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ENTOMOPHAGY — AN EVALUATION OF QUALITY AND ACCEPTABILITY OF RAPHIA PALM WEEVIL LARVAE (*RHYNCHOPHORUS PHOENICIS*) AS INFLUENCED BY THERMAL PROCESSING METHODS

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Abstract
In this study, the quality and acceptability factor of Raphia palm weevil larvae (Rhynchophorus phoenicis) as influenced by different thermal processing methods were investigated. Raphia palm weevil larvae (n=1000) were randomly distributed into four groups of 250 larvae per group according to a treatment, namely: T1 = boiling (100 °C), T2 = roasting (120 °C) T3 = frying (160 °C) and T4 = oven-drying (180 °C). All treatments lasted 20 minutes. Analyses were carried out to determine the physical, chemical, vitamin and mineral composition, and microbial load. In addition, sensory characteristics were evaluated. Weevil larvae processed by the boiling method had the highest cooking yield (97.59%), water holding capacity (21.78%) and the lowest cooking loss (2.41%). The protein and fat content was higher in weevil larvae processed by frying (37.63% and 17.70%, respectively), while moisture was lowest (18.68%) in oven-dried larvae. The calcium, magnesium and phosphorus content was higher in oven-dried larvae, while there were no significant differences in iron, manganese, zinc and vitamins in the processed larvae irrespective of the methods. Boiled larvae had a higher microbial load, while fried and oven-dried larvae had the lowest microbial load. Fried larvae elicited highest sensory characteristics except tenderness, which was higher in boiled larvae, but fried larvae had higher overall acceptability than those processed by other methods. Therefore, it has been shown that the frying method is an appropriate method of processing Raphia palm weevil larvae for enhanced quality and acceptability.

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Introduction

The most pressing nutritional problem in the developing countries is the shortage of protein in the diets of a large section of the population. The acute shortage, especially of animal protein, has been attributed to the phenomenal rise in the price of conventional animal protein sources such as meat, milk and eggs [1]. This led to malnutrition in most developing nations, hence the call for more studies on alternative or unconventional animal protein sources such as snails, rodents, frogs and insects [2]. Insects have been presented as an attractive alternative source of protein as they serve as natural food for many vertebrates including humans [3]. Although insects are not traditional food in many cultures, there is a growing public interest and demand for them due to their nutritional importance [4,5,6,7]. Among insect species that are used for food, *Rhynchophorus phoenicis* (Raphia palm weevil) larvae are considered the major source of dietary lipids and protein, especially in developing and under-developed countries where consumption of animal protein is limited as a result of economic factors [8,9]. Palm weevil larvae have been shown to be high in crude protein, fatty acids, minerals and vitamins [10,11,12,13,14]. However, the nutritional value of palm weevil larvae changes according to preparation and a processing method adopted [15,16]. Hence, there is a need to explore nutrient potentials and processing methods for palm weevil larvae exploitation to bridge the gap between animal protein production, supply and consumption [17]. This line of reasoning evoked this study interest to investigate the quality and acceptability factors of *Rhynchophorus phoenicis* as influenced by thermal processing methods.

Materials and methods

Collection and preparation of weevil samples

Live palm weevil larvae (n = 1000) were purchased from Itokin in Epe local government area of Lagos State. They were transported to the Meat Science Laboratory of the Department of Animal Production, Olabisi Onabanjo University, Ayetoro Campus in a well-ventilated container within 24 hours.

Preparation

Larvae were killed and prepared following the methods outlined by [18,19]. The killing of larvae was carried out by immersing them is 15 liters of warm water at 37 °C and stirred for five minutes with a wooden stick. The water was drained from the larvae and the process was repeated twice in order to remove volatile anti-nutritional compounds (Pentacosane) that are known to cause temporary blindness [18]. The larvae were chilled in a refrigerator at 4 °C for 24 hrs prior to further processing and analysis [20].

Processing of larvae

Larvae were removed from the refrigerator, washed, and divided into four groups of 250 larvae each according to the processing method as follows:

T1 = Boiling method (250 larvae)
T2 = Roasting method (250 larvae)
T3 = Frying method (250 larvae)
T4 = Oven-drying (250 larvae)

The processing methods were applied in triplicate with the following regimes:

Boiling: Larvae were wrapped in cellophane papers and boiled in water at 100 °C for 20 minutes.

Roasting: Larvae were sticked and roasted on a charcoal glowing fire at 120 °C for 20 minutes.

Frying: Larvae were fried at 160 °C for 20 minutes.

Oven-drying: Larvae were dried at 180 °C for 20 minutes.

In the roasting, frying, and oven-drying methods, larvae were turned over at intervals of 5 minutes.

Measurement of parameters

Physical factors

Cooking loss

Larvae in each group were weighed before and after thermal processing. Larvae were taken out when the temperature at the center of the test larvae reached 65 °C and then cooled. After that, the cooking loss was calculated by the following equation [21].

$$\text{Cooking loss (\%)} = \frac{W_0 - W_1}{W_0} \times 100 \quad (1)$$

Where:

W_0 = weight of larvae before processing;
W_1 = weight of larvae after processing.

Cooking yield

The cooking yield of larvae in each group was calculated by the equation according to [22].

$$\text{Cooking yield (\%)} = \frac{W_1}{W_0} \times 100 \quad (2)$$

Where:

W_0 = weight of larvae before processing;
W_1 = weight of larvae after processing.

Thermal shortening

The thermal shortening of larvae in each group was calculated by the equation prescribed by [20]:

$$\text{Thermal shortening (\%)} = \frac{L_0 - L_1}{L_0} \times 100 \quad (3)$$

Where:

L_0 = Length of larvae before processing;
L_1 = Length of larvae after processing.

Water holding capacity (WHC)

The water holding capacity (WHC) of larvae was determined according to the procedures of [21]. The larvae were minced and 5g was taken and heated at 70 °C in a water bath for 30 minutes, cooled and centrifuged at 1,000 rpm for 10 minutes. Total moisture was measured and WHC was calculated using the following equation:

$$\text{WHC (\%)} = \frac{(T - S) \times 0.951}{W_0} \times 100 \quad (4)$$

Where:

T = Total water content;
S = Separated water content;
0.951 = Pure water amount for larvae moisture that was separated under 70 °C.

Chemical factors

Moisture content

The moisture content of processed larvae was determined following the procedures described in [23] by weighing 2 g of ground larva samples from each group into crucible of the known weight and drying at 100–105 °C for 24 hrs in an oven until a constant weight was attained. The moisture content was calculated as follows:

$$\text{MC (\%)} = \frac{W_1 - W_0}{W_2 - W_0} \times 100 \quad (5)$$

Where:

W_0 = *Wt* of empty crucible;
W_1 = *Wt* of crucible + dried sample *Wt*;
W_2 = *Wt* of crucible + wet sample *Wt*.

Crude Protein

Crude protein of processed larvae was determined using the Kjehdahl method as described in [23]. Samples of minced larvae each weighing 700 mg were placed in a Kjehdahl digestion tube. The digesting catalysts (5g of K_2SO_4 + 0.5g of $CuSO_4$) and 25ml of concentrated H_2SO_4 were added. The samples were digested for 1 hr, cooled and 20ml of deionized water and 25ml of 40% NaOH were added. The samples were distilled and NH_3 liberated was collected into boric acid, and titrated with 0.1 HCl. A blank titer was prepared and titrated alongside the tested samples, and the crude protein was calculated as follows:

$$\text{CP (\%)} = \frac{(St - Bt) \times 14 \times 6.25}{Sw} \times 100 \quad (6)$$

Where:

St = sample titer;
Bt = blank titer;
Sw = sample weight;
14 = molecular weight of N_2;
6.25 = N_2 conversion factor.

Crude fat (Ether Extract)

The fat content of processed larvae was determined following the procedures described in [23] by weighing 5g of dried minced larva samples into thimbles and putting into an Allihn Condenser of the Soxhlet extraction apparatus.

Petroleum ether (250 ml) as an extractant was poured into a pre-dried boiling flask and the solvent was heated for 14 hours to extract the fat. The solvent was evaporated using a vacuum condenser. The boiling flask with the extracted fat was dried in an oven at 100 °C for 30 minutes, cooled in a desiccator at 27 °C and weighted. The flask containing oil/fat was weighed and dried in an oven to a constant weight and fat content was calculated as follows:

$$\text{Crude fat (\%)} = \frac{Wo}{Ws} \times 100 \qquad (7)$$

Where:

Wo = weight of oil;

Ws = weight of sample.

Ash content

The total ash content of processed larvae was determined according to [23]. Test portions (1 g) from samples of each group were weighted into pre-heated crucibles and incinerated overnight in a Muffle furnace at 550 °C until white ash free of carbon was obtained. The crucibles were removed from the Muffle furnace, cooled in a desiccator at a room temperature of 27 °C and reweighed. The ash content of the samples was calculated using the equation:

$$\text{Ash (\%)} = \frac{Wa}{Ws} \times 100 \qquad (8)$$

Where:

Wa = weight of ash;

Ws = weight of sample.

Crude fiber

This was determined according to the procedures of [23] by weighting 1 g of minced larva samples from each treatment into a flask, adding 200 ml of 1.25% H_2SO_4 and heating the mixture under reflux for 1 hr. The mixture was filtered through a Buckner funnel, the residues were washed back into the flask with 200 ml of 0.31M NaOH and the mixture was heated for another 1hr. An amount of 2 ml of 180 iso-amyl alcohol was added and the mixture was filtered through fiber sieve cloth. The residues were washed with hot water twice and were transferred into dried weighed crucibles which were oven dried at 550 °C for 4 hrs. The crucibles with the residues were cooled in a desiccator at 27 °C and weighed. The percentage of crude fiber was obtained using the equation as follows:

$$\text{CF (\%)} = \frac{Wt_0 - Wt_1}{Ws} \times 100 \qquad (9)$$

Where:

Wt_0 = Wt. of oven dried sample;

Wt_1 = Wt of ash dried sample;

Ws = weight of sample.

Carbohydrate value

The carbohydrate (CHO) values of larva samples from each treatment were calculated as the difference between 100 and the sum of the percentages of moisture, protein, ash and total fat (proximate composition) according to the procedures of [23]. Thus, CHO values were obtained by this equation.

$$\text{CHO (\%)} = 100 - \text{Proximate composition.}$$

Vitamins and minerals

Vitamins and minerals of processed larva samples from each treatment were determined following the procedures described by [23].

pH value

The pH values of processed and minced larva samples from each treatment were measured using a pH meter (Model H-18424 Micro-Computer, Hanna Instruments, Romania) as described by [24].

Sensory evaluation

Sensory evaluation of processed larvae was carried out using a 10-member semi-trained panel following the procedures of [25]. Processed larva samples were cooled at a room temperature of 27 °C and were served to panelists on clean saucers. The larva samples were evaluated one after the other. The panelists were provided with unsalted crackers and clean water to clear the condition of the palate between tasting samples. The panelists rated the processed larva samples using a 9-point hedonic scale, wherein 1 = dislike extremely and 9 = like extremely for color, flavor, tenderness, juiciness, texture and overall acceptability.

Experimental design and statistical analysis

This study was conducted using completely randomized design (CRD). The results from this study were applied to analysis of variance (ANOVA) using [26] and significant means were verified at a level of 50% ($p < 0.05$) with the Duncan multiple range test of the same software.

Results and discussion

Physical characteristics

The change in physical properties of processed palm weevil larvae is shown in Table 1. The cooking loss after processing showed significant differences depending on the processing method ($p < 0.05$). The cooking loss was lowest (2.41%) in boiled larvae (T1) and highest in oven-dried larvae (T4) followed by that in fried larvae (T3). The results showed that the cooking yield was lowest (88.85%) in oven-dried larvae (T4) and highest (97.59%) in boiled ones (T1). The results of the larva thermal shortening demonstrated a similar trend with the cooking loss. The thermal shortening was highest (19.63%) in oven-dried larvae (T1) and lowest (11.99%) in boiled ones (T1). The results of the water holding capacity (WHC) of processed larvae reflected the similar trend with the cooking yield. WHC was highest (21.78%) in boiled larvae (T1) and lowest (17.13%) in oven-dried larvae (T4). Both the results of the cooking loss and thermal shortening showed the same trends, the values for both variables increased from boiling to oven-drying indicating the fact that both variables increased as the temperature applied in the processing methods rose. The results observed for both variables agree with the findings of [27], who reported that when insects/larvae underwent thermal processing both the cooking loss and thermal shortening increased due to the temperature growth depending on the intensity of heat because moisture was lost in the process. The same line of thought is applied to WHC, which is the ability of any edible larvae to retain some appreciable moisture after processing. This variable differed between the treatments decreasing with an increase in temperature as more moisture was retained in the larvae that were processed by the method that required lower degree of temperature according to [28].

Table 1. Physical characteristics of Raphia palm weevil larvae depending on the processing method

	Treatments				
	T1	T2	T3	T4	
Variable	Boiling	Roasting	Frying	Oven-drying	SEM
Cooking loss (%)	2.41^{d}	5.95^{c}	9.66^{b}	11.15^{a}	0.02
Cooking yield (%)	97.59^{a}	94.05^{b}	90.34^{c}	88.85^{d}	0.01
Thermal shortening (%)	11.99^{d}	14.53^{c}	15.28^{b}	19.63^{a}	0.02
WHC (%)	21.78^{a}	20.42^{b}	18.34^{c}	17.13^{d}	0.03

abcd: Means in the same row with different superscripts are statistically significant ($p < 0.05$)
WHC = Water Holding Capacity

Table 2 shows the results of the chemical composition and pH of processed larvae. There were significant differences in the values of all variables with the exception of pH values ($p < 0.05$). Boiled larvae had the highest moisture content compared to larvae processed by other methods (26.43%), while oven-dried larvae showed the lowest moisture content (18.63%). Crude protein was lowest in oven-dried larvae (27.17%), while fried larvae had the highest protein content (37.63%) followed by those larvae that were boiled (32.60%). The fat content was highest in fried larvae (17.70%) followed by boiled ones (15.57%), while it was lowest in over-dried larvae (11.43%). The ash content was highest (5.63%) in oven-dried larvae and lowest in boiled ones (3.37%), while roasted and fried ones had similar values. The carbohydrate (CHO) content was highest in oven-dried larvae (37.04%) and lowest in fried ones (19.63%), while roasted larvae had the value (27.29%) close to that in oven-dried ones. The oven-dried larvae had significantly higher crude fiber content, while it was lower and similar in boiled and roasted larvae. There was no significant difference in the pH of processed larvae across the four treatment methods ($p<0.05$). The result obtained for the moisture content of processed larvae in this study agrees with [29] who reported 26% moisture, but is different from [28,30] who recorded lower values in boiled larvae. Although boiling and roasting treatments are generally known to coagulate protein, the protein content in fried larvae was higher than in boiled and roasted larvae. The reason for this could be the contribution of protein in the oil used for frying and the inherent protein in the larvae according to [31] who reported that palm weevil larvae elicited higher protein when fried than when boiled or roasted. The same explanation goes for the fat content of processed larvae, but the crude fiber content was higher in oven-dried larvae probably due to dehydration as a result of high temperature, which was not so high in other treatment methods, especially boiling and roasting. The values of the crude fiber content obtained in this study corresponded to those reported by [29] for edible insect larvae. The values of ash and pH obtained in this study are close to the values reported by [32] who recorded a range of 3–6% for the ash content and 7–9 for pH of processed larvae.

The carbohydrate content was highest in oven-dried larvae as a result of high dehydration and denaturation of protein with higher protein coagulation in oven-dried larvae.

Table 2. Chemical composition and pH of Raphia palm weevil larvae depending on the processing method

Variable	Treatments				
	T1	T2	T3	T4	
	Boiling	Roasting	Frying	Oven-drying	SEM
Moisture (%)	26.43^{a}	24.57^{b}	20.23^{c}	18.63^{d}	0.32
Crude protein (%)	32.60^{b}	30.20^{c}	37.63^{a}	27.27^{a}	0.40
EE (fat) (%)	15.57^{b}	13.37^{c}	17.70^{a}	11.43^{d}	0.36
Ash (%)	3.37^{c}	4.57^{b}	4.77^{b}	5.63^{a}	0.29
CHO (%)	22.03^{d}	27.29^{c}	19.63^{b}	37.04^{a}	0.73
Crude fiber (%)	3.40^{c}	3.67^{c}	4.63^{a}	5.7-^{a}	0.24
pH	7.30	7.26	6.90	7.10	0.19

abcd: Means in the same row with different superscripts are statistically significant ($p < 0.05$)
CHO = Carbohydrate

The results of the content of some vitamins and minerals in processed palm weevil larvae are shown in Table 3. The level of ascorbic acid was highest (0.60 mg/100 g) in boiled larvae and lowest (0.39 mg/100 g) in oven-dried samples of larvae, while the level of ascorbic acid in roasted larvae (0.57 mg/100 g) was close to that of boiled larvae. The niacin level was highest (2.66 mg/100 g) in boiled larvae and lowest (2.21 mg/100 g) in oven-dried larvae. Also, the thiamine level was highest in the boiled larva samples (0.15 mg/100 g) and lowest in oven-dried larvae with a value of 0.08 mg/100 g. A sequential decrease in the content of vitamins in larvae treated by different processing methods was observed for all vitamins except riboflavin, which content increased irrespective of the level of heat applied in processing of larvae.

The results obtained for vitamins in this study agree with [33], who reported that ascorbic acid, niacin and thiamine were susceptible to heat destruction, while riboflavin was not. Hence, the numerical decrease in the levels of ascorbic acid, niacin and thiamine was observed in the larva samples treated by different processing methods, while riboflavin significantly increased ($p < 0.05$), because it was not affected by heat. The levels of some minerals such as calcium, magnesium, phosphorus and sodium increased significantly in this study as heat increased due to processing methods, while others such as manganese and zinc increased insignificantly under heat. Dobermann et al. [6] showed that generally minerals in insects are not susceptible to heat depending, though, on a level and type of thermal processing that is employed. The same observation was recorded in this study as none of the processing methods employed affected the mineral composition of the weevil larvae adversely.

Table 3. Content of some vitamins and minerals of Raphia palm weevil larvae depending on the processing method, (mg/100g)

Variable	Treatments				
	T1	T2	T3	T4	
	Boiling	Roasting	Frying	Oven-drying	SEM
Vitamins					
Ascorbic acid	0.60	0.57	0.43	0.39	0.19
Niacin	2.66	2.56	2.32	2.21	0.04
Riboflavin	0.14^d	0.18^c	0.22^b	0.25^a	0.03
Thiamine	0.15	0.12	0.10	0.08	0.02
Minerals					
Calcium	260.00^c	280.00^b	290.00^a	290.00^a	8.15
Magnesium	90.00^d	93.30^c	96.70^b	100.00^a	7.69
Manganese	0.03	0.03	0.04	0.04	0.02
Phosphorus	153.30d	160.00^c	168.30^b	185.00^a	7.69
Sodium	52.20^d	61.00^a	54.36^c	58.67^b	0.11
Zinc	15.80	16.62	16.01	16.03	0.04

abcd: Means in the same row with different superscripts are statistically significant ($p < 0.05$)

Table 4 shows the results of the microbial load of palm weevil larvae processed by different thermal methods. The total viable count was highest in boiled larvae (2.2×10^5 cfu/g) compared with the microbial load of larvae processed by roasting (1.1×10^5 cfu/g), frying (1.0×10^5 cfu/g) and oven-drying (1.0×10^5 cfu/g), respectively. Similar results were observed for the total yeast count with boiled larvae having the highest load (2.0×10^2 cfu/g) compared to larvae processed by other three methods, namely, roasting (1.1×10^2 cfu/g), frying (1.0×10^2 cfu/g) and oven drying (1.1×10^2 cfu/g). There were no significant differences in the fungal and staphylococcal loads of processed larvae. The trend of microbial contamination of processed larvae followed a degree of heat applied. The number of microbes decreased as thermal methods with higher temperatures were employed. Boiled and roasted larvae carried higher ($p < 0.05$) levels of microbes than fried and oven-dried larvae as a result of lower degrees of temperature involved in their processing. The results observed in this study agree with the findings of [15] who studied the effect of processing palm weevil larvae by cooking and drying as well as storage and reported that higher temperature reduced the number of microbes on the larvae processed. The larvae processed in this study were not stored; however, the level of asepsis of the product was assessed in relation to handling during processing, therefore a degree of contamination of the product (larvae) was not higher than the recommended level of tolerance and consumerism [34].

Table 4. Microbial counts of Raphia palm weevil larvae depending on the processing method, (cfu/g)

Variable	Treatments			
	T1	T2	T3	T4
	Boiling	Roasting	Frying	Oven-drying
Total viable count	$2.2^a \times 10^5$	$1.1^b \times 10^5$	$1.0^b \times 10^5$	$1.0^b \times 10^5$
Total fungal count	1.2×10^4	1.3×10^4	1.0×10^4	1.0×10^4
Total Staphylococcus count	0.10×10^3	0.10×10^3	0.01×10^3	0.01×10^3
Total yeast count	$2.0^a \times 10^2$	$1.1^b \times 10^2$	$1.0^c \times 10^2$	$1.1^b \times 10^2$

abc: Means in the same row with different superscripts are statistically significant ($p < 0.05$)

The results of sensory evaluation of palm weevil larvae processed differently are shown in Table 5. All eating quality variables significantly differed across the processing treatments ($p < 0.05$). Weevil larvae processed using the frying method showed the highest values ($p < 0.05$) of color, (7.00) flavor (7.50), juiciness (6.70), texture (6.80) and overall acceptability (7.50), while tenderness was highest (6.30) in boiled larvae. Larvae processed by oven-drying had the lowest eating quality values. For meat and meat products to be palatable and acceptable to consumers, the palatability factors must be significantly high coupled with the reasonable water holding capacity, moisture, protein, and fat contents of a piece of meat [35,36]. The sensory scores of fried palm weevil larvae were high, as well as the WHC, moisture, protein and fat content, which are needed to enhance flavor, juiciness, and hence, high acceptability. Overall acceptability of fried larvae was high due to the aforementioned characteristics, which in addition to high color and texture scores may attract consumers to accept fried weevil larvae more than those processed by other methods. The results of sensory evaluation of larvae processed by frying were in agreement with the findings of [37] who reported that consumers preferred fried meats rather than those processed using other thermal processing methods.

Table 5. Sensory scores for Raphia palm weevil larvae depending on the processing method

Variable	Treatments				
	T1	T2	T3	T4	
	Boiling	Roasting	Frying	Oven-drying	SEM
Color	5.00^c	6.00^b	7.00^a	4.00^d	0.96
Flavor	4.10^d	6.30^b	7.50^a	5.20^c	0.93
Tenderness	6.30^a	5.40^b	3.90^c	2.80^d	0.86
Juiciness	3.10^c	5.50^b	6.70^a	3.00^c	1.01
Texture	4.30^c	5.40^b	6.80^a	3.20^d	1.12
OA	3.30^d	6.10^b	7.50^a	4.50^c	1.34

abcd: Means in the same row with different superscripts are statistically significant ($p<0.05$)
OA = Overall Acceptability

Conclusion

Thermal methods have been applied to process insects, especially palm weevil larvae, to enhance their eating factors. This study was carried out to investigate the quality and acceptability factors of *Rhyncophorus phoenicis* processed by different thermal methods — boiling, roasting, frying and oven-drying. This study showed that palm weevil larvae processed by the frying method had the low cooking loss, thermal shortening, microbial load, and high WHC, cooking yield, content of protein, fat, minerals, vitamins and sensory characteristics. Therefore, it has been shown that the frying method is an appropriate method to process *Rhyncophorus phoenicis* for better eating quality factors and higher consumer acceptability.

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