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TheNutritive, textural and sensory attributes of frankfurter fortified with graded levels of edible Palm weevil larvae (*Rhynchophorus phoenicis* F)

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Abstract

Consumption of excessive dietary fat has been linked to health-related diseases necessitating reduction of fat in meat products as a response to consumers' preferences. Replacement of fat in frankfurter have been achieved with different ingredients. However, there is little information on Palm weevil larvae (PWL) as fat replacement in frankfurter. Hence, the quality of frankfurter incorporated with PWL was assessed. The PWL were cleaned, head removed and ground (GPWL). Frankfurter ingredients and production was done following standard procedures. Five treatments ($T_1$10% lard) T_2, T_3, T_4 and T_5 contains 2.5, 5.0, 7.5 and 10% GPWL substituted for lard. Five independent replicates of each treatment were prepared separately. Yield, proximate composition, iodine value, fatty acid, Texture Profile Analysis (TPA) and sensory characteristics were determined using standard procedures. Data were subjected to ANOVA at $P_{\alpha 0.05}$. The yield (80.38- 87.85%), crude protein (54.95- 67.55%) and ash (6.01-6.80%) contents of GPWL frankfurters were higher (P<0.05) while ether extract (15.50-18.10%) was (P<0.05) lower. The iodine values of 10% lard (1.73) and 2.5% GPWL frankfurters were not different (P>0.05) but these were significantly higher (P<0.05) than 0.40, 0.90 and 0.80 recorded for 5.0, 7.5 and 10% GPWL frankfurters, respectively. No statistical variation (P>0.05) exist among the selected fatty acids of the frankfurters. The TPA showed chewiness (16.40N) and hardness (48.58N) of 10% lard frankfurter were significantly (P<0.05) lower while the springiness (0.69) was higher (P<0.05). Sensory attributes revealed appearance (7.37; 7.03), flavour (7.53; 7.17), after taste (5.93; 6.00) and acceptability (7.73; 7.04) of 10% lard and 2.5% GPWL frankfurters, respectively were similar (P>0.05). Juiciness of 10% lard (6.80), 2.5%, (6.73), 5% (6.63) and 7.5% (6.57) GPWL frankfurters were similar (P>0.05).
Partial replacement of lard with palm weevil larvae resulted in a more nourishing frankfurter however, replacement with lard should not exceed 5% in order to obtain frankfurter with good colour appeal and organoleptic characteristics.

Keywords: Nutrient composition, lard, substitution, palm weevil larvae, texture

Running title: texture, nutrient and sensory profile of frankfurter fortified with edible Palm weevil larvae

Les attributs nutritifs, texturaux et sensoriels de la saucisse de Francfort enrichie de niveaux gradués de larves comestibles du charançon du palmier (Rhynchophorus phoenicis F)

Résumé

La consommation excessive de graisses alimentaires a été associée à des maladies liées à la santé nécessitant une réduction des graisses dans les produits carnés en réponse aux préférences des consommateurs. Le remplacement de la graisse dans la saucisse de Francfort a été réalisé avec différents ingrédients. Cependant, il existe peu d'informations sur les larves de charançon du palmier (LCP) comme substitut de graisse dans la saucisse de Francfort. Par conséquent, la qualité de la saucisse de Francfort incorporée au LCP a été évaluée. Les LCP ont été nettoyés, étêtés et meulés (GPWL). Les ingrédients et la production de Frankfurter ont été effectués selon des procédures standard. Cinq traitements ($T_1$10 % saindoux) T_2, T_3, T_4 et T_5 contiennent 2,5, 5,0, 7,5 et 10 % de GPWL substitué au saindoux. Cinq répliques indépendantes de chaque traitement ont été préparées séparément. Le rendement, la composition immédiate, l'indice d'iode, les acides gras, l'analyse du profil de texture (APT) et les caractéristiques

sensorielles ont été déterminés à l'aide de procédures standard. Les données ont été soumises à une ANOVA à Pα0,05
Le rendement (80,38-87,85 %), la teneur en protéines brutes (54,95-67,55 %) et en cendres (6,01-6,80 %) des saucisses de Francfort GPWL étaient plus élevées (P<0,05) tandis que l'extrait d'éther (15,50-18,10 %) était (P<0,05) inférieur. Les valeurs d'iode des saucisses de Francfort 10 % saindoux (1,73) et 2,5 % GPWL n'étaient pas différentes (P>0,05) mais elles étaient significativement plus élevées (P<0,05) que les valeurs de 0,40, 0,90 et 0,80 enregistrées pour les saucisses de Francfort 5,0, 7,5 et 10 % GPWL, respectivement. Aucune variation statistique (P>0,05) n'existe parmi les acides gras sélectionnés des saucisses de Francfort. L'APT a montré que la mastication (16,40 N) et la dureté (48,58 N) de la saucisse de Francfort à 10 % de saindoux étaient significativement (P < 0,05) inférieures, tandis que l'élasticité (0,69) était supérieure (P < 0,05). Les attributs sensoriels ont révélé que l'apparence (7,37 ; 7,03), la saveur (7,53 ; 7,17), l'arrière-goût (5,93 ; 6,00) et l'acceptabilité (7,73 ; 7,04) de 10 % de saindoux et de 2,5 % de saucisses de Francfort GPWL étaient similaires (P> 0,05). La jutosité des saucisses de Francfort GPWL à 10 % (6,80), 2,5 %, (6,73), 5 % (6,63) et 7,5 % (6,57) était similaire (P> 0,05).
Le remplacement artificiel du saindoux par des larves de charançon du palmier a donné une saucisse de Francfort plus nourrissante. Cependant, le remplacement par du saindoux ne doit pas dépasser 5 % afin d'obtenir une saucisse de Francfort avec un bon attrait de couleur et des caractéristiques organoleptiques.

Mots-clés : Composition nutritive, saindoux, substitution, larves de charançon du palmier, texture

Introduction

Fat from animal sources especially pork back fat is an important ingredient in sausages or frankfurter production (Abdolghafour and Saghir, 2015). Inclusion of fat in frankfurter preparation has a major effect on texture, juiciness, mouth feel, flavour (Amini Sarteshnizi *et al*., 2015) and improves consumer over all acceptability (Tobin *et al*., 2013) of the meat product.

Nowadays, there is is advocate on reducing fats consumption (Ritzoulis *et al*., 2010) especially from animal fat due to health-related diseases associated with its excessive intake (Biswas *et al.,* 2011). Subsequently, the increased demand for healthier meat products which has led to a progressive shift by health-conscious consumers towards low fat meat products (Yang *et al*., 2007; Biswas *et al.,* 2011). The meat product industry is now geared towards modification or development of meat products that contain less animal fat (Choi *et al*., 2009) by using ingredients that contain low fat but are nutritious and have health benefits (Hartmann *et al*., 2020). This modification can be achieved through reformulation which aimed at developing meat products with reduce fat without affecting its flavour, smell and at the same time maintaining product acceptance (Méndez-Zamora *et al*., 2015) thus the search for alternative fat sources.

The choice of edible insects as alternative food source arises from the nutritional benefits they offer such as its richness in protein, minerals (Li *et al.,* 2013; Nowak *et al*., 2016) and fat content that ranged between 14.48 -18.35% (Akande *et al.,* 2020a). They have been increasingly used to enrich various food products in protein such as gluten-free bread (Da Rosa Machado and Thys, 2019), snacks where it serves as a substitute to animal protein (Banjo *et al*., 2006; Kinyuru *et al.,* 2009; Ojinnaka *et al.,* 2016) and high energy biscuits (Akande *et al.,* 2020b).

One of such edible insect is the African palm weevil larvae (*Rhychophorus phoenicis* F), a delicacy in many parts of Nigeria and other countries in Africa where it is found. It is **a** nutrient-rich traditional cuisines usually merged with foods (Ayensu *et al*., 2019). It is high in protein (Elemo *et al.,* 2011; Parker *et al*., 2017) and a good source of energy, minerals and vitamins (Zielinska *et al*., 2015; Nongonierma and FitzGerald, 2017; Kohler *et al*., 2019). The fat content (32-34%) (Parker *et al*., 2018) in African Palm weevil larvae is rich in oleic, linoleic and palmtoleic when compared with lard (Okunowo et al., 2017; Omojola *et al*., 2023). However, despite its nutritional benefits its economic values have been poorly exploited.

Considering the technological and functional properties of fat in emulsified products, it becomes imperative to investigate the contribution and effect of partial replacementof lard with palm weevil larvae (PWL) on the chemical composition, texture and sensory characteristics of frankfurter sausages.

Materials and methods

Location of study

The experiment was carried out at the Meat Science and Processing Unit of the Department of Animal Science Kwame Nkrumah University of Technology (KNUST) Kumasi, Ghana.

Sources of raw materials

Palm weevil larvae (PWL) were obtained directly from a farm in Ejisu while pork and lard were purchased from the Kumasi abattoir all in Ghana. The ice packs and food grade curing salt and phosphates were obtained from the Meat Science and Processing Unit of the Department of Animal Science, Kwame Nkrumah University of Technology (KNUST) Kumasi, Ghana. All other ingredients were purchased from Kumasi Central Market, Ghana.

Frankfurter production

Lean meat and lard were minced using meat grinder (super wolf MADO MEW 513, Maschinferfabrik Domhan, GmbH, Germany) through a 3 mm and 5 mm plates, respectively (Wannee Tangkham and Frederick LeMieux, 2017). The palm weevil larvae were also cleaned of dirt, head removed and washed before grinding.

Ground Palm weevil larvae (GPWL) were used at different ratios (on weight basis) as a replacement for lard in the frankfurter. The study consists of five treatments, the control (T_1) frankfurter consists of 70% pork, 10% lard and 20% of other ingredients which includes curing salt (sodium nitrite and potassium sorbate), ice packs, phosphate and spices/seasonings (Table 1). Differing amounts of lard (2.5, 5.0, 7.5 and 10%) were replaced with the same portion of GPWL (T_2 2.5, T_3 5.0, T_4 7.5 and T_5 10) while the other ingredients remained the same. Research has shown that substitution level of poultry meat in sausage production did not exceed 20% (Souza *et al*., 2019) hence, the need not to exceed the replacement of 20% inclusion of GPWL.

The frankfurter was produced following the procedure of Wan Rosli *et al*. (2015). Five independent replicates of each batch were prepared the same way and each replicate was ground separately. The average weight, length and diameter of each sample were 300 g, 100 mm and 26 mm, respectively. The pH, cooking loss, water holding capacity, proximate composition, texture profile and sensory attributes were determined on freshly prepared frankfurter while fatty acid composition was carried on the stored frankfurter. The test samples were sealed and stored in a freezer at -18°C prior to the analyses according to method of Huda *et al.* (2010).

Table 1: Ingredients formulations of frankfurter-type sausages incorporated with graded level of ground Palm Weevil Larvae (GPWL)

	Graded levels of palm weevil larvae				
Ingredients (g)	T_1 (0%)	T_2 (2.5%)	T_3 (5%)	T_4 (7.5%)	T_5 (10%)
Ground meat	700	700	700	700	700
GPWL	0	25	50	75	100
Pork fat	100	75	50	25	0
Ice flakes	150	150	150	150	150
Spices*	30	30	30	30	30
Curing salt	15	15	15	15	15
Phosphate	5	5	5	5	5
Total	1000	1000	1000	1000	1000

GPWL= Ground Palm Weevil Larvae
spices* curry, red pepper, onions and garlic (all in powder)

Parameters measured

pH

The pH was measured using a digital pH meter (MP 230, Mettler Toledo, Switzerland). Approximately 3 g of cooked frankfurter sample was added to distilled water (27 mL). The pH meter was calibrated using standard buffers of pH 4.0, 7.0 and 9.0 at 25ºC (Seo *et al*., 2016). This was determined on raw batter (emulsion) and freshly prepared frankfurter and measurements were performed in triplicates.

Proximate composition analysis

The proximate composition including moisture, crude protein, crude fat and crude ash of the emulsion and GPWL frankfurter were performed according to AOAC (2002) methods. The amount of total protein was analyzed using Kjeldahl method while fat was determined by

Soxhlet extraction. All measurements were replicated in triplicates.

Cooking loss and Product yield

The yield due to cooking was determined for each treatment-replication combination (Yang *et al*. 2007). Weight of uncooked and cooked sausages were recorded and cooking loss and product yield were calculated as follows:

$$\text{Cooking loss (\%)} = \frac{\text{uncooked weight (g)} - \text{cooked weight (g)}}{\text{uncooked weight (g)}} \times 100$$

$$\text{Product yield (\%)} = \frac{\text{cooked weight}}{\text{uncooked weight}} \times 100$$

Water holding capacity (WHC)

The WHC was determined with some modifications following the procedure of Dzudie *et al*. (2005). A sample of 0.3 g was placed between two filter paper grade 1 and pressed between two 12 x 12 cm plexi-glass plates for 20 min under 1 kg of weight pressure. Due to the force exerted on the sample, the released liquids were impregnated in the paper and they were considered as meat-free water. In addition, pressed meat area and liquid released, were determined following the Image J software (Image j® 1.40 g, Wayne Rasband, National Institutes of Health, USA). Water holding capacity was performed in triplicate and was determined using the following equation

$$\text{Water release} = \frac{(\text{total surface area} - \text{meat layer area})\text{cm} \times 61.1 \times 100}{\text{Total moisture of meat sample (mg)}} \quad \text{………...equation 1}$$

$$\text{WHC} = 100 - (\%)\ \text{free water} \quad \text{……….. equation 2}$$

Fatty acid composition

The fatty acid profile of fat-reduced frankfurters containing ground palm weevil larvae (GPWL) was determined by exposing the samples to gas chromatography (Hu *et al*., 2016). The fatty acid compound was identified by matching the retention times of the frankfurter samples with a mixed fatty acids standard (Supelco™ 37 FAME Mix 47885-U, USA). Triplicate measurements of fatty acid of each sample per batch were conducted

Texture Profile Analysis

A Texture Analyzer (TA.XT2/ Plus Upgrade, Stable Micro Systems, Surrey, UK) with a two bite compression setup was used to assess the textural characteristics of the frankfurter for adhesiveness, gumminess, resilience, hardness, springiness, cohesiveness and chewiness. The Texture Analyzer was equipped with a cylindrical probe of 36 mm. The mechanical test conditions include a 50% compression rate, 5 mm/s of cross head speed for the pre-test, test and post- tests speeds and 5 g of automatic trigger load. The samples were cut into slices which were 12.5 mm thick and 26 mm in diameter and the measurements were carried out 16 times for each treatment. The parameters extracted were as follows: hardness (maximum force of the first compression), springiness (distance of the detected height during the second compression divided by the original compression distance i.e. distance 2/distance 1), cohesiveness (area of work during the second compression divided by the area of work during the first compression i.e. area 2/area1), chewiness (hardness ×cohesiveness × springiness) and resilience (calculated by dividing the up stroke energy of the first compression by the down stroke energy of the first compression i.e. area4/area3).

Sensory Analysis

Forty-five (45) untrained participants were used for the evaluation of the fresh frankfurters and all participants were volunteers solicited from the Department of Animal Science, Kwame Nkrumah University of Technology (KNUST) Kumasi, Ghana. The participants were presented with three digits randomly coded samples. Each preparation was evaluated using a 9-point hedonic scale (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4= dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1= dislike extremely). The parameters evaluated were acceptability of appearance, colour, tenderness, flavour, after taste, mouth feel and overall liking. Participants were required to cleanse their palates with biscuit and water between tasting the samples.

Statistical analysis

For each treatment, five batches were used and the data were analyzed by one-way ANOVA using the SAS statistical software (SAS Institute, 2012) to determine differences at significant level at $P_{\alpha}0.05$.

Results and Discussion

Yield, pH and water holding capacity (WHC)

The values presented on Table (2) showed thatthe pH (5.63-5.78) of the raw batters (emulsion) and cooked frankfurters (5.66-5.95) were not significantly different (P>0.05) from each other. The cooking loss (20.41%) of frankfurter with 10% lard inclusion was significantly higher (P<0.05) than 19.62% (2.5% lard), 19.03% (5.0% lard), 18.41% (7.5% lard) and 12.15% (10% lard). The yield from GPWL frankfurters ranges from 80.38-87.85% while WHC ranged from 12.00-22.00% and these are significantly higher (P<0.05) than 79.59% (yield) and 10.00% (WHC) obtained for frankfurter with 10% lard inclusion.

Table 2: pH, water holding capacity and yield of lard-reduced frankfurters substituted with graded levels ground palm weevil larvae

Parameters	Graded levels of palm weevil larvae					LSD
	T_1 (0%)	T_2 (2.5%)	T_3 (5%)	T_4 (7.5%)	T_5 (10%)	
pH (raw batter)	5.63	5.75	5.77	5.82	5.78	0.24
pH	5.66	5.82	5.85	5.84	5.95	0.45
Cooking loss (%)	20.41^{a}	19.62^{b}	19.03^{c}	18.41^{d}	12.15^{e}	0.55
Product yield (%)	79.59^{e}	80.38^{d}	80.97^{c}	81.59^{b}	87.85^{a}	0.55
WHC (%)	10.00^{e}	12.00^{d}	14.00^{c}	16.00^{b}	22.00^{a}	0.55

[abcd]Means in the same row with different superscript are significantly different (P<0.05)
WHC= water holding capacity

Yield, cooking loss and Water holding capacity

The result of this study as presented on Table (2) revealed that there is a direct relationship between GPWL inclusion, product yield and WHC but inversely proportional to cooking loss. This implies that cooking yield was significantly improved by GPWL addition and this trend was also observed by (Agbango, *et al*. 2021). This improvement could be attributed to the increase in moisture binding (WHC) by the added GPWL. This is because the more a product is able to hold onto its water during application of force (WHC) the more the yield from such product and the less the cook out (cooking loss) from the product. The high cooking loss in the lard frankfurter could be due to excessive fat separation and water released during cooking (Talukder, 2015). The decrease in cooking loss of GPWL frankfurters is of economic benefit especially in commercial food industry because the lower the cooking loss the more the yield implying more available product for sale.

The result of this study correlates with the report of Gao *et al.* (2013) who reported an increase in the yield of frankfurters when pork back fat was substituted with pre-emulsified sun flower oil. A reduction in cooking loss was also reported by Pereira *et al*. (2020) who reduces back pork fat in sausage production with unripe banana by-products. A similar result was also reported by Choi *et al.* (2013) whoreduced frankfurter fat levels from 30 to 20%by partially substituting pork back fat with a mixture of sunflowerseed oil and *makgeolli lees*fiber.

Proximate composition

The residual dry matter (86.10%-96.40%), crude protein (54.95- 67.55%) and ash (6.01-6.80%) contents of the GPWL frankfurters (Table 3) were significantly higher (P<0.05) than 82.97 (residual dry matter), 51.80% (CP) and 5.40% (ash) recorded for frankfurter with 10% lard inclusion. The ether extract (20.80%) of the frankfurter with 10% lard was significantly higher (P<0.05) than 15.10-18.10% obtained when GPWL was substituted for lard in frankfurter.

Table 3: Chemical composition of lard-reduced frankfurters substituted with graded levels of ground palm weevil larvae

Parameters (%)	Graded levels of palm weevil larvae					LSD
	T_1 (0%)	T_2 2.5%)	T_3 5.0%)	T_4 (7.5%)	T_5 (10.0%)	
Residual dry matter	82.97^{d}	86.10^{c}	89.75^{b}	94.80^{a}	96.40^{a}	1.15
Crude protein	51.80^{c}	54.95^{b}	54.94^{b}	67.20^{a}	67.55^{a}	0.50
Ash	5.40^{d}	6.01^{c}	6.10^{c}	6.61^{b}	6.80^{a}	0.14
Ether extract	20.80^{a}	18.10^{b}	17.50^{c}	15.10^{d}	15.50^{d}	0.85
Crude fibre	0.09	0.08	0.07	0.06	0.06	0.50

[abcd]Means in the same row with different superscript are significantly different (P<0.05)

The high crude protein and ash contents obtained in this study could be as a result of the high protein (44.29%; 66.30%) and ash (5.86%; 5.20%) contents (Okaraonye and Ikewuchi, 2008; Elemo, *et al*., 2011).of palm weevillarvae. It might also be attributed to the high water holding capacity and low cooking loss of the GPWL frankfurters which makes most of the nutrients to be retained within the product hence the high nutrient content. It would have been expected that the fat contents of the GPWL frankfurters would increase as GPWL inclusion increases because of the high fat content (37.12% Elemo *et al.* (2011); 19.54% Okaraonye and Ikewuchi, 2008) of PWL. However, the reverse is observed and the trend (fat reduction) agree with the report of Wan Rosli *et al*. (2015), Gao *et al*. (2013) and Pereira *et al*. (2020) who reported low fat contents of frankfurter when back fat was substituted in the production of frankfurter.

The crude protein, fat and ash contents obtained in this study was higher than 14.29-`16.22% (CP), 10.74-11.41% (fat) and 1.55-1.92% (ash) reported by Wan Rosli *et al.* (2015) for chicken frankfurter incorporated with *Pleurotus sajor-caju* (PSC) powder. It is also higher than 10.28-10.96% (CP) and 8.90-13.35% (fat) found in low fat frankfurter incorporated with inulin and pectin(Méndez-Zamora *et al*., 2015) or 15.12-15.32% (CP), 11.02-11.42% (fat) and 2.29-3.21% (ash) obtained in frankfurter incorporated with unripe banana by-products (Pereira *et al*., 2020). However, the ash contents of all the frankfurters obtained in this study falls within the range (6.35-7.88% and 13.20-18.68%) of values reported by Méndez-Zamora *et al.* (2015) and Gao *et al*. (2013) respectively.

Iodine value and Fatty acid profile

The iodine values of 10% lard (1.73) and 10% GPWL (1.40) frankfurters were similar (P>0.05) but significantly higher (P<0.05) than 0.40, 0.80 and 0.90 obtained in 2.5%, 5.0% and 7.5% GPWL frankfurters respectively. Although no significant differences (P>0.05) exist in the amount of each of the selected fatty acids evaluated but numerically it was observed that as the inclusion of GPWL increases, the amount of these fatty acid decreases in GPWL frankfurters.

Table 4: Iodine value and amounts of some selected fatty acid (mg/100g) of lard-reduced frankfurter substituted with graded levels of ground palm weevil larvae

Graded levels of Palm weevil larvae						
Parameters g/100g	T_1 (0.0%)	T_2 (2.5%)	T_3 (5.0%)	T_4 (7.5%)	T_5 (10.0%)	LSD
Iodine value	1.73^a	0.40^c	0.90^b	0.80^b	1.40^a	0.39
Arachidonic	0.05	0.02	0.03	0.02	0.02	0.15
Lauric	0.04	0.03	0.02	0.02	0.01	0.14
Palmitic	0.05	0.04	0.02	0.02	0.02	0.54
Linoleic	0.05	0.04	0.03	0.02	0.02	0.55
Oleic	0.05	0.04	0.03	0.02	0.02	0.58
Stearic	0.03	0.03	0.02	0.02	0.01	0.44

[abcd]Means in the same row with different superscript are significantly different (P<0.05)

Iodine value and Fatty acid profile

Iodine value is used to measure the degree of unsaturation of oil/fat and it is usually expressed as the number of grams of iodine absorbed by 100g of oil or fat. The higher the iodine value the higher the degree of unsaturation of the oil/fat. It was expected that the unsaturation of the GPWL frankfurters will decreased as the inclusion level of GPWL increases because of the low ether extract recorded in GPWL frankfurter (Table 3). However contrary to this, the iodine value showed that the unsaturation of the GPWL frankfurters increased as inclusion level was increased. This probably indicated that GPWL contained more of unsaturated fatty acid components.

The fatty acid composition of food is of great importance because of the great impact it has on the nutritional value, oxidative stability and sensory properties. The result revealed that all the fatty acids assessed, although not significant but numerically decreases as the GPWL inclusion increases. This might implies that the amount of fat in the GPWL frankfurters are reduced compared with the amount present in 10% lard frankfurter. This is evident in the low ether extract recorded in all the GPWL frankfurters. This is also reflected in the decreased rating of the GPWL frankfurters juiciness by the panelists because fat is one of the factors that contributes to juiciness of a product. Nutritionally, the reduced amount of fatty acid especially the saturated fatty acids (SFA) (lauric, stearic and palmitic) is good for the consumers because saturated fatty acids (SFA) have been reported to increase low density lipoproteins (LDL) hence, blood cholesterol levels (Rodriquez-Carpena, *et al.,* 2012).

Textural characteristics (Texture Profile Analysis)

The textural characteristics of the frankfurters displayed showed that the attributes which include hardness (49.70 -51.55), chewiness (2.18-4.76), adhesiveness (0.83-1.56), gumminess (58.49-77.94) of all GPWL frankfurters were significantly higher (P<0.05) than 48.58, 16.40, 0.57, 41.09 recorded in 10% lard frankfurter for hardness, chewiness, adhesiveness and gumminess respectively.

The cohesiveness (0.21) of 10% lard frankfurter is significantly lower (P<0.05) than 0.63 (5.0%), 0.69 (7.5%) and 0.76 (10%) recorded for GPWL frankfurters but similar (P>0.05) to 0.46 obtained frankfurter with 2.5% GPWL inclusion. The springiness (0.69) of 10% lard frankfurter was significantly higher (P<0.05) than 0.59 (2.5%), 0.54 (5.0%), 0.49 (7.5%) and 0.47 (10%) recorded in GPWL frankfurters. There was no significant difference (P>0.05) in the resilience (0.04-0.08) of all the frankfurters.

Table 5: Texture profile analysis of lard-reduced frankfurters substituted with graded levels of ground palm weevil larvae

Graded levels of ground Palm weevil larvae						
Parameters	T_1 (0.0%)	T_2 (2.5%)	T_3 (5.0%)	T_4 (7.5%)	T_5 (10.0)	LSD
Cohesiveness	0.21^b	0.46^{ab}	0.63^a	0.69^a	0.76^a	0.46
Chewiness(N)	16.40^d	21.80^c	36.00^b	35.50^b	47.60^a	0.28
Adhesiveness (kg/sec)	0.57^c	0.83^b	1.06^b	1.46^a	1.56^a	0.36
Gumminess	41.09^d	58.49^c	63.41^b	72.80^a	77.94^a	5.46
Hardness (N)	48.58^d	49.70^c	50.01^b	50.03^b	51.55^a	0.46
Resilience	0.08	0.07	0.05	0.04	0.07	0.60
Springiness (mm)	0.69^a	0.59^b	0.54^c	0.49^d	0.47^d	0.04

^{abcd}Means in the same row with different superscript are significantly different (P<0.05)

Substituting lard with GPWL in frankfurter production affected the textural characteristics of the reduced-fat frankfurter (GPWL frankfurters). Fat have influence on the rheological and structural properties of meat product and its reduction in meat product is expected to affect the textural properties of such product (Souza *et al.,* 2019) hence the changes observed in this study. The gumminess and chewiness of frankfurters in this study behaves similarly which agreed with the report of Selgas *et al*. (2005) that gumminess and chewiness are secondary parameters that depend on the hardness of meat product and based on this they behave similarly.

The increase in hardness of GPWL frankfurter correlates with the report of the taste panelists who recorded a decrease in tenderness of as the inclusion of GPWL increases. The increased hardness, chewiness, cohesiveness and adhesiveness of GPWL frankfurters could be as result of the firmer texture caused by reduction in fat content of the frankfurters. This firmer texture can be attributed to the presence of more tight connections among the meat particles and a more-denser structure (caused by the reduction in fat) thus more firm structure (Han and Bertram, 2017). The report of this study also agrees with Garcıa *et al*. (2002) who reported that low fat sausages with added cereal fibre (wheat fibre) were harder, less elastic and less adhesive. Mendoza *et al*. (2001) also reported a decrease in adhesiveness, springiness and cohesiveness when dietary inulin was used as substitute in low-fat sausages.

The reduced springiness of GPWL frankfurters could be attributed to the reduced rate at which the frankfurter springs back to its original position after chewing as a result of the increase in hardness. However, this contradicts the report of Wan Rosli *et al.* (2015) who reported an increase in springiness of oyster mushroom-based frankfurters. The values of hardness obtained in this study were lower than 51.25-71.50N obtained by Pereira *et al*. (2020) and 56.34-57.76N obtained by Gao *et al*. (2013) while the values of chewiness obtained falls within the range of 29.38-41.35N and 36.39-38.30N reported by Pereira *et al*. (2020) and

Gao *et al.* (2013) respectively.The cohesiveness of the frankfurters in this study was lower than 0.713-0.737 (except for frankfurter substituted with 10% GPWL) reported by Gao *et al.* (2013) while some still falls within 0.56-0.68 recorded by Pereira *et al*. (2020) for frankfurters substituted with unripe banana by-products. However, the springiness (0.84-0.89mm) obtained by Pereira *et al.* (2020) and 0.916-0.924mm recorded by Gao *et al*. (2013) are higher than the values obtained in this study.

Sensory characteristics

The sensory liking for appearance (7.37; 7.03), flavour (7.53;7.17) and acceptability (7.73; 7.04) of 10% lard and 2.5% GPWL frankfurters respectively were significantly similar (P>0.05) but higher (P<0.05) than 6.80; 6.27; 5.40 (appearance), 6.67; 5.90; 5.83 (flavour) and 6.77; 6.20;6.07 (acceptability) recorded for frankfurter with 5%, 7.5% and 10% GPWL replacement respectively. The tenderness (6.90) and mouth feel (7.60) of frankfurter with 10% lard inclusion were significantly higher (P<0.05) than 6.13, 6.10, 5.53, 5.33 (tenderness) and 6.60, 6.60, 6.53, 6.33 (mouth feel) obtained when GPWL was replaced with lard at 2.5%, 5.0%, 7.5% and 10% inclusion levels respectively. The panelists rated the after taste (5.93) of 10% lard and 2.5% GPWL (6.00) frankfurters (GPWL) were significantly not different (P>0.05) but these are lower (P<0.05) than 6.93, 7.40 and 7.63 recorded for 5%, 7.5% and 10% GPWL frankfurters respectively. The juiciness of frankfurters with 10% lard (6.80), 2.5% (6.73), 5% (6.63) and 7.5% (6.57) GPWL frankfurters were similar (P>0.05) but are significantly higher (P<0.05) than 6.17 obtained in frankfurter with 10% GPWL inclusion.

Sensory characteristics of food such as appearance, aroma, texture and taste have distinct and influential effects on food acceptability (Piqueras-Fiszman and Spence, 2015). Food appearance is an important factor that determines the selection and acceptability of food products. The sensorial attributes obtained in this study showed that irrespective of the GPWL inclusion, the colour/appearance of the frankfurters were still appealing and acceptable

Table 6: Sensory properties of lard-reduced frankfurters substituted with graded levels of ground palm weevil larvae

Graded levels of ground Palm weevil larvae						
Parameters	T_1 (0.0%)	T_2 (2.5%)	T_3 (5.0%)	T_4 (7.5%)	T_5 (10.0%)	LSD
Appearance	7.37^a	7.03^a	6.80^b	6.27^b	5.40^c	0.87
Flavour	7.53^a	7.17^a	6.67^b	5.90^c	5.83^c	0.36
After taste	5.93^d	6.00^d	6.93^c	7.40^b	7.63^a	0.15
Tenderness	6.90^a	6.13^b	6.10^b	5.53^c	5.33^c	0.49
Juiciness	6.80^a	6.73^a	6.63^a	6.57^a	6.17^b	0.61
Mouth feel	7.60^a	6.60^b	6.60^b	6.53^c	6.33^c	0.82
Acceptability	7.73^a	7.04^a	6.77^b	6.20^b	6.07^c	0.75

[abcd]Means in the same row with different superscript are significantly different (P<0.05)

to the panelists. As expected, the panelists rated the frankfurter with 10% lard as highly tendered and more flavouful because fat contributes to succulence, texture and flavour of meat products (Miklos *et al.*, 2011).

The juiciness of the 10% lard frankfurter could also be due to its high fat contents because fat has a positive influence on softness, juiciness and flavor of food (Schmiele, *et al*., 2015) thus the acceptability of this frankfurter by the panelists. The decline in acceptability of GPWL frankfurters could be as a result the high after taste observed by the panelist because any small changes in the reformation of a food can have a relatively large effect on its acceptability.

Conclusion

The reduced textural characteristics and low panelists preference of palm weevil larvae frankfurter showed that frankfurter is affected by partial inclusion of the larvae in frankfurter production. However, the organoleptic assessment showed that palm weevil larvae frankfurters had good colour appeal juiciness and flavour. The study further elucidated that partial replacement of lard with palm weevil larvae resulted in a nutrient-rich meat product with reduced fat content indicating that the inclusion of this larvae in frankfurter production may not be only nourishing but also healthier. Thus, partial replacement of animal fats with palm weevil larvae is a feasible way to improve the nutritive profile of frankfurter.

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