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Physical Quality, Nutritional Composition and Consumer Acceptability of Chocolate Biscuits Produced with Finger Millet (*Eleusine Coracana* L.)

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Abstract

Over and undernutrition both co-exist in South Africa and are on the rise. Strategies in place are failing to combat these issues, while the literature suggests that food-based strategies focusing on utilising nutritive traditional and indigenous crops could complement the current strategies. Two finger millet (FM) varieties (high-tannin and tannin-free) were used at different substitution levels (0% [control], 30, 50 and 70% (FM flour: wheat flour [w/w]) to prepare composite chocolate biscuits. The biscuit samples' physical quality, nutritional composition and consumer acceptability were assessed using standard methods. As the proportion of FM increased, the biscuits' spread factor decreased whilst they became darker. The FM-substituted biscuits had a significantly higher fat, fibre and mineral content relative to the control. The firmness (texture), crispness and overall acceptability of the biscuits slightly decreased when the proportion of either variety of FM was increased. The biscuit in which 30% of wheat is substituted with either of the two FM varieties would be acceptable to consumers and still be superior in nutrient content compared with the standard chocolate biscuits. Thus, by partially substituting wheat with FM in biscuits, there is potential to develop nutrient-rich, sensory-acceptable food products that appeal to health-conscious consumers as well as those seeking an enjoyable, healthier snack.

Keywords: Biscuits, sensory evaluation, e*leusine coracana*, indigenous crops, snack

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Introduction

The rising prevalence of non-communicable diseases such as obesity, cardiovascular disease, and diabetes mellitus (DM) in developing countries, including South Africa, has been linked to increased urbanisation and unhealthy lifestyles (Tydeman-Edwards et al., 2018, Pheiffer et al., 2018). The nutrition transition has shifted dietary patterns toward a higher intake of refined carbohydrates, saturated fats, and sugar-sweetened beverages, while reducing the consumption of fruits and vegetables, moving away from traditional diets that are based on grains, fruits and vegetables (Mutyambizi et al., 2019). Concurrently, undernutrition and micronutrient deficiencies persist, particularly in low-income communities, where diets are dominated by energy-dense but nutrient-poor staples such as maize meal and bread (Faber et al., 2017, Govender et al., 2017). To address these dual challenges, there is a growing need for food-based strategies that promote the use of nutrient-dense, indigenous crops as alternatives to conventional staples such as wheat (Mabhaudhi et al., 2018). Finger millet (FM) (*Eleusine coracana*) is a traditional crop grown in parts of Africa and Asia and has the potential to be incorporated as a food-based strategy as it is nutritionally superior to other grains and can adapt to infertile soils (Shobana et al., 2013, Rathore et al., 2019). In India and Africa, it is grown by households of low income due to its long-term sustainability as it can be grown for many years without insect or pest infestations (Rathore et al., 2019). In areas of central and eastern Africa and India, FM is traditionally eaten as a staple food (Shobana et al., 2013). FM grain is known for its superior nutritional composition and health properties (Shobana et al., 2013). The protein quality of FM grain is superior to many other grains, consisting of 44.7% essential amino acids (Ramashia et al., 2019). The dietary fibre content of FM (19.1 g/100 g) is significantly higher than that of all other millets, wheat, and rice (Chandra et al., 2016). The dietary fibre content of FM contributes to its high nutritional and functional importance (Ramashia et al., 2019). Dietary fibre possesses many health benefits, such as protection against cardiovascular disease, DM, colon cancer, and obesity (Priyanwada et al., 2020). It is higher in calcium than other cereals and is also rich in phosphorus, iron, potassium, zinc and vitamin A (Shobana et al., 2013). Calcium plays an essential role in growing children, pregnant women, the elderly and people suffering from obesity, DM and malnutrition (Ramashia et al., 2019). This whole grain has many promoting properties, such as anti-diabetic, anti-microbial, antioxidant, anti-inflammatory, and probiotic (Shobana et al., 2013). By incorporating FM into South African diets and developing affordable, accessible products, it is possible to address both undernutrition and the rising burden of non-communicable diseases (NCDs). This approach aligns with the need to diversify food systems and promote underutilised nutrient-rich crops to improve food and nutrition security (Mabhaudhi et al., 2018)

Despite its many advantages, FM grain has been found to have undesirable sensory properties due to it being high in phenolic compounds, including tannins, in some of its varieties; therefore, there is a need to address this challenge when formulating innovative food products containing FM, such as baked goods substituted with FM (Shobana et al., 2013). Although it is not nutritionally adequate, wheat grain contains gluten proteins, which are responsible for the viscoelasticity of baked goods. Substituting wheat with FM could change the physical quality of the biscuits. Therefore, there is a need to investigate the effects of FM on the physical quality and consumer acceptability of baked goods. Biscuits have several advantages as a candidate for fortification; for example, they are energy-dense, shelf-stable and popular among several population groups globally, including in developing regions, particularly sub-Saharan Africa. Biscuits are among the most widely consumed bakery products worldwide, favoured for their convenience, ready-to-eat nature, palatability, affordability and extended shelf life compared to other baked goods (Arshad et al., 2007, Nagi et al., 2012). Furthermore, global acceptance makes biscuits an effective vehicle for nutritional fortification to enhance essential nutrients such as fibre, protein and functional ingredients (Sulieman et al., 2019). Variations in the biscuit formulations result in a variety of biscuit types and hence their key quality characteristics, such as colour and texture (Manley, 2011). FM is brown in colour, and so are chocolate biscuits; therefore, partial substitution of wheat with FM may not negatively affect the colour of the chocolate biscuits. Phenolic compounds, especially tannins, are found in FM grain, a strong astringent flavour to food (Shobana et al., 2013), but some of the ingredients in chocolate biscuits have a strong but desirable flavour and aroma, which may mask the undesirable sensory properties of FM grain. Chocolate biscuits containing brown FM may be as acceptable as standard chocolate biscuits because chocolate biscuits are characteristically brown. There have been several studies that have looked at the use of indigenous ingredients in biscuit making. However, these studies have found different acceptable substitution levels and have been conducted in other parts of the world and not South Africa (Ashritha et al., 2022, Bashir et al., 2022, Abioye et al., 2018, Omoba et al., 2015, Vinay, 2023, Kaur et al., 2020, Jayawardana et al., 2021). Furthermore, these studies have not explored the use of cocoa in the baking of biscuits. Taste preferences are inherently influenced by cultural, regional, and environmental factors, leading to significant variability across different populations. As a result, findings from sensory studies conducted in other parts of the world cannot be directly generalised to South Africa due to distinct taste profiles and dietary habits unique to its population. Moreover, within South Africa itself, the diverse culinary traditions and food preferences across the nine provinces introduce additional variability, making it challenging to extrapolate results from one region to the entire country. This underscores the necessity for region-specific sensory research to accurately capture and address the unique preferences and consumption patterns of local populations, ensuring the development of culturally relevant and acceptable food products. Such an approach not only enhances the validity of the findings but also supports the creation of tailored solutions that resonate with the target demographic. Therefore, this study aimed to determine the effects of partially substituting wheat with FM on the quality of chocolate biscuits in a selected area within the KwaZulu-Natal province, South Africa.

Methodology

The current study was a cross-sectional experimental study design. Chocolate biscuits were prepared using different substituted levels [0% (control), 30%, 50% and 70%] of wheat flour with FM flour (tannin-free and high-tannin). The choice of FM substitution levels was according to a study by Siwela (Siwela, 2009). Figure 1 presents the conceptual framework of the methodology.

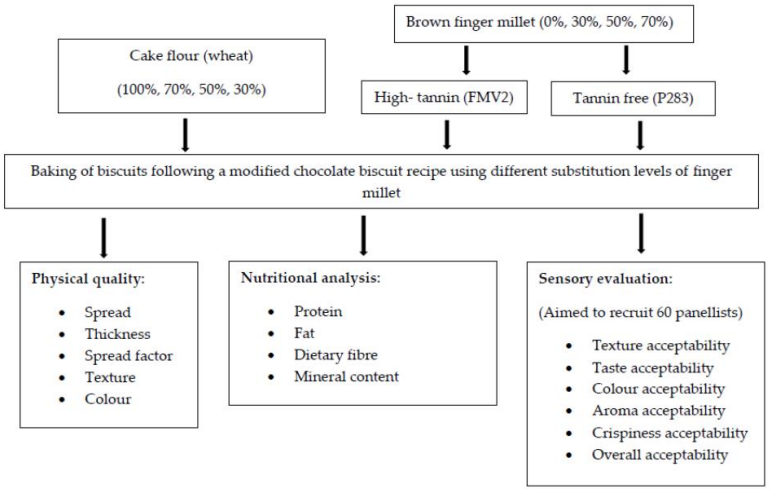

Figure 1: Conceptual framework of the methodology

The sensory evaluation panel was purposely sampled from a population of the entire staff and student body of the School of Agricultural, Earth and Environmental Sciences (SAEES), University of KwaZulu-Natal (UKZN), Pietermaritzburg campus. The 70 panellists were of mixed gender, age and race and were frequent consumers of chocolate biscuits. Only two varieties of plant material were selected for the current study. Both the FM varieties chosen were brown; however, they differed in the tannin content. The varieties were identified as tannin variety and non-tannin variety using the Vanillin-HCl method. The condensed tannin content was quantified using the Vanillin-HCl method as described by Price et al. (1978), incorporating a blank subtraction to account for extract colouration. For the determination of total phenolics, an extraction procedure was employed, with 100% methanol substituted for acidified methanol. Both the sample extracts and the vanillin reagent (comprising 4% HCl in methanol and 0.5% [w/v] vanillin in methanol) were equilibrated to 30°C in a thermostat-regulated water bath prior to mixing. In test tubes, 1 ml of sample extract was combined with 5 ml of vanillin reagent and incubated at 30°C in the water bath for 20 minutes. Sample blanks were prepared by replacing the vanillin reagent with 4% HCl in methanol. Absorbance measurements were taken at 500 nm, with catechin serving as the reference standard (Price et al., 1978). The tannin content of the high-tannin FM (FMV2) was 0.84 mg of catechin equivalents/100 mg, db (0.84% w/w catechin equivalents, db)

FM varieties, high-tannin FM (FMV2) and tannin-free FM (P283) were obtained from UKZN. Only the tannin-free FM (P283) variety was cleaned. First, the grain was sieved using a 2 mm aperture-size sieve. This was to get rid of the big pieces of foreign particles. Then, a 1 mm aperture-size sieve was used to remove smaller particles from the FM grain. Thereafter, the grain was winnowed. Sieves with aperture sizes 12 µm, 53 µm and 1000 µm were used for winnowing. Winnowing helped further separate any dust or foreign particles from the grain. Both varieties of FM were then transferred into marked plastic bags for milling. Both varieties of FM were milled using a centrifugal laboratory mill (2MI Retsch GmbH & Co, Haan, Germany). The flour of either FM variety that passed through a 0.5 mm screen was collected. Both high-tannin FM flour and tannin-free FM flour were brown in colour. In terms of the preparation of biscuits, a standard chocolate biscuit recipe (Anderson, 1917) was tested and adjusted to form the modified chocolate biscuit recipe used in this study. The following changes were made: grated lemon rind and coconut were removed from the recipe. The method for making the biscuits involved beating two eggs (pick n pay) in a bowl, then gradually adding 200 g of white sugar (pick n pay), while continuing to beat until the sugar dissolves. 100 g of margarine (obtained from a local [Pietermaritzburg] supermarket) was incorporated into the mixture and mixed thoroughly. The dry ingredients, including 30 g of corn flour (*Maizena*), wheat, high-tannin and tannin-free FM flours at variable proportions (Table 1), were sifted together and gently stirred into the egg mixture. The remaining ingredients purchased from a local supermarket (5 g baking powder, 3 g NaCl, 3 g cinnamon and 30 g cocoa) were added and mixed until combined. The chocolate biscuits were moulded by loading dough onto a 12.5 ml spoon (this was done as the dough had a low consistency). The biscuits were baked at 190°C for 10-15 minutes. Table 1 shows the wheat flour and FM ratios that were used in the recipe.

Table 1. Amount of finger millet and wheat flour used at different substitution levels to make 90 standard (control) and composite biscuits

Product name	Finger millet (g)	Wheat flour (g)
Wheat flour FM biscuit (Control)	0	120
Tannin-free FM biscuit (30% substitution)	36	84
High tannin FM biscuit (30% substitution)	36	84
Tannin-free FM biscuits (50% substitution)	60	60
High tannin FM biscuit (50% substitution)	60	60
Tannin-free FM biscuits (70% substitution)	84	36
High tannin FM biscuit (70% substitution)	84	36

All ingredients were of food-grade standards (purchased from a local supermarket), and preparation of the biscuit samples was carried out in a certified bench-top food processing room (laboratory) with observation of food safety protocols (HACCP/GMP). The hazard control framework inherently ensured product safety as it was aligned with ISO 22000 principles for low-risk, shelf-stable products. Thus, it was not necessary to analyse the food samples for microbiological safety. The spread and thickness of the biscuits were measured with a ruler after the biscuits had cooled down. The diameter (spread) of 10 biscuit samples was measured, and the mean diameter was calculated. For height, 10 biscuits were stacked on top of each other, and the height was measured, and the mean height calculated. The spread factor of the biscuit samples was calculated using the following equation:

$$Spread\ factor = \frac{Spread\ of\ biscuit}{Thickness\ of\ biscuit}$$

It is more scientific to analyse the colour of biscuits using a colorimeter and express the colour as Hunter L*a*b* values. Similarly, it is more scientific to analyse the texture of the biscuits quantitatively using a texture analyser. Because the researchers did not have access to the instruments named, the colour and texture of the biscuit samples were analysed qualitatively. The qualitative analysis was carried out by one of the researchers, who is a Food Scientist by training and specialised in Cereal Science and Technology (including baking). The researcher generated texture and colour descriptors for the biscuits and then analysed the biscuit samples and the control against the generated texture and colour descriptors. An outsourced laboratory conducted the nutritional analysis. The nutritional composition of the wheat flour, high tannin FM flour, tannin-free FM flour and five chocolate biscuit samples (0%, 30% and 70% substitution) was determined using standard methods (AOAC, 2003, AOAC, 2002). The nutritional composition of biscuit samples substituted with 50% FM was not

analysed. Nutritional analysis was duplicated for each of the replicate samples. The samples were analysed for the following nutrients; protein, moisture, fat, total minerals (ash) and Neutral detergent fibre (NDF).

Sensory evaluation

Seventy staff and students were recruited from SAEES, UKZN, Pietermaritzburg campus to participate in the sensory evaluation. The consumer panel comprised of participants of mixed gender, race, and age. A preliminary pilot study involving 10 staff and students from the School of Social Science, UZKN, Pietermaritzburg, was conducted prior to the main study to evaluate the acceptability of the recipes and refine the methodologies as needed. This ensured that the panellists who participated in the pilot did not participate in the main study. No changes were made to the methodology of the study. For the main study, participants evaluated seven chocolate biscuits for taste acceptability, colour acceptability, texture acceptability, aroma acceptability, crispiness acceptability, and overall acceptability using a 9-point hedonic scale [1 (dislike extremely) to 9 (like extremely)]. The hedonic rating test falls under the affective test class of sensory evaluation, whereby the consumer panel is not trained on how to assess sensory properties but literally uses their perceptions to analyse the product. The researchers only explained the rating scale and the sensory attributes being evaluated. Seven types of chocolate biscuits were given a three-digit number code, which was obtained from the table of random numbers (Heymann, 1995). The serving order of samples was determined using a table of random permutations of nine (Heymann, 1995). A polystyrene plate was then divided into nine equal parts, and seven sample codes were stuck on it. A quarter piece of each chocolate biscuit was then placed on the plates according to the labels. A cup of water, a plate of seven biscuits, a questionnaire and a pencil were placed in each cubicle (Figure 2). The cubicle was made of cardboard and allowed each panellist to have privacy during the tasting of the biscuits. This approach also helped minimise bias by ensuring that participants were unable to communicate with one another during the sensory evaluation. Sensory evaluation data were gathered over two consecutive days, with a total of four sensory evaluation sessions conducted for the assessment. There was sufficient time allocated (one hour) for each panellist to complete the sensory evaluation questionnaire. The time in between each session was used to set up for the next tasting session. The panellist was randomly assigned to individual cubicles for seating. Prior to the commencement of the sensory evaluation session, all panellists completed a consent form. Subsequently, the sensory evaluation procedure was thoroughly explained to each panellist by trained research assistants.

Figure 2: Sensory evaluation set-up

Ethical approval was obtained from UKZN, Humanities and Social Science Ethics Committee (HSS/0105/10PGD). The gatekeeper's permission was granted by the Register of UKZN prior to conducting the study. A consent form was given to each participant to complete and sign prior to participating in the sensory evaluation. Data was coded and thereafter entered into an Excel spreadsheet and cross-checked for errors. The data was then transferred into a statistical package for the Social Sciences (SPSS) version 25 (SPSS Inc., Chicago, IL, USA). The nutritional and sensory evaluation data were analysed using appropriate statistical tests, including ANOVA and Tukey tests. Means and standard deviations were also calculated and presented. A p-value of <0.05 was regarded as statistically significant.

Results

Physical quality of composite biscuits

Figure 3 illustrates the baked composite biscuits. Table 2 presents the physical characteristics of the composite wheat-FM chocolate biscuits at varying substitution levels and the physical characteristics of the different varieties of FM. It is clear that the control chocolate biscuit (0% FM substitution) had the highest spread (73 mm). As FM was added at different substitution levels, the spread of the chocolate biscuits decreased irrespective of the variety of FM. The control chocolate biscuit (0% FM) had the lowest thickness (9.4 mm). The high-tannin and tannin-free chocolate biscuits were thicker in size in comparison to the control chocolate biscuits. With regard to texture, biscuits substituted with either FM variety differed from the control. Generally, chocolate biscuits containing FM were gritty, crumbly, crispy and had large air spaces compared to the control chocolate biscuits. The control chocolate biscuit was the lightest brown colour in comparison to the biscuits containing FM.

Figure 3: Baked biscuits

[OC, standard (control) chocolate biscuits; 2A, biscuits substituted with 30% tannin-free finger millet (FM); 2B, biscuits substituted with 30% high-tannin FM; 3A, biscuits substituted with 50% tannin-free FM; 3B, biscuits substituted with 50% high-tannin FM; 4A, biscuits substituted with 70% tannin-free FM and 4B, biscuits substituted with 70% high-tannin FM].

Further, chocolate biscuits containing high-tannin FM had the darkest brown colour. A common trend noted was that the grittiness, crumbliness, crispiness and air spaces in the chocolate biscuits increased as the FM substitution increased. The biscuit samples became darker in colour as the FM substitution level was increased. As stated earlier, it is more scientific to analyse the colour of the biscuits quantitatively using a colorimeter. Colour is then expressed in Hunter L*a*b* values. Similarly, it is more scientific to analyse texture quantitatively using a texture analyser and express texture in Newtons (to indicate) the hardness of the biscuits. Unfortunately, as stated earlier, the researchers did not have access to a colorimeter and a texture analyser during the study. Table 2 indicates that, in general, the chocolate biscuits substituted with FM had a lower spread factor relative to the control chocolate biscuits.

Table 2. Physical characteristics of composite wheat-FM chocolate biscuits

Biscuits	Substitution level (%)	Code	Spread (mm)	Thickness (mm)	Spread factor	Texture	Colour
			Mean ± SD				
Wheat flour (0% finger millet) (Control)	0	OC	73 ± 0.89^{e}	9.4 ± 0.06^{a}	7.76	fine, compact, not crumbly, gritty or crispy	Light brown, lighter than all other biscuits
P283 (tannin free finger millet)	30	2A	68 ± 0.63^{d}	11.1 ± 0.05^{d}	6.13	Small airspaces, not crumbly, gritty or crispy	Dark brown but lighter than other biscuits except control
	50	3A	66 ± 0.63^{bc}	11.7 ± 0.10^{e}	5.64	Larger air spaces than 2A, 2B and control, slight crisp and slightly crumbly	Similar to 2A and lighter than tannin biscuits
	70	4A	64 ± 0.63^{a}	10.2 ± 0.10^{b}	6.27	Larger and more air spaces than all others. Similar amounts of air spaces to 4B, very crispy, gritty and crumbly	Darker than all other tannin- free biscuits, 2B and 3B
FMV2 (High tannin finger millet)	30	2B	67 ± 0.63^{cd}	10.4 ± 0.06^{b}	6.44	Less compact, more airspaces compared to 2 A but airspaces are still small, not crispy, gritty or crumbly	Darker than 2A and other non-tannin biscuits
	50	3B	67 ± 0.63^{cd}	12.0 ± 0.11^{f}	5.58	Slight crisp, grit and crumble. Larger and more air spaces than control, 2A, 2B and 3 A	Darker than 2A , 3A and 2B
	70	4B	65 ± 0.63^{ab}	10.8 ± 0.23^{c}	6.02	Similar air spaces to 4A and more than all the others. Very crispy, gritty and crumbly	Similar colour to 4A

Means with different letters in the same column are significantly different at p <0.05, according to the Tukey test

Nutritional composition of composite biscuits

Table 3 and Table 4 show the nutritional composition of the flour used to prepare the composite wheat-FM chocolate biscuits and the nutritional composition of the wheat-FM chocolate biscuits, respectively.

Table 3. Nutritional composition of flours used to produce composite wheat-finger millet chocolate biscuits (g /100 g, dry basis)

Flours	Nutritional Composition (Mean ± SD)				
	Protein	Fat	Moisture	Fibre	Total mineral content (ash)
Wheat flour	13.00±0.11^{a}	1.00±0.02^{b}	12.25±1.06^{a}	1.69±0.21^{b}	0.61±0.01^{b}
Tannin free FM	12.66±0.33^{a}	0.84±0.01^{b}	13.75±0.35^{a}	18.21±0.78^{a}	3.30±0.08^{a}
High tannin	8.50±0.06^{b}	1.87±0.08^{a}	13.50±0.00^{a}	19.93±1.08^{a}	3.32±0.16^{a}

SD: Standard deviation; FM: Finger millet; Means with different letters in the same column are significantly different at p< 0.05 according to the Tukey test.

Table 3 shows that the high tannin FM flour has a significantly lower protein content 8% [(w/w]) than the wheat flour (control) (13%) and tannin-free FM flour (12.66%) The fat content in the high tannin FM flour was significantly higher (1.87%) than the wheat flour (control) (1%) and tannin free FM (0.84%) ($p<0.05$). Both varieties of FM had a significantly higher fibre and total mineral content (ash) content than wheat flour. Table 4 shows that the protein content of the control chocolate biscuit (7.43%) was significantly higher than chocolate biscuits containing either FM variety ($p<0.05$). The fat content of the control chocolate biscuit (8.20%) was significantly lower than that of the biscuits containing high-tannin FM, but the control biscuits were higher in fat compared with the biscuits containing the tannin-free FM. The control biscuit had a significantly lower fibre content (6.26%) than the FM biscuits ($p<0.05$). The total mineral content of the control chocolate biscuits (2.62%) was significantly lower than tannin-free FM chocolate biscuits at 30% (2.97%) and 70% (2.83%) substitution and high tannin FM chocolate biscuits (70%) substitution (3.00%) ($p<0.05$). Overall, the results show that as flour of either FM variety was increased, the mineral content and fibre content increased, whilst protein content decreased.

Table 4. Nutritional composition of composite wheat-finger millet chocolate biscuits (g /100 g, dry basis)

Chocolate biscuits	Subst (%)	Nutritional Composition (Mean ± SD)				
		Protein	Fat	Moisture	Fibre	Total mineral content (ash)
Control (100% wheat flour)	0	7.43±0.06^{a}	20.12±0.22a	6.25±0.35^{a}	6.26±0.18^{c}	2.62±0.0^{c}
Tannin free FM (P283)	30	6.81±0.21^{ab}	19.33±0.51^{bc}	5.00±0.00^{b}	6.37±0.27^{c}	2.83±0.02b
	70	6.50±0.23^{b}	18.20±0.14d	5.25±0.35^{b}	8.60±0.12^{ab}	2.97±0.0a
High tannin FM (FMV2)	30	7.40±0.15^{a}	19.01±0.09^{c}	5.50±0.00^{ab}	6.76±0.89^{bc}	2.82±0.05^{c}
	70	6.51±0.28^{b}	19.79±0.23^{ab}	5.00±0.00^{b}	8.71±0.42^{a}	3.00±0.04^{a}

Subst (%): % (w/w) substitution of wheat flour with finger millet; SD: Standard deviation; FM: Finger millet. Means with different letters in the same column are significantly different at p< 0.05, according to the Tukey test

Consumer acceptability of composite biscuits

Table 5 presents the consumer acceptability of composite wheat-FM chocolate biscuits. The addition of FM and the specific variety of FM did not significantly affect the taste, colour, or aroma acceptability of the chocolate biscuits ($p > 0.05$). The taste and colour acceptability of the control chocolate biscuit was comparable to all other biscuits evaluated (6.13 and 6.67, respectively). The texture acceptability of the control biscuit (6.07) was comparable to biscuits containing 30% and 70% tannin-free FM and 50% and 70% high-tannin FM. However, biscuits made with 50% tannin-free FM had slightly lower texture acceptability (5.44), while those with 30% high-tannin FM had slightly higher texture acceptability (6.29) compared to the control biscuit ($p < 0.05$). Additionally, the texture acceptability of biscuits with 50% tannin-free FM (5.44) was slightly lower than that of other tannin-free FM biscuits ($p < 0.05$). The aroma acceptability of the control biscuit (5.90) was similar to that of all other biscuits. For crispiness, the control biscuit (5.04) was comparable to biscuits with 30% tannin-free FM. However, biscuits containing 50% and 70% tannin-free FM exhibited slightly lower crispiness acceptability, while those with 50% and 70% high-tannin FM had slightly higher crispiness acceptability. Notably, the biscuit made with 30% high-tannin FM demonstrated significantly higher crispiness acceptability ($p < 0.05$). The overall acceptability of the control biscuit (6.05) was similar to biscuits containing 30% tannin-free FM and 50% and 70% high-tannin FM. However, biscuits with 50% and 70% tannin-free FM exhibited slightly lower overall acceptability, while those with 30% high-tannin FM showed slightly higher overall acceptability.

Table 5. Consumer acceptability of composite wheat-finger millet biscuits

Composite biscuits	% Subst.	Acceptability (Mean±SD)					
		Taste	Colour	Texture	Aroma	Crispiness	OA
Control (100% wheat flour)	0	6.13±1.69^{a}	6.67±1.21^{a}	6.07±1.46^{ab}	5.90±1.35^{a}	5.04±1.85^{bcd}	6.05±1.52^{ab}
Tannin-free FM	30	6.00±1.57^{a}	6.53±1.14^{a}	5.77±1.49^{ab}	5.75±1.56^{a}	5.16±1.93^{bcd}	6.06±1.21^{ab}
(P283)	50	6.41±1.52^{a}	6.54±1.27^{a}	5.44±1.61^{b}	5.96±1.41^{a}	4.39±1.91^{d}	5.91±1.48^{b}
	70	5.99±1.68^{a}	6.46±1.37^{a}	5.54±1.40^{ab}	5.91±1.42^{a}	4.96±1.90^{cd}	5.96±1.39^{b}
High-tannin FM	30	6.57±1.45^{a}	6.77±1.27^{a}	6.29±1.53^{a}	6.33±1.23^{a}	6.43±1.56^{a}	6.73±1.26^{a}
(FMV2)	50	6.60±1.51^{a}	6.64±1.33^{a}	6.07±1.57^{ab}	6.19±1.41^{a}	5.56±2.00^{abc}	6.48±1.40^{ab}
	70	6.19±1.59^{a}	6.70±1.21^{a}	6.17±1.60^{ab}	6.41±1.53^{a}	5.89±1.74^{ab}	6.32±1.38^{ab}

Substitution (%): (w/w) substitution of wheat flour with finger millet; SD: standard deviation; OA: overall acceptability; FM: Finger millet; Means with different letters in the same column are significantly different at p< 0.05 according to the Tukey test

Discussion

This study aimed to evaluate the impact of partially replacing wheat flour with FM on the physical quality, nutritional composition and consumer acceptability of chocolate biscuits in a selected area within the KwaZulu-Natal province, South Africa. The study results demonstrated that the control chocolate biscuit exhibited a significantly greater spread compared to both FM-containing biscuit varieties. Additionally, the control chocolate biscuit had the lowest thickness, while the thickness increased progressively with the incorporation of FM. These trends are consistent with Kaur et al. (2020), who attributed the reduced spread ratio in FM-substituted biscuits to the high fibre content of FM, which interferes with gluten network formation and gas retention during baking. Similarly, Jayawardana et al. (2021) reported comparable reductions in the spread ratio with FM substitution, further corroborating these findings. The smaller spread factor observed in FM-containing biscuits may be due to the dilution of gluten by FM. Wheat is the ideal cereal grain for baking because it contains gluten proteins that are extensible and cohesive, which are responsible for the expansion and integral structure of baked products (Hoseney, 1994). On the other hand, FM grain is known not to contain gluten proteins and, therefore, lacks the functional property for baking. Chocolate biscuits substituted with FM exhibited distinct textural properties compared to the control chocolate biscuits. FM-incorporated chocolate biscuits were characterised by a gritty, crumbly, and crispy texture and had larger air spaces, contrasting the uniform structure of the control chocolate biscuits. Similar texture alterations were reported by Rajiv et al. (2011), where FM incorporation in muffins resulted in increased hardness and branny mouthfeel (Rajiv et al., 2011). The high fibre content found in either FM variety was probably responsible for the crumbliness and grittiness, as well as ungelatinsed starch. Ungelatinsed starch and fibre components are known to be particulate and gritty and, therefore, contribute to a gritty texture. Additionally, FM is known to have high starch gelatinisation temperatures, which are between 65-69°C. However, starch gelatinisation in biscuits only occurs at 115°C, such high temperatures in starch are most likely not reached during baking (Hoseney, 1994). Thus, ungelatinised starch might have also contributed to the crumbliness and grittiness of the composite biscuits. This study demonstrated that the control chocolate biscuits exhibited the lightest brown colour, while those containing high tannin FM displayed the darkest brown colour, consistent with findings by Jaywardana et al. (2021). The intensified colour in the chocolate biscuits incorporated with FM is likely attributed to pigmented compounds in the testa, which may interact

during baking to enhance browning (Chandra et al., 2016). Furthermore, the tannin-containing FM variety was dark, thus imparting a dark colour on the biscuits compared to the light non-tannin FM variety. The effect of cocoa was the same on both types of biscuits.

Changes in the protein, fibre and fat content of the biscuits correspond with the levels of these nutrients in the wheat flour and the flours of two FM grain varieties (Table 3). Both FM had higher fibre and ash content and lower protein content compared with wheat flour, and hence as the FM flour substitution level was increased, the fibre and ash content of the biscuit samples containing flour of either of the FM varieties increased, whilst their protein content decreased (Table 4). For fat content, the flour of the tannin-free FM variety had a lower fat content than wheat flour, whilst the flour of the high-tannin FM variety had a higher fat content compared with the wheat flour (Table 3). Hence, the observed decrease in the fat content of the biscuit samples with the increase in the flour of the tannin-free FM was increased, whilst the fat content change was vice versa for the biscuits in which the flour of the high-tannin FM variety was increased. On the other hand, the fat content of FM varieties has been found either higher or lower than that of other cereal grains, including wheat (e.g. (Chandra et al., 2016; Ramashia et al., 2019). Thus, the results of the current study confirm the variations reported previously, as the tannin-free FM variety had a lower fat content compared to wheat flour, whereas the high-tannin FM variety was higher in fat than wheat flour (Table 3). The higher fat content in FM chocolate biscuits may offer nutritional benefits, as FM contains essential fatty acids critical for neural development and cholesterol regulation, as also indicated by Ramashia et al., (2019). FM-supplemented chocolate biscuits exhibited a significantly higher fibre content compared to the control chocolate biscuit ($p<0.05$), consistent with studies demonstrating increased fibre in FM-substituted chocolate biscuits (Kaur et al., 2020, Jayawardana et al., 2021). The elevated fibre content is attributed to the FM's unique multi-layered structure (five layers), distinct from other millets (Shobana et al., 2013), and its inherently higher fibre levels relative to wheat, rice and maize (Chandra et al., 2016). FM fibre-rich profile correlates with health benefits such as reduced risks of cardiovascular disease, DM, obesity and colon cancer (Priyanwada et al., 2020). Promoting FM integration into food formulations represents viable dietary strategies to mitigate NCD risks. The results of the current study indicate a significant increase in the total mineral content of the chocolate biscuits with the addition of FM ($p<0.05$), with the control biscuit being similar to the results of previous studies (Jayawardana et al., 2021, Kaur et al., 2020). Finger millet varieties have often been found to have higher mineral content, including calcium, iron, phosphorus, magnesium and vitamins A and B compared with other millets, wheat and maize (Chandra et al., 2016). While it is well known that tannins interfere with the absorption of minerals and other nutrients, the relatively high increased levels of mineral content due to increased levels of FM would offset the proportion of minerals not absorbed due to the tannins. Moreover, tannins are known to have high anti-oxidative properties, which increase the potential to mitigate the risk of degenerative health conditions like cancer. No significant differences were observed in taste, colour or aroma acceptability across the chocolate biscuit formulations. The control chocolate biscuit's texture acceptability (6.07) aligned with formulations containing 30-70% tannin-free FM and 50-70% high tannin FM. However, the 30% high tannin FM substitution achieved the highest texture, crispiness and overall acceptability scores. While prior studies identified 50% FM substitution as preferred (Jayawardana et al., 2021, Kaur et al., 2020), this study highlights the 30% high tannin FM-containing chocolate biscuit as the most preferred across all sensory parameters, emphasising its superior balance of taste, texture and consumer appeal. The implication of this finding is that there is potential for developing nutrient-rich, sensory-acceptable food products that cater for health-conscious consumers or those seeking an enjoyable, healthy snack. FM incorporated at 30% substitution can enhance the nutritional composition of foods and make them a healthier alternative to refined flour-based snacks. This study further shows that the taste and texture can be maintained even when adding FM at 30% substitution, which is crucial for consumer adoption.

Conclusion

It is evident that the addition of FM in chocolate biscuits decreased the spread of the biscuits, increased the thickness and darkened the colour of the biscuits; however, this did not affect the consumer acceptability of the product in terms of colour acceptability. Nutritional analysis showed an increase in fat, dietary fibre and mineral content of the biscuits with the addition of FM. The biscuit substituted with 70% high-tannin FM had the highest nutrient content in terms of fibre and total mineral content. It is clear that FM is a nutritionally superior crop to wheat, and if incorporated into food products and food-insecure household diets, it may have the potential to help reduce both over- and undernutrition and be a good, healthy alternative for health-conscious individuals. Additionally, based on the consumer acceptability of FM biscuits, it is evident that the ideal substitution level was 30% tannin-containing FM. Opportunities for further research include research on FM biscuits and other baked products substituted at 30% to investigate their amino acid profile and micronutrient content.

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References

Abioye, V., Olatunde, S. & Elias, G. (2018). Quality Attributes of Cookies Produced from Composite Flours of Wheat, Germinated Finger Millet Flour and African Yam Bean. *International Journal of Research-Granthaalayah,* 6**,** 172-183.

Anderson, H. S. (1917). *Food and Cookery*, Pacific Press.

AOAC (2002). *Official Methods of Analysis of the Association of Analytical Chemists International*, Maryland, AOAC International.

AOAC (2003). *Official Methods of Analysis of the Association of Analytical Chemists International*, Gaithersburg, ML, USA, AOAC International.

Arshad, M. U., Anjum, F. M. & Zahoor, T. (2007). Nutritional assessment of cookies supplemented with defatted wheat germ. *Food chemistry,* 102**,** 123-128.

Ashritha, T., Kumari, B. A., Jyothsna, E. & Srinivasulu, M. (2022). Sensory Evaluation and Consumer Acceptance of Jaggery Based Minor Millet (Foxtail and Little Millet) Biscuits. *Biological Forum: An International Journal*, 14(4), 628-633.

Bashir, M., Ibrahim, A., Idi, A. & Abdulmalik, M. (2022). Proximate Composition, Sensory Evaluation and Production of Cookies (biscuit) from Finger Millet and Wheat Flour. *Fudma Journal of Sciences,* 6**,** 1-6.

Chandra, D., Chandra, S. & Sharma, A. (2016). Review of Finger Millet (Eleusine coracana (L.) Gaertn): A Powerhouse of Health-Benefiting Nutrients. *Food Science and Human Wellness,* 5**,** 149-155.

Faber, M., Wenhold, F. A. & Laurie, S. M. (2017). Dietary Diversity and Vegetable and Fruit Consumption of Households in a Resource-Poor Peri-Urban South Africa Community Differ By Food Security Status. *Ecology of Food and Nutrition,* 56**,** 62-80.

Govender, L., Pillay, K., Siwela, M., Modi, A. & Mabhaudhi, T. (2017). Food and Nutrition Insecurity in Selected Rural Communities of KwaZulu-Natal, South Africa—Linking Human Nutrition and Agriculture. *International Journal of Environmental Research and Public Health,* 14**,** 17.

Hoseney, R. C. (1994). Principles of Cereal Science and Technology. American Association of Cereal Chemists. *Inc. Minnesota, USA. p,* 270.

Jayawardana, S. A. S., Samarasekera, J. K. R. R., Hettiarachchi, G. H. C. M. & Gooneratne, J. (2021). Formulation and Quality Evaluation of Finger Millet (Eleusine Coracana (L.) Gaertn.) Flour Incorporated Biscuits. *Food Science and Technology International***,** 10820132211020839.

Kaur, A., Kumar, K. & Dhaliwal, H. S. (2020). Physico-chemical Characterization and Utilisation of Finger Millet (Eleusine coracana L.) Cultivars for the Preparation of Biscuits. *Journal of Food Processing and Preservation,* 44**,** e14672.

Mabhaudhi, T., Chibarabada, T. P., Chimonyo, V. G. P., Murugani, V. G., Pereira, L. M., Sobratee, N., Govender, L., Slotow, R. & Modi, A. T. (2018). Mainstreaming Underutilized Indigenous and Traditional Crops into Food Systems: A South African Perspective. *Sustainability,* 11**,** 172.

Manley, D. (2011). Manley's Technology of Biscuits, Crackers and Cookies, Elsevier.

Mutyambizi, C., Booysen, F., Stokes, A., Pavlova, M. & Groot, W. (2019). Lifestyle and Socio-Economic Inequalities in Diabetes Prevalence in South Africa: A decomposition analysis. *PLoS One,* 14**,** e0211208.

Nagi, H., Kaur, J., Dar, B. & Sharma, S. (2012). Effect of Storage Period and Packaging on the Shelf Life of Cereal Bran Incorporated Biscuits. *American Journal of Food Technology,* 7**,** 301-310.

Omoba, O. S., Dada, O. O. & Salawu, S. O. (2015). Antioxidant Properties and Consumer Acceptability of Pearl Millet–Tiger Nut Biscuits. *Nutrition & Food Science,* 45**,** 818-828.

Pheiffer, C., Pillay-Van Wyk, V., Joubert, J. D., Levitt, N., Nglazi, M. D. & Bradshaw, D. (2018). The Prevalence of Type 2 Diabetes in South Africa: A Systematic Review Protocol. *BMJ Open,* 8**,** e021029.

Price, M. L., Van Scoyoc, S. & Butler, L. G. (1978). A Critical Evaluation of the Vanillin Reaction as an Assay for Tannin in Sorghum Grain. *Journal of Agricultural and Food Chemistry,* 26**,** 1214-1218.

Priyanwada, L., Ruvini, L., Barana, J. & Janak, V. (2020). A Comparative Study on Nutritional and Nutraceutical Properties of Finger Millet (Eleusine Coracana) and Rice (Oryza sativa). *World Journal of Biology Pharmacy and Health Sciences,* 1**,** 017-024.

Rajiv, J., Soumya, C., Indrani, D. & Venkateswara Rao, G. (2011). Effect of Replacement of Wheat Flour With Finger Millet Flour (Eleusine Corcana) on the Batter Microscopy, Rheology and Quality Characteristics of Muffins. *Journal of Texture Studies,* 42**,** 478-489.

Ramashia, S. E., Anyasi, T. A., Gwata, E. T., Meddows-Taylor, S. & Jideani, A. I. O. (2019). Processing, Nutritional Composition and Health Benefits of Finger Millet in sub-Saharan Africa. *Food Science and Technology,* 39**,** 253-266.

Rathore, T., Singh, R., Kamble, D. B., Upadhyay, A. & Thangalakshmi, S. (2019). Review on Finger Millet: Processing and Value Addition. *Journal of Pharm Innov,* 8**,** 283-329.

Shobana, S., Krishnaswamy, K., Sudha, V., Malleshi, N., Anjana, R., Palaniappan, L. & Mohan, V. (2013). Finger Millet (Ragi, Eleusine coracana L.): A Review of its Nutritional Properties, Processing, and Plausible Health Benefits. *Advances in Food and Nutrition Research,* 69**,** 1-39.

Siwela, M. 2009. *Finger Millet Grain Phenolics and their Impact on Malt and Cookie Quality.* University of Pretoria.

Sulieman, A. A., Zhu, K.-X., Peng, W., Hassan, H. A., Obadi, M., Siddeeg, A. & Zhou, H.-M. (2019). Rheological and Quality Characteristics of Composite Gluten-Free Dough and Biscuits Supplemented with Fermented and Unfermented Agaricus Bisporus Polysaccharide Flour. *Food Chemistry,* 271**,** 193-203.

Tydeman-Edwards, R., Van Rooyen, F. C. & Walsh, C. M. (2018). Obesity, Undernutrition and the Double Burden of Malnutrition in the Urban and Rural Southern Free State, South Africa. *Heliyon,* 4**,** e00983.

Vinay, G. (2023). A Comparison Study on Nutritional, Textural and Sensory Evaluation of Biscuits Made From Millet. *International Journal of Science and Research (IJSR),* 12**,** 1278-1282.