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Influence of Preparation and Processing Methods on the Physico-chemical Properties of *Oryctes rhinoceros* Larvae

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ABSTRACT

The growing world population with increasingly demanding consumers has led to considering insects as part of are normal diet since they are good sources of proteins, and could therefore potentially contribute to global food security. This study produced *Oryctes rhinoceros* L. larvae powder and investigated the impact of preparation and processing methods (degutted; roasted and dried) on some quality parameters of *O. rhinoceros* larvae powder. Each batch was prepared with and without their gut respectively. Physico-chemical analyses were determined on the powder, while sensory evaluation was carried out on the whole *O. rhinoceros* larvae using standard procedures. Moisture content of the powders ranged from 3.57 - 5.66%, protein content (51.60 - 62.65%), fat (8.71 – 12.67%), ash (3.97 - 10.25%), fibre (15.57 - 19.52%) and carbohydrate (0.12 - 6.56%). The results of functional properties revealed a range of 2.64 – 2.98 mg/g for water absorption capacity, oil absorption capacity of 2.43- 2.70 mg/g and bulk density of 0.48 – 0.51 g/mL. Processing (roasting and oven drying) had no significant effect on the sensory and physico-chemical properties of whole *O. rhinoceros* larvae and *O. rhinoceros* larvae powder, while the removal of the gut significantly contributed to the improvement of the quality and sensory appeal of *O. rhinoceros* larvae.

Introduction

The escalating economic growth, the continuous problem of protein malnourishment, the exponentially growing global population and the increasing demand for food (particularly protein-based) has resulted in an urgent call for new, safe and high-value protein foods. These has shifted focus towards entomophagy as potential sources of proteins for humans (van Huis et al., 2013). Historically, insects are accepted in their fresh form as a complete food in many regions, especially in Asia, Africa, and America (Murefu et al., 2019). They provide sufficient nutritional value, particularly protein (Zielinska et al., 2018), but a technological advancement in food production has greatly eliminated insects from our diets (Gao et al., 2018). Nongonierma and FitzGerald (2017) ascribed the re-emergence of edible insects as a viable food group because of their nutritional, environmental, and economic value. It is also an approach to achieve global food security (van Huis, 2015) and combat protein malnutrition.

Coconut rhinoceros beetle (*Oryctes rhinoceros* L.) is an abundant, but underutilized edible insect species in Nigeria. It is a major pest of coconut palms, which belong to the order *Coleoptera* and family *Scarabaeidae*. It has three developmental stages – pupa, larvae and adult. The larvae are usually cream (milky white) with reddish brown head and grows to about 60-100 mm long (Ooi, 1988). They feed on decomposing organic matter (Giblin-Davis, 2001; Muniappan, 2002) and are beneficial in nutrient recycling. The adults are shiny dark brown or black in colour, stout and are 35-50 mm long (Bedford, 1974). Adults coconut rhinoceros beetle are known to destroy standing coconut palms by burrowing into the crown to feed

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on its sap and consequently damaging unopened leaves and attracting other beetle species and harmful microorganisms (Giblin-Davis, 2001).

Oryctes rhinoceros larvae is a well-appreciated meal in the Southern and South Western parts of Nigeria. It is called ‘Ipe” by the Yorubas, “Osori” by the Ijaws, “Tam” in Ogoniland, and “Utukuru” by the Ibos (Ekpo and Onigbinde, 2005; Okaraonye and Ilewuchi, 2009). It is rich in protein and mainly consumed fried, but may also be consumed raw, boiled, smoked, grilled etc. or processed into powder or paste. The powder and paste are used as flavour enhancers and to improve protein quality.

Processing *O. rhinoceros* is a promising approach as it removes moisture, reduces microorganisms, antinutrients and subsequently extends the shelf life, making it safer for consumption, versatile in use and easy for handling and packaging. The physical and chemical properties of insects are affected during processing, storage, preparation and consumption (Fennema, 1996). The functional properties of edible insects also play an important role in the food processing and formulation of food products.

Despite the numerous health benefits of insects, many barriers in the development of insects as food remain, because the concept of insect foods is not a conventional Western eating habit (Murefu et al., 2019). The negative perceptions, which limit the use of insects as a typical dining option may be related to the fact that people perceive insects as a source of fear or disgust and neglect the high nutritive value (van Huis, 2016). Overcoming such an inherent attitude is the main challenge facing the edible insect industry (Yen, 2009). Mishyna et al., 2019; Nongonierma and FitzGerald, 2017; Purschke et al., 2018; Yi et al., 2016; Han et al., (2017) suggested that developing insect-based ingredients and incorporating edible insects in already familiar foods may be acceptable for an insect phobic culture rather than providing insects directly as a food option.

Culturally, edible insects are consumed whole (with their gut) which may disgust the consumer and affect the taste when consumed or quality when processed. Many strategies are applied to mask the ‘yuck’ factor and increase the acceptance of insects to get numerous health benefits in order to reduce food insecurity and malnutrition, especially in the developing countries. This study thus investigated the effect of processing (with the gut -whole and without the gut-degutted) on some quality factors of *O. rhinoceros* larvae powder. The study determined the physico-chemical properties of *Oryctes rhinoceros* larvae powder with a view of revealing its potential in food formulation.

Materials and methods

The biological materials used were larvae of coconut rhinoceros (*Oryctes rhinoceros*), collected from a farm in Osogbo, Osun State. *Oryctes rhinoceros* larvae were cleaned under running water to remove adhering compost, soaked in a 5% brine solution for 20 minutes and drained. The *Oryctes rhinoceros* larvae were divided into 2 batches. The first batch was subdivided into 2 lots the first lot (DWG) was oven dried at 50 ˚C to constant weight, while the second lot (RWG) was roasted at 180 ˚C for 3 hrs and oven dried at 50 ˚C till a constant weight was achieved. The second batch was degutted by opening up the larvae to remove the gut, rinsed thoroughly and further divided into 2 lots. The first lot (DDG) was oven dried at 50 ˚C to constant weight, while the second lot (RDG) was roasted at 180 ˚C for 3 hrs and further oven dried at 50 ˚C till a constant weight was achieved. About 100 g of each sample was set aside for the sensory evaluation. Each lot was further pulverised, packaged in low density polyethylene (LDPE) and stored in air tight containers till further analysis.

Analyses

Proximate composition

Proximate analysis (moisture, crude protein, fat, ash and carbohydrate contents) was carried out using standard AOAC procedures (AOAC, 2012).

Water and oil absorption capacities

Water and oil absorption capacities were determined according to the method described by Sathe and Salunkhe (1981) with the slight modification. 10 mL of distilled water was added to 1 g of *O. rhinoceros* larvae powder in a beaker. The suspension was stirred using a magnetic stirrer for 5 minutes and then centrifuged at 3000 rpm for 30 minutes. Water absorption capacity was calculated as a percentage of water bound per gram flour. For oil absorption capacity, distilled water was replaced with vegetable oil and expressed as a percentage of water bound per gram flour.

Bulk density

Bulk density was determined using the method described by Oladele and Aina (2007). About 50 g of *O. rhinoceros* larvae powder sample was transferred into a 100 mL measuring cylinder and the volume was taken as (V_1). The measuring cylinder was gently tapped until a constant volume was obtained and noted as (V_2).

$$Bulk\ Density\ \left(\frac{g}{mL}\right) = \frac{W}{V_1 - V_2}$$

Hygroscopicity

Hygroscopicity of *O. rhinoceros* larvae powder was measured according to Cai and Corke (2000). About 1 g of the powder was weighed into a pre-weighed petri dish and placed in an airtight desiccator filled with a saturated solution of NaCl (75% RH) at 25 ± 2 °C for 7 days. Hygroscopicity was expressed as % hygroscopicity. Hygroscopicity values obtained were not considered as absolute values, since the powders were exposed to abusive conditions (unpacked in high relative humidity), so the objective was to evaluate variation among processing. The hygroscopicity of the powder was calculated by weight difference as follows:

$$\%\ Hygroscopicity = \frac{(\%W_I + \%F_W)}{(100 + \%W_I)} \times 100$$

where

$$\%WI = \frac{(c - b)}{(b - a)} \times 100$$

where $\%F_W$ = free water; c = weight of plate and sample at equilibrium; b = weight of plate and powder; a = weight of plate

Colour

The surface colour was measured using a handheld tristimulus colorimeter (Chroma Meter CR – 400) calibrated with a CIE standard illuminant D_{65}. The colour coordinates L^*, a^*, b^* of the CIELab colour space were determined in triplicate, where L^* denotes lightness, and varies from zero (black) to 100 (white), a^* varies from -60 (green) to +60 (red) and b^* varies from - 60 (blue) to +60 (yellow) according to Kumar and Mishra (2006). A glass petri dish containing the samples was placed under the aperture of the colorimeter.

Sensory evaluation

Freshly dried and roasted whole *O. rhinoceros* larvae (as discussed above) were used and presented respectively in plate as ready-to-eat (RTE) food. About 25 untrained panelists who were familiar with the consumption of insects were asked to access sensory attributes such as taste, appearance, flavour, mouth feel, colour, and overall acceptability of *O. rhinoceros* larvae using a 9-point hedonic scale from 'like extremely' to dislike extremely'.

Statistical analysis

The data generated was subjected to the analysis of variance (ANOVA), followed by Tukey's test to separate means and determine significant level ($p > 0.05$) using SPSS 20.0 version.

Results and discussion

Proximate composition of Oryctes rhinoceros larvae powder

The proximate composition of *Oryctes rhinoceros* larvae powder is shown in Table 1. The moisture content of the samples ranged between 3.57 – 5.66%. The moisture content of a product is important for storage stability of the product. The low moisture content is a suggestion of good shelf life for the powder. The degutted samples had lower moisture content than the samples with the gut. Protein values ranged between 51.60 – 62.65% and were higher than the values (33.97% and 48%) reported by Egba et al., (2014) and Olowu et al., (2012), respectively. The relatively high protein content can be compared with the protein values of 50.79%, 55.77% and 70.76% in the studies carried out by Okaraonye and Ikewuchi (2009), Offiah et al., (2019) and Omotoso, (2015), respectively, for dried *Oryctes rhinoceros*. The high protein content indicates that the larvae are rich in protein and can contribute significantly to the daily protein requirement of humans which is about 23-56 g (Chaney, 2006). The values of protein are significantly different ($p<0.05$) from each other. According to FAO (2013), preparation and processing methods applied influence the nutritional composition of edible insects. This was observed as the degutted samples had higher protein content than samples processed with their guts. The undigested fibre in its gut possibly contributed to the lower protein content in the whole *O. rhinoceros* larvae powder (Doloriel, 2018). The dried samples also yielded better protein content than the roasted samples. The decrease in the protein content of the roasted samples could have been caused by the high roasting temperature, as high temperatures cause a reduction in protein content as a result of charring leading to Maillard reaction. The fat content of the samples ranged from 8.71 - 12.67%. The values are all significantly different from each other ($p<0.05$). Fats are essential in the structural and biological functioning of cells and they help in the transport of nutritionally essential fat soluble vitamins (Omotoso, 2006). Omotoso (2015) recorded fat contents of 15.35% and 7.47% for *Oryctes rhinoceros* larvae. However, Ekpo, 2011 reported fat content of 66.61% for *Rhynchophorus phoenicis*. The values of the ash content ranged between 3.97 – 10.25%. The ash content values of 8.02% and 11.83% were recorded by Omotoso (2015) and Offiah et al., (2019). It was observed that the degutted samples had lower ash content when compared to the samples with the gut, while processing methods had no significant effect. The relatively high ash content of the samples with the gut is a sign that the larvae powder is high in mineral content, as ash has been reported to be a measure of the mineral content (Alinnor and Akalezi, 2010). This signified that the intestine contributed greatly to the ash content and hence the mineral content of the insect. The values of crude fibre ranged between 15.57– 19.52%. Crude fibre has been reported to enhance nutritional performance as well as act as a catalyst in the digestion and absorption in the intestines (Ogungbenle et al., 2009). Offiah et al., (2019) and Omotoso (2015) reported fibre contents of 9.72% and 17.94% for *O. rhinoceros.* The study revealed that the degutted samples had higher fibre content than the samples processed with their gut microflora. The values of carbohydrates were between 0.12 - 6.56%. There was a significant difference in the carbohydrate content of the samples. The result of this study is contrary to that reported by Olowu et al. (2012), who reported a carbohydrate content of 20.35% in *O. rhinoceros.* The carbohydrate content of the samples with guts can be compared to the value of 4.08% reported by Offiah et al., (2019). The low carbohydrate content reported in this study suggests that the larvae is not energy giving food.

Functional properties of Oryctes rhinoceros larvae powder

The results of the functional properties of *Oryctes rhinoceros* larvae powder are presented in Table 2. The water absorption capacities were between 2.64 – 3.03 mg/g. Water absorption capacity (WAC) indicates the extent of starch gelatinization. It represents the ability of a product to associate with water under conditions where water is limited (Singh, 2001). The dried degutted sample had the highest WAC. Processing and preparation methods had no significant effect ($p<0.05$) on the water absorption capacities of *O. rhinoceros* larvae powder. The WAC suggests that the powder can be important in soup preparation. The mean values of the oil absorption capacity (OAC) were between 2.41- 2.67 mg/g. It was discovered that the samples with their guts had higher oil absorption capacity and were significantly different ($p<0.05$) than the degutted samples. Drying and roasting methods had no significant effect ($p<0.05$) on the OAC. High water and oil absorption capacities indicate the potential use for food formulation, especially in baked products and pastries where water and oil retention are crucial.

The bulk density was between 0.48 – 0.51 g/mL with no significant difference ($p<0.05$) between the samples. The bulk density is the measure of the heaviness of a flour sample. It gives an indication of the volume of the packaging material required. These properties are influenced by several factors, such as moisture content, hygroscopic nature, particle size distribution and particle size of the material.

Table 1. Proximate values of dried and roasted *Oryctes rhinoceros* larvae powder

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fibre (%)	Carbohydrate (%)
RWG	5.66±0.41^a	51.60±0.49^d	8.7±0.19^c	10.25±0.14^a	15.57±0.21^d	6.56±0.16^a
DWG	5.48±0.29^a	53.46±0.22^c	9.82±0.04^b	9.68±0.25^b	16.57±0.13^c	5.58±0.18^b
RDG	4.53±0.22^b	59.22±0.13^b	12.06±0.62^a	4.40±0.32^c	19.52±0.24^a	0.18±0.04^c
DDG	3.57±0.25^c	62.65±0.24^a	12.67±0.10^a	3.97±0.13^c	17.02±0.31^b	0.12±0.02^c

Each value is a mean standard deviation ± of duplicate; Key: RWG - roasted with gut; DWG - dried with gut; RDG – degutted roasted; DDG – degutted dried

Table 2. Functional properties of dried and roasted *Oryctes rhinoceros* larvae powder

Sample	Water absorption capacity (mg/g)	Oil absorption capacity (mg/g)	Bulk density (g/mL)
RWG	2.74±0.05^b	2.64±0.03^a	0.50±0.02^a
DWG	2.81±0.04^b	2.67±0.06^a	0.50±0.02^a
RDG	2.64±0.04^b	2.45±0.11^b	0.48±0.01^a
DDG	3.03±0.04^a	2.41±0.05^b	0.51±0.01^a

Each value is a mean ± standard deviation of duplicate. Key: RWG - roasted with gut; DWG - dried with gut; RDG – degutted roasted; DDG – degutted dried

Hygroscopicity of Oryctes rhinoceros larvae powder

Table 3 shows mean values of the hygroscopicity of *O. rhinoceros* larvae powder. The hygroscopicity values ranged from 7.46 - 8.49 g/100 g. Hygroscopicity is the ability of food powder to absorb moisture from a high relative humidity environment (Jaya and Das, 2004). The evaluation of food powder's hygroscopicity is important because of the influence of packaging (degree of caking, loss of fluidity) and it is also associated with the chemical, physical and microbiological stability of the product. According to the GEA Niro Research Laboratory (2003) classification, samples having hygroscopic values less than 10% are classified as non-hygroscopic; 10.1 - 15.0% slightly hygroscopic; 15.1 - 20.0% hygroscopic; 20.1 - 25.0% very hygroscopic and greater than 25% as extremely hygroscopic, thus in this study, the recorded values can be classified as non-hygroscopic. Different variations in the hygroscopic behaviour of food powders are attributed to the size of the powder, as finer particles have higher contact surfaces and therefore higher number of active sites (Costa et al., 2003). There was no significant difference in the value obtained for hygroscopicity; it can therefore be inferred that the methods involved in processing and preparation had no effect on the hygroscopic behaviour of *O. rhinoceros* larvae powder.

Colour parameters of Oryctes rhinoceros larvae powder

The colour parameters of the samples are shown in Table 4. Retention of colour after thermal processing may be used to predict the extent of quality deterioration of food resulting from exposure to heat. The L* values ranged between 25.59 - 36.56. The L* value can give some indication of colour differences, as powder of higher colour intensity will have a lower L value. The degutted samples had the highest L* value, thus indicating a low colour intensity. At the a* (green-red) and b* (blue-yellow) axes, the values ranged from 2.96 - 6.75 and 7.64 to 13.67, respectively. At the a* axis, the values of the samples processed with the guts were significantly higher, while at the b* axis, the values obtained for the degutted samples were higher. This implied that the samples with guts tended towards the red axis, while the degutted samples tended more towards the yellow axis. Processing methods had a significant effect on the a* and b* values, at both axes; the dried samples had lower values than the roasted samples. This also indicates that the roasted samples tended more towards the red and yellow coordinates respectively than the dried samples.

Sensory evaluation of Oryctes rhinoceros larvae

The mean of the sensory scores is presented in Table 4. The mean value of the taste score of the samples ranged from 4.46 to 6.64. The taste scores of the degutted whole *O. rhinoceros* larvae samples were significantly higher than values obtained for samples processed with their guts. This is a sign that the gut affected the taste of the larvae. In terms of aroma, colour and crunchiness, the mean values ranged between 4.40 – 6.42, 4.73 - 6.40 and 4.70 - 6.60, respectively. The process of removing the guts of the samples had a positive influence on the taste, aroma, colour, crunchiness and overall acceptability as the degutted whole *O. rhinoceros* larvae samples had a higher score in all these parameters than the whole *O. rhinoceros* larvae samples treated with their guts. The processing technique (roasting and oven drying) had no significant effect on the taste, colour, aroma, crunchiness and overall acceptability of the samples.

Table 3. Hygroscopicity and colour parameter of *Oryctes rhinoceros* larvae powder

Sample	Hygroscopicity (g/100 g)	Colour		
		L*	a*	b*
RWG	8.0±1.84[a]	30.25±0.36[b]	6.75±0.06[a]	10.72±0.14[b]
DWG	7.64±0.47[a]	25.59±0.20[c]	4.98±0.30[c]	7.64±0.07[d]
RDG	8.49±2.22[a]	36.18±0.27[a]	5.26±0.13[b]	13.67±0.15[a]
DDG	8.15±0.92[a]	36.56±0.28[a]	2.96±0.02[d]	10.72±0.14[c]

Each value is a mean ± standard deviation of duplicate

Table 4. Sensory evaluation of whole dried and roasted *Oryctes rhinoceros* larvae

Sample	Taste	Aroma	Colour	Crunchiness	Overall acceptability
RWG	4.46±1.12[b]	4.40±1.18[b]	4.73±0.80[b]	4.70±0.81[b]	4.60±0.98[b]
DWG	4.67±1.29[b]	5.07±0.96[b]	5.13±1.06[b]	5.20±0.68[b]	4.90±1.06[b]
RDG	6.60±0.91[a]	6.20±0.86[a]	6.40±0.91[a]	6.60±0.82[a]	6.53±0.83[a]
DDG	6.64±1.08[a]	6.42±0.93[a]	6.21±0.90[a]	6.50±1.01[a]	6.50±1.02[a]

Each value is a mean ± standard deviation of triplicate. Key: RWG - roasted with gut; DWG - dried with gut; RDG – degutted roasted; DDG – degutted dried

Conclusions

The results obtained from this study show that degutted *O. rhinoceros* larvae powder has superior quality in terms of protein content, fat content and sensory properties. The high nutritional value, especially protein of *O. rhinoceros* larvae powder can be considered the main factor justifying its use as an alternative to animal protein for human food to combat protein-energy malnutrition. Although processing (roasting and oven drying) had no significant effect on the physico-chemical and sensory properties of *O. rhinoceros* larvae, preparation techniques in terms of gut removal had a significant positive effect on the quality of the powder. The sensory appeal may be the key to *O. rhinoceros* larvae being valued as a pleasurable component of a meal as there were variations due to how the samples were prepared. *O. rhinoceros* larvae powder can be processed in various ways and can find application in the food industry in form of condiments, supplements, enhancers, etc.

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