the crackers samples, and found to be safe for consumption up to 60 days.

Table 8 Microbial safety of crackers.

Samples	**Total plate count (CFU/g)**	**Yeast and mold count (CFU/g)**	**Coliform count (CFU/g)**
Control crackers	2.3×10^4	-	-
Optimized veldt grape crackers	1.8×10^4	-	-

Values are mean±standard deviation of triplicate samples.

Storage stability of crackers

Moisture and water activity play a crucial role in the storage of crackers. There is a slight increase in the moisture level of the crackers from the 0th day to the 60th day shown in Table 9. An increase in moisture might be related to the nature of packed crackers and a corresponding increase in the water activity (*aw*) value of both crackers was also observed. Simultaneously, the FFA content of crackers was found to increase which might be attributed to an increase in moisture content. As moisture promotes hydrolytic rancidity, however, the presence of bioactive compounds lowers the development of rancidity. Optimized crackers exhibit lower values of PV and FFA than control crackers owing to the bioactive composition present in them. The total plate count increases with respect to time and is found to be below the acceptable limit. This study suggests that the crackers samples were shelf stable for up to 60 days at ambient storage conditions.

Table 9 Storage study of crackers.

Parameters	Days	Control crackers (A)	Veldt grape sweet crackers (B)
Moisture content %	0th day	5.14±0.04^{a}	5.65±0.05^{a}
	30th day	5.99±0.03^{b}	6.045±0.01^{b}
	60th day	6.27±0.0^{c}	6.321±0.08^{c}
Water activity	0th day	0.24±0.00^{a}	0.28±0.00^{a}
	30th day	0.26±0.00^{a}	0.29±0.00^{a}
	60th day	0.28±0.00^{a}	0.30±0.12 ^{a}

Peroxide value (meq O_2 /kg)	0^{th} day	0.46 ± 0.08^{a}	0.28 ± 0.09^{a}
	30^{th} day	2.29 ± 0.24^{b}	2.19 ± 0.22^{b}
	60^{th} day	5.47 ± 0.04^{c}	5.29 ± 0.12^{c}
Free fatty acid (%)	0^{th} day	0.03 ± 0.05^{a}	0.03 ± 0.01^{a}
	30^{th} day	0.40 ± 0.01^{b}	0.37 ± 0.03^{b}
	60^{th} day	0.75 ± 0.03^{c}	0.72 ± 0.04^{c}
Total plate count (CFU/g)	0^{th} day	ND	ND
	30^{th} day	0.8×10^{4a}	0.5×10^{4a}
	60^{th} day	2.3×10^{4b}	1.8×10^{4b}

Values are average±standard deviation of triplet samples. Average values with different superscripts in the same column are significantly different ($p<0.05$); ND-Not Detected

Conclusion

The present study demonstrates the health benefits of crackers incorporated with foxtail millet, chia seeds, and veldt grape has enhanced the nutritional value and functional properties without adverse effects on their sensory attributes. From the results, the preparation of crackers is a healthy option to utilize millets as well as enriched with bioactive compounds from chia seeds and underutilized herb helps in increasing the intake of protein, minerals, and antioxidants with good storage stability.

Conflict of interest

The authors declare no conflict of interest.

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