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EFFECTS OF DIFFERENT WASHING AND CURING METHODS ON THE PROXIMATE COMPOSITION, MINERAL, MICROBIAL AND SENSORY PROPERTIES OF SNAIL MEAT

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ABSTRACT

The study was carried out using completely randomized design to determine the effect of different washing methods on the proximate composition, mineral, microbial characteristics and sensory properties of cured snail meat. The best washing agent was selected for further processing after washing with lime, alum, salt and ash through sensory evaluation. Snails from the best washing agents were divided into four portions to correspond to the following curing humectant which were used in cook-soak equilibration: salt alone, salt + glycerol, salt + potassium-sorbate and salt + potassium-sorbate + glycerol. The cured samples were analyzed for proximate composition, mineral, microbial characteristics and sensory properties. Results showed that lime-washed snail meat had the highest score for overall acceptability and had similar scores for color, odor, texture and proximate composition with samples washed with salt, alum and ash, and was selected for further processing. Curing with various humectants did not lead to significant differences ($p > 0.05$) in sensory characteristics except that samples cured with salt + glycerol + potassium-sorbate solution was judged to be tougher/harder and the color was neither liked nor disliked compared to others. Curing also reduced the moisture content due to osmotic dehydration but the protein, fat, ash, zinc, total pigment and pH increased due to the concentration effect. Samples cured with glycerol were higher in moisture content but lower in water activity. Therefore, lime-washed snail meat appears to be better than other methods but the different curing humectants used did not show significant difference ($p > 0.05$) on the physicochemical properties of cured snail meat.

Key words: cured, humectant, sensory evaluation, snail meat, washing agent

INTRODUCTION

Snail meat is cherished and considered a delicacy in most parts of the world. The meat is highly priced due to some qualities it has over other meat types. There is high demand for snail meat globally despite the fact that some communities forbid the touching and eating of snail meat (Pissia *et al*., 2022), although it is mostly done in tropical Africa. Such belief system in some communities is to appease their gods. They believe that the gods will be angry when they touch or eat snail meat. International consumption of snail products is about 400,000 tons which is equivalent to about 2,000,000 tons of fresh snail (ZASBDC, 2008). Many people pick the snails around their houses, process and cook the meat for consumption. However, some people buy the snails from the market men and women who also collect from the wild or from their snail farms. Some people also process the meat and package it for export. The nutrient composition of snail meat is high when compared to other meat sources. The crude protein content is high and its amino acid profile is equally outstanding. The mineral composition especially iron is high. The influence of processing methods on the nutrient composition of snail meat is already established. Iwanegbe *et al.* (2018) reported a high protein value in seasoned smoke-dried product which demonstrated that smoke component has preservative influence because of the polyphenols which have antimicrobial properties.

Processing of snail meat is a challenge to many who may be interested in consuming the meat. The greatest challenge is always on the removal of the slimy substances that covers the outermost part of snail meat. Different processing methods have been applied locally to remove these slimy substances. These methods include the use of wood ash, lemon etc. These washing methods have effects on the physicochemical properties of snail meat. Storage and preservation methods equally affect the chemical properties and storability of snail meat. Iwanegbe *et al*. (2018) observed that the pH of the product under refrigeration condition was lower than product under room storage but higher than

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product under freezer storage. For extended shelf life and increase in nutritive component of snail meat, there should be a combined effect of seasonings, smoke-drying and cold storage. This study was, therefore, designed to investigate the effects of different washing and curing methods on the characteristics and physicochemical properties of snail meat.

MATERIALS AND METHODS

Location of Study

The study was carried out in the laboratory of the Department of Food Science and Technology, University of Nigeria, Nsukka, Nigeria.

Sample Procurement and Processing of Infusing Solutions

Four different types of infusing solutions were prepared for this experiment as shown in Table 1. Literature values for the concentrations of humectants (glycerol, NaCl, and potassium-sorbate) were utilized in all solutions. The concentration of glycerol and salt were determined according to the guidelines of Ibe (2003) and Ugha (2005), respectively; whereas, the potassium-sorbate content adhered to the methodology established by Okonkwo (2001).

The ratio of snail meat to infusing solution was kept constant (1:2) in accordance with Obanu *et al.* (1975). The cook-soak equilibration method was used to process the meat samples. Four cooking pots were used for the formulated solutions, one for each. The contents were allowed to cook for 15 min. and the temperature measured and maintained at about 85°C with a thermometer. The pots were removed from the source of heat and the solution drained from the meat. The contents of the four pots were transferred into four sets of dishes with lid covered. The four samples were labeled and were all equilibrated for 4 h.

Experimental Design

Completely randomized design was used in the experiment. Two snails were used in each three replicates of the treatments in separate experiments.

Processing of Preliminary Products

The snails were de-shelled and trimmed of the offal after which they were washed and then taken for proximate composition analysis.

Analysis of Samples

Moisture content determination

This was determined using the hot air oven method of AOAC (1990). Before being used, crucibles were washed and dried in an oven at 100°C for about 10 min. and cooled in a desiccator for about 5 min. The weights of the dishes were taken. About 2-5 g of the meat sample was introduced into each dish and placed in the oven and dried at 100°C for 24 h. Thereafter, the dishes with the samples were cooled in the desiccator and reweighed. The drying, weighing, cooling, and weighing processes were repeated until fairly constant weight was obtained. The percentage moisture was then calculated as:

$$\%\ moisture\ content = moisture\ loss \div weight\ of\ sample \times 100.$$

Ash content determination

The method recommended by AOAC (1990) was used. A silica dish was heated to about 600°C, cooled in desiccators and weighed. Then, 2 g of the meat sample was weighed into the dish. The temperature of the furnace was increased to about 500°C after the dish and its contents had been placed in it. This temperature was maintained for 6 h. The percentage ash was calculated using the formula:

$$\%\ ash = weight\ of\ ash \div weight\ of\ sample\ used \times 100.$$

Fat content determination

Fat was determined using the Soxhlet extraction method as described by AOAC (1990). About 5 g of the minced meat sample was transferred into a rolled filter paper and then into the extraction thimble. This was put into the Soxhlet extractor with a solvent, petroleum ether which has a boiling range of 60-80°C, for a period of 4-8 h, after which complete extraction was made. The solvent was recovered through condensation leaving the oil in the flask. The oil was dried in the oven to drive off any residual solvent and moisture, cooled in a desiccator and weighed. The fat content was expressed as a percentage of the raw material, thus:

$$\%\ fat = weight\ of\ extracted\ fat \div weight\ of\ sample\ used \times 100$$

Crude protein determination

This was carried out using the micro-Kjeldahl digestion method as described by AOAC (1990). About 2 g of the meat sample was weighed into a 100-ml Kjeldahl flask followed by the addition of 20 ml of concentrated sulphuric acid and a catalyst mixture (composed of 2 g anhydrous sodium sulphate + 1 g copper sulphate). The flask was placed on the digester or an electric heater in a fume chamber. This mixture was gently boiled at first until blackening occurs, then heat was increased as solution clears.

Table 1: Composition of infusing solutions for snail meat

Ingredients	Salt (%)	Salt + potassium-sorbate (%)	Salt + glycerol (%)	Salt + potassium-sorbate + glycerol (%)
Glycerol	-	-	25.00	25.00
NaCl	3.00	3.00	3.00	3.00
Potassium-sorbate	-	0.50	-	0.50
H_2O	71.50	71.50	71.50	71.50

Thereafter, the flask was allowed to cool, the neck was rinsed with distilled water and the content was heated for a further period until all specks disappeared. After heating, the content was transferred after several washing into a 250 ml volumetric flask and was made up to the mark after cooling. Steam was passed through Markam micro-Kjedahl distillation apparatus for about 10 min. About 5 ml of boric acid indicator was placed in 100/250 ml conical flask. This was placed under the condenser such that the condenser tip was on the surface of the liquid. About 5 ml of the diluted digest was placed in the distillation apparatus and was rinsed down with distilled water and 5 ml of 60% sodium hydroxide was also added. This was let in carefully, leaving behind a little to prevent the ammonia from escaping. Steam was let through for about 5 min. and the liberated ammonia was collected and titrated against 0.01M HCl to the end point. The quantity of HCl of 0.01M HCl that changed the indicator from green to pinkish colour was noted. Percentage crude protein was calculated using the formula:

$$\%\ crude\ protein = 0.0001401 \times 6.25 \times 250 \times T \times 100 \div w \times 5;$$

where T is titre value and w is weight of sample.

pH determination

This was determined using pH meter- an expandable ion analyzer. About 5 g of the minced meat sample was measured out and homogenized in 50 ml of distilled water. The pH meter was standardized using buffer solutions of pH 4.0 and 9.0. Sufficient time was allowed for stabilization before taking reading.

Water activity

This was done using the activity meter (Model 5083). The sample was left to equilibrate for 3 h at the end of which the value was read.

Total pigmentation

The method of Hornsey (1956) as modified by Pearson and Gillet (1996) was used. The extracting solution was made up by using 4 ml of concentrated hydrochloric acid (HCl) and 16 ml of distilled water and the volume made up to 200 ml with acetone. Total pigmentation was extracted from 2 g ground snail meat weighed into a test tube and 9 ml of the acetone/water mixture was added. The mixture was allowed to stand for 1 hour before being filtered using double No. 42 Whatman filter paper. The absorbance of the filtrate was determined at 640 nm. Total pigmentation was calculated by multiplying the absorbance at 640 nm by 680.

Mineral determination

The method of AOAC (1990) was used. About 2 g of the sample were weighed into a crucible and ashed in a muffle furnace at 550°C for 6 h. The ash was cooled and 5 ml of 30% HCl added and boiled for 10 min, while covering the crucible with a watch glass. After boiling, the sample was cooled and filtered into a 100 ml volumetric flask. The crucible was washed with distilled water and the washings added to the ash filtrate. The ash filtrate was then made up to 50 ml with distilled water. An aliquot of the filtrate was aspirated into the atomic absorption spectrophotometer (AAS) (Pye Unicam) and the absorbance values corresponding to the different minerals recorded. Standard solutions of the minerals were also prepared and aspirated into the AAS and their absorbance values recorded. The percentage of the element in the samples was recorded from the absorbance values of the samples and standard solutions.

Sensory evaluation

The methods of Brennan *et al.* (1977) were adopted for all cured snail meat samples. Texture, odour, colour and overall acceptability were carried out on the sample using a 20-person semi-trained panel of judges and a 7-point hedonic scale of 7–extremely liked, 6–moderately liked, 5–slightly liked, 4–neither liked nor disliked, 3–slightly disliked, 2–moderately disliked, and 1–extremely disliked. Ranking test was done in the preliminary snail meat samples to detect difference among sample groups in other to select the best sample preferred by the assessors for production for the study and quality evaluation as described by Ihekoronye and Ngoddy (1985) and Iwe (2002). All the test samples were coded to prevent bias. The panelists were allowed enough time to make their assessment.

Microbial analysis

The microbial analyses were carried out on the snail meat. The total viable count (TVC), coliform count, and mold count were determined using the pour-plate method as described by Harrigan and McCance (1976). The TVC was done by using disposable petri dishes and test tubes. The test tubes were washed and sterilized in an oven. Then, 1 g of the sample was ground and put into serial dilution bottle which had been previously sterilized and shaken for about 2 min. About 9 ml of Ringer's solution (this was prepared by dissolving a tablet of quarter strength Ringer's tablet in 500 ml of distilled water and autoclaved for 15 min.) was poured into the test tube and 1 g of sample was added to get 10^{-1} dilution. From the one in ten dilution, 1 ml was pipette into another test tube containing 9 ml of Ringer's solution to get 10^{-2} dilution. To each of the plates (petri dishes) in duplicates, 15 ml of standard sterile agar medium at 45°C was added and 1 ml of each sample dilution was pipetted into the plates containing the medium. This was mixed thoroughly by rocking the plates lasting for 10 s. The plates were allowed to set and then inverted and incubated for 24 h at 37°C. Counting of colony formed was done and recorded as colony forming unit (cfu), thus:

$$\frac{cfu}{ml} = average\ count \times dilution\ factor$$

Mold count
The method used in TVC was applied here. The difference in this method was the use of Sabouraud dextrose agar in place of standard sterile agar. The incubation period was for 2 days.

Coliform count
The method used in TVC was applied here. The diffe -rence in this method was the use of Maconkey agar.

Data Analysis
A randomized complete block design according to Arua *et al.* (1997) was applied. Correlation and regression analyses were carried out to establish relationship among variables. Rates of change were obtained through solving for the regression coefficient for each parameter per unit time.

RESULTS AND DISCUSSION

Sensory Characteristics of Washed Snail Meat

Colour of washed snail meat
The results obtained from colour evaluation (Table 2) showed that the sample treated with ash was significantly different ($p < 0.05$) when compared with other treatments and was described as 'moderately dark' (3.30 ± 1.56). This may be as a result of the nature of this washing agent (ash) which darkened the snail meat after washing. The differences in colour among snail meat samples washed with lime, alum and salt were not significant ($p > 0.05$).

Odour of washed snail meat
Table 3 shows the result of odour evaluation of washed snail meat. Although the washing agents almost had similar effect on the odour of the snail meat samples, those washed with lime, alum and salt were described as moderately pleasing as they respectively scored 5.15 ± 1.60, 4.65 ± 1.50, and 5.30 ± 1.03. Sample washed with ash was described as neither pleasing nor displeasing (4.35 ± 1.66) and was significantly different ($p < 0.05$) from those washed with lime, alum and salt.

Table 2: Colour of washed snail meat

Sample treatment	Score*	Description
Lime	4.05 ± 1.43^{a}	Neither bright nor dark
Alum	4.05 ± 1.36^{a}	Neither bright nor dark
Salt	4.15 ± 1.81^{a}	Neither bright nor dark
Ash	3.30 ± 1.56^{b}	Moderately dark

* - values are mean ± standard deviation. Means with the same superscript are not significantly different ($p > 0.05$).

Table 3: Odour of washed snail meat

Sample treatment	Score*	Description
Lime	5.15 ± 1.60^{a}	Moderately pleasing
Alum	4.65 ± 1.50^{a}	Moderately pleasing
Salt	5.30 ± 1.03^{a}	Moderately pleasing
Ash	4.35 ± 1.66^{b}	Neither pleasing nor displeasing

* - values are mean ± standard deviation. Means with the same superscript are not significantly different ($p > 0.05$).

Texture of washed snail meat
Due to the varied compositions of these washing agents, they had different effects on the texture of the snail meat as shown in Table 4. Thus, the differences in the effects of various washing methods on the texture were significant ($p < 0.05$). Sample washed with salt had the highest value (5.80 ± 0.83) and was described as 'hard/tough'. This may be as a result of the effect of salt on raw meat in which salt is known to produce hardening effect on the muscle as a result of its effect on water holding capacity. Hence, snail meat washed with salt appeared to be tougher than others. There was no significant difference ($p > 0.05$) between the sample washed with ash and the one washed with lime.

Overall acceptability of washed snail meat
The overall acceptability in Table 5 shows that sample washed with ash had the lowest score (4.65 ± 1.31) and was not found to be statistically different from others ($p > 0.05$). Each sample was shown by the panelists to be moderately pleasing. Samples washed with lime had the highest score (5.15 ± 1.39) and appeared to be the most preferred by the judges.

Proximate Composition of Washed Snail Meat

The proximate composition of snail meat produced using different washing methods is shown in Table 6. For protein content, there was no significant difference ($p > 0.05$) among the values due to the different washing methods. Thus, the different treatments had a similar effect on the protein content of snail meat. The protein content is high and comparable to that of raw beef samples. This result obtained was in accordance with work done by previous studies (Okonkwo and Anyaene, 2009; Olatidoye and Sobowale, 2016), showing that snail meat is a rich source of protein. The moisture content obtained for the different snail meat samples were not significantly different from each other ($p > 0.05$). The high level of moisture content observed agreed with that reported by Iwanegbe *et al.* (2018). This high moisture content observed in raw snail meat is also comparable to raw beef and other raw meat products (Lawrie, 1991).

Table 4: Texture of washed snail meat

Sample treatment	Score*	Description
Lime	4.00 ± 1.52^{a}	Neither hard nor soft
Alum	4.90 ± 0.91^{b}	Moderately hard/tough
Salt	5.80 ± 0.83^{c}	Very hard/tough
Ash	4.20 ± 1.53^{ab}	Neither hard nor soft

* - values are mean ± standard deviation. Means with the same superscript are not significantly different ($p > 0.05$).

Table 5: Overall acceptability of washed snail meat

Sample treatment	Score*	Description
Ash	4.65 ± 1.31^{a}	Moderately desirable
Alum	5.05 ± 0.94^{ab}	Moderately desirable
Salt	5.05 ± 0.50^{ab}	Moderately desirable
Lime	5.15 ± 1.39^{b}	Moderately desirable

* - values are mean ± standard deviation. Means with the same superscript are not significantly different ($p > 0.05$).

Table 6: Chemical composition of washed snail meat (wet basis)

	Lime	Alum	Salt	Ash
Protein (%)	17.96 ± 0.00	18.51 ± 1.39	16.65 ± 0.62	17.85 ± 0.47
Moisture (%)	75.48 ± 4.28	73.30 ± 1.55	71.55 ± 0.78	74.03 ± 2.37
Fat (%)	0.25 ± 0.00	0.26 ± 0.04	0.18 ± 0.04	0.23 ± 0.04
Ash (%)	0.97 ± 0.21[a]	0.95 ± 0.35[a]	3.45 ± 0.42[b]	1.45 ± 0.14[a]
Carbohydrate (%)	5.34 ± 4.28	6.98 ± 1.25	8.17 ± 0.30	6.44 ± 2.64
Minerals (mg 100-g^{-1})				
Iron	0.61 ± 0.004[a]	2.99 ± 0.007[b]	3.16 ± 0.049[c]	0.745 ± 0.06[a]
Zinc	0.78 ± 0.001[a]	2.90 ± 0.014[b]	2.80 ± 0.049[b]	6.18 ± 0.007[c]

Means ± standard deviation with the same superscript are not significantly different ($p > 0.05$).

According to Table 6, snail meat is low in fat making it healthy for consumption. This result showed that there was no significant difference ($p > 0.05$) in the values obtained for the fat content with different methods of washing. The low lipid content of samples agrees with that reported by Okonkwo and Anyaene (2009) and Olatidoye and Sobowale (2016). The ash content of the snail meat after washing with different washing solutions or media is shown in Table 6. There was a significant difference ($p < 0.05$) between the sample washed with salt and the sample washed with other washing agents. The increase in the ash content for the sample washed in salt may probably be as a result of the use of salt which contains sodium as one of its constituents. It is probable that the snail meat absorbed more salt during washing compared with the ash content which also contains salts of other components.

The iron and zinc content of snail meat samples observed in Table 6 is less than 3 mg 100-g^{-1} except for sample washed with ash which contained 6.18 mg 100-g^{-1} of zinc and sample washed with salt that contained 3.16 ± 0.04 mg 100-g^{-1} of iron. These are both higher than iron and zinc contents reported by Lucia *et al*. (1993) for *Helix pomatia* containing 1.71 ± 0.08 and 0.19 ± 0.00 mg 100-g^{-1}, respectively. When compared with chicken, the liver which contains 5.53 mg 100-g^{-1} had the highest content of iron in the body (Lucia *et al*.,1993) as a result of the presence of iron in the haeme pigment of the porphyrin ring structure present in hemoglobin found in large quantity in the liver.

Selection of Acceptable Washed Sample for Snail Meat Products

Snail meat washed with lime had the highest score for overall acceptability and had similar scores for color, odor and texture with samples washed with salt and alum. Based on this, it was selected for use for subsequent processing and analysis.

Effects of Curing on Snail Meat

Colour evaluation of cured snail meat

The result of colour evaluation in Table 7 shows that treatment with salt + glycerol + potassium-sorbate produced an effect significantly different ($p < 0.05$) when compared with other treated samples. This could probably be due to the combined effect of both potassium-sorbate and glycerol in the solution. The effects produced by salt + potassium-sorbate and salt + glycerol were not significantly different from those due to salt alone ($p > 0.05$). Treatments with salt alone as well as salt + glycerol and salt + potassium-sorbate resulted in the moderate liking of the colour of the snail meat. However, combination of salt + glycerol + potassium-sorbate resulted in reduced acceptability of the colour of the cured products.

Odour evaluation of cured snail meat

There was no significant difference ($p > 0.05$) in odour between all the treatments (Table 8). This shows that the curing ingredients used had almost the same effect on the odour of the snail meat as each was rated moderately pleasing. Nonetheless, sample cured with salt alone scored highest (5.30 ±1.50).

Texture of cured snail meat

The result obtained for the texture evaluation (Table 9) shows the effect of different constituents on the snail meat. Sample treated with salt + glycerol + potassium-sorbate was significantly different ($p < 0.05$) from other treatments on all other samples. This is because it was found to be harder than other samples due to the combined effects of salt, glycerol and potassium-sorbate on the texture of the snail meat. In contrast, the sample treated with salt + potassium-sorbate was found to be least hard.

Table 7: Colour evaluation of cured snail meat

Sample treatment	Score*	Description
Salt	5.10 ± 1.119[a]	Moderately liked
Salt + potassium-sorbate	4.65 ± 1.182[a]	Moderately liked
Salt + glycerol	5.35 ± 1.226[a]	Moderately liked
Salt + glycerol + potassium-sorbate	3.50 ± 1.432[b]	Neither liked nor disliked

* - values are mean ± standard deviation. Means with the same superscript are not significantly different ($p > 0.05$). Samples were washed with lime before processing.

Table 8: Odour evaluation of cured snail meat

Sample treatment	Score*	Description
Salt	5.30 ± 1.525[a]	Moderately pleasing
Salt + potassium-sorbate	4.85 ± 1.348[a]	Moderately pleasing
Salt + glycerol	4.95 ± 1.050[a]	Moderately pleasing
Salt + glycerol + potassium-sorbate	4.70 ± 1.490[a]	Moderately pleasing

Explanations are as in Table 7.

Table 9: Texture of cured snail meat

Sample treatment	Score*	Description
Salt	4.50 ± 1.318[a]	Moderately hard
Salt + potassium-sorbate	4.00 ± 1.522[a]	Neither hard nor soft
Salt + glycerol	4.60 ± 1.231[a]	Moderately hard
Salt + glycerol + potassium-sorbate	5.50 ± 1.100[b]	Very hard/tough

Explanations are as in Table 7.

Effect of curing on moisture content of snail meat
The moisture content of cured snail meat is shown in Table 10. The moisture content of uncured snail meat was 75.80 ± 4.28. This shows that curing reduces moisture content of samples, most probably due to osmotic dehydration; hence, cured snail meat samples had lower moisture content than the uncured samples. Samples treated with salt + glycerol and those treated with salt + glycerol + potassium-sorbate had higher moisture content of 56.50 ± 2.12 and 58.50 ± 2.12, respectively than the samples treated with salt alone and salt + potassium-sorbate which had moisture content of 34.50 ± 3.53 and 46.50 ± 0.71, respectively. This may likely be as a result of the effect of glycerol which serves as humectant. Glycerol, due to its volatility and polarity, may contribute to apparent moisture content (56.50 ± 2.12). Okonkwo (2001) reported similar higher moisture content on beef samples treated with glycerol when compared to non-glycerol containing samples.

Effect of curing on water activity of snail meat
The water activity of the uncured snail meat was 0.92, which was higher than that of the cured samples. This indicates that the curing process successfully reduced the water activity. However, sample treated with salt and salt + potassium-sorbate had the higher water activity of 0.91 and 0.81 respectively when compared with other cured samples. Although potassium-sorbate had a well documented anti-fungal and anti-microbial properties in food, it has little or no effect on reducing water activity. Sample treated with salt + glycerol and sample treated with salt + glycerol + potassium-sorbate, which contained glycerol (a humectant) as one of its curing ingredients had lower water activity due to the ability of glycerol to bind water and reduce water activity. Hence, samples containing glycerol had lower water activity than those without glycerol.

Effect of curing on protein content of snail meat
The result obtained for protein in Table 10 showed that the protein value obtained after the cook-soak-equilibration process was higher than that obtained before cook-soak-equilibration. This increase is likely due to the concentration effect resulting from moisture loss, which appears to be in agreement with the report of Egbunike and Okunbanjo (1999) that intermediate moisture meat are meats low in moisture content and contain three to four times the raw protein equivalent per unit weight; making them less bulky. The crude protein for the control sample (not cured), 17.96% was greater than crude protein of 16.97% as reported by Olatidoye and Sobowale (2016). It is also greater than protein of 16.35 ± 0.67% reported by Ozogul *et al.* (2005) for *Helix pomatia.* As a mini livestock animal, the crude protein content is considerably high even though less than the boneless chicken breast of 21.8%. The differences in crude protein content among samples (Table 10) may be as a result of the different curing ingredients used which had several different effects on moisture loss and concentration of nutrients including the level of crude protein in the snail. Sample treated with salt + glycerol had the highest level of crude protein (28.68 ± 1.63%), while sample treated with salt + potassium-sorbate had the least protein content (23.86 ± 0.04%).

Effect of curing on fat content of snail meat
The fat content as shown in Table 10 for snail meat is 0.5%. The sample cured with glycerol alone had the highest level of fat content even higher than the sample not cured. This could probably be due to the nature of glycerol which can also be extracted with ether. The sample cured with salt had higher fat content of 0.188% than sample treated with salt + potassium-sorbate and salt + glycerol + potassium-sorbate. This difference could likely be attributed to the effects of the additional ingredients used. Maria *et al*. (2003) reported that the raw meat of the different animal species cured with salt was found to have a reduced lipid, but high protein content when compared to same animal when not cured.

Effect of curing on the ash content of snail meat
The ash content of the uncured snail meat was found to be 0.97 ± 0.21%. This is less than that obtained from the cured sample. The increase in ash content for cured sample maybe due to heat application which likely increased rate and quantity of curing ingredients absorbed (Igene and Ekanem, 1985) or may also be as a result of the presence of the curing ingredients used, i.e., NaCl and potassium-sorbate. Sample cured with salt alone had the highest ash content of 8.20 ± 1.48% while sample cured with salt + glycerol had the least ash content of 3.15 ± 0.071%. This could be related to the rate of penetration of ingredients into the snail meat; hence, the extent of dilution of the components.

Table 10: Physico-chemical characteristics of the cured snail meat products (wet basis)*

	Salt	Salt + potassium-sorbate	Salt + glycerol	Salt + glycerol + potassium-sorbate	Not curing (control)
Moisture (%)	34.50 ± 3.53	46.50 ± 0.71	56.50 ± 2.12	58.50 ± 2.12	75.80 ± 4.28
Water activity	0.91	0.81	0.80	0.79	0.92
Protein (%)	24.95 ± 0.014	23.86 ± 0.042	28.68 ± 1.63	26.49 ± 1.32	17.96 ± 0.00
Fat (%)	0.188 ± 0.002	0.025 ± 0.003	0.55 ± 0.001	0.025 ± 0.001	0.50 ± 0.002
Ash (%)	8.20 ± 1.48	4.40 ± 1.661	3.15 ± 0.071	4.40 ± 0.636	0.97 ± 0.21
Zinc (mg 100-g^{-1})	2.15 ± 0.212	1.565 ± 0.049	2.425 ± 0.035	2.20 ± 0.141	1.795 ± 0.021
Iron (mg 100-g^{-1})	0.19 ± 0.014	0.315 ± 0.035	0.16 ± 0.028	1.515 ± 0.586	6.075 ± 0.035
Total pigmentation (ppm)	24.32	113.28	42.24	105.64	86.40
pH	8.30	8.30	8.00	8.70	7.70

* - values are mean ± standard deviation. Means with the same superscript are not significantly different ($p > 0.05$).
Samples were washed with lime before processing

Effect of curing on mineral content of snail meat
The Fe an Zn contents of snail meat were < 3 mg 100-g^{-1} except for the uncured sample with Fe content of 6.075 ± 0.035 mg 100-g^{-1}. The Fe an Zn contents of the uncured sample were 6.075 ± 0.035 and 1.795 ± 0.021 mg 100-g^{-1}, respectively which are higher than those of *Helix pomatia* with 1.71 and 1.35 mg 100-g^{-1}, respectively as reported by Ozogul *et al.* (2005).

Effect of curing on total pigmentation of snail meat
The uncured samples were used as the control for the treatments. The results of the analysis showed a marked difference among the samples. Salt and salt + glycerol had the highest value of total pigment.

Effect of curing on the pH of snail meat
The pH of raw snail meat was near neutrality (7.7). Sample cured with salt + glycerol + potassium-sorbate had the highest pH of 8.5, while sample cured with salt + glycerol had the lowest pH of 8.0. Samples containing potassium-sorbate had high pH values. This may be due to the presence of potassium-sorbate.

Effects of curing on microbial characteristics of cured snail meat
Table 11 compares the microbial profile of uncured snail meat (control) with that cured after storage for 12 days. The uncured (control) sample spoiled before the 4th day and storage was discontinued. There were also significant differences ($p < 0.05$) in the growth of total viable count on snail meat cured with different substances at varying storage periods. Sample cured with salt alone spoilt after 8 days and storage was discontinued but this is contrary to the result obtained by Okonkwo and Anyaene (2009) whose storage medium spoilt in the control after 24 h of storage.

There was a gradual trend in growth of TVC for cook-soaked snail meat. The control sample without curing had the highest TVC and was not able to last throughout the storage period. Sample cured with salt + potassium-sorbate and salt + glycerol + potassium-sorbate had the least TVC throughout the storage period. This may be due to the antimycotic effect of potassium-sorbate in the curing mixture.

From the result in Table 12, there was less faecal contamination of the cook-soaked snail meat. The decrease in value for the sample cured with salt when compared with the control sample (uncured) may be as a result of the bacteriostatic effect of salt in addition to heat. The no-growth observed in other treated samples may be due to the effect of various curing ingredients used in the mixture and their respective effects. Since the samples were also cooked before equilibration, it appeared that most coliforms were destroyed during the process of cooking/heating because coliforms are known to be heat sensitive.

There was a general increase in the mold count of cook-soak equilibrated snail meat as shown in Table 13. At the initial storage period, the control sample without curing had the highest mold count and this sample got spoilt and was discarded after the first analysis. There was no observable growth in the sample treated with salt + potassium-sorbate. This may be due to the antimycotic effect of potassium-sorbate as a curing agent.

Table 11: Changes in total viable count of cured snail meat*

Storage time (days)	No treatment (control)	Salt	Salt + potassium-sorbate	Salt + glycerol	Salt + glycerol + potassium-sorbate
0	6.00 ± 0.71^{a}	2.19 ± 0.71^{b}	1.74 ± 0.71^{e}	2.04 ± 1.41^{c}	1.78 ± 0.00^{d}
4	ND	3.68 ± 17.67^{a}	3.59 ± 7.10^{b}	3.54 ± 11.31^{c}	3.13 ± 16.26^{d}
8	ND	4.13 ± 0.70^{d}	4.46 ± 1.41^{b}	4.60 ± 0.00^{a}	4.41 ± 0.71^{c}
12	ND	ND	4.70 ± 0.71^{b}	5.70 ± 0.00^{a}	4.47 ± 0.00^{c}

* - values are means (log_{10} count, cfu g^{-1}) of duplicate determination ± standard deviation. Means with the same superscript are not significantly different ($p > 0.05$). ND - not determined because sample was discarded due to spoilage.

Table 12: Change in coliform count of cured snail meat*

Storage time (days)	Salt	Salt + glycerol	Salt + potassium-sorbate	Salt + glycerol + potassium-sorbate	No treatment (control)
0	1.70 ± 0.71	0	0	0	2.00 ± 0.34
4	1.18 ± 0.71	0	0	0	ND
8	0	0	0	0	ND
12	ND	0	0	0	ND

* - values are means (log_{10} count, cfu g^{-1}) of duplicate determination ± standard deviation,
ND - not determined because sample was discarded due to spoilage, 0 - no growth.

Table 13: Change in total mold count of cured snail meat*

Storage time (days)	Salt	Salt + potassium-sorbate	Salt + glycerol	Salt + glycerol + potassium-sorbate	Control (no treatment)
0	0.00 ±0.00	0.00 ± 0.00	2.18 ± 0.00	1.30 ± 0.00	3.00 ± 0.71
4	1.48 ± 0.00	0.00 ± 0.00	1.78 ± 0.00	1.70 ± 0.71	ND
8	3.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.00 ± 0.00	ND
12	5.70 ± 0.71	0.00 ± 0.00	4.00 ± 0.00	5.69 ± 0.71	ND

* - values are means (log_{10} count, cfu g^{-1}) of duplicate determination ± standard deviation,
ND - not determined because sample was discarded due to spoilage.

CONCLUSION

Snail meat washed with lime had the highest score for overall acceptability and had similar scores for color, odor, texture and proximate composition with samples washed with salt, alum and ash. Lime-washed snail meat was then selected for further processing. Curing also reduced the moisture content due to osmotic dehydration but due to concentration effect, increased the protein, fat, ash, zinc, total pigment and pH. Among the cured products, those containing glycerol were higher in moisture content but lower in water activity. However, the use of different curing humectants did not affect the physicochemical properties of the snail meat.

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