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Research article

Assessment of Mulberry Silkworm Pupae and African Palm Weevil larvae as alternative protein sources in snack fillings

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ABSTRACT

The search for alternative food sources especially protein to meet the nutritional demand of the projected 9 billion world population by 2050 is now critical. Edible insect is an alternative source of protein in many African and Asian cuisines where beef, pork and chicken are perceived to be relatively expensive. The current study evaluates Mulberry Silkworm Pupae (MSP) and African Palm Weevil larvae (APW) as substitute to the mainstream proteins in snacks fillings, and also assessing the consumer acceptability of the new products. The chemical composition showed that MSP is higher in protein and soluble fibre contents while APW is higher in crude fat, crude fibre, zinc, manganese and calcium contents. The cooked edible insects were rich in both essential and non-essential amino acids. When used as fillings for snacks, the protein content of the snacks produced with APW and MSP compared favourably well with the snacks produced with beef fillings. The fat contents of the snacks were 18 % lower than those of snacks made with beef fillings. The mineral contents of the snack with APW were significantly higher than the other samples. There was no significant difference in the taste and overall acceptability of samosa snack produced with beef, APW and MSP. African palm weevil larvae and Mulberry silkworm pupae could serve as alternative sources of protein in the production of snacks and cuisines, and a viable source of income generation.

1. Introduction

Going by the current pace of global food production, much is still needed to be done to meet the food demand of the increasing population. Food insecurity is still rife in many developing countries in Africa and Asia where population is astronomically increasing (Belluco et al., 2013; Rumpold and Schlüter, 2013b). Environmental questions and animal welfare are issues dominating debates in the developed countries necessitating the search for alternative protein source outside the mainstream animal proteins including fish, chicken, pork and beef (Belluco et al., 2013). Tackling protein-energy malnutrition in the developing countries and cardiovascular-related diseases caused by red meat in developed countries makes the search for alternative food sources highly imperative (Bryant et al., 2003).

Entomophagy is the practise of eating insects. About 2 billion people worldwide eat insect regularly (Van Huis et al., 2013). The choice of edible insects as alternative food source arises from its richness in protein, and minerals and the nutritional benefit they offer to human (Li et al., 2013; Nowak et al., 2016). It is also a source of income as the production of silkworm alone generated over US$50 million to the Thailand economy in 2004 (Sirimungkararat et al., 2010) and several processing techniques have been developed to explore the delicacy in Korea (Ji et al., 2015).

Insects are a class within the arthropod group that have a chitinous exoskeleton (a three-bodied part consisting of the head, thorax and abdomen) and have served as a food source for humanity for ages (Van Huis et al., 2013). They have been described by the Food and Agricultural Organisation (FAO) as alternative food sources with high nutritional value (Rumpold and Schlüter, 2013a; Van Huis et al., 2013). Insects are a healthy and sustainable source of high-quality proteins (Van Huis et al., 2013). Arthropods like lobsters and shrimps were once considered poor-man's food in the West, but they are now expensive delicacies. Edible insects have a number of comparative advantages than livestock. They have high reproduction rate, emit lesser amount of greenhouse gases, very low environmental pollution, low cost of production with relatively low water consumption and per kilogram more protein than beef or pork (Oonincx and de Boer, 2012). These advantages notwithstanding, the rate of use of edible insects and studies on the same is still very low as consumption is characterised by repulsive feelings (Kim et al., 2017).

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Edible insects are increasingly used to enrich various food products in protein such as bread (Roncolini et al., 2019), gluten-free bread (Da Rosa Machado and Thys, 2019), wheat pasta (Duda et al., 2019), high energy biscuits (Akande et al., 2020) amongst others. Edible insects have also been used in diverse quantities in snacks where it serves as a substitute to animal protein (Banjo et al., 2006; Kinyuru et al., 2009; Ojinnaka et al., 2016). Samosa and pie are among the major snacks in Africa with beef, chicken or fish as the major protein fillings in the flour-rich snacks. Diversifying the sources of protein in these common snacks with the use of edible insects, that have been processed and blended with other materials, will create additional alternative food sources which may also enhance the marketability and utilization of edible insects in several other cuisines.

The current study is aimed at creating alternative food sources with the use of African palm weevil larvae (*Rhynchophorus phoenicis*) and the mulberry silkworm pupae (*Bombyx mori*) in snacks to overcome prejudices against insects and overcome repulsive feeling; and assessing the physicochemical composition and consumer acceptability.

2. Materials and methods

2.1. Source of materials

Flour, margarine, baking powder, salt, eggs, Irish potato, onions, vegetable oil and beef were purchased from a local market in Akure, Ondo State, Nigeria. The African palm weevil larvae (*Rhynchophorus phoenicis*) was obtained from a farm in Agbuta, Gbonyin Local Government Area, Ode–Ekiti, Nigeria, while the Mulberry silkworm pupae (*Bombyx mori*) was purchased from the sericulture section of the Wealth Creation Agency (WECA), Akure, Ondo State, Nigeria. All other chemicals used for analyses were of analytical grade.

2.2. Ethical approval

The research was considered and approved by the ethical committee of School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Ondo State, Nigeria with reference number: FUTA/SAAT/2019/013.

2.3. Production of boiled edible insects, fillings and snacks

2.3.1. Boiled insect production

Edible insects boiled without seasonings was prepared with 100 g of each of the edible insects with 150 ml of potable water and boiled for 15 min. The boiled insects were then blended with an electric blender for 10 min until a smooth texture was obtained. For the edible insects boiled with seasonings, the same procedure was followed as above with 5 g of salt and 10 g of seasoning cube. The resultant mixture for the edible insects boiled with or without seasonings were used for the proximate, dietary fibre, mineral and amino-acid analyses.

2.3.2. Fillings and snacks production

Pie: The mixing composition of the fillings and snacks is shown in Table 1. The all-purpose flour was first mixed thoroughly with margarine before all the other ingredients were added and kneaded to form a dough. The fillings for pie were produced using beef, African palm weevil larvae or mulberry silkworm pupae as major source of protein. To 150 g of each protein source, seasonings were added and boiled for 15 min in 200 mL water. The boiled content was then blended together (Binatone Kitchen machine KM-1250). For the pie, 100 g of fresh Irish potatoes which was boiled with 150 mL of water for about 10 min was added to the blended mixture alongside diced onions and fried in 10 mL of vegetable oil for about 5 min. Equal quantities of the different fillings were then scooped into the kneaded dough (carefully cut out with a pie cutter), sealed and baked in the oven at a temperature of about 205 °C for 35 min.

Samosa: The all-purpose flour and the margarine were first mixed thoroughly before the addition of water into the mixture which was then kneaded on a smooth platform. The fillings for samosa was produced using beef, AWP or MSP. To 100 g of each of the protein source, seasonings were added and allowed to boil in 200 mL water for 15 min. The resultant mixture was then blended, and mixed with 10 g of fresh pepper and 10 g onions which was thoroughly mixed together and fried in 5 mL of vegetable oil. Then, 2 g each of the fillings for each batch of samosa was then scooped into the carefully cut out samosa wraps and then deep fried in vegetable oil until brown.

2.4. Proximate composition of the edible insects and the snacks (pie and samosa)

All analyses were carried out using AOAC (2000) method. The moisture content was determined using hot-air oven method at a temperature of 105 °C for three hours. Crude protein content was determined using Kjeldahl method and 4.76 and 6.25 were used as conversion factor for snacks with edible insects and beef respectively (Janssen et al., 2017). The crude fibre was determined using acid and alkali digestion method. Fat and ash contents were determined using the soxhlet extraction

Table 1. Snacks production materials and proportion.

Snacks Production Materials	Pie			Samosa		
	1	2	3	1	2	3
Dough production						
Flour (g)	600	600	600	300	300	300
Margarine (g)	200	200	200	50	50	50
Water (mL)	200	200	200	300	300	300
Egg (mL)	50	50	50	-	-	-
Salt (g)	0.5	0.5	0.5	-	-	-
Baking powder (g)	1.0	1.0	1.0	-	-	-
Filling Production						
Beef (g)	150	-	-	100	-	-
African Palm Weevil (g)	-	150	-	-	100	-
Silkworm Pupae (g)	-	-	150	-	-	100
Seasoning (g)	6.6	6.6	6.6	3.3	3.3	3.3
Salt (g)	5	5	5	5	5	5
Onion (g)	5	5	5	5	5	5
Irish Potato (g)	100	100	100	-	-	-
Fresh Pepper (g)	-	-	-	10	10	10

Table 2. Nutrient composition of the boiled edible insects with or without seasonings.

Parameters	SWOS[1]	SWS[2]	PWOS[3]	PWS[4]
Moisture (%)	52.4 ± 0.31^{a}	50.7 ± 0.61^{b}	40.8 ± 0.12^{d}	46.3 ±0 .25^{c}
Protein (%)	17.1 ± 0.48^{a}	16.3 ± 0.40^{b}	11.3 ± 0.05^{d}	11.6 ± 0.09^{c}
Fat (%)	15.31 ± 0.39^{b}	14.48 ± 0.01^{c}	18.35 ± 0.05^{a}	15.10 ± 0.10^{b}
Crude fibre (%)	0.80 ± 0.01^{c}	0.25 ± 0.01^{d}	5.25 ± 0.14^{b}	6.56 ± 0.24^{a}
Soluble fibre (%)	16.0 ± 0.00^{b}	20.8 ± 0.02^{a}	10.9 ± 0.02^{c}	9.7 ± 0.04^{d}
Insoluble fibre (%)	80.3 ± 0.10^{a}	79.3 ± 1.50^{a}	83.7± 3.30^{a}	84.1 ± 3.30^{a}
Ash (%)	1.01 ± 0.01^{c}	2.12 ± 0.01^{b}	0.28 ± 0.01^{d}	2.72 ± 0.02^{a}
Carbohydrate (%)	13.40 ± 0.58^{d}	16.17 ± 0.18^{c}	24.01 ± 0.03^{a}	17.73 ± 0.35^{b}
Energy (Kcal/100g)	260 ± 1.45^{b}	260 ± 0.59^{b}	306 ± 0.13^{a}	253 ± 0.54^{c}
Energy (KJ/100g)	1086 ± 1.45^{b}	1088 ± 0.59^{b}	1280 ± 0.13^{a}	742 ± 0.54^{c}
Iron (ppm)	1.42 ± 0.63^{d}	3.07 ± 0.03^{a}	1.96 ± 0.05^{c}	2.40 ± 0.07^{b}
Zinc (ppm)	2.03 ± 0.04^{c}	1.88 ± 0.02^{d}	4.22 ± 0.03^{b}	5.94 ± 0.07^{a}
Manganese (ppm)	0.21 ± 0.21^{c}	0.21 ± 0.01^{c}	1.11 ± 0.01^{a}	1.01 ± 0.02^{b}
Calcium (ppm)	2.49 ± 0.13^{d}	4.27 ± 0.09^{c}	7.13 ± 0.04^{a}	6.53 ± 0.42^{b}
Phosphorus (ppm)	55.7 ± 1.44^{a}	55.9 ± 0.84^{a}	44.7 ± 1.58^{b}	44.7 ± 0.48^{b}

Values are Mean ± SD· Values with different letters across the row differ significantly at $p < 0.05$.
[1] Silkworm pupae without seasonings.
[2] Silkworm pupae with seasonings.
[3] Palm weevil larvae without seasonings.
[4] Palm weevil larvae with seasonings.

method and incineration at 550 °C respectively. The carbohydrate content was obtained by difference.

2.5. Soluble and insoluble fibre determination

The dietary fibre comprises of the soluble fibre and the insoluble fibre which was determined by the modified Klason dietary fibre method derived from the standardized method using AOAC (1995).

2.6. Mineral determination

The mineral determination of the edible insects and snacks produced were carried out using the Atomic Absorption Spectrophotometer, as described by AOAC (2005). The sample (0.5 g) was digested in 20 mL each of acid solution of nitric acid and sulphuric acid. The resultant solution was subjected to heating until white fumes becomes noticeable. The clear solution obtained was diluted with distilled water until 50 mL was attained and it was filtered using a filter paper. The standard working solutions of each elements to be analyzed for were prepared to plot the standard calibration curve. The calibration curves were used to determine the concentration of the element of interest in the sample.

2.7. Amino acid determination

About 30 mg of defatted boiled edible insects were hydrolysed with 6 M HCl and used for amino acid analysis. The amino acid analysis was carried out using the ion exchange chromatography method (FAO/WHO, 1991) with the Technicon Sequential Multisample (TSM) Analyser (Technicon Instruments Corporation, New York). The duration of analysis for each sample was 76 min with a gas flow rate of 0.50 mL/min at 60 °C. Measurement and calculation of the net height of the peak of each amino acids produced by the chart recorder of the analyser was done. The amino acid values reported was the averages of replicate determinations. Internal standard used was norleucine. For tryptophan analysis, the defatted sample was hydrolysed using 4.6 mol/L potassium hydroxide. Waters C18 reversed phase column (3.9 × 150mm) (Waters Miliford, MA) was used in the analysis of tryptophan. The solvents and gradient conditions was carried out according to the method of Hariharan et al. (1993).

2.8. Sensory analysis

The sensory analysis of the pie and samosa snacks produced from edible insects was carried out according to ethics of School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Ondo State, Nigeria as stated in subsection 2.2. Grading of the snacks was done on a nine-point hedonic scales where 1 = 'dislike extremely' and 9 = 'like extremely'. Informed consents were obtained from the twenty semi-trained panelists including male and female who were familiar with the consumption of edible insects. The test samples were served to the panelists in a random order. Pies and samosas were evaluated separately based on four attributes: taste, aroma, appearance, and overall acceptability.

2.9. Statistical analyses

All analyses were carried out in triplicates and the differences between means were determined by one-way ANOVA. Sample means were separated using Duncan's multiple range test with SPSS version 17 (SPSS Inc., Chicago, IL, USA), and considered statistically significant if $p < 0.05$.

3. Results and discussion

3.1. Proximate composition of boiled edible insects

The proximate composition of the African palm weevil larvae and Mulberry silkworm pupae boiled with or without seasonings is shown in Table 2. Seasonings were added to enhance their delicacy and palatability. The moisture content for the edible insects when boiled with or without seasonings ranged from 40.8 - 52.4%. Mulberry silkworm boiled without seasonings had the highest moisture content while the African Palm weevil had the lowest. The ash content of the edible insects ranged from 0.28 - 2.72%. Boiling with seasoning significantly increased the ash contents in both African palm weevil and Mulberry silkworm larvae an indication that they are rich in minerals.

The fat content of the edible insects ranged between 14.48 -18.35%. This is within the range reported for over 100 edible insects (Chen et al., 2009). Fat is very important for the digestion; it stores energy and protect vital organs. Fat is also very important in retaining the flavour of food (Aiyesanmi and Oguntokun, 1996).

Table 3. Amino acids (mgAA/100g protein) profile of the boiled edible insects.

Amino acids	SWOS[1]	SWS[2]	PWOS[3]	PWS[4]	*RDA[10]
Essential Amino acids					
Valine	4.62 ± 0.04^a	4.61 ± 0.05^a	4.65 ± 0.05^a	4.61 ± 0.04^a	3.5
Threonine	4.32 ± 0.06^a	3.98 ± 0.04^b	4.35 ± 0.04^a	4.30 ± 0.05^a	3.4
Isoleucine	4.60 ± 0.08^b	4.22 ± 0.04^c	6.08 ± 0.16^a	6.11 ± 0.05^a	2.8
Leucine	7.63 ± 0.07^b	8.08 ± 0.05^a	7.63 ± 0.18^b	7.67 ± 0.05^b	6.6
Lysine	8.42 ± 0.05^a	8.43 ± 0.04^a	7.60 ± 0.02^b	7.52 ± 0.05^b	5.8
Methionine	2.13 ± 0.21^{ab}	2.46 ± 0.03^a	2.03 ± 0.07^b	2.02 ± 0.05^b	2.2
Phenylalanine	3.94 ± 0.07^a	3.73 ± 0.06^a	3.73 ± 0.32^a	3.87 ± 0.05^a	2.8
Histidine	2.46 ± 0.06^c	2.52 ± 0.04^c	5.57 ± 0.11^a	3.22 ± 0.06^b	1.9
Tryptophan	1.20 ± 0.06^c	1.61 ± 0.04^a	1.50 ± 0.02^{ab}	1.43 ± 0.05^b	1.1
Non- essential Amino acids					
Glutamate	15.92 ± 0.43^a	15.02 ± 0.06^a	13.49 ± 0.72^b	13.86 ± 0.05^b	-
Glycine	4.83 ± 0.04^a	4.02 ± 0.03^c	4.22 ± 0.03^b	4.18 ± 0.05^b	-
Alanine	7.34 ± 0.04^a	5.92 ± 0.01^b	5.51 ± 0.04^c	5.47 ± 0.05^c	-
Serine	4.33 ± 0.08^a	4.00 ± 0.03^a	4.15 ± 0.35^a	4.30 ± 0.05^a	-
Proline	3.38 ± 0.05^a	3.14 ± 0.03^b	3.05 ± 0.02^{bc}	2.99 ± 0.05^c	-
Aspartate	8.02 ± 0.04^b	8.79 ± 0.05^a	8.07 ± 0.10^b	8.08 ± 0.04^b	-
Arginine	6.19 ± 0.06^a	6.36 ± 0.03^a	5.50 ± 0.11^b	5.19 ± 0.43^b	2
Tyrosine	2.45 ± 0.38^b	3.21 ± 0.09^a	2.87 ± 0.16^{ab}	2.86 ± 0.16^{ab}	-
Cysteine	1.78 ± 0.05^b	1.72 ± 0.04^b	2.61 ± 0.04^a	1.40 ± 0.08^c	-
TEAA[5]	54.44 ± 1.47^a	53.60 ± 2.05^a	54.19 ± 1.30^a	54.69 ± 1.75^a	-
TNEAA[6]	37.54 ± 1.88^a	37.44 ± 0.14^a	35.69 ± 1.32^a	34.13 ± 1.31^a	-
TAA[7]	89.81 ± 6.42^a	89.83 ± 3.76^a	94.35 ± 0.20^a	88.21 ± 2.77^a	-
TSAA[8]	4.08 ± 0.35^a	4.22 ± 0.04^a	4.41 ± 0.20^a	3.36 ± 0.16^b	-
% TSAA	44.73 ± 0.64^b	41.84 ± 0.61^c	58.54 ± 0.92^a	39.99 ± 1.13^c	-
TEAA/TAA%	57.20 ± 2.24^a	60.37 ± 1.22^a	60.65 ± 0.77^a	60.61 ± 0.72^a	-
TAEAA[9]	4.68 ± 0.80^a	5.77 ± 0.48^a	4.88 ± 0.84^a	5.34 ± 0.05^a	-

Values are Mean ± SD. Values with different letters across the row differ significantly at $p < 0.05$.
[1] SWOS (Mulberry silkworm pupae boiled without seasonings).
[2] SWS (Mulberry silkworm pupae boiled with seasonings).
[3] PWOS (African palm weevil boiled without seasonings).
[4] PWS (African palm weevil boiled with seasonings).
[5] TEAA Total essential amino acid.
[6] TNEAA total non-essential amino acid.
[7] TAA total amino acids.
[8] TSAA total sulphur amino acids (Cysteine + Methionine).
[9] TAEAA total aromatic essential amino acids (Phenylalanine + Tryptophan).
[10] RDA Recommended Dietary Allowance, *FAO/WHO (1991).

The crude fibre content of the edible insects ranged between 0.25 - 6.56%. The African palm weevil larvae boiled with or without seasonings are exceptionally high in crude fibre when compared to the Mulberry silkworm pupae which may be due to the presence of chitin in their exoskeleton. Chitin in Chinese edible insects have been reported to have medicinal value (Chen et al., 2009).

The protein content of edible insects ranged between 11.3 – 17.1 %. Boiled Mulberry silkworm pupae have crude protein contents that were significantly higher than that of African palm weevil larvae. Both African palm weevil larvae and the mulberry silkworm pupae are rich sources of protein when cooked with or without any seasonings. These values are within the range reported for over 100 different edible insects in China (Chen et al., 2009). Qualitatively, the protein of insects such as silkworm pupae has been analysed and found to be safe for human consumption (Zhou and Han, 2006). The carbohydrate content ranged between 13.40 – 24.01 % while the energy value ranged between 742 - 1280 kJ/100g. While the edible insects are rich source of protein, they also supply energy. Other edible insects also from Europe have been reported to be good sources of protein and equally supply energy (Zielińska et al., 2015).

3.2. Mineral composition of edible insects

Table 2 showed that edible insects boiled with and without seasonings are rich in minerals such as iron, zinc, manganese, calcium, and phosphorus which are all important supplements essential for the human body. The high content of iron and zinc is of particular interest as a way to alleviate deficiencies that could be found in the diet of pregnant women in the developing world (Mlcek et al., 2014; Scholl, 2005) and gluten-free diets that are nutritionally deficient in minerals (Rybicka, 2018). The zinc, manganese and calcium contents of the edible insects were significantly higher in African palm weevil larvae boiled with or without seasonings when compared with Mulberry silkworm pupae. The phosphorus content of Mulberry silkworm pupae was however 25% higher than that of African palm weevil larvae. Many authors have compiled the nutrient composition of several edible insects and reported that they are rich sources of iron, manganese, magnesium, phosphorus

Table 4. Chemical composition of the pies and samosas.

Parameters	Pie			Samosa		
	PWB[1]	PWS[2]	PWAP[3]	SWB[4]	SWS[5]	SWAP[6]
Moisture (%)	11.5 ± 0.10^{a}	11.5 ± 0.04^{a}	10.4 ± 0.15^{b}	20.4 ± 0.06^{y}	26.6 ± 0.06^{x}	19.2 ± 0.07^{z}
*Protein (%)	16.0 ± 0.09^{a}	14.8 ± 0.05^{b}	12.6 ± 0.05^{c}	14.2 ± 0.14^{y}	14.7 ± 0.04^{x}	13.3 ± 0.02^{z}
Fat (%)	29.55 ± 0.15^{a}	27.20 ± 0.10^{b}	24.15 ± 0.15^{c}	27.40 ± 0.11^{x}	24.55 ± 0.55^{y}	22.40 ± 0.20^{z}
Crude fibre (%)	5.10 ± 0.10^{b}	4.86 ± 0.10^{c}	5.73 ± 0.05^{a}	4.20 ± 0.20^{y}	4.56 ± 0.03^{x}	4.61 ± 0.45^{x}
Soluble fibre (%)	9.8 ± 0.00^{b}	9.8 ± 0.20^{b}	10.8 ± 0.00^{a}	9.1 ± 0.03^{y}	8.8 ± 0.07^{z}	9.8 ± 0.04^{x}
Insoluble fibre (%)	89.8 ± 0.34^{a}	89.0 ± 0.66^{a}	89.1 ± 3.12^{a}	90.4 ± 0.05^{x}	91.0 ± 0.04^{x}	90.2 ± 0.04^{x}
Ash (%)	0.04 ± 0.10^{b}	1.46 ± 0.00^{a}	0.05 ± 0.03^{b}	0.60 ± 0.01^{z}	1.71 ± 0.06^{x}	1.64 ± 0.01^{y}
Carbohydrate (%)	37.27 ± 0.15^{c}	40.13 ± 0.15^{b}	47.08 ± 0.20^{a}	37.01 ± 0.03^{y}	27.92 ± 0.62^{z}	38.90 ± 3.35^{x}
Energy (Kcal/100g)	479 ± 0.4^{a}	465 ± 0.3^{b}	456 ± 0.4^{c}	451 ± 0.3^{x}	391 ± 1.2^{z}	410 ± 3.6^{y}
Iron (ppm)	2.41 ± 0.21^{b}	2.30 ± 0.01^{c}	3.63 ± 0.02^{a}	2.38 ± 0.11^{y}	2.16 ± 0.01^{z}	3.22 ± 0.03^{x}
Zinc (ppm)	1.75 ± 0.03^{c}	2.02 ± 0.03^{b}	5.22 ± 0.03^{a}	1.83 ± 0.49^{y}	1.92 ± 0.03^{y}	2.04 ± 0.05^{x}
Manganese (ppm)	0.26 ± 0.03^{c}	0.34 ± 0.05^{b}	0.35 ± 0.01^{a}	0.31 ± 0.01^{y}	0.31 ± 0.21^{y}	0.42 ± 0.02^{x}
Calcium (ppm)	4.34 ± 0.03^{c}	5.34 ± 0.07^{b}	7.59 ± 0.02^{a}	7.05 ± 0.07^{z}	7.23 ± 0.02^{y}	8.21 ± 0.02^{x}
Phosphorus (ppm)	44.9 ± 2.8^{b}	49.8 ± 1.1^{a}	41.8 ± 0.7^{c}	44.7 ± 0.75^{y}	44.4 ± 1.24^{z}	45.8 ± 0.68^{x}

Values are Mean ± SD. Values with different letters across the row differ significantly at $p < 0.05$ for either pie or samosa samples respectively.
*Protein Conversion factors for snacks with edible insects and beef are 4.76 and 6.25 respectively.
[1] PWB (Pie with beef).
[2] PWS (Pie with silkworm pupae).
[3] PWAP (Pie with African Palm weevil larvae).
[4] SWB (Samosa with beef).
[5] SWS (Samosa with silkworm pupae).
[6] SWAP (Samosa with African Palm weevil larvae).

and zinc (Rumpold and Schlüter, 2013a; Zielińska et al., 2015; Kim et al., 2017).

3.3. Dietary fibre composition of edible insects

The dietary fibre which comprises of the soluble fibre and insoluble fibre showed that the soluble fibre present in the edible insects boiled with or without seasonings ranged between 9.7 - 20.8%. These values are quite higher than that obtained by Montowska et al. (2019) for edible cricket powders (obtained by roasting). This difference may be attributed to the composition of the different edible insects and their processing conditions. The insoluble fibre however ranged between 79.3 - 84.1%, with the mulberry silkworm having significantly highest percentage. The results showed that the edible insects are rich in both soluble and insoluble fibre which are not found in beef and are very important in the maintenance of digestive system and in prevention of diseases. Consumption of insect dietary fibre could be used as a replacement for plant dietary fibre thereby reducing glycaemic index in food (Belluco et al., 2013).

3.4. The amino acid composition of edible insects

The amino acid composition of the edible insects is shown in Table 3. The African palm weevil larvae and Mulberry silkworm pupae contain ample amount of glutamate and aspartate with values ranging from 13.49 - 15.92 mgAA/100g protein and 8.02–8.79 mgAA/100g protein. Glutamate is an acid that is known for its taste enhancing ability when it combines with inosinate to form umami (Badejo, 2016). The most abundant essential amino acids are valine, threonine, isoleucine, leucine and lysine. Zielińska et al. (2015) reported the amino acid composition of edible insects in Poland and found lysine and leucine to be the most abundant which correlates with the present findings. Nutritionally, the essential amino acids in the boiled insects (with or without seasonings) were higher than the FAO/WHO (1991) recommended daily allowances except for methionine that was lower in some of the boiled insects.

The proportion of essential amino acid to total amino acid ranged from 57.2 to 60.65%. These values are higher than the minimum of 39, 26, and 11% considered to be adequate for ideal protein food intake of infants, children, and adults, respectively (FAO/WHO, 1991; Wu, 2016). According to WHO (1985), the amino acid score of silkworm pupae reached 100. Elemo et al. (2011) have also shown that the amino acid of African palm weevil compares favourably with that of egg. Snacks developed from these edible insects will be good sources of amino acids.

3.5. Chemical composition of pie and samosa snacks produced with edible insects' fillings

The chemical composition of the snacks produced with beef, Mulberry silkworm pupae and African palm weevil larvae as fillings is shown in Table 4. The protein content of the pie samples ranged from 12.6 – 16.0%. The pie produced with the beef has the highest protein content followed by the pie produced with mulberry silkworm pupae. The protein content of the pie produced with African palm weevil larvae was the lowest. Unlike the pie, the protein content of the samosa samples ranges from 13.3 – 14.7% with samples produced with the mulberry silkworm pupae as filling having the highest protein content. The protein content of samosa produced with mulberry silkworm pupae was significantly higher than that produced with beef as filling. From the findings, mulberry silkworm pupae and the African palm weevil larvae compared favourably well with beef as fillings and are excellent sources of protein which can be used as an alternative to conventional sources of protein such as beef (Kim et al., 2017; Shantibala et al., 2014).

The fat content of the pie snacks produced ranged from 24.15-29.55%. The sample with beef filling had the highest fat content followed by the pie with silkworm pupae filling. The pie with African palm weevil larvae had the lowest fat content. The fat content of the samosa samples ranged from 22.40 - 27.40%. The samosa samples having silkworm and African palm weevil fillings have significantly lower fat content compared to samosa with beef filling. This shows that the fat present in edible insects is lower compared to the fat in beef (Van Huis et al., 2013). The fatty acid content of edible insects is different from fat in beef, as insects have higher essential fatty acid content, which the human body needs (Chen et al., 2009).

The crude fibre content of the pie samples ranged from 4.86 - 5.73%, with the pie samples produced with African palm weevil larvae having

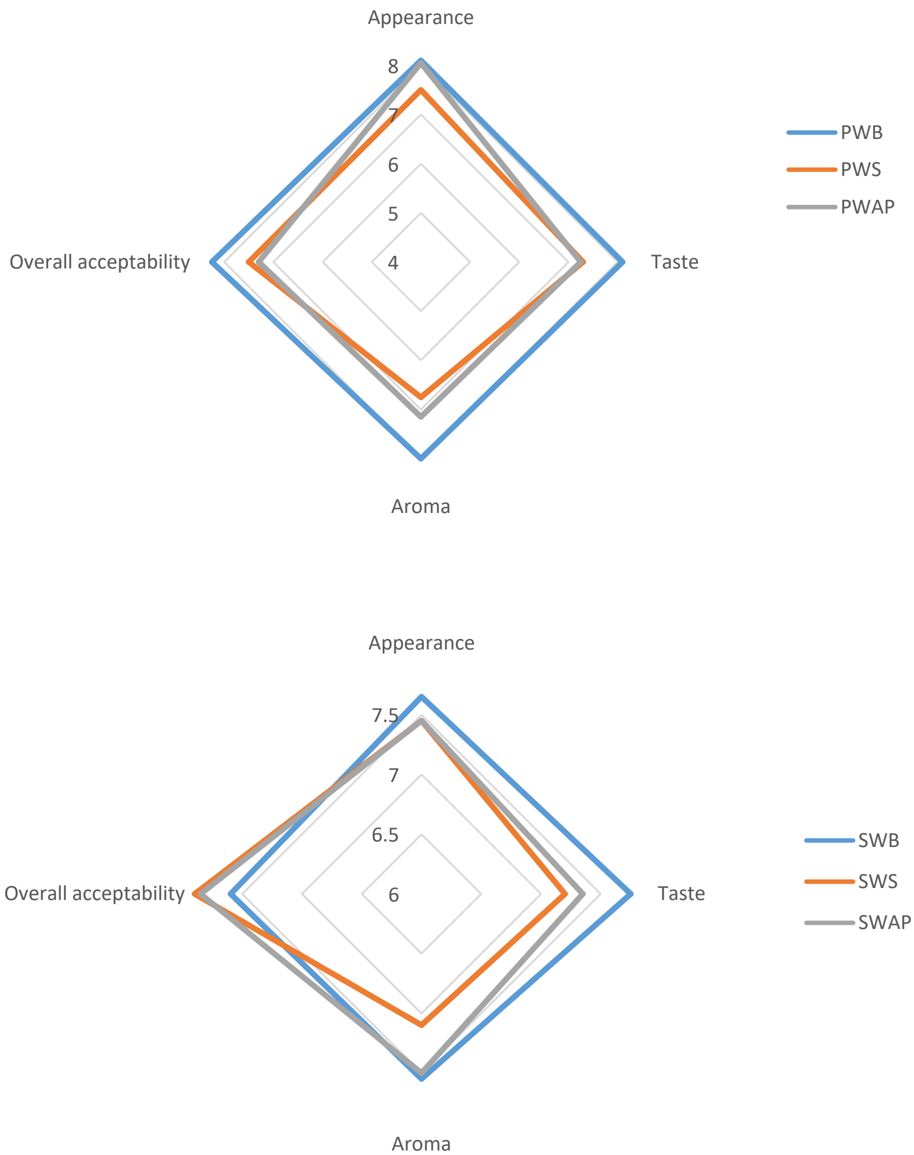

Figure 1. Sensory evaluation results for the pies (a) and samosas (b) with different fillings. PWB (Pie with beef) PWS (Pie with silkworm pupae) PWAP (Pie with African Palm weevil larvae). SWB (Samosa with beef) SWS (Samosa with silkworm pupae) SWAP (Samosa with African Palm weevil larvae).

the highest value. This can be attributed to the chitin content present on its body. The fibre content of the samosa samples ranges from 4.20 - 4.61% with samples produced with the African palm weevil larvae having the highest value. The ash content of the pie and samosa produced with silkworm filling are 1.46% and 1.71% respectively. These values were significantly higher than ash content of other samples. The energy value of the pie samples ranged from 456 – 479 kcal/100g while those for samosa ranged from 391 – 451 kcal/100g. Although the energy value of the snacks made with beef filling was the highest, edible insects filling also gave comparable energy values. The values obtained were higher than those reported for selected wild and farmed edible insect worldwide except for green (weaver) ant, Australian plague locust and Ivory Coast termite (FAO, 2012).

3.6. Dietary fibre composition of the snacks

The soluble fibre in the pie snacks ranged from 9.8 - 10.8%, the pie snacks produced with African palm weevil larvae had the highest soluble fibre content. There was no significant difference between the soluble fibre content of the pies filled with beef or silkworm. The insoluble fibre contents ranged from 89.0 – 89.8%. There was no significant difference between the insoluble fibre contents of the pies irrespective of the fillings.

Similarly, with samosa snacks, the soluble fibre content ranged from 8.8 - 9.8%, with samosa produced with African palm weevil larvae having the highest soluble fibre content. The insoluble fibre content ranged from 90.2 – 91.0%, with no significant difference between the samples.

3.7. Mineral composition of edible insect snacks

The iron content of the pie snacks ranged from 2.30-3.63 ppm, with the pie produced with the African palm weevil larvae having the highest value. Iron is a component of haemoglobin and myoglobin that carries oxygen and acts as a cofactor of various enzymes. The zinc, manganese and calcium content were highest in the pie snacks produced with the African palm weevil larvae. Phosphorus was highest in the pie snack produced with the mulberry silkworm pupae. Phosphorus and Calcium are important constituents of the bone and as such edible insect will supply the minerals in abundance and will be good for children. The iron content of samosa snack ranged from 2.16 – 3.22 ppm, with the samosa samples produced with the African palm weevil larvae having the highest value. The zinc, manganese, calcium and phosphorus content were highest in the samosa samples produced with the African palm weevil larvae.

3.8. Sensory evaluation of the pie and samosa samples

The sensory evaluation carried out on the samosa snack showed that there was no significant difference in the aroma, appearance, overall acceptability of the snacks with beef, silkworm or African palm weevil fillings (Figure 1b). This may be due to the fact that the edible insects have been blended with other ingredients and rarely visible to the eye and the repulsive feeling unexpressed by the panelists. A major limitation was with the number of panelists used in the analysis. As this is a new product, we intentionally employed the free-will services of people who are familiar with the consumption of beef, silkworm and African palm weevil. The ratings with the pie (Figure 1a) were equally very good but there was no significant difference between the pie with silkworm and African palm weevil fillings.

4. Conclusions

This study demonstrated the fact that edible insects (Mulberry Silkworm Pupae and African Palm weevil larvae) can serve as an alternative to beef in pie and samosa snacks production as this is evident in the high protein and mineral contents. The amino acid profile also showed that protein is of a high quality. Consumer acceptability of the new snacks was not significantly different from the snack filled with beef. Incorporation of edible insects into snack may be one of the ways to encourage entomophagy, an environmentally friendly alternative to beef consumption. This may be a very useful low-cost alternative food source in most developing and developed nations. It is hoped that the several advantages of edible insect and the palatability in snacks will cause a big shift in perception and an increase in processing and consumption. It is however imperative to carry out further studies on the consumers' acceptability on a larger scale.

Declarations

Author contribution statement

Olamide A. Akande: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Oreoluwa O. Falade: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Adebanjo A. Badejo: Analyzed and interpreted the data; Wrote the paper.

Ifeoluwa Adekoya: Contributed reagents, materials, analysis tools or data.

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