ECRONICON OPEN ACCESS

EC NUTRITION
Research Article

Fortification of Rice-Based *Masa* Diet with Edible Insects: A Possible Tool for Combating Protein Deficiency in Pregnant Mothers and School Children

Otitoju Grace Taiwo Olawale[1,2]*, Otitoju Olawale[3], Kolade John Joseph[4], Ibrahim Ajibola Nihmot[1] and Uwakwe Linda[2]

[1]*Department of Nutritional Sciences, College of Human Sciences, Texas Tech University, Lubbock, USA*

[2]*Department of Food Science and Technology, Faculty of Agriculture and Life Sciences, Federal University, Wukari Taraba State, Nigeria*

[3]*Department of Biochemistry, Faculty of Pure and Applied Sciences, Federal University, Wukari Taraba State, Nigeria*

[4]*Department of Home Economic and Food Science, University of Ilorin, Kwara State, Nigeria*

***Corresponding Author:** Otitoju Grace Taiwo Olawale, Department of Nutritional Sciences, College of Human Sciences, Texas Tech University, Lubbock, USA and Department of Food Science and Technology, Faculty of Agriculture and Life Sciences, Federal University, Wukari Taraba State, Nigeria.

Received: July 17, 2024; **Published:** November 12, 2024

Abstract

The nutritional composition and sensory properties of *masa* produced from rice enriched with edibles insects [grasshopper (*Zonocerus variegatus*) and caterpillar (*Lepidopteran larva*)] were evaluated. The rice, grasshopper and caterpillar flour were blended in the ratios of 100:0 (control), 95:5, 90:10, 85:15, 80:20, 75:25 respectively. Sensory attributes, proximate compositions and amino acids profile were determined using standard analytical methods. The result showed that control sample (100% rice-*masa*) was preferred by consumers with a mean score above 7 in all the sensory parameters considered. Similarly, the result also shows significant ($p < 0.05$) increase in protein, ash, fibre, and carbohydrate contents while ash and moisture content decrease significantly in the enriched *masa*. Again, essential amino acid distributions histidine, isoleucine, leucine, methione, phenylalanine, threonine, tryptophan, valine, lysine and the non-essential amino acid arginine, glutamate, cysteine, glycine, proline, serine, alanine, aspartate, tyrosine enriched with 15 and 25% caterpillar increased significantly ($p < 0.05$). Also, the essential and non essential amino acid contents in samples enriched with 5, 10 and 20% grasshopper were significantly increased ($p < 0.05$). This study shows that enriching rice-*masa* with grasshopper and caterpillar has the potential of raising the nutritional status of the snack. Thus, this may be recommended as snack or breakfast meal for school feeding program as well as a possible means in fighting hidden hunger and malnutrition. This research showed that caterpillar and grasshopper used as enriching agents could serve as excellent sources of protein to combat protein-energy malnutrition and supply limiting amino acids to the rice-based *masa*.

Keywords: *Cereal-Based Foods; Edible Insects; Limiting Amino-Acids; Protein-Dense Masa*

Introduction

Currently, the cost of food item has increased astronomically all over the world with Nigeria having her own portion in a more dramatic increase leading to the diversification of interest to carbohydrate rich food. Carbohydrate foods are most consumed food among households with its consequent effect on protein deficiency among vulnerable groups (pregnant mothers and infants). The prevalence and incidence of protein-energy malnutrition has been identified as one of the most important public health problems in Africa, especially in

Nigeria [1,2]. Several attempts have been made to combat this nutritional problem, but the strategies seem to be far from the solution because they are expensive, mostly imported, and not readily available to the rural and average households in the country. Therefore, there is the need to source for alternative means that meets the protein needs of the populace. Protein-energy malnutrition among preschool children is a major public health problem across the country. Nutritious food of high protein and energy value based on cereal-legume combination have been suggested by several authors [3,4].

In African countries, traditional foods such as *masa* play a critical role in the nutrition of the population. *Masa* is a fermented single - cereal based puff food commonly consumed as a breakfast cake or snack in the Northern region of Nigeria by the Hausa and Fulani people [5]. It could be eaten alone or together with soup. *Masa* being a cereal based food could be prepared from rice (*Oryza sativa* L.), maize (*Zea mays*), millet (*Pennisetum typhoideum*) or sorghum (*Sorghum vulgare*) [6].

The most common one is the rice-based *masa* and the other ingredients for its preparation are active dry yeast, sugar, water, potash and salt. To produce, the rice is milled into flour and grits. The grits are cooked and eventually mixed with the flour (1:2). The paste is eventually fermented for 12 - 16h with yeast, the obtained batter is neutralized with trona (potash) and toasted in pans with individual cuplike depressions [7]. Microorganisms which have been isolated during rice *masa* production include lactic acid bacteria such as, *Lactobacillus plantarum, Pediococcus* sp. and *Micrococcus* sp., and fungi: *Aspergillus, Penicillium, Rhizopus* and *Saccharomyces* sp. [8]. The production of '*masa*' is, however, carried out mainly by lactic acid bacteria and the yeast *S. Cerevisiae* [8]. Like other single-cereal-based foods, *masa* is deficient in the essential amino acid, lysine, threonine, and methionine. The masa contains about 80% of starch, with the mixture of amylase and amylopectin. However, *masa* is rich in B-complex vitamins; it has little quantity of vitamin A, D and C. Also, it contains minerals like calcium, phosphorus and iron. It is a good source of protein, calories and vitamins, especially B-complex vitamins, compared to the raw unfermented ingredients [9].

Although rice is rich in many macros and micronutrients that is useful for human growth and development, it lacks the lysine and tryptophan. Therefore, its daily consumption has been associated with severe protein malnutrition, causing cases like Kwashiorkor, Marasmus in children [10], and susceptibility to diseases like tuberculosis and gastroenteritis [11].

Therefore, combining this rice with a protein rich source that can supply all essential amino acids required by man would not only boost the protein content of the rice but also the nutrient density of the *Masa* [10]. Furthermore, edible insects have been reported have the potential to be a sustainable, healthy, accessible, nutrient-rich, and palatable food source, with over 2100 species consumed in over 113 countries across Africa, Asia, and Latin America [12].

The consumption of insects has recently received more attention because of its promising potential in contributing to livelihoods and mitigating food security problems around the world [13]. The increase in food prices as a result of the possibility of world population being about 9 billion by 2050, will prompt the search for cheap alternative sustainable protein sources. Entomophagy, which refers to the consumption of insects by humans, is an environmentally friendly approach to increasing food for consumption, and contributing to food security across the world [13]. They also have the potential to solve the environmental issues associated with the conventional supply chain [14].

Although, some variations are present in the nutritional composition of the edible insects based on their diet, developmental stage, sex, species, growth environment, and analytical methods employed [15]. They have been reported to contain more protein than conventional animal protein sources like meats (20%) and chicken eggs (25%) [16]. Averagely, edible insects have protein in the ranges of 35 - 60% dry weight and 10 - 25% fresh weight [17]. Edible insects in Orthoptera family; crickets, grasshoppers, locusts; are highly rich in protein [18].

Several review articles have been written on edible insects and research has been conducted to maximize their values, harness their food potential and solve issues of food security. Several studies have reported that most of the foods consumed by children in many parts of developing nations are deficient in essential macro and micronutrients [19-24]. In view of these nutritional problems, several strategies have been used to formulate food [25,26] through a combination of locally available under-utilized food crops that complement each other.

To the best of our knowledge, no research has utilized edible insect in boosting the nutritional density of rice-based cake (*masa*). Therefore, this research studies the impact of two edible insects; Caterpillar (*Lepidopteran larva*) and Grasshopper (*Zonocerus variegates*), on the nutritional quality, amino acid profile and sensory acceptability of *masa*.

Materials and Methods

Materials

White rice grains (*Oryza sativa*) 900g, Royal Instant Dry Yeast 34g, *trona* (sodium bicarbonate) 4g, salt, vegetable oil, onions, sugar and potash used for this study were purchased at new market Wukari, Taraba state.

Fresh grasshoppers and caterpillars were washed and cleaned and roasted in fry pan after the samples were seasoned with salt. Roasted grasshoppers (500g) and caterpillars (500g) were also purchased from a local seller at Wukari, Taraba State.

Methods

Insect processing

The roasted insects (grasshopper and caterpillar) were further oven dried (Model NL-9023A, NLMI, England) at 50°C until dried. The dried insects were milled in a locally fabricated miller into powder and packaged separately in an airtight container until needed.

Rice preparation

The white rice was prepared by washing 500g as shown in figure 1 below. After washing, 125g was weighed and cooked by boiling in potable water until it softens. The remaining 375g of the rice sample was soaked for six hours. After which the 125g boiled rice was mixed with the 375g-soaked rice and packaged for further processing.

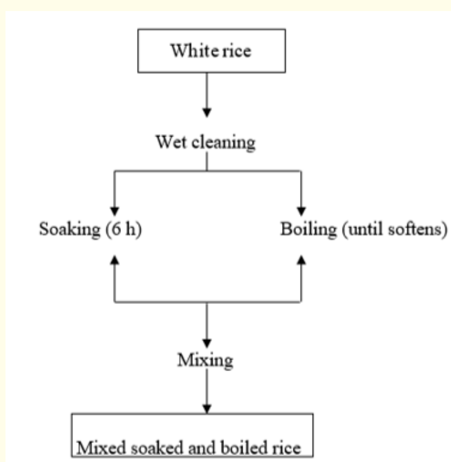

Figure 1: *Flow chart for rice preparation.*

Experimental design

A completely randomized design (CRD) was used and is presented in table 1 below.

Samples	Rice (%)	Caterpillar (%)	Grasshopper (%)
RM (Control)	100	-	-
RCM1	95	5	-
RCM2	90	10	-
RCM3	85	15	-
RCM4	80	20	-
RCM5	75	25	-
RGM1	95	-	5
RGM2	90	-	10
RGM3	85	-	15
RGM4	80	-	20
RGM5	75	-	25

Table 1: *Experimental design for rice-edible insect enrichment.*

Masa preparation

Masa was prepared using the modified method of Owusu-Kwarteng and Akabanda [27] (2014) (Figure 2 below). The prepared rice mixture was wet milled into fine paste. The paste was divided into two portions of equal weight. Each portion was divided into five samples (A-E and F-J). To the first rice portions 5, 10, 15, 20 and 25g of caterpillar powder were added to give samples RCM1-RCM5. To the second rice portions 5, 10, 15, 20 and 25g of grasshopper powder were added to get samples RGM1-RGM5. This is done in accordance to the design given in table 2 above. A control prepared from 100% rice was also prepared. The mixture was formulated according to the recipe (Table 1 above), baker-yeast (4g) was added to each of the paste and was allowed to ferment for 3 hr. Trona water (24 ml), Sugar (15g) and salt (1g) were mixed and added to the fermented batter, it was stirred vigorously. Batter was taken using a medium-sized spoon and fried in a cuplike depression with little oil as done in pancake making for 5 - 8 min.

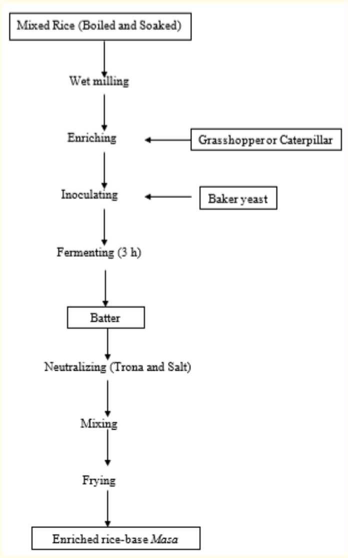

Figure 2: *Flow chart for Masa production [27].*

Analytical methods

Proximate analysis of *masa*

Proximate composition including moisture content, Ash content, crude protein content, crude fat content, crude fiber content and carbohydrate content were analyzed using the standard AOAC methods [28].

Amino acid profile

This was performed as described by AOAC (2016). Each of the sample was dried at 70°C to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the applied biosystems PTH amino acid analyzer. The following steps were involved in the analyses.

Defatting of sample

The sample was defatted using chloroform/methanol mixture of ratio 2:1. About 4g of the sample was put in extraction thimble or wrapped in filter paper and extracted for 15 hours in a soxhlet extraction apparatus.

Nitrogen determination by micro-Kjeldahl method

The nitrogen of protein and other compounds were converted to ammonium sulphate by acid digestion with boiling sulphuric acid.

Methodology: A known weight of sample (250 mg) was placed in Kjeldahl flask and 200 mg of catalyst mixture (potassium sulphate, copper sulphate and selenium powder) was added.

Concentrated sulphuric acid (10.0 cm^3) was added to the content of the flask. The mixture was heated gently for few minutes until frothing ceases and heat was increased to digest for 1 ½ h. The flask content was allowed to cool and made to a known volume with distilled water (100 cm^3).

Aliquot (10.0 cm^3) of the dilute solution of the digest was distilled by pipetting the volume into the distillation chamber of micro Kjeldahl distillation apparatus. Into the distillate, 10.0 cm^3 of 40% sodium hydroxide solution was added and steam distilled into 10.0 cm^3 of 4% boric acid containing mixed indicator (note colour from red-green) titrate with standard 0.01N or 0.02N hydrochloric acid to grey end point.

a = Titre value for the sample.

b = Titre value for the blank.

c = Volume to which digest is made up with distilled water.

d = Aliquot taken for distillation.

e = Weight of dried sample (mg).

Hydrolysis of the sample

A known weight (mentioned in the calculation sheet) of the defatted sample was weighed into glass ampoule. About 7 ml of 6N HCL was added and oxygen was expelled by passing nitrogen into the ampoule (this is to avoid possible oxidation of some amino acids during hydrolysis e.g. methionine and cystine). The glass ampoule was then sealed with Bunsen burner flame and put in an oven preset at 105°C

± 5°C for 22 hours. The ampoule was allowed to cool before broken open at the tip and the content was filtered to remove the humins. It should be noted that tryptophan is destroyed by 6N HCL during hydrolysis.

The filtrate was then evaporated to dryness using rotary evaporator (EV400Touch, 115V, 60Hz, USA). The residue was dissolved with 5 ml to acetate buffer (pH 2.0) and stored in plastic specimen bottles, which were kept in the freezer.

Loading of the hydrolysate into analyzer for amino acid identification

The amount loaded was 60 microlitre. This was dispensed into the cartridge of the analyzer. The analyzer is designed to separate and analyze free acidic, neutral and basic amino acids of the hydrolysate.

Amino acid values calculation

An integrator attached to the Analyzer calculates the peak area as proportional to the concentration of each of the amino acids.

Calorific content calculation

Calorific content was calculated using the water factor method as described by AOAC (2016). The values obtained for protein, fat and carbohydrate were used to calculate the calorific content of the samples as expressed below:

Calorific value (kcal/100 g) = (P×4.0) + (F×9.0) + (C×3.75).

Where protein content (%) = P, Fat content (%) = F and carbohydrate content (%) = C.

Sensory evaluation

The sensory evaluation of the *masa* samples was performed with the aid of 15 judges which was selected at random using the affective method of sensory evaluation. The sensory attributes analyzed were: colour, mouth-feel, aroma, texture, taste and general acceptability on a 9-point hedonic scale as described by (Ihekoronye and Ngoddy 1985 as cited in Yola and Timothy, 2012); 1 = like extremely, 2 = like very much, 3 = like moderately, 4 = like slightly, 5 = neither like nor dislike, 6 = dislike slightly, 7 = dislike moderately, 8 = dislike very much and 9 = dislike extremely.

Statistical analysis

The data were presented as the mean values ± standard deviation of three independent readings per analysis on every sample. The results were analyzed statistically using IBM SPSS version 23.0 by two-way analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT), was used to separate the means at $p < 0.05$. Plotting graphs for presentation of data was performed using Microsoft excel version 2016 (Microsoft, Redmond, WA, USA).

Results and Discussions

Proximate compositions of rice-*masa* enriched with edible insects flour

The proximate composition of rice-masa enriched with edible insects (caterpillar or grasshopper) is presented in table 2 below. There was a significant ($p < 0.05$) difference between the crude protein content of the control and that of the enriched rice-base *masa.* The Protein contents obtained in all samples were between 7.32 - 12.09%. The control sample (RM) had the least protein content while sample (RCM5) prepared from 75% rice enriched with 25% caterpillar had the highest protein content. The protein content of the control (7.32%) is higher than 4.7% reported by Lawal., *et al.* [29] on *masa* prepared from white rice and pearl millet. The difference on this content could be a result of variations in cultivars [30]. The crude protein of the control is also higher than 4.23% recorded by Samuel., *et al*. [31] made from rice purchased in Ibadan, Oyo state Nigeria.

The protein content of sample RCM5 being the highest (12.09%) was higher than that recorded by Samuel., *et al*. [31] on *masa* made from 80% rice: 10% soybean: 10% crayfish and that of Lawal., *et al*. [29]. This is an expected occurrence as edible insects are better sources of protein than plants and sea foods [14,32,33]. The high protein level can boost the nutritional quality of food [34] and contribute to the nutritional well-being of the consumers with the possibilty of combatting nutrition insecurity that arises from protein- energy malnutrition in Nigeria.

Samples	Protein (g/100g)	Fat (g/100g)	Ash (g/100g)	Fiber (g/100g)	Moisture (g/100g)	Carbohydrate (g/100g)	Energy (kJ/100g)
RM	$7.32^{f} \pm 0.03$	$38.89^{a} \pm 0.14$	$3.68^{e} \pm 0.04$	$2.55^{e} \pm 0.08$	$11.58^{a} \pm 0.13$	$35.99^{g} \pm 0.18$	2189
RCM1	$9.09^{de} \pm 0.01$	$28.86^{b} \pm 0.07$	$3.09^{f} \pm 0.04$	$0.25^{f} \pm 0.78$	$7.89^{b} \pm 0.12$	$50.83^{c} \pm 0.06$	2089.6
RCM3	$9.06^{e} \pm 0.01$	$23.72^{cb} \pm 0.37$	$3.58^{e} \pm 0.04$	$3.51^{d} \pm 0.09$	$6.78^{e} \pm 0.13$	$53.36^{b} \pm 0.62$	1937.9
RCMS	$12.09^{a} \pm 0.08$	$28.11^{b} \pm 0.06$	$3.82^{d} \pm 0.02$	$3.68^{c} \pm 0.03$	$7.54^{c} \pm 0.42$	$44.77^{e} \pm 0.06$	2010
RGM1	$9.93^{b} \pm 0.02$	$18.85^{c} \pm 0.09$	$4.23^{b} \pm 0.06$	$4.83^{b} \pm 0.04$	$7.11^{d} \pm 0.06$	$55.07^{a} \pm 0.11$	1798
RGM2	$9.18^{d} \pm 0.03$	$27.77^{b} \pm 0.11$	$5.52^{a} \pm 0.08$	$3.76^{c} \pm 0.06$	$5.76^{g} \pm 0.63$	$48.02^{d} \pm 0.35$	2003
RGM4	$9.76^{c} \pm 0.06$	$30.38^{b} \pm 7.13$	$4.03^{c} \pm 0.04$	$6.31^{a} \pm 0.08$	$6.32^{f} \pm 0.12$	$38.22^{f} \pm 0.16$	1947

Table 2: *Proximate compositions of Rice-masa enriched with caterpillar or grasshopper flour.*

Values are means ± standard deviation of 3 replicates. Mean within a column with different superscripts were significantly different at p < 0.05. RM- 100% rice masa (control). RCM1 - 95:5% rice-caterpillar masa, RCM3- 85:15% rice-caterpillar masa RCM5 - 75:25% rice-caterpillar masa, RGM1 - 95:5% rice-grasshopper masa, RGM2- 90:10% rice-grasshopper masa and RGM4- 80:20% rice-grasshopper masa.

Based on the crude fat content which ranged from 18.85 - 38.89% (Table 2 above) with the control having the highest crude fat content and being significantly (p < 0.05) different from that of the enriched samples. This fat content is relatively higher than the fat content of four (4) varieties of local white rice in Nigeria studied by Olalekan., *et al*. [36], eight (8) varieties of Indian rice studied by Verma and Srivastav [37] and 19.9% of rice-based *masa* recorded by Samuel., *et al.* [31]. Apart from the difference being attributable to variations in cultivars and location of local white rice purchase, there is also a possibility of the increment being a result of the fermentation process and time the rice was exposed to in the *masa* making process. According to Adejuwon., *et al.* [38], fermentation of maize improved the fat content of *ogi* from 10.28 - 15.24%. This therefore agrees with the report that fermented foods are crucial in providing food security, enhancing livelihoods, and improved nutrition and social well-being of the people [39]. The sample (RGI) produced from 80% rice and 20% grasshopper had the highest fat content (30.38%) amongst the enriched samples. This can be attributed to the high fat composition of grasshopper which is an implication of the high level of polyunsaturated fatty acid (PUFA) they contain [40]. This value is higher than 18.9% recorded by Samuel., *et al*. [31] on rice-based *masa* produced from 80% rice and 20% crayfish or the 20.8% of the *masa* made from 80% rice and 20% soybean. Notably, the fat content (28.86%) of the sample RCM1 made from 95% rice and 5% caterpillar flour is significantly (p > 0.05) the same as that of the RGM4. This is in disagreement with the conclusion of Siulapwa., *et al*. [41] that grasshopper is a better source of fat (49%) than caterpillar (12.1%), although their research was on adult caterpillar, this research used the larvae. The findings agree with that of Tzompa-Sosa., *et al.* [42] who reported that caterpillars have higher fat content (8.6 - 15.2 g/100g) than grasshoppers (3.8 - 5.3 g/100g) and other insects in the *Orthoptera* species.

The ash contents of all the samples were significantly (p < 0.05) different with the exception of the control and sample RCC which had significantly (p > 0.05) the same (Table 2 above). The ash content is an indication of the mineral contents of the samples [43]. Minerals are crucial for the effective performance of the tissues and can act as a second messenger in the biochemical mechanism [44]. With the local white rice having ash contents between 1.53 - 1.78% [36], this higher value of the samples (3.09 - 5.52%) could also be attributed to the fermentation process the rice was subjected to in the processing. Notably, is the sample prepared from 90% rice and 10% grasshopper, having 5.52% ash content, the increment could be due to the grasshopper being rich in minerals with potassium (k) being the most abundant. The variation in values may be due to difference in variety of rice and the products used in the enrichment [30].

The fiber content were between 0.25 - 6.31 g/100g, the values were relatively higher than that reported by Samuel., *et al*. [31] on *masa* prepared from rice, soybean and crayfish. The samples enriched with grasshopper were observed (Table 2 above) to have more fiber content than those enriched with caterpillar. It was also observed that the sample (RCM1) with the least fiber content (0.25%) was that enriched with caterpillar at 5%. This could be due to the high dietary fiber content of grasshopper which has been reported [45,46].

The enrichment of rice-*masa* with edible insects caused a reduction ($p < 0.05$) in the moisture content of *masa* from 11.58% to values between 5.76 - 7.82% (Table 2 above). The lower moisture content of the enriched samples makes them more stable than the control. This implies an improvement in the storage value of *masa* as lower moisture content of product would reduce microbial spoilage [35]. In addition, Samuel., *et al.* [31] reported the moisture content of rice-based *masa* enriched with soybean and crayfish to be high. The variation may be due to level of dehydration method (frying) of the snacks (*masa*). The moisture contents of the samples were lower than that of local white rice (13.19 - 13.96%) [36], this could be due to the cooking process (frying) the samples were subjected to. The observed moisture was lower than that (56%) reported by Nkama and Malleshi [47] on *masa* made from rice, pear millet, cowpea and groundnut. It is also lower than (47%) that of Samuel., *et al*. [31] made from rice, soybean and crayfish, combined in different proportions. This could be due to the fact that the edible insects used in the enrichment have low moisture contents (9.1% for caterpillar and 4.5% for grasshopper) unlike the cereals and legumes used by the other authors [41].

The *masa* has high carbohydrate content (35.99 - 55.07%) as shown in table 2 above. This is expected as it is a cereal based product. Samuel., *et al*. [31]reported the carbohydrate content of rice-based masa enriched with soybean and crayfish to be 21.9 - 23.8%. This result does not agree with that recorded in this research, it however, also agrees that *masa* is rich in carbohydrate. The carbohydate content is lesser than that of uncooked rice which is about 71.4 - 81.7 g/100 g of rice [29,37]. This reduction could due to leaching that occurred during soaking and boiling of the rice in *masa* processing. According to Frias., *et al*. [48] soaking alone brings about 19 - 20% reduction in available carnohydrates, while soaking and boiling of food can result in 23 - 24% reduction of available carbohydrates. The research conducted by Hartati., *et al.* [49] also showed that there is a dignificant implication of heating on carbohydrate contents of cocnut milk.

Identification and quantification of amino acids present rice-*masa* enriched with edible insects

In all the samples, nine (9) essential amino acids and nine (9) non-essential amino acids were identified and quantified. These samples include the control and the ones enriched with caterpillar and grasshopper. The amino acids profile of the *masa* are presented in figure 3 below.

The incorporation of caterpillar and grasshopper into *masa* resulted in significant ($p < 0.05$) increase in all the amino acid studied as can be seen in figure 3 below. Amino acids are the building block of protein molecule [35]. Therefore, the increase in the amino acid composition of *masa* produced using caterpillar and grasshopper could be due to the inherent protien contained in the edible insects.

This is in line with an increase in amino acid content of *masa* produced from maize, *acha* and soybean [50]. The high amino acid profile of *masa* enriched with caterpillar and grasshopper could imply a high hydrolytic potential of caterpillar and grasshopper protien. This will result in a high rate of digestibility, bioavaliability and absorption of caterpillar and grasshopper protien in the body [35].

Although lysine was present in the control sample, the quantity was lower than that of all the samples enriched with caterpillar flour. The sample (RCM5) prepared from 75% rice and 25% caterpillar flour had the highest lysine content with that of 80% rice and 20% (RGM4) grasshopper flour pacing second. The sample with the lowest (5%) proportion of caterpillar flour (RCM1) as expected had the least lysine content as opposed to other enriched samples. This finding is in line with several reports from many authors [32,51,52] who have stated that cereal crops lack lysine in significant quantity and edible insects are good sources of complete amino acids [14,23].

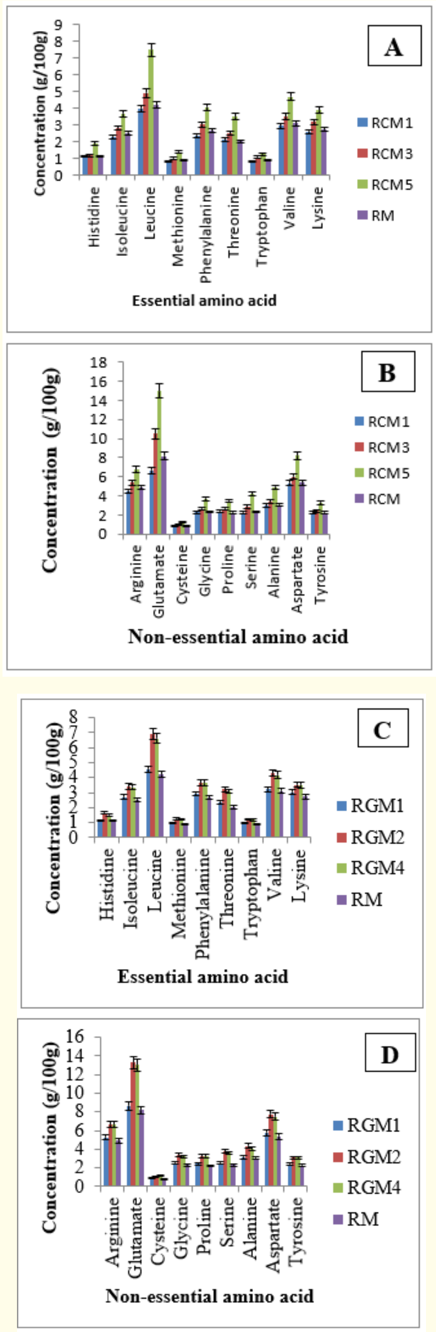

Figure 3: *Amino acid profile of rice-masa enriched withedible insects.*

A is essential amino acid profile of rise-masa enriched with caterpillar, B is non-essential amino acid profile of rice-masa enriched with caterpillar, C is essential amino acid profile of rise-masa enriched with grasshopper, D is non-essential amino acid profile of rice-masa enriched with grasshopper. RCM1- 95:5% rice-caterpillar masa, RCM3- 85:15% rice-caterpillar masa, RCM5- 75:25% rice-caterpillar masa and RM- 100% rice masa (control). RGM1- 95:5% rice-grasshopper masa, RGM2- 90:10% rice-grasshopper masa, RGM4- 80:20% rice-grasshopper masa and RM- 100% rice masa (control).

The substitution of rice with caterpillar at 25% brought about a 41.8% increase in the rice-*masa* lysine content (2.73 - 3.87 g/100 g). Enrichment of rice-*masa* with 20% grasshopper flour brought about a 28.2% increase in the lysine content. This is 13.6% lesser than the caterpillar used at 25%. Regardless, grasshopper is also a good source of lysine (6.39 g/100 g) [32].

However, enrichment with caterpillar at 5% level had no significant effect on the lysine content, rather a decrease (4.8%) in the lysine content (2.73 - 2.6 g/100g) was observed. While that enriched with grasshopper at 5% level (RGM1) brought about an (10.62%) increment from 2.73 - 3.02 g/100g. This result goes on to support the claims of Tome and Bos [53] (2007) that edible insect can act as protein boost in cereal-based foods which are the major staple food in developing countries and are limiting in amino acids [32].

Sensory analysis

The sensory analysis was focused on the intensities of the sensory attributes of the enriched rice-*masa* in comparison with the control based on the subjective judgment of the semi-trained panelist.

Sensory attribute of rice-*masa* enriched with caterpillar flour samples is presented in figure 4 below.

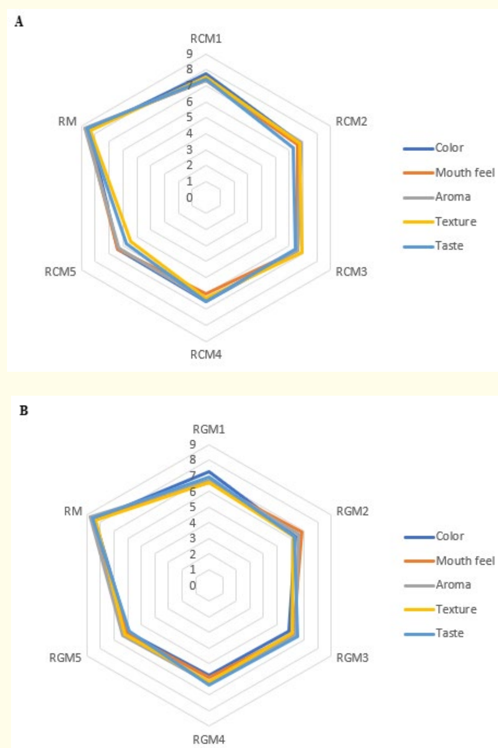

Figure 4: *Sensory chart for rice-masa enriched with edible insects.*

A is rice-masa enriched with caterpillar and B is rice-masa enriched with grasshopper.

RCM1- 95:5% rice-caterpillar masa, RCM2- 90:10% rice-caterpillar masa, RCM3- 85:15% rice-caterpillar masa, RCM4- rice caterpillar masa, RCM5- 75:25% rice-caterpillar masa, RGM1- 95:5% rice-grasshopper masa, RGM2- 90:10% rice-grasshopper masa, RGM3- 85:15% rice-grasshopper masa, RGM4- 80:20% rice-grasshopper masa RGM5- 75:25% rice-grasshopper masa and RM- 100% rice masa (control).

In all the attributes checked, the control sample made from 100% rice (RM) was the most accepted by the panelists. For colour, in all the samples, the colour acceptance reduced as the edible insects proportion incresead. Significantly ($p < 0.05$) as can be seen in figure 4A and 4B above. The control, however had the highest degree of likeness (8.40) which on the 9-point scale is almost liked very much by the panelists.

Based on mouth-feel, there was a significant ($p < 0.05$) difference among the samples acceptance. Degree of likeness in terms of mouth feel decreased with increase in the level of insects added to the rice. RM also showed highest degree of likeness in terms of mouth feel as well as other attributes including aroma, texture and taste as compared to the enriched samples.

In general, all samples were moderately accepted as their average values were above 5.00 and mostly between 6 and 7 which is like moderately on the 9-point hedonic scale. The exceptions were the taste ratings of samples RCM5 (5.73) and RGM5 (5.87) which were prepared from 75% rice and 25% caterpillar and grasshopper flour respectively.

Conclusion

The study shows that, individually, caterpillar and grasshopper are effective in improving the nutritional components of *masa.* Their contribution to the protein content of the rice-*masa* is highly desirable with both edible insects contributing balanced amino acids to the *masa.* Most crucial is the lysine contribution to the amino acid profile. Lysine supply is very important as it plays a crucial role in achieving sustainable global protein supply.

Although, the degree of likeness was lesser when compared to the control sample, the enriched rice-*masa* had acceptance within good degree (6 and 7) in terms of colour, mouthfeel, aroma, texture and taste.

Bibliography

1. Ubesie A and Ibeziakor N. "High burden of protein-energy malnutrition in Nigeria: beyond the health care setting". *Annals of Medical and Health Science Research* 2.1 (2012): 66-69.

2. de Vries-Ten Have J., *et al*. "Protein intake adequacy among Nigerian infants, children, adolescents and women and protein quality of commonly consumed foods". *Nutrition Research Reviews* 33.1 (2020): 102-120.

3. Paarree Vasantha Kumari and Sangeetha Narayanasamy. "Nutritional significance of cereals and legumes based food mix-A review". *International Journal of Agricultural and Life Sciences* 3.1 (2017): 115-122.

4. Nicole S Affrifah., *et al*. "Nutritional significance, value-added applications, and consumer perceptions of food legumes: A review". *Legume Science* 5.4 (2023): e192.

5. Ayo JA., *et al*. "Effect of groundnut paste on the quality of maize based masa". *Pakistan Journal of Nutrition* 7.4 (2008): 557-560.

6. Ndukwe JK., *et al*. "Diet diversification and priming with *Kunu*: An indigenous probiotic cereal-based non-alcoholic beverage in Nigeria". *Beverages* 9 (2023): 14.

7. Clayton DA., *et al*. "Food handlers beliefs and self-reported practices". *International Journal of Environmental Health Research* 12.1 (2002): 25-39.

8. Sanni AI and Adesulu AT. "Microbiological and physico-chemical changes during fermentation of maize for massa production". *African Journal of Microbiology Research* 7.34 (2013): 4355-4362.

9. USDA FoodData Central (usda.gov).

10. Temba MC., *et al*. "The role of compositing cereals with legumes to alleviate protein energy malnutrition in Africa". *International Journal of Food Science and Technology* 51.3 (2016): 543-554.

11. Rizwana B., *et al*. "Protein-energy malnutrition: a risk factor for various ailments". *Critical Reviews in Food Science and Nutrition* 55.2 (2015): 242-253.

12. Jackson Ishara., *et al*. "The contribution of commonly consumed edible insects to nutrition security in the Eastern D.R. Congo". *Scientific Reports* 14 (2024): 16186.

13. Zabentungwa TH., *et al*. "Nutritional composition of edible insect consumed in Africa: A systematic review". *Nutrients* 12.9 (2020): 2786.

14. Kim TK., *et al*. "Edible insects as a protein source: a review of public perception, processing technology, and research trends". *Food Science of Animal Resources* 39.4 (2019): 521-540.

15. van Huis A and Oonincx DGAB. "The environmental sustainability of insects as food and feed A review". *Agronomy for Sustainable Development* 37 (2017): 43-50.

16. Mlcek J., *et al*. "A comprehensive look at the possibilities of edible insects as food in Europe-a review". *Polish Journal of Food and Nutrition Sciences* 64.3 (2014): 147-157.

17. Schluter O., *et al*. "Safety aspects of the production of foods and food ingredients from insects". *Molecular Nutrition and Food Research* 61.6 (2017): 1600520.

18. Rumpold BA and Schluter OK. "Nutritional composition and safety aspects of edible insects". *Molecular Nutrition and Food Research* 57.5 (2013): 802-823.

19. Brabin BJ and Coulter JBS. "Nutrition-associated disease". In: Manson's Tropical Disease. Saunders: London (2003): 561-580.

20. Otitoju GTO and Otitoju O. "Effect of plantain inclusion (Abgabga and Pita 22 Musa AAB) on nutrient composition of infant complementary foods". *JDAN* 2.1 (2011): 16-21.

21. Klunder HC., *et al*. "Microbiological aspects of processing and storage of edible insects". *Food Control* 26.2 (2012): 628-631.

22. Lesnik JJ. "Termites in the hominin diet: A meta-analysis of termite genera, species and castes as a dietary supplement for South African robust australopithecines". *Journal of Human Evolution* 71 (2014): 94-104.

23. Kouřimská L and Adámková A. "Nutritional and sensory quality of edible insects". *NFS Journal* 4 (2016): 22-26.

24. Jideani AIO and Netshiheni RK. "Selected edible insects and their products in traditional medicine, food and pharmaceutical industries in Africa: utilisation and prospects". Future Foods (2017).

25. Lalude LO and Fashakin AA. "Development and nutritional assessment of a weaning food from sorghum and oil-seed". *Pakistan Journal of Nutrition* 5.3 (2006): 257-260.

26. Ijarotimi OS and Ashipa F. "Evaluation of nutritional composition, sensory and physical properties of home processed weaning food based on low cost locally available food materials". *Nutrition and Food Science* 36.1 (2006): 6-17.

27. Owusu-Kwarteng J., *et al*. "Effect of soybean fortification on fermentation characteristics and consumer acceptability of Hausa Koko, a Ghanaian fermented porridge". *Journal of Applied Biosciences* 28 (2010): 1712-1717.

28. Association of Official Analytical Chemists [AOAC]. Official Method of Analysis of the AOAC (Horwitz Editor) Eighteenth Edition. Washington (DC), AOAC (2016).

29. Lawal RA., *et al*. "Chemical composition, antinutrients, vitamins and mineral composition of Masa (fermented puff batter) produced from pearl millet and local white rice". *Nigerian Food Journal* 37.1 (2020): 91-95.

30. Bonte DR and Picha DH. "Carbohydrate-related changes in sweet-potato storage roots during development". *Journal of the American Society for Horticultural Science* 125.2 (2000): 200-204.

31. Samuel FO., *et al*. "Nutrition and sensory evaluation of rice base *masa* enriched with soybean and crayfish". *Food and Nutrition Sciences* 6.2 (2015): 234-241.

32. Inje FO., *et al*. "Protein quality of four indigenous edible insect species in Nigeria". *Food Science and Human Wellness* 7.2 (2018): 175-183.

33. Gałęcki R., *et al*. "Potential utilization of edible insects as an alternative source of protein in animal diets in Poland". *Frontiers in Sustainable Food Systems* 5 (2021): 1-8.

34. Imathiu S. "Benefits and food safety concerns associated with consumption of edible insects". *NFS Journal* 18 (2020): 1-11.

35. Ajayi O., *et al*. "Nutritional properties of *Sakada* produced from blends of cassava and Africa yam bean flour". *Acta Universitatis Cibiniensis. Series E: Food Technology* 24.2 (2020): 215-222.

36. Olalekan ASA., *et al*. "Nutritional composition and heavy metal profile of Nigerian rice varieties". *Current Research in Nutrition and Food Science* 7.2 (2019): 1-11.

37. Verma Dk and Srivastav PP. "Proximate composition, mineral content and fatty acids analyses of aromatic and non-aromatic Indian rice". *Rice Science* 24.1 (2017): 21-31.

38. Adejunwo Adejuwon KP., *et al*. "Effect of fermentation on nutritional quality, growth and hematological parameters of rats fed sorghum-soybean-orange flesh sweet potato complementary diet". *Food Science and Nutrition* 9.2 (2020): 639-650.

39. Adesulu AT and Awojobi KO. "Enhancing sustainable development through indigenous fermented food products in Nigeria". *African Journal of Microbiology Research* 8.12 (2014): 1338-1343.

40. Torruco-Uco JG., *et al*. "Chemical, functional and thermal characterization, and fatty acid profile of the edible grasshopper (*Sphenarium purpurascens Ch.*)". *European Food Research and Technology* 245.2 (2019): 285-292.

41. Siulapwa N., *et al*. "Nutritional value of four common edible insects in Zambia". *IJSR - International Journal of Scientific Research* 3.6 (2012): 876-884.

42. Tzompa-Sosa DA., *et al*. "Insect lipid profile: aqueous versus organic solvent-based extraction methods". *Food Research International* 62 (2014): 1087-1094.

43. Harris GK and Marshall MR. "Ash analysis". In: Nielsen, S.S. (eds) Food Analysis. Food Science Text Series. Springer, Cham (2017).

44. Whitney E and Rolfes SR. Nutriçao. Ed Cengage Learning, São Paulo (2008): 342.

45. Sepuuya G., *et al*. "Nutritional composition, quality, and shelf stability of processed *Ruspolia nitidula* (edible grasshoppers)". *Food Science and Nutrition* 5.1 (2016): 103-112.

46. Ibarra-Herrera CC., *et al*. "Nutritional content of edible grasshopper (*Sphenarium purpurascens*) fed on alfalfa (*Medicago sativa*) and maize (*Zea mays*)". *CyTA - Journal of Food* 18.1 (2020): 257-263.

47. Nkama I and Mallesh ING. "Production and nutritional quality of traditional Nigerian masa from mixtures of rice, pearl millet, cowpea, and groundnut". *Food and Nutrition Bulletin* 19.4 (1998): 366-373.

48. Frias J., *et al*. "Influence of processing on available carbohydrate content and antinutritional factors of chickpeas". *European Food Research and Technology* 210 (2000): 340-345.

49. Hartati Y., *et al*. "Effect of temperature and heating time on chemical and proximate characteristics of laksan sauce as a Palembang traditional food". *Pakistan Journal of Nutrition* 17.2 (2018): 64-70.

50. Malomo AA and Abiose SH. "Protein quality and functional properties of masa produced from maize, acha and soybean". *Food Research* 3.5 (2019): 556-563.

51. Banjo AD., *et al*. "The nutritional value of fourteen species of edible insects in Southwestern Nigeria". *African Journal of Biotechnology* 5.3 (2006): 298-301.

52. Cerritos R. "Insects as Food: An ecological, social and economical approach". *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 4.27 (2009): 1-10.

53. Tome D and Bos C. "Lysine requirement through the human life cycle". *Journal of Nutrition* 137.6 (2007): 1642S-1645S.

Volume 19 Issue 9 September 2024