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ORIGINAL ARTICLE

Acceptability and Nutritional Quality of Finger Millet (*Eleusine coracana*) Cookies Enriched with Cricket (*Acheta domesticus)*

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Abstract

The triple burden of malnutrition, characterized by being overweight, hidden hunger, and underweight, is prevalent in Sub-Saharan Africa, including Kenya. Edible crickets are recognized as a sustainable and affordable source of food rich in proteins, lipids, vitamins, and minerals. On the other hand, finger millet is also rich in proteins, nutrients, and antioxidants. This study evaluated the nutritional value of finger millet cookies enriched with crickets alongside the control (finger millet cookies with no cricket enrichment). Formulated cookies were analyzed for sensory attributes and general acceptability by women with children under the age of five years old. The history and motivation of entomophagy of these women were also assessed. Cricket-based cookies had less moisture content and carbohydrate but were rich in protein, crude fibre, crude fat, ash, calcium, copper, iron, manganese, phosphorous, and zinc compared to the control. About 60% of women had the experience of eating insects or insect-based foo. Insects are mainly eaten based on their available and accessible resources (47%) and have high nutritional value (43%). Cricket-based cookies had overall acceptability of 3.3/5.0 based on the texture, mouthfeel, colour, and aroma. Thus, the study recommends that the sensory attributes of cricket-based foods need further improvement to make them appealing without altering their nutritional value should be the target of concern.

Key words: Finger millet, Crickets, Cookies, Malnutrition, Food security

1. Introduction

Globally, almost every country in the world faces severe nutrition-related challenges encompassing double and triple-burden malnutrition. According to the 2021 Global Nutrition Report (GNR), approximately 149.2 million, 45.4 million and 38.9 million children under five years of age worldwide are stunted, wasted, and overweight, respectively. Moreover, the report indicates that we are still off course to meet five out of six global maternal, infant, and young children nutrition (MIYCN) targets on stunting, wasting, low birth weight, anaemia and childhood overweight. Sub-Saharan Africa contributes to the most significant burden of malnutrition in Africa. Children under five years are susceptible to being underweight, stunted, wasted, and even mortality. Between the years 2009 to 2019, the number of stunted children under five years in Africa has risen, while in other regions, the rates are declining (UNICEF/WHO/WB, 2020). Moreover, more than ten million Kenyans suffer from chronic food insecurity, at the same time, two to four million required emergency food assistance occasionally (Kenya National Bureau of Statistics, 2014). Poverty is the key cause of malnutrition in Kenya and other developing countries since access to healthy and sufficient food is imperative

in achieving full physiological and psychological well-being (Belluco *et al.*, 2013). Edible insects such as crickets can provide nutrition security, however, there a need of awareness creation covering a variety of products developed from these insects (Mwiinga *et al.*, 2022).

Extraordinarily, crickets such as *Acheta domesticus* and *Scapsipedus* spp. are rich in proteins (60 g/100g), fats (25 g/100g), and energy (1777Kcal/100g) which can positively impact the health, livelihood and environment (Maiyo *et al.*, 2022; Magara *et al.*, 2021; Losey & Vaughan, 2006). Crickets are also rich in iron, selenium, zinc, copper, and magnesium (Magara *et al.*, 2021).

Finger millet is high in important amino acids and minerals. It contains protein (12.8 g/100), fiber (3.9 g/100g), calcium (350 mg/100g), iron (3.9 mg/100g), and energy (328 kcal/100g), among other minerals. Like crickets, it is easy and cheap to produce and is environmentally friendly. Finger millet is a healthier cereal substitute for rice and wheat. It is gluten-free and rich in protein and amino acids. Finger millet is known to aid brain development in growing children (Thapliyal & Singh, 2015). Hence, when combined with crickets, millet flour it can provide nutritional and health benefits.

Nonetheless, Kenyan food systems are not highly diverse because we depend on staples such as maize and rice to fulfill our dietary needs. This calls for improving nutritional systems by developing diverse nutritious and high-quality foods to improve nutrition. Also, protein sources are limited because animal proteins such as goat meat are not easily accessible (Kinyuru *et al.*, 2012). The accessibility is affected by the economic status of people, the high prices of conventional proteins and the lack of a multipronged media approach to edible insects' acceptability (Mwiinga *et al.*, 2022). Crickets have been sought to provide high mineral and protein content which can be utilized as an affordable source of foods and snacks. Antioxidants found in finger millet are known to fight heart diseases and lifestyle disorders. Moreover, finger millet has a low glycemic index which helps with diabetes (Smart Food Global, 2019). The two ingredients are locally available, and although neglected, they are highly nutritious.

Millet cookies and cricket biscuits have been made before, and their nutritional potential has been explored. However, a combination of both ingredients to make cookies to address food and nutrition security is yet to be explored. Therefore, formulating millet cookies enriched with cricket flour seeks to address malnutrition, although its effectiveness is still unknown. Hence, this study aimed to formulate and determine the nutritional value, organoleptic aspects, and acceptability of millet cookies (snacks) enriched with cricket flour to address malnutrition in children.

2. Materials and Methods

2.1. Source of Materials

The ingredients for the cookies were cricket flour, millet flour and wheat flour. The crickets (*Acheta domesticus*) were sourced from the cricket farm at Jaramogi Oginga Odinga University of Science and Technology. The crickets were harvested and frozen at -20°C to stop enzymatic activities and inactivate microorganism activities. They were then blanched at 98°C for 6 minutes to kill any pathogens that might be present. They were then oven dried at 50°C for 72 hours and milled to flour using a blender. The cricket flour was sieved, packaged and stored in a cool, dry place to be used in the preparation of the cookies (Aboge *et al.*, 2021). Finger millet grains (*Eleusine coracana*) were purchased from local markets in

Nairobi, Kenya. To get millet flour, the finger millet grains were soaked for 16-18 hours and dried. The soaking was to reduce the anti-nutritional factors, especially the phytic acid, which tends to prevent the absorption of other minerals like zinc, iron, and calcium. The finger millet grains were milled at a local miller and sieved to obtain fine flour. The flour was also packaged and stored in a cool dry place. Product development was done at the food processing laboratory at Jaramogi Oginga Odinga University of Science and Technology.

2.2. Flour Formulation and Preparation of Formulated Cookies

The ingredients and their composition for the formulation of cookies are provided in **Table 1**. The flour formulation entailed cricket flour which was 10% of the main source of carbohydrates. The main source of carbohydrates was a combination of millet and wheat flour in a ratio of 3:1. The wheat flour was purposely to help in binding the cricket and millet flour during preparation.

Table 1: Ingredients for the preparation of cookies enriched with cricket

Ingredients	Amount
Wheat flour	75 grams
Millet flour	225 grams
Cricket flour	30 grams
Margarine	100 grams
Sugar	100grams
Eggs	2 eggs
Vanilla	2 teaspoons

The processing involved in the preparation of finger millet cookies enriched with cricket flour has been illustrated in **Figure 1**. The ingredients required for the preparation of the cookies were weighed according to the recipe. For each formulation 330g of flour were used. Refined wheat flour, finger millet flour, cricket flour and other powder ingredients were sieved. After sieving, margarine and sugar were creamed using a mixer until it was soft and fluffy. The essence (vanilla) and eggs was added, followed by the flour mixture (wheat flour, finger millet flour and cricket flour) and baking powder were put into the mixture, and then stirred until the dough was formed. Sheeting of dough and cut out using a mold was done. The shaped dough was transferred to a baking pan, and then baking started with the oven at a temperature of 200°C for 15 min. Cooling of the baked products was done at room temperature. The prepared cookies were packed in their packaging materials. Both formulated cookies prepared from finger millet enriched with cricket were prepared in three replicates. The cookies to be used as a control were purchased from the local supermarket. The control consisted of family classic cookies sold in most supermarkets.

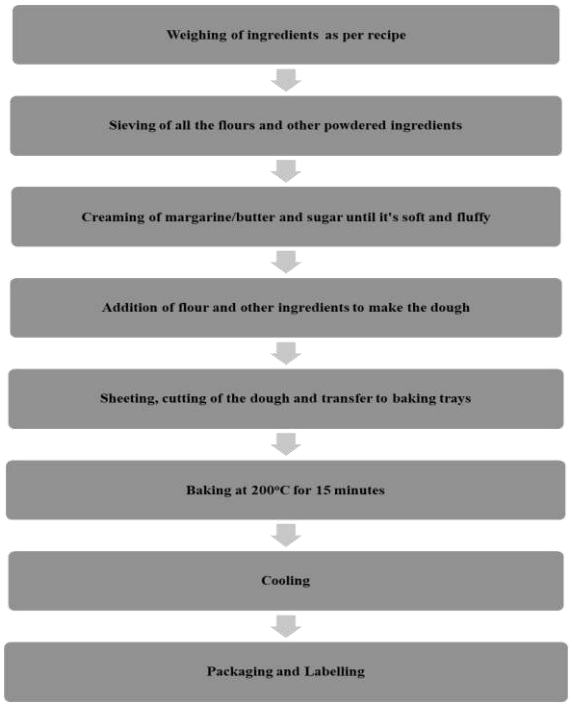

Figure 1: A summary step of the preparation of cakes enriched with crickets

2.3. Analysis of Proximate Composition

Proximate analysis of both cricket-based cookies and commercially available cookies (control) was determined using the Association of Official Analytical Chemists (AOAC) method in three replications. The moisture content of the cookies was obtained in an air oven set at 105oC (method 925.10). The crude protein was determined using the Kjedahl method 978.04 by calculating the nitrogen value and multiplying it with 6.25 (N × 6.25). The ash content was determined by incinerating the samples in a muffle furnace at 550oC, and crude fat was obtained by using the Soxhlet extraction method (method 930.09). The crude fibre was obtained by the enzymatic-gravimetric method of Prosky (AOAC, 1990). The content of carbohydrates was determined using the difference between 100 and the sum of the other contents, i.e., protein, crude fibre, ash, and fat (CHO% = [100−protein %−fat %−crude fibre %−ash %).

2.4. Evaluation of Mineral Composition

Mineral analysis (Ca, Mg, K, Fe, and Zn) was performed by atomic absorption spectroscopy (AAS). The mineral compositions were performed in triplicates for both formulated cookies and the commercially available cookies. The choice of minerals was influenced by the fact that most individuals in the study area were found deficient in these minerals (Ohanenye *et al.,* 2021).

2.5. Acceptability Study of Cricket-Based Cookies

2.5.1. Study Area

The acceptability study was conducted in Machakos County. Machakos is located 63 km southeast of Nairobi, Kenya. The population in Machakos County has rapidly increased from 150,041 in2009 to 1,421,932 based on 2019 census (KNBS, 2019). Machakos is surrounded by hilly terrain, with a high number of family farms. Machakos county was reported to have 8.1% underweight children and 26.5% stunted children (KDHS, 2014).

Although the agroecological condition of the area is semi-arid with medium agricultural potential, - the production is not sufficient due to inappropriate farming practices, unreliable rainfall, and low dietary diversification (Machakos County Development Office, 2018).

2.5.2. Sampling and Socio-Demographic Profiles of Participants

The acceptability study involved a panel of thirty women of child-bearing age. The selection of 30 women was based on purposive sampling by considering that they were willing to participate in the study and they have children under the age of 5 years. Using a questionnaire, the socio-economic data that were collected from women panelists included age, marital status, employment status, religion, and educational level.

2.5.3. History and Motivation of Entomophagy

The history (frequency of eating insects) and motivation for eating insects such as availability and accessibility, nutritional values, and taste and aroma among the 30 selected women were assessed and recorded.

2.5.4. Sensory Analysis

The formulated finger millet cookies enriched with cricket flour and control (commercially available cookies) were subjected to sensory analysis. The control had no enrichment of cricket flour. Thirty selected women were trained on organoleptic evaluation parameters as well as the use of the 5-point hedonic scale on taste, aroma, colour, mouthfeel and texture. The data collection questionnaires were both in English and Swahili. Each individual received five cookies

after the training. Data enumerators helped the individuals fill out the 5-point hedonic scale where needed. The 5-point hedonic scale included 1 = dislike very much, 2 = dislike slightly, 3 = neither like nor dislike, 4 = like slightly, and 5 = like very much. After-taste ratings such as pleasant, unpleasant, and neutral were also evaluated.

2.6. Data Analysis

Descriptive statistical analyses such as proportions, means, and standard deviations were used to summarize the data. Data sets of proximate compositions and mineral contents were subjected to analysis of variance (ANOVA). ANOVA was also used to analyze the effect of the Socio-demographic profile on variables with hedonic values, while the logistic regression was used to analyze the after-test scores. Statistical analysis was performed using R statistical package version 4.0.5.

3. Results and Discussion

3.1. Results

3.1.1. Proximate Composition

There was a significant variation of proximate composition between the control and formulated cookies ($P<0.0001$). Compared with the control (family classic cookies), formulated cookies had significantly high protein, crude fibre, crude fat, and ash and significantly low moisture content and carbohydrate (**Table 2**).

3.1.2. Mineral content

The mineral compositions varied significantly ($P<0.001$) between formulated cookies and the control (**Table 3**). The formulated cookies had significantly high calcium, copper, iron, manganese, phosphorus and zinc.

Table 2: Proximate composition (%) of formulated and control cookies

Proximate composition	Control	Formulated cookies	F-Value	P-Value
Moisture content	5.14 ±0.14 ^{b}	2.09 ±0.44 ^{a}	21.034	<0.001
Protein	3.13 ±0.18 ^{a}	8.68 ±0.63 ^{b}	69.268	<0.001
Crude fiber	0.30 ±0.01 ^{a}	2.77 ±0.23 ^{b}	13.703	<0.001
Crude fat	8.04 ±0.85 ^{a}	11.37 ±1.08 ^{b}	24.953	<0.001
Carbohydrate	82.09 ±0.89 ^{b}	72.82 ±1.57 ^{a}	193.41	<0.001
Ash	1.30 ±0.02 ^{a}	2.28 ±0.11 ^{b}	2.172	<0.001

Different letters adjacent to mean ± standard deviation in each row indicate there is a significant difference between formulation and control

3.1.3. Socio-Demographic Characteristics of the Respondents for Sensory Analysis

A panel of 30 women of child-bearing age participated in the study. Their demographic characteristics and proportion are represented in **Table 4**. The participants were of age between 20 to 49 years, married couples, self-employed, Christians, and educated to tertiary level.

Feeding practices among the participants were identified as the leading cause of malnutrition and were associated with ignorance and poverty. With 66.7% of the participants having attained tertiary education, there was adequate knowledge and information significant to make informed

decisions about the cookies. Information and knowledge were critical factors influencing consumer decisions and choices. About 73.3% of the women were married; therefore, responsible for making informed choices about food purchases and consumption with the help of their husbands, who are the head of most of the households.

Table 3: Mineral contents (mg/100g) in the formulated and control cookies

Minerals	Control	Formulated cookies	F-Value	P-Value
Calcium	11.37±0.93 [a]	55.34±6.72 [b]	4348.4	<0.001
Copper	0.07±0.00 [a]	0.71±0.14 [b]	0.911	<0.001
Iron	1.68±0.05 [a]	2.44±0.37 [b]	1.307	<0.001
Manganese	0.07±0.01 [a]	0.83±0.10 [b]	1.306	<0.001
Phosphorus	12.21±0.23 [a]	60.03±11.47[b]	3146.1	<0.001
Zinc	0.09±0.00 [a]	2.32±0.23 [b]	11.158	<0.001

Different letters adjacent to mean ± standard deviation in each row indicate there is a significant difference between formulation and control.

3.1.4. Experience and Motivation for Eating Insects

Sixty percent of the participants (60%) had a history of entomophagy, while 40% had never eaten insects or food products formulated with insects (Table 5).

Table 4: Socio-Demographic characteristics of the respondents

Characteristic	Category	Frequency (n)	Percentage (%)
Age group	20-29	14	46.7
	30-39	12	40.0
	40-49	4	13.3
Marital status	Married	22	73.3
	Single	5	16.7
	Widowed	1	3.3
	Divorced	2	6.7
Employment status	Employed	10	33.3
	Self-employed	17	56.7
	Unemployed	3	10.0
Religion	Christianity	28	93.3
	Islam	2	6.7
Educational level attained/completed	Primary	3	10.0
	Secondary	7	23.3
	Tertiary	20	66.7

Table 5: History of entomophagy

Ever eaten an insect or insect product	Frequency	Percentage
No	12	40
Yes	18	60

The motivation for eating insects and insect-based products by the participants varied significantly (P<0.001). Respondents cited the availability and accessibility of insects (47%) and insects having high nutritional value (43%) as the main motivation for eating insects or insect-based products. However, taste and aroma were the least motivation according to 10% of the respondents (**Figure 2**). Colour and aroma did not highly appeal to the participants, leading to low acceptability. Despite insect-based foods being high in nutritional value, it is evident that the nutritional value of foods is not the main motivational factor for food intake. According to the observation, it was clear that acceptability among participants was based on availability and accessibility 47%.

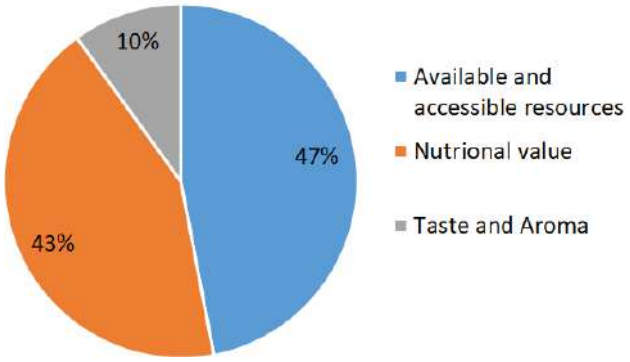

Figure 2: Motivation for eating the cricket-millet cookies for the participants

3.1.5. Acceptability and After-Taste Rating of Millet Cookies Fortified with Edible Crickets

The hedonic ratings of formulated cookies differed significantly among the attributes (P<0.001). Acceptability of the cookies about taste was the highest (4.1), followed by aroma (3.8), then colour (3.4), mouth feel, and texture received least ratings (2.7 and 2.5 respectively) (**Figure 3**). The overall acceptability was 3.3.

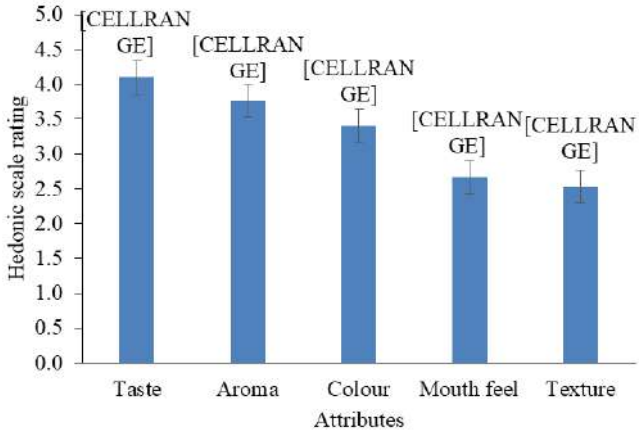

Figure 3: Hedonics after taste rating of the cookies by the participants

Participants had different perceptions of the after-taste rating of the cookies, as shown in (**Figure 4**). Approximately 43% of the participants considered that the cookies had a pleasant after-taste. About 40% of participants considered that cookies had an unpleasant after-taste, and 17% of participants were not sure of the after-taste rating of the cookies.

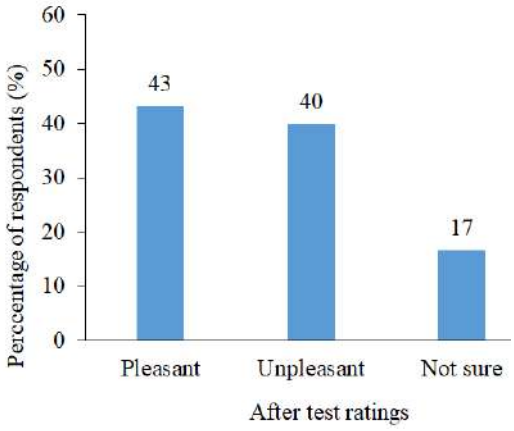

Figure 4: After-taste rating of the cookies by the participants

3.2. Discussion

3.2.1. Proximate and Mineral Composition of Formulated Cookies

In this study, we find nutritional and mineral contents were improved in cricket-based cookies compared to the control. Cricket-based cookies had less moisture content, while rich in protein, crude fiber, crude fat and ash. This is in agreement with a previous study where crickets have been used in food formulations (Maiyo *et al.*, 2022). The mineral contents of the cricket-based cookies were high in terms of calcium, copper, iron, manganese, phosphorous, and zinc. The nutritional component of the crickets satisfied the required levels for individuals of all ages, particularly women of childbearing age; therefore, the cricket-based cookies can be used sufficiently as a supplement for nutrient-rich diets. Conclusions made by previously conducted research have revealed that foods enriched with edible insects have a high nutritional component compared to foods that are not insect-based. A study conducted by Kinyuru *et al.* (2021), showed an increase in the nutritional content of cereal-cricket porridge. Compared to the current study, previous studies revealed that foods enriched with dagaa fish (*Rastrineobola argenta*), and edible insects such as termites (*Macrotermes* spp.), or crickets (*Acheta domesticus*) had high energy, fat, and protein contents (Kinyuru *et al.*, 2015, Konyole *et al.*, 2014; Pauter *et al.*, 2018). Conversely, in line with the current research, a study by Pauter *et al.* (2018), reveals that edible-based foods had low levels of carbohydrates.

The increased levels of nutritional components in the cookies can be attributed to cricket flour. According to Kipkoech *et al.* (2017), crickets are rich in proteins, fats, energy, fiber, and minerals, such as zinc, iron, copper, calcium, manganese, phosphorous, and amino acids. Notably, crickets' protein content is relatively higher than that of other protein sources such as eggs, milk, and meat. El Khoury & Anderson (2013) state that when foods are enriched with proteins, the proportion of carbohydrate content decreases in a food matrix. The increase in proteins in most of the mostly consumed food is in line with the current nutritional and dietary trend, whereby foods with low sugar content and high proteins are being favoured over foods with high sugar content. Protein and other nutritional components being high in cricket-based foods, the formulated cookies can play a significant role in helping combat the problem of malnutrition and food sustainability.

Cookies enriched with crickets had high levels of zinc, iron, copper, calcium, manganese, and phosphorous compared to the control. These observations agree with the findings of Maiyo *et al.* (2022). Cricket-based cookies, therefore, can play a significant role in meeting the nutritional requirements of children.

3.2.2. Sensory Evaluation of the Formulated Cookies

3.2.2.1. Socio-Demographic Characteristics of Participants

Poor feeding practices are among the leading reasons for malnutrition and are associated with poverty and ignorance (Debela *et al.*, 2017). With a high percentage of women (66.7%) having attained tertiary education and 23.3% having attained secondary education, they had sufficient information required to make informed decisions and choices of the formulated cookies. A high percentage of the women (73.3%) were married; therefore, they were responsible for feeding their households. In terms of employment, a high percentage of the women (56.7%) were self-employed; thus, their income levels were low.

The low-income state limits the ability of individuals to access nutritional foods that is sufficient and safe (Kamau *et al.*, 2018). Preferences for eating of insects or insect-based foods are sometimes influenced by the history and culture of entomophagy (Elena *et al.*, 2019). In this study, the majority of the women (60%) had a history of consuming insects or insect-based foods.

The consumption of crickets is incredibly low despite their nutritional value. Various institutions have projects related to insect production and encouraging farmers to engage in insect farming to promote a culture of insect consumption, hence attaining food sustainability and curbing malnutrition in the country. Low consumption of edible insects is a result of various aspects of individuals. The level of education and knowledge of an individual, social and cultural norms, neophobia, and disgust are the significant factors contributing to the low acceptability of insect-based foods (Megido *et al.*, 2016).

3.2.2.2. Sensory Evaluation and Acceptability of Cricket-Based Cookies

The general acceptability and willingness to consume foods depend on various individual attributes. Notably, attributes such as physical appearance, colour, aroma, and texture are perceived before the intake of food, while attributes such as taste are perceived after food intake (Lawless & Heymann, 2010). The identified attributes were low-rated in the formulated cookies, thus the overall low acceptability of the cricket-based cookies. In comparison to the current study, other studies, such as those carried out by Konyole *et al.* (2012) and Pauter *et al.* (2018), insect-based foods have low acceptability when it comes to consumption. The cricket-enriched cookies were rich in high levels of proteins and a wide range of amino acids; hence, they were darker than the unformulated cookies. The cookies were also gritty due to the exoskeleton of the crickets and the silicates found in the finger millet and the head of the cricket too. The texture and mouthfeel influenced the people's low acceptability of the cookies. The cricket-based cookies' aroma and taste were rated higher than other sensory attributes.

4. Conclusion

Enriching foods, such as cookies, with crickets, plays a vital role in improving their nutritional value. Cricket-based cookies had less moisture content and carbohydrate but were rich in protein, crude fibre, crude fat, ash, calcium, copper, iron, manganese, phosphorous, and zinc. There is a generally moderately high acceptability rate (3.3/5.0) of the consumption of insects and insect-based foods. Most women who participated in the sensory analysis were of the age of 20-29 years, married, self-employed and have attained tertiary education. Attractive sensory factors are significant for increasing the acceptability of cricket-based cookies among individuals. In that case, it is important to devise ways and methods that can be used to improve the sensory attributes of crickets and cricket-based foods to make them appealing without altering their nutritional value. Also, it is essential to create awareness among people aiming at informing and increasing their knowledge about the importance and health benefits associated with the consumption of cricket-based foods, such as finger millet-cricket-based cookies. In doing so, the general acceptability and consumption rate of cricket-based foods will be improved.

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Conflict of interest

The authors declare that there are not conflicts of interest.

Ethics

This study was ethically reviewed and permitted by the Ethical Review Committee and Board of Postgraduate Studies of JOOUST. Permission to collect data was obtained from the JOOUST Division of Research, Innovation, and Outreach (RIO) under approval number ERC 22/11/2-29. A research license (NACOSTI/P/22/21848) was also obtained from The National Commission for Science, Technology, and Innovation. The participants in the study completed consent forms and were assured of anonymity.

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