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ORIGINAL ARTICLE

Nutritional Composition and Sensory Evaluation of Biscuits Fortified with Sorghum (*Sorghum bicolor)* and Cricket Powder (*Acheta domesticus*) for Improved Food Security

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Abstract

This study aimed at generating knowledge on the nutritional composition and sensory evaluation of biscuits fortified with sorghum flour and cricket powder. Four biscuits samples were formulated by substituting wheat flour with sorghum flour and cricket powder at 0, 20, 40, and 60%. The results showed that, the fortification improved some nutrient contents of biscuits significantly ($p<0.0001$). Protein content increased from 10.9 to 17.4% in the four biscuits, fats from 17.3 to 22.7%, ash from 1.1 to 2.00%, crude fiber from 3.59 to 5.58%, energy from 3192 to 3335 Kj/100 g. Iron (Fe) content also increased significantly from 23.3 to 52.1%. However, carbohydrate content decreased from 66.6 to 52.3% in the four biscuits respectively. Copper content decreased drastically with increased fortification while dry matter, calcium, and zinc contents varied inconsistently across the four biscuits. For sensory attributes, appearance, aroma, texture, taste and overall acceptability were significantly ($p<0.0001$) higher in the fortified biscuits. However, all the fortified biscuits were accepted, but biscuits fortified at 40% were the most accepted with higher ratings for appearance, aroma, texture and overall acceptability.

Practical Application

Fortification of biscuits with sorghum flour and cricket powder is a viable option to improve food security, nutritional value of food products and to enhance acceptability of crickets and other edible insects since products developed from them have improved nutritional value.

Keywords: Food Security, Cricket, Fortification, Sensory Evaluation, Nutritional composition, Sorghum.

1. Introduction

Food insecurity and malnutrition are the current twin-problems affecting many poor and rural communities across the world (Van Huis, 2013), and constitute one of the serious concerns in developing economies (FAO, 2014). Elevated levels of food insecurity and malnutrition witnessed in many rural and remote areas across the world continue to deflate the global economy (Kettler *et al.,* 2020). Towering over these problems require innovative and sustainable approach to food production and consumption. Edible insects products are emerging as innovative, promising and sustainable approaches in addressing the issues of food security, malnutrition and income generation (Pascucci & Magistris, 2013; Tran *et al.,* 2015). They are viable option for supplying a sustainable and high quality food resource due to their high nutrient content, minimal environmental impacts and low cost of production (Van Huis, 2013). They provide a rich source of protein, fatty acids, energy, fiber, minerals and vitamins compared to traditional protein sources such as meat (Lensvelt & Steenbekkers, 2014). In fact, their consumption has been lauded as one of the pathways for improving food security and nutritional needs of different human groups across the world (Fellows *et al.,* 2014a). Insects benefits extends to animal production by providing an alternative protein source for animal feeding with greater efficiency, lower resource use, increased productivity, and at the same time ensures environmental and economic sustainability (Oonincx *et al.,* 2010; Adegbeye *et al.,* 2020). Globally, about 2,000 species of insects are reported to be edible (van Huis, 2016) although, most consumptions are domiciled in Europe, South America, East Asia and only some parts of East and Southern Africa (Van Huis, 2013). Their low wide-spread consumption has been mainly attributed to unfamiliarity with the practice. Attempts to promote edible insects' consumption through awareness creation and sensitization on their nutritional properties and health benefits have evoked different intrigues among those unfamiliar with the practice**.** Some of the dominant concerns are; old-fashioned practice, poor textural and visual attributes of the insects and health-related fears (Aboge *et al.,* 2021). Development of insect-based products through fortification or value addition to increase their consumption is an area that has recently gained a lot of interest (Wendin & Nyberg, 2021). Commonly reported practices in insect product development or value addition include; grinding them into meal or processing into pastes, using their powder to make porridge, wheat buns, noddle and muffins (Fellows *et al.,* 2014b). This study contributes to the process by developing biscuits enriched with sorghum flour and crickets powder in an effort to diversify insect-based food products and to increase their consumption. The study uniquely utilizes sorghum in addition to wheat and cricket in developing biscuits as opposed to the conventional use of wheat alone in most confectionaries. Sorghum is a drought-resistant crop native to Africa and is used as staple food for over 500 million people living in the arid and semi-arid tropics (Wagaw, 2019). Sorghum is the main staple crop for the populations that are the poorest and most food insecure in the world (Mwadalu & Mwangi, 2013). It has the potential to increase development and food security in such populations. However, due to a lack of a ready market, insufficient processing capacities, and poor processing efficiency levels, sorghum's economic contribution is little (Kazungu, 2022). The majority of African households typically include cereals in their meals especially wheat, making them the most practical means of supplying vital nutrients like protein to underdeveloped and vulnerable regions (Achi & Asamudo, 2019). Due to its nutritional and economic benefits, composite flour made from wheat and other cereals is increasingly being used in baking of food items (Kadam *et al.,* 2012). Moreover, compositing wheat flour with other locally available cereals and root crops have been reported to be equally desirable (Dauda *et al.,* 2018). Earlier studies have also pointed the benefits of biscuits fortified with cricket powder in connection to a variety of foods (Da Rosa Machado & Thys, 2019). This study aimed at generating knowledge on nutritional composition and sensory attributes of biscuits fortified with sorghum-cricket powder.

2. Materials and Methods

2.1. Source of Materials

The ingredients for the biscuits were wheat flour, house cricket powder (*Acheta domesticus*) and sorghum flour (*Sorghum bicolor*). The cricket obtained were 10 weeks old raised in the insects farm at Jaramogi Oginga Odinga University of Science and Technology (JOOUST) farm. Immediately after harvesting, crickets were frozen at −20 °C to inactive microorganism and enzymes activities, and then blanched at 98 °C for 5 minutes to kill the pathogens, washed with cold water, oven dried at 65°C for 24 hours and then milled to cricket powder, and then sieved through 250 m mesh sieve size. The cricket powder was kept in polyethylene bags and stored at -18°C before being used to make biscuits. Wheat flour was purchased from a local supermarket in Bondo town, Kenya, whereas sorghum grains were bought from a local market then sorted, washed, dried then milled and sieved through a 250 µm mesh sieve to obtain fine flour. In order to preserve the flour before the creation of the biscuit dough, the prepared flours were each packaged, kept at room temperature, and then used. The sorghum-crickets-based biscuits product development was done in the JOOUST food processing laboratory.

2.2. Flour Formulation

The formulation of biscuits flour was based on the Method of the American Association of Cereal Chemists (Method 10–50D, 2000a) as adopted by Morais *et al.,* (2021), with the same ingredients but different substitution levels (**Table 1**). Four biscuit flours were formulated differing in the substitution levels of wheat with a combination of sorghum flour (SF) and cricket powder (CP) at 0% (no substitution), 20% (SF-10% & CP-10%), 40% (SF-25% & CP-15%), and 60% (SF-40% & CP-20%) as adopted by (Awobusuyi *et al.,* 2020). The flours were denoted as WFB (wheat flour biscuit), WSCB1 (wheat-sorghum-cricket biscuit-1), WSCB2 (wheat-sorghum-cricket biscuit-2), WSCB3 (wheat-sorghum-cricket biscuit-3) by replacing an equivalent amount of wheat flour (**Table1**).

2.3. Biscuits Preparation

For each formulation, 2000 g of flour was used and additional ingredients included; sugar 450 g, 9 eggs, vanilla essence 5 ml, salt 5 g, 10 g baking powder and 450 g of margarine (**Table 2**). The ingredients were mixed together in a bowl until a uniform consistency was obtained in about 5 minutes (Otieno *et al.,* 2021). The biscuits ingredients were added in a mixture and kneaded for 3 minutes to make firm dough. The dough was rolled on trays with rolling pin and divided into round shapes with a biscuit cutter (Saad, 2015). Then it was transferred into aluminum baking sheets. The biscuits were baked at a temperature of 230°C for 15 minutes, allowed to cool down at room temperature for 30 minutes, and then labeled with the corresponding letters of the flours before being stored in airtight containers for proximate and mineral analysis and sensory evaluation (**Table 2**).

2.4. Determination of Nutritional Composition

The biscuit samples were dried in an oven to obtain dry matter content according to (AOAC, 1990), ash content obtained by incinerating in a muffle furnace at 550 °C, crude protein was done according to Kjeldahl method by calculating nitrogen value and multiplying it by a factor 6.25 according to (AOAC, 1990). Crude fat was

Table 1: Biscuits Flour Formualtion

Ingredients	Relative Concentrations			
Biscuit sample	WFB	WSCB1	WSCB2	WSCB3
Wheat flour (%)	100	80	60	40
Sorghum flour (%)	0	10	25	40
Cricket powder (%)	0	10	15	20

estimated by Soxhlet extraction method (AOAC, 1990); the crude fibre was determined by using enzymatic gravimetric method-Prosky (AOAC, 1990). The carbohydrate content was calculated as the difference between 100 and the sum of the percentages of water, protein, fat, ash and dietary fibre. Minerals concentration; Iron (Fe), Calcium (Ca), Copper (Cu) and Zinc (Zn) were measured by Atomic Absorption Spectrophotometer (Model AA-7000 Shimadzu, Kyoto, Japan) (AOAC, 2000). These minerals were selected because they are currently of public health concern especially in sub-Saharan Africa where most of their deficiencies are reported (Ohanenye *et al.,* 2021).

Table 2: Quantity of each ingredient in the biscuit formula

Ingredients	WFB	WSCB 1	WSCB 2	WSCB3
Wheat flour (g)	2000	1600	1200	800
Sorghum flour (g)	0	200	500	800
Cricket powder (g)	0	200	300	400
Sugar (g)	450	450	450	450
Margarine (g)	450	450	450	450
Eggs(pieces)	9	9	9	9
Baking powder(ml)	10	10	10	10
Vanilla(ml)	5	5	5	5
Salt (ml)	5	5	5	5

2.5. Sensory Evaluation

Sensory evaluations of the developed cricket-sorghum fortified biscuits were done by 100 randomly selected panelists. The panelists comprised of postgraduate and undergraduate students from Jaramogi Oginga Odinga University of Science and Technology, Bondo (Kenya), and local residents in the area surrounding Bondo town. A standard sensory evaluation technique was followed to minimize the bias and ensure that participants did not influence each other. A five-point hedonic scale with ratings ranging from 1-5 was used in rating the sensory attributes of the biscuits (5-represented the highest score (like extremely), 4-(like very much), 3-(neither like nor dislike), 2- (dislike very much) and 1-(dislike extremely). Colour, taste, texture, aroma/smell and overall acceptability were the attributes selected for the test. The participants were requested to provide informed consent and were allowed to voluntarily participate in the exercise. All the biscuit samples were provided randomly at a time to each participant in well-labeled containers without informing them of their contents. A glass of water was provided for rinsing the mouth before the participants were allowed to taste other biscuits. The participants were asked to rate the biscuits on the sensory qualities which in this case were taste, texture, smell, color, and overall acceptability.

2.6. Statistical Analysis

R-studio software (R- 4.1.3 -2022 editions) was used to analyze the generated data on both the nutritional and sensory evaluation of the biscuits. Means and standard deviations of all the dependable variables in this study were calculated. One-Way Analysis of variance (ANOVA) was used to determine the effects of the biscuits fortified with sorghum-cricket powder on the nutritional content and sensory evaluation of the biscuits. Mean comparison was done using the Fisher's Least Significant Difference (LSD) test to determine whether significant differences exist between means ($p < 0.05$).

3. Results and Discussion

3.1 Proximate Composition

Protein, fat, crude fiber, ash and energy contents of biscuits fortified with sorghum flour and cricket powder improved significantly ($p<0.001$) with increased substitution levels (**Table 3**), while the carbohydrate content of the flours decreased significantly with increased substitution of wheat with sorghum-cricket powder. Proximate analysis results showed that the addition of sorghum flour and cricket powder significantly increased the nutritional contents of the biscuits from 10.9 to 14.3, 15.2, and 17.4% for protein, 17.3 to 17.8, 21.0 and 22.7% for fat, 1.1 to 1.4%, 1.47 and 2.00% for ash, and 3.59 to 4.16, 5.29 and 5.58% for crude fiber and energy contents of the biscuits also improved from 3192 to 3262, 3282, and 3335 Kj/100 g. However, the carbohydrate content decreased from 66.6 to 61.9, 58.0, and 52.3% for 0, 20, 40 and 60% fortified biscuits respectively. Dry matter contents varied inconsistently across the four biscuits formulated. The biscuit labeled WSCB3 (60%) was the most nutritious in terms of protein, fat, fibre, ash and energy. Fortification of wheat-based biscuits with sorghum flour and cricket powder improved the proximate contents of the biscuits except for the carbohydrate content. The improved protein contents of the biscuits indicates that all the biscuits can be considered as good protein sources as showed by WHO, (2007). This is particularly good in the present times when the world is confronted with the challenges of protein-energy malnutrition especially in infants and young children. Proteins are important for regular body growth and development because they assist in the synthesis of new tissues and the repair of worn-out tissues in the body. According to Adeola *et al.*(2017), proteins are also components of hormones, enzymes, and other critical biological activities.

Improvement in the protein content of dishes treated with edible insects is not a new concept (Kinyuru *et al.,* 2021).

Table 3. Proximate composition of biscuits fortified with sorghum flour and cricket powder

Biscuit	Dry matter (%)	Protein (%)	Fat (%)	Ash (%)	Crude fibre (%)	Carbohyrate (%)	Energy (Kcal)
WFB	93.8±0.03^{b}	10.9±0.04^{d}	17.3±0.04^{d}	1.1±0.01^{c}	3.59±0.02^{d}	66.6±0.04^{a}	3192±0.57^{d}
WSCB1	94.7±0.03^{a}	14.3±0.01^{c}	17.8±0.03^{c}	1.45±0.03^{b}	4.16±0.02^{c}	61.9±0.04^{b}	3262±0.47^{c}
WSCB2	93.5±0.03^{c}	15.2±0.01^{b}	21.0±0.02^{b}	1.47±0.05^{b}	5.29±0.06^{b}	58.0±0.01^{c}	3282±0.34^{b}
WSCB3	90.4±0.02^{d}	17.4±0.02^{a}	22.7±0.02^{a}	2.00±0.02^{a}	5.58±0.02^{a}	52.3±0.03^{d}	3335±0.29^{a}
p-value	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001

Each values presented as Mean ± Standard deviation of three replicates. The p-values in each column followed by different superscripts differ significantly (*p≤0.05*)

Preceding studies reported improved contents of protein, fiber, fat and energy contents for a cereal-cricket composite complementary porridge (Aboge *et al.,* 2022) and muffins (Egonyu *et al.,* 2021). Sorghum-cricket composite biscuits have a much lower carbohydrate content since cricket has a low carbohydrate content of 52.3, 58.0 and 52.3 g/100g for 20, 40 and 60% fortified biscuits respectively compared to unfortified biscuits 66.6 g/100g (**Table 3**). Furthermore, similar to the present study, the latter studies reported a reduction in the carbohydrate content of food enriched with cricket's powder. Unlike wheat used to make the biscuits, sorghum flour and cricket powder are poor sources of carbohydrate. The findings of this study is consistent with those of other studies carried out on cereal-based diets supplemented with edible insects; (Aboge *et al.,* 2022; Zielińska *et al.,* 2021) who also reported lower carbohydrates contents in their respective studies. The sorghum-cricket fortified biscuits have much more fat contents compared to non-fortified biscuits of 22.7, 21.0, 17.8 and 17.3 g/100g for 60, 40, 20 and 0% biscuits respectively.

The increase in fat content of the biscuits can be attributed to the addition of cricket's powder since they are high in fatty acids. Fat improve energy and act as a carrier for fat-soluble vitamins in the body. They also supply vital fatty acids to the diet, which are required for good health as reported by Haque *et al.,* (2013). This makes the biscuits good for provision of fats that will contribute to body growth, energy supply and immune function. Improved ash contents of the biscuits with addition of sorghum flour and cricket powder agrees with the findings of Aboge *et al.* (2022) and Otieno *et al.,* (2021). Similarly, Galli *et al.,* (2020) and Osimani *et al.,* (2018) have shown similar outcomes, reporting an increase in the ash level of various fortified foods when cricket powder was added. The crude fiber of non-composite biscuit of 3.59 which was lower compared to fortified biscuits of 5.58, 5.29 and 4.16 g/100g for 60, 40 and 20% biscuits respectively. However, the crude fiber levels of 5.29 and 5.58 g/100 g in sorghum-cricket composite biscuits, respectively, were presumably within the range of not more than 5 g of dietary fiber and other non-absorbable carbohydrates per 100 g dry matter (FAO/WHO, 1994). In a previous study, biscuits were fortified with fermented cassava and crickets to increase their fiber, protein, and fat contents (Otieno *et al.,* 2021). Ash contents of the biscuits also improved with addition of sorghum flour and cricket powder. Ash is regarded as a good substitution indicator of mineral content of any substance as it constitutes the inorganic components. Increased replacement levels in all samples led to an improvement in the fiber content of the fortified biscuits. The increase in fiber content is due to the use of more sorghum flour, which contains more fiber than house cricket powder. The current findings support previous studies that showed that adding cricket and mesquite powder to sponge cakes greatly enhanced their overall dietary fiber content (Goranova *et al.,* 2021). Ash contents of the biscuits also improved with addition of crickets and sorghum in the fortified biscuits as 22.7, 21.0, and 17.8 g/100g for 60, 40 and 20% respectively, compared to 17.3 g/100 for non-fortified biscuits. Ash is regarded as a good substitution indicator of mineral content of any substance as it constitutes the inorganic components.

3.2. Mineral Contents (Zn, Fe, Ca & Cu)

Iron (Fe) and Zinc (Zn) levels in the biscuit fortified with sorghum flour and cricket powder improved with increased substitution (Figure 2).

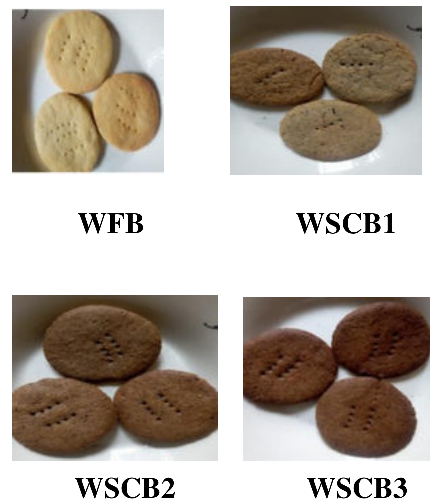

Figure 1: Biscuits formulated at different level of sorghum and cricket inclusions

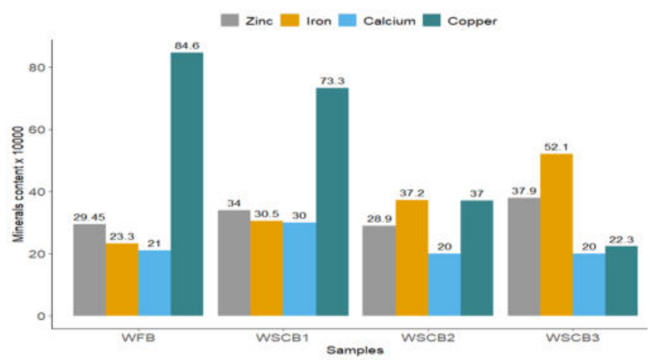

Figure 2: Mineral contents of biscuits fortified with sorghum flour and cricket powder and Non-fortified biscuit (mg/100g)

On the contrary, the copper contents of the biscuits decreased with an increase in substitution levels. The calcium content on the other hand had inconsistent variations. In terms of other minerals, iron and zinc contents of the cricket-fortified biscuits improved with the addition of more sorghum flour and cricket powder. This finding was comparable to that of Maiyo *et al.* (2022), who reported that cricket fortified biscuits have higher minerals contents compared to non-fortified biscuits. A contrary phenomenon was observed in copper contents of the fortified biscuits, which showed a decrease with addition of sorghum-cricket powder. The calcium content of the formulated biscuits on the other-hands varied inconsistently. Minerals are vital for proper functioning of physiological processes (Ohanenye *et al.,* 2021, Adeola *et al.,* 2017). Iron is important for energy metabolism, as well as is needed in the immune system, cognitive development, and also in physical performance (Kuntadi *et al.,* 2018). It has been established that iron shortage has a detrimental effect on immunological functions, infection-related morbidity, physical capability, and job performance across the board (Aspuru *et al.,* 2011). Due to severe anemia from iron deficiency, adults who are exposed to cold environments struggle to regulate their body temperatures. It also impairs behavior and cognitive ability at any age (Clark, 2008). Iron and Zinc are some of the vital minerals whose their deficiencies are common problem in child nutrition in sub-Saharan Africa (Ohanenye *et al.,* 2021). Zinc is necessary for healthy neutrophil and natural killer cell development and function, which is a component of innate immunity (Prasad, 2020). Recently, recently, the role of zinc in regulating oxidative stress has been related to a number of chronic human diseases, including atherosclerosis and associated vascular diseases, mutagenesis and cancer, neurodegeneration, immunologic disorders, and the aging process (Prasad *et al.,* 2004). The sorghum-cricket-fortified biscuits being rich in these two minerals would enhance nutrition of young children and that of the general population when consumed in sufficient quantities. Mineral deficiency results from a shortage in dietary minerals that are necessary for human health and is brought on by a poor diet, decreased mineral absorption after consumption, or inadequate mineral utilization. Examples of mineral deficiencies that have a negative impact on people's health are calcium, iron, and zinc deficiencies (Gharibzahedi & Jafari, 2017). Particularly, deficiency of calcium in the body has been linked to osteoporosis, osteomalacia, and rickets, whereas a deficiency in iron has been linked to anemia. Stunting, diarrhoea, and pneumonia are effects of zinc deficiency in young children (Farias *et al.,* 2020). As a result, sorghum-cricket fortified biscuits' enhanced mineral content can benefit in the elimination of mineral deficiency, especially in children.

3.3. Sensory evaluation of the biscuits

Except for colour (p=0.0519), significant differences were observed in the ratings for appearance, aroma, texture, taste and overall acceptability (Table 4). The latter attributes were rated significantly higher in cricket-fortified biscuits compared to non-cricket biscuit. There was no statistically difference in the ratings for all these attributes among cricket-fortified biscuits. It was noted that the 40% composite biscuits received the highest rankings for appearance (4.37), aroma (4.45), and overall acceptability (8.13). Although respondents preferred the texture (4.37) and flavor (4.45) of the enriched biscuits at 60% while the scores of colour are almost the same for all biscuits 4.05, 4.26, 4.19 and 4.13 for WFB, WSCB1, WSCB2 and WSCB3 respectively (Table 4). When compared to fortified biscuits, the ratings for appearance, color, aroma, texture, taste, and overall acceptability of non-fortified biscuits made from 100% wheat were found to be low at 3.94, 4.05, 3.89, 3.75, 3.79, and 3.93, respectively. Non-fortified biscuit was the least accepted whereas fortified biscuits at 40% were the most appreciated by the panelists. However, all the four biscuits were accepted by the participants according to the ratings.

Table 4: Sensory evaluation of cricket-fortified biscuits compared to non-cricket biscuits

Sample	Appearance	Colour	Aroma	Texture	Taste	Overall acceptability
WFB	3.94±1.29b	4.05±1.22a	3.89±1.26b	3.75±1.40b	3.79±1.37b	3.93±1.24b
WSCB1	4.31±0.895a	4.26±0.928a	4.39±0.942a	4.35±0.983a	4.43±0.795a	4.52±0.759a
WSCB2	4.37±1.00a	4.19±0.940a	4.45±0.869a	4.27±0.920a	4.36±0.905a	4.65±0.575a
WSCB3	4.33±0.817a	4.13±0.991a	4.38±0.962a	4.37±0.895a	4.45±0.657a	4.43±0.685a
p-value	0.0096	0.519	<0.000	<0.000	<0.000	<0.000

Each value presented as Mean ± Standard deviation of three replicates. The p-values in each column followed by different superscripts differ significantly (*$p \leq 0.05$*)

On specific sensory attributes, the brown colour of cricket biscuits became more intense with increased concentration of sorghum flour and cricket powder in the biscuits. This is in line with the findings of Aboge *et al.* (2021) which reported a change in colour of porridge from brown to dark brown upon addition of cricket powder. The colour change can be attributed to the addition of sorghum flour and cricket powder which were basically brown in colour. However, unlike with cricket-based porridge (Aboge *et al.*, 2021), the colour change of the biscuits did not influence their acceptability and this results is in agreement with those of Awobusuyi *et al.* (2020). For aroma, the sorghum-cricket fortified biscuit at 40% had the best aroma according to the participants and this could be attributed to the balance in the main ingredients from wheat, sorghum and cricket, and the resulting starch balance which, when heated through cooking generate a sweet smell compared to other biscuits. The variations in volatiles produced during the baking process may also be attributed to the disparities in both the flavor and aroma among the cookies samples (Mohsen *et al.*, 2009). However, higher concentration of cricket powder in the biscuits reduced the score of their aroma, meaning that the aroma contributed by crickets was not acceptable to the participants. For appearance, sorghum-cricket fortified biscuits at 40% were the most appreciated while non-cricket fortified biscuits were the least liked, although the appearances of all biscuits were accepted according to the ratings. Sorghum enriched biscuits have been previously reported to have good appearance (Maiyo *et al.*, 2022). Appearance is a complex attribute that include visual and textural attributes like colour, shape and texture. Colour and texture of the fortified biscuits were accepted and rated higher contributing to the liking of their appearance.

In fact, the grade for the biscuits fortified at 40% was higher because of the biscuits' brown color. This highlights the importance of color in determining appearance and provides clear proof of its higher ratings. Lower ratings of appearances for the other biscuits can be attributed to their low ratings for colour and texture as contributed by proportionate ingredients in their formulation. However, table (4) shows the statistical analysis of the overall acceptability of biscuits made from composite flours. The findings make it clear that supplementation had a major impact on the biscuits' overall acceptability.

4.0 Conclusions

Biscuits supplemented with the high inclusion of sorghum flour and cricket powder had the best nutritional composition and were the most accepted in terms of appearance, aroma and overall acceptability. Fortification of biscuits with sorghum flour and cricket powder is therefore a viable option not only to improve nutritional value of food products but to enhance acceptability of crickets and other edible insects. Further studies should assess the other chemical components of the biscuits not determined in this study including the amino acids profile, fatty acid composition, vitamin contents, storage stability and shelf life.

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Authors' contributions

The first author conceptualized, designed and conducted the study, interpreted the results and prepared the manuscript draft. The second, third and fourth authors contributed to the design, interpretation of the results, drafting of the manuscript, reviewed and approved the manuscript for publication.

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Ethics Approval and Consent to Participate

Ethical approval was granted by JOOUST-Ethics review committee under the division of Research, Innovation and Outreach (RIO) with approval number ERC/7/4/22(1). Research permit granted by National Commission for Science, Technology and Innovation (NACOSTI) with identification number 578335. Informed consents were given in writing by the participants after voluntarily agreed to participate in the sensory evaluation. They were well informed of the ingredient of the biscuits before participation.

Conflict of interest

The authors declare that there are no conflicts of interest.

Ethics

This Study does not involve Human or Animal Testing.

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