ESTIMATION OF AMINO ACIDS, THIOBARBITURIC ACIDS AND FREE FATTY ACIDS IN PALM WEEVIL *(RHYNCHOPHORUS PHOENICIS)* LARVAE FRIED AT DIFFERENT TIME INTERVALS DURING AMBIENT AND REFRIGERATED STORAGE

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Abstract
*This study investigated the influence of frying at different time intervals of 2, 5 and 7 min on the amino acids, thiobarbituric acids (TBA) and free fatty acids (FFA) of palm weevil (*Rhynchophorus phoenicis*) larvae during ambient and refrigerated storage, as affected by different packaging materials. A total of eighteen (18) amino acids were identified and quantified from fresh and fried palm weevil larvae samples, consisting of essential and non essential types. The essential amino acids include histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Leucine was highest (9.48 g/100g protein) in the sample fried for 2 min while the lowest (8.30) was recorded for the fresh sample. Among other essential amino acids identified from the fried palm weevil samples, higher quantities of phenylalanine, valine and histidine were observed for the sample fried for 2 and 5 min than their counterparts fried for 7 min, indicating that any of the two time intervals may be optimal for processing palm weevil larvae, as this may enhance amino acid, and hence nutritional in the product. Lower values of FFA (KOH/g lipid) were recorded on day 3 of storage than days 5 and 7 where increase was observed. Samples fried for 2 min generally had lower FFA than those fried for 5 and 7 min (*$p < 0.05$*), however FFA was observed to increase correspondingly with time of frying. For samples stored at ambient temperature (30ºC), the highest value (8.24) of FFA was recorded for sample fried for 7 min and packaged in brown paper on day 7 of storage. There was generally no significant difference (*$p > 0.05$*) in FFA and TBA of the different samples based on the packaging materials used during storage at ambient and refrigeration conditions, and therefore any of the three packaging materials (brown paper, aluminium foil and polyethylene) may be recommended for storage of fried palm weevil larvae. Conclusively, refrigerated samples recorded lower values of FFA and TBA than those stored at ambient temperature, indicating that refrigeration may reduce the occurrence of FFA and TBA development in the product during storage.*

Keywords: frying; amino acids; thiobarbituric acid; free fatty acids; packaging materials; palm weevil (*Rhynchophorus phoenicis*) larvae

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INTRODUCTION

Species of *Rhynchophorus* are major pests of date palms, coconut palms, oil palms and sugarcane. Though they are very destructive, their nutritional potentials have endeared them to man. The palm weevil, *Rhynchophorus phoenicis*, is highly cherished in many tropical countries, including Nigeria. It inhabits oil palms, coconut and raphia palm and is found in wide geographical areas spanning different climates such as Africa, southerm Asia and southern America (Okoli et al., 2019). The weevil is attracted to dying or damaged parts of plants, cut or split palm trunks and can also attack undamaged palms as well as decaying sugarcane. Palm grub is the larvae of the weevil; they are available from the wild and also culturable under laboratory conditions (Opara et al., 2012).

The larva of *R. phoenicis*, a Coleoptera of Curculionidae family is used as traditional food in several African countries, including Nigeria, where it is commonly found. In these countries, it serves as delicious meal. The high cost of animal protein has directed interest towards several insects as potential sources of proteins for humans. Among the insect species, *R. phoénicis* larvae are considered the major sources of dietary lipids and proteins. They are consumed world wide, especially in developing and under developed countries where consumption of animal protein may be limited because of economic, social, cultural or religious factors (Womeni et al., 2012).

There is a growing concern over worldwide malnutrition, largely among the low-income groups found in rural areas and the slums of cities. However, there are many underused food sources already in existence, which may be exploited to ameliorate this nutritional deficiency, one of which is edible insects (Okunowo et al., 2017). Edible insects have a long history in the nutrition of man - in some cases they are eaten as emergency food, staple food or as a delicacy. In Africa, Asia and Latin America for example, insects are eaten and used to prepare delicacies (Van-Huis et al., 2013). Information is scarce about the actual number of insect species consumed by humans worldwide; however, at the last count 2037 species of insects have been reported as food for humans. Reports have shown that many of the edible insects contain satisfactory amount of nutrients (protein, carbohydrate, fatty acids and minerals) required by humans (Rumpold & Schlüter, 2013).

As people continue to discriminate more on the type and sources of foods on the grounds of increasing health concerns and nutritional awareness, indigenous food sources such as the palm weevil (*R. phoenicis*) would become popular as alternative to red meat and chicken egg. Research into the advancement of production volume of *R. phoenicis* may therefore help improve economies, if global and industrial demands are created. Edible insects are traditional foods all over the world and are highly nutritious. Notable examples of these insects are *R. phoenicis*, termites, *Macroterms nigeriense*, *Cirina forda*, variegated grasshopper etc (Okoli et al., 2019).

The aim of this study was estimate the amino acids, thiobarbituric acids and free fatty acids in palm weevil (*Rhynchophorus phoenicis*) larvae fried at different time intervals during ambient and refrigerated storage. The palm weevil larvae samples were separately packaged in three different materials prior to storage.

MATERIALS AND METHODS

Source of raw materials

Life larvae of edible palm weevil (*Rhynchophorus phoenicis*) were obtained from Idemiri North Local Government Area of Anambra State, Nigeria. They were placed in aerated plastic buckets and transported to the Food processing laboratory in the Department of Food Science and Technology, Michael Okpara University of Agriculture, Abia State, Nigeria, for processing and analyses. Certain aspects of the processing and analyses were also carried out in the central laboratory of National Root Crops Research Institute, Umudike, Abia State, Nigeria

Preliminary processes

Prior to the main processing of frying, the edible palm weevil larvae were sorted to remove the dead ones, dirt and other debris such as feeds. Subsequently, they were washed in excessive running tap water to remove mud, sand and other extraneous materials. The life weevil larvae were then immersed inside boiling water for 1-2 min in order to kill them; they were thereafter drained to remove water and hung on bamboo barbecue skewers, with two palm weevil larvae per skewer.

Frying of palm weevil (*Rhynchophorus phoenicis*) larvae

Frying of the palm weevil larvae (already hung on bamboo skewers) was done in vegetable oil (Kings, Nigeria) inside frying pans over low burning fire at temperature of 90±2ºC for different time intervals of 2, 5 and 7 min (Figure 1). The oil in the fried palm weevil larvae were then drained and allowed to cool, after which samples were taken for analyses.

Determination of amino acid profile of the fresh and fried palm weevil (*Rhynchophorus phoenicis*) larvae

The amino acid profiles in the samples were determined using methods described by Benitez (1989). Sample were dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and then analyzed in Applied Biosystems PTH Amino Acid Analyzer (model 120A, USA).

Figure 1. Fried palm weevil (*R. phoenicis*) larvae

Determination of free fatty acid (FFA) contents of the fresh and fried palm weevil (*R. phoenicis*) larvae

FFA of the fresh and fried palm weevil (*R. phoenicis*) larvae were determined by weighing 5 g each from the samples. This was comminuted and the lipid extracted, followed by alkali titration using standard procedures as described by Association of Official Analytical Chemists (AOAC, 2005).

Determination of thiobarbituric acid (TBA) contents of the fresh and fried palm weevil (*R. phoenicis*) larvae

TBA values were determined for the fresh and fried palm weevil (*R. phoenicis*) larvae samples using the methods described by Brewer et al. (1992). Ten grams of comminuted samples were blended with 15 ml of cold extracting solution containing 9% perchloric acid. The resulting slurry was transferred quantitatively to 100 ml volumetric flasks and made up to 50 ml each with distilled water. The slurry was then filtered through Whatman no. 2 filter paper. Fifty millilitre of the filtrate was transferred to a test tube and 5 ml of 0.02 N TBA reagent was added and mixed thoroughly. The tube was kept in the dark for 17 h and the absorbance read at 530 nm with a spectrophotometer (Spectronic 20). TBA values were calculated from the standard solutions of tetraethoxypropane.

Determination of pH of the fresh and fried palm weevil (*R. phoenicis*) larvae

pH measurement was done by dipping the pH electrode into homogenates of crushed palm weevil larvae using the method described by Manthey et al. (1988). All measurements were carried out at room temperature using a pH meter (WTW Inolab, Weihem, Germany)

Statistical analysis

Data, which depended the fried palm weevil (R. phoenicis) larvae samples at different time intervals of 2, 5 and 7 min, were analyzed according to a completely randomized design with three replicates. Data were subjected to variance analyses and differences between means were evaluated by Duncan's multiple range test using SPSS statistic programme, version 10.01 (SPSS 1999). Significant differences were expressed at $p < 0.05$.

RESULTS AND DISCUSSION

In this investigation, frying was adopted for processing palm weevil (*R. phoenicis*) larvae, a beetle commonly found in West African countries, especially Nigeria. The fresh and fried samples of palm weevil (*Rhynchophorus phoenicis)* larvae were subjected to analyses of amino acids, free fatty acids (FFA) and thiobarbituric acids (TBA), in order to determine effect of frying on their quality characteristics.

The amino acid profiles (g/100mg protein) of the fresh and fried palm weevil larvae samples are presented in Table 1. A total of eighteen (18) amino acids were identified and quantified from the fresh and fried palm weevil larvae samples. The amino acid composition of the samples indicate that palm weevil larvae could be a good source of amino acids for human nutrition. The palm weevil samples were observed to contain all essential amino acids needed by human, including histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine, suggesting that the larvae may be a good source of some amino acids that the body may not be able to synthesize (Hajirostamloo and Mahastie, 2008). Leucine was highest (9.48 g/100g protein) in the sample fried for 2 min while the lowest (8.30) was recorded for the fresh sample. Among other essential amino acids identified from the fried palm weevil samples, higher quantities of phenylalanine, valine and histidine were observed for the sample fried for 2 and 5 min than their counterparts fried for 7 min. This may imply that any of the two frying periods may be optimal for enhancing nutritional intake of amino acids in palm weevil larvae. The reduction in the concentrations of some of the amino acids in the fried samples in comparison with their fresh counterpart could obviously be due to the effect of heat, which may have resulted in some degrees of denaturation (Anyalogbu et al., 2015).

Table 1: Amino acid profile of fresh and fried palm weevil (*R. phoenicis*) larvae, compared with other protein sources

Amino acids (g/100g Protein)	Fresh	Frying 2 min	Frying 5 min	Frying 7 min	Whole Egg (g/100g protein)	Rhynchophorus phoenicis larvae (g/100g protein)	Crickets (g/kg protein)
Leucine	8.30	9.48	8.99	8.36	1.09	6.74	11.7
Lysine	6.29	7.64	7.43	7.69	0.80	5.83	9.56
Isoleucine	3.79	3.40	3.21	3.78	0.78	2.41	6.65
Phenylalanine	7.08	6.14	5.88	4.06	0.71	4.22	5.87
Tryptophan	0.86	0.97	1.36	2.07	-	-	1.44
Valine	4.09	4.27	5.44	3.65	0.85	3.94	9.84
Methionine	1.93	1.23	1.07	2.15	0.42	2.18	2.74
Proline	3.23	4.97	3.25	1.04	0.52	14.0	9.86
Arginine	8.99	5.33	5.59	7.16	0.76	5.52	13.6
Tyrosine	3.44	3.41	3.09	2.79	0.52	3.15	10.7
Histidine	3.01	3.23	2.33	2.04	0.30	2.58	3.64
Cystine	1.09	0.91	0.84	1.16	0.30	1.59	1.61
Alanine	4.47	3.90	4.47	1.98	0.73	4.82	15.0
Glutamic Acid	15.11	14.96	15.57	12.82	1.58	13.0	18.9
Glycine	4.08	4.51	4.01	3.49	0.41	3.36	8.83
Threonine	3.36	3.11	3.05	3.98	0.63	3.61	6.21
Serine	4.70	3.40	2.94	1.77	0.95	3.90	6.67
Aspartic Acid	12.85	10.96	12.61	16.81	1.20	8.62	13.00
Source(s)	This study	This study	This study	This study	FAO, 1970	Okunowo et al., 2017	Finke, 2015

From the results of the amino acids identified in the palm weevil larvae samples in the present study, one may infer that useful proteins required by human are inherent in palm weevil larvae. This may be useful in human diet formulations, as the larvae can be processed into other forms (such as powder) for possible incorporation as additives in enrichment of foods. Hence, the palm weevil larvae may help promote food security, especially in terms of protein intake by the majority of the populace in tropical developing countries such as Nigeria, where many people cannot afford expensive sources of protein, due to poor per capita income.

Table 2. Free fatty acid contents (KOH/g lipid) of fresh and fried palm weevil larvae (*R. phoenicis*) in different packaging materials during ambient and refrigerated storage

Storage condition	Samples	Storage period (Days)	Packaging Materials		
			Brown paper	Aluminium foil	Polyethylene
Ambient (30°C)	Fresh	-	7.99^{c}±0.81	7.99^{b}±0.81	7.99^{a}±0.81
	Frying 2 min	0	7.94^{c}±1.20	7.94^{b}±0.75	7.94^{a}±1.27
		3	7.96^{c}±0.54	7.96^{b}±1.29	7.97^{a}±1.92
		5	7.99^{c}±0.76	8.06^{a}±0.91	8.02^{a}±1.08
		7	8.15^{b}±0.01	8.16^{a}±0.18	8.16^{a}±1.27
	Frying 5 min	0	7.90^{k}±0.16	7.90^{b}±2.01	7.90^{b}±2.01
		3	7.92^{c}±0.75	7.95^{b}±1.29	7.93^{b}±1.75
		5	7.99^{c}±0.52	8.16^{a}±0.16	8.03^{a}±0.18
		7	8.24^{a}±0.01	8.20^{a}±0.66	8.21^{a}±2.13
	Frying 7 min	0	7.94^{c}±0.89	7.84^{c}±1.20	7.84^{c}±1.29
		3	7.92^{c}±1.40	7.95^{b}±0.61	7.92^{b}±2.10
		5	7.99^{c}±1.75	8.18^{a}±0.19	8.05^{a}±0.28
		7	8.24^{a}±0.01	8.21^{a}±1.24	8.25^{a}±0.19
Refrigeration (2-4°C)	Fresh	-	7.99^{c}±0.01	7.99^{b}±0.18	7.99^{b}±0.21
	Frying 2 min	0	7.94^{c}±2.10	7.94^{b}±1.29	7.94^{b}±1.29
		3	7.95^{c} ±1.02	7.93^{b}±2.03	7.93^{b}±1.34
		5	7.96^{c}±0.73	7.99^{b}±1.02	7.98^{b}±1.20
		7	7.97^{c} ±0.54	7.99^{b}±1.87	7.98^{b}±2.19
	Frying 5 min	0	7.90^{c}±0.83	7.90^{b}±1.29	7.90^{o}±1.23
		3	7.90^{c}±1.09	7.93^{b}±0.80	7.93^{b}±2.19
		5	7.93^{c} ±0.97	7.98^{b}±1.29	7.98^{b}±0.88
		7	7.95^{c} ±1.23	7.99^{b}±1.28	7.98^{b}±1.29
	Frying 7 min	0	7.94^{c}±0.73	7.84^{c}±0.93	7.84^{c}±2.01
		3	7.93^{c} ±0.55	7.93^{b}±1.02	7.94^{b}±1.77
		5	7.97^{c} ±0.57	7.98^{b}±1.74	7.98^{b}±1.54
		7	7.97^{c} ±0.19	7.99^{b}±0.64	7.98^{b}±1.87

Values are means of replicate determinations; Means across columns with different superscripts are significantly different ($p < 0.05$)

Comparison of the amino acids in palm weevil larvae and whole eggs indicate that the former contain higher concentrations than the latter (FAO, 1970), making palm weevil larvae a good source of protein over egg. However, the amino acids of crickets reported by Finke (2015) were higher than that of palm weevil in the present study. Furthermore, many of the amino acids recorded in this study for fresh palm weevil larvae were comparable in concentrations to those reported by Okunowo et al. (2017), the slight variations may be due to possible differences in the varieties and species used in the different studies.

Table 3: Thiobarbituric acid contents (mg malondialdehyde/kg) of fresh and fried palm weevil larvae (*R. phoenicis*) in different packaging materials during ambient and refrigerated storage

Storage condition	Samples	Storage period (Days)	Packaging Materials		
			Brown paper	Aluminium foil	Polyethylene
Ambient (30^{o}C)	Fresh	-	$5.23^{c}\pm0.87$	$5.23^{b}\pm0.87$	$5.23^{bc}\pm0.87$
	Frying 2 min	0	$5.20^{c}\pm0.32$	$5.20^{b}\pm1.27$	$5.20^{bc}\pm0.94$
		3	$5.72^{b}\pm0.17$	$6.20^{a}\pm1.92$	$6.23^{a}\pm1.23$
		5	$5.74^{b}\pm0.82$	$6.35^{a}\pm1.84$	$6.40^{a}\pm0.94$
		7	$6.11^{a}\pm1.01$	$6.63^{e}\pm1.72$	$6.68^{a}\pm0.75$
	Frying 5 min	0	$5.18^{d}\pm1.29$	$5.18^{w}\pm1.18$	$5.18^{bc}\pm1.82$
		3	$5.64^{b}\pm1.23$	$6.25^{a}\pm1.82$	$6.23^{a}\pm0.93$
		5	$5.60^{b}\pm1.73$	$6.38^{a}\pm1.23$	$6.40^{a}\pm0.44$
		7	$6.21^{a}\pm2.81$	$6.66^{a}\pm1.53$	$6.68^{a}\pm0.97$
	Frying 7 min	0	$5.18^{d}\pm1.28$	$5.18^{bc}\pm1.29$	$5.18^{bc}\pm0.45$
		3	$5.60^{b}\pm1.27$	$6.25^{a}\pm1.27$	$6.21^{a}\pm1.26$
		5	$5.64^{b}\pm2.13$	$6.40^{a}\pm1.12$	$6.39^{a}\pm1.27$
		7	$6.24^{a}\pm0.55$	$6.66^{a}\pm1.28$	$6.65^{a}\pm0.83$
Refrigeration (2-4^{o}C)	Fresh	-	$5.23^{c}\pm1.24$	$5.23^{b}\pm0.27$	$5.23^{bc}\pm0.88$
	Frying 2 min	0	$5.20^{c}\pm1.11$	$5.20^{b}\pm1.26$	$5.20^{bc}\pm0.99$
		3	$5.21^{c}\pm1.32$	$5.21^{b}\pm0.82$	$5.22^{bc}\pm1.25$
		5	$5.23^{c}\pm1.17$	$5.76^{r}\pm0.94$	$5.85^{b}\pm1.24$
		7	$5.33^{c}\pm1.24$	$5.76^{r}\pm1.26$	$5.86^{b}\pm2.38$
	Frying 5 min	0	$5.18^{d}\pm1.82$	$5.18^{bc}\pm1.45$	$5.18^{bc}\pm2.09$
		3	$5.22^{c}\pm1.18$	$5.18^{bc}\pm1.23$	$5.19^{bc}\pm0.47$
		5	$5.25^{c}\pm1.33$	$5.76^{b}\pm1.28$	$5.85^{b}\pm1.82$
		7	$5.30^{c}\pm1.29$	$5.75^{b}\pm1.92$	$5.84^{b}\pm0.96$
	Frying 7 min	0	$5.18^{d}\pm1.52$	$5.18^{bc}\pm1.72$	$5.18^{bc}\pm1.07$
		3	$5.18^{d}\pm1.29$	$5.19^{bc}\pm1.87$	$5.19^{bc}\pm0.08$
		5	$5.73^{b}\pm1.86$	$5.75^{b}\pm1.23$	$5.85^{b}\pm0.73$
		7	$5.73^{b}\pm1.23$	$5.76^{b}\pm1.31$	$5.85^{b}\pm1.22$

Values are means of replicate determinations; Means across columns with different superscripts are significantly different ($p < 0.05$)

The result of the amino acids recorded in the present study also corroborates the report of Okaraonye & Ikewuchi (2008) and Ekpo (2010) who carried out similar research investigation on palm weevil larvae.
The fresh and fried palm weevil larvae samples, packaged in brown paper, aluminium foil and polyethylene, were subjected to determination of FFA (KOH/g lipid), and result is shown in Table 2. Palm weevil larvae generally contain high fat contents, which are capable of degenerating into free fatty acids.
Higher values of FFA have been associated with foods containing higher fat contents than those with lower fat. It is therefore not surprising that high values of FFA were recorded for the different palm weevil samples in the present study. Lower values of FFA were recorded on day 3 of storage than days 5 and 7 where increase in value was noted.

Table 4: pH of fresh and fried palm weevil larvae (*R. phoenicis*) in different packaging materials during ambient and refrigerated storage

Storage condition	Samples	Storage period (Days)	Packaging Materials		
			Brown paper	Aluminium foil	Polyethylene
Ambient (30ºC)	Fresh	-	6.00^{a}±1.29	6.00^{a}±1.29	6.00^{a}±1.29
	Frying 2 min	0	5.95^{a}±0.17	5.95^{a}±1.26	5.95^{a}±1.27
		3	5.55^{a}±0.99	5.61^{a}±0.91	5.70^{a}±1.43
		5	5.50^{a}±0.48	5.57^{b}±0.17	5.56^{b}±0.98
		7	5.35^{b}±1.26	5.56^{b}±1.83	5.41^{b}±1.03
	Frying 5 min	0	5.95^{a}±0.43	5.88^{a}±1.27	5.88^{a}±1.73
		3	5.52^{a}±0.51	5.61^{a}±1.24	5.65^{a}±0.86
		5	5.40^{b}±1.82	5.56^{b}±1.93	5.56^{b}±1.62
		7	5.31^{b}±1.73	5.50^{b}±1.46	5.35^{b}±1.26
	Frying 7 min	0	5.95^{a}±0.95	5.88^{a}±1.53	5.88^{a}±0.98
		3	5.50^{a}±0.81	5.61^{a}±1.28	5.60^{a}±0.77
		5	5.40^{b}±1.27	5.56^{b}±1.25	5.56^{b}±1.26
		7	5.30^{b}±1.45	5.50^{b}±1.34	5.35^{b}±1.73
Refrigeration (2-4ºC)	Fresh	-	6.00^{a}±2.08	6.00^{a}±1.23	6.00^{a}±1.28
	Frying 2 min	0	5.95^{a}±0.76	5.95^{a}±0.89	5.95^{a}±1.33
		3	5.56^{a}±1.27	5.60^{a}±1.25	5.55^{b}±1.56
		5	5.50^{a}±1.34	5.50^{b}±1.66	5.50^{b}±0.77
		7	5.35^{b}±1.98	5.55^{b}±1.42	5.40^{b}±1.45
	Frying 5 min	0	5.95^{a}±0.92	5.88^{a}±0.99	5.88^{a}±1.24
		3	5.56^{a}±0.17	5.61^{a}±0.75	5.55^{b}±1.67
		5	5.55^{a}±0.99	5.51^{b}±1.32	5.51^{b}±0.55
		7	5.30^{b}±0.75	5.50^{b}±1.26	5.35^{b}±0.98
	Frying 7 min	0	5.95^{a}±1.73	5.88^{a}±1.63	5.88^{a}±1.25
		3	5.56^{a}±1.64	5.60^{a}±1.22	5.54^{b}±1.43
		5	5.55^{a}±0.98	5.50^{b}±1.26	5.50^{b}±1.23
		7	5.31^{b}±1.23	5.50^{j}±0.83	5.35^{b}±1.28

Values are means of replicate determinations; Means across columns with different superscripts are significantly different ($p < 0.05$*)*

Samples fried for 2 min generally had lower FFA than those fried for 5 and 7 min ($p < 0.05$), however FFA was observed to increase correspondingly, with time of frying. For samples stored at ambient temperature (30ºC), the highest value (8.24) of FFA was recorded for sample fried for 7 min and packaged in brown paper on day 7 of storage. There was generally no significant difference ($p > 0.05$) in FFA of the different samples based on the packaging materials used, and therefore any of the three packaging materials may be recommended for storing fried palm weevil larvae, since storage is for few days. The refrigerated samples recorded lower values of FFA than those stored at ambient temperature, indicating that refrigeration may reduce the occurrence of FFA development in foods during storage. Similar observations recorded for the samples stored at ambient temperature, were observed for those stored under refrigeration, especially on the trend of FFA in the palm weevil larvae samples in different packaging materials. It will therefore be advantageous to store fried palm weevil larvae at refrigeration temperature, as this reduces degree of FFA development in the product, and this may enhance storage of the product.

Table 3 shows the TBA in the fresh and fried palm weevil larvae samples during storage at ambient and refrigerated temperatures. TBA values (mg malondialdehyde/kg) were observed to increase correspondingly with time of frying, and time of storage, possibly due to conversion of fat to FFA, and subsequently to TBA (Olaoye, 2016). The packaging materials used had no significant effect ($p > 0.05$) on the TBA of the samples, during storage at ambient and refrigeration conditions. It was however observed that TBA values were lower in the samples stored at refrigerated condition than their counterparts stored at ambient temperature. It may therefore be said that fried palm weevil samples should be kept under refrigeration, especially when the product will stay for days before consumption. This will help reduce the TBA development, and hence lower rancidity development through lipid oxidation in food products. Furthermore, rancidity development due to high TBA during storage may cause off flavor (Olaoye, 2016).

The pH of fresh palm weevil larvae was 6.0, while lower values were recorded for the fried samples packaged in different packaging materials (Table 4). The pH of the samples packaged in the different materials was not statistically different from one another ($p > 0.05$), however values were lower in the samples at days 5 and 7, compared with day 3. The slight reduction noted during storage could be due to possible metabolic activities of microorganisms, as reported by Onilude et al. (2002) and Olaoye & Dodd (2010).

CONCLUSION

In conclusion, storage of fried palm weevil larvae in brown paper, aluminium foil and polyethelene as packaging materials had no significant effect ($p > 0.05$) on the FFA, TBA and pH of the product during ambient and refrigerated storage. From the results of this study, it is suggested that fried palm weevil larvae be stored at refrigerated condition when immediate consumption is not required, as this helps reduce development of FFA and TBA, which may help prolong storage quality of the product.

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