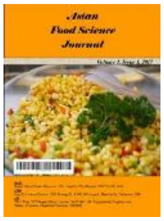

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Effect of Processing, Storage Days and Storage Temperatures on Lipid Oxidation and Palatability of Processed Snail Meat Products

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Authors' contributions

This work was carried out in collaboration between all authors. Author II designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JOI and GUE managed the analyses of the study. Author JUO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The effect of processing methods, storage days (d) and storage temperatures on the lipid oxidation and palatability of processed snail meat products was carried out in this study. Samples of snail meat products were subjected to 2-thiobarbituric acid (TBA) test for Malonaldehyde(MA) with water-TBA reagent as blank periodically at 0, 5, 10, 15, 20, 25 and 30 d. Meat samples were served to trained panellists who evaluated the products based on colour, flavour, tenderness, juiciness and overall acceptance. The results showed that the unseasoned-fried product had the lowest lipid oxidation values 0.04, 0.13 and 0.19 mg malonaldehyde/kg meat in all the storage periods at 0-5, 10-20 and 25-30 d respectively. Lipid oxidation values of products stored for 10-20d

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were 0.2565, 0.3040 and 0.3548. Lipid oxidation values were lower in freezer stored product than refrigerated product at 0-20d. Lipid oxidation values increased with increasing storage days for all the products. The seasoned smoke-dried product had lower lipid values throughout the storage period than the seasoned fried product. The regression curve for colour was a = 5.282 and b = -5.342 while acceptability was a = 4.455, b = -3.438. This relationship implies that TBA values give a strong estimate of colour and acceptability.

Practical Applications: Four different treatments were considered for evaluation; unseasoned fried (USF), seasoned fried (SF), seasoned oven- dried (SOD) and seasoned smoke-dried (SSD) and the products were kept under three storage conditions (room, fridge and freezer). The regression relationships between TBA values and the sensory attributes (colour and overall acceptance) of the products were evaluated. Our results suggest that cold storage and proper packaging retard the development of lipid oxidation in snail meat products. Smoke-drying with seasonings had lower lipid oxidation values than the seasoned fried product throughout the storage period. The shelf life of processed meat could be extended by smoke-drying and curing without adverse effect on the quality and overall acceptance of meat.

Keywords: Lipid oxidation; snail; processing; products.

1. INTRODUCTION

Fat is an important ingredient of processed meat products and has a significant influence on the binding properties, tenderness, juiciness, mouth feel and overall appearance. In addition, fat contributes to the rheological properties of these products [1].

Oxidation of lipids can occur in foods containing substantial amounts of fat, like milk and meat products, oils, nuts and also those that contain only minor amounts of lipids, such as vegetable products. Practically all quality attributes of food can be affected by this process. Thus, aroma changes result from new volatile odorous compounds formed, flavour modifications are caused by hydroxyl acids, the colour darkens as a result of a condensation reaction between oxidation products and proteins, and finally, a new texture might be attributed to the oxidative induction of protein cross-links [2]. Apart from producing undesirable changes in flavour and loss of food quality, lipid oxidation increases the level of malondialdehyde (MDA) in foods. MDA is genotoxic, reacting with DNA in human cells [3,4].

Snails are considered a delicacy in many countries and are staple part of the diet in parts of Asia where red meat and poultry are scarce sources of protein. In Nigeria, it is now accepted that the use of mini-livestock such as snails, rodents and other small livestock in the wild can substantially improve the living conditions of people in urban and rural areas by acting as a valuable source of protein supplement to diet as well as generating additional income [5,6]. Snails have a long-standing importance as a source of human food and products from snail belong to foodstuff with high nutritional value [7]. It is an adequate protein source with low lipid content in its essential fatty acid composition (linolic and linoleic acids) and polyunsaturated fatty acids with more than 20 C-atoms (0. 45-2.66%) [8].

The snail is usually consumed after thermal processing which may entail boiling, frying or smoke-drying. From toxicological perspectives, fresh meat and fish are safer than frozen ones, because it has been demonstrated that freezing results in increased accumulation of MDA in meat and fish [9]. Thus thermal treatment of fresh samples may be safer. However, prolonged heating is known to also increase the level of lipid oxidation by a combination of several processes including disruption of muscle cell structure, inactivation of anti-oxidant enzymes and release of oxygen and iron from myoglobin [10].

This study attempts to determine the effect of different processing methods and storage temperature/periods on the lipid oxidation and palatability of snail meat products with a view to determining the safest processing method.

2. MATERIALS AND METHODS

2.1 Preparation of Snail

The snails used for this experiment were collected from Ekiuwa market in Edo State. A total of 150 adult snails (*Archachatina marginata)* with the mean live weight of 346.85 g, were used. They were transferred to the University of Benin where they were killed.

Snails were fasted for 24 hours to empty the gut and to reduce contamination during killing. The snails were weighed using an electronic scale, killed using a kitchen knife and separated into meat, shell, waste and fluid. The meats were washed with alum to remove the slime and cut to have a uniform weight range of 50-55 g.

Snails were cured in a prepared pickle solution containing 1.5% salt, 1.5% sugar, 0.5% thyme, 0.30% nutmeg, 0.30% ginger,1.50% red pepper, 0.05% sodium sorbate, 0.05% sodium tripolyphosphate, 0.50% curry, 1.50% onion for 24hours in refrigeration temperature, before processing snails by frying, smoke-drying and oven-drying. However, the control was devoid of spices before frying.

2.2 Processing Methods

Pickle cured snail meat was skewed and smoke-dried at 90°C for 2 hours 15 minutes in a smoking kiln at Kilishi factory, Ekenwan campus. Each snail meat was spread out with a stick in a traditional bush meat processing manner to increase the surface area of the meat exposed to smoke and heat. The meat samples were spread on racks in the smoking kiln to ensure uniform smoking and drying of the individual product.

Pickle cured snails were fried at 170°C in a deep pan fryer with Soya oil. 20 minutes into frying, meats were removed from the oil, allowed to cool and weighed.

Pickle cured snail meats were oven-dried at 90°C for 4 hour 30 min using electric oven. The racks inside the oven were wrapped with foil paper before the meats were spread on them.

Snail meat products were allowed to cool, the products were packaged one per cellophane for all the products except seasoned smoked product that was skewed and sealed in low density cellophanes with the use of sealing machine.

2.3 Storage Temperatures and Period

Three storage temperatures were used.

- Room temperature (28.5°C)
- Refrigeration temperature (9.5°C)
- Freezer temperature (-12.5°C)

Snail meat products were stored for total duration of 30 d and meat samples were withdrawn for analyses as follows: 0 (control), 5, 10, 15, 20, 25, 30 d

2.4 Lipid Oxidation

Samples of snail meat products were subjected to 2-thiobarbituric acid (TBA) test for Malonaldehyde(MA) with water-TBA reagent as blank periodically at 0, 5, 10, 15, 20, 25 and 30 d. The level of rancidity was determined by measuring colour reaction using a spectrophotometer at wavelength of 530 nm. The absorbance was multiplied by a factor 7.8 [11,12,13,14 and15].

2.5 Sensory Evaluation

Meat samples were served to trained panelists who evaluated the products based on 5- point Hedonic scale as described by Larmond [16]. Samples were coded for example, as 311 (unseasoned fried), 312 (seasoned fried), 412 (seasoned oven-dried) and 512 (seasoned smoke-dried). Colour, tenderness, flavour, juiciness and overall acceptability of the products were scored by the panelists. 5=like extremely, 4=like moderately, 3=neither like nor dislike, 2=dislike moderately, 1=dislike extremely.

2.6 Statistical Analysis

Data generated were subjected to analysis of Variance using Genstat statistical package and Duncan's multiple range tests was used to separate significant means (P=0.05). Correlation analysis was also carried out.

3. RESULTS AND DISCUSSION

3.1 Lipid oxidation of Snail Meat Products

The analyses of the result of this study revealed that the lipid oxidation value of raw snail (*Achatina marginata*) after washing with alum was 0.003 mg MA/kg meat. After processing, the lipid oxidation values of the various products of snail increased above the raw sample. Asgar et al. [17 and 2] reported that exposure to oxygen, grinding during processing and transition metals such as iron and copper enable the primary radicals to form and accelerate the process of lipid oxidation. Rhea et al. [18] reported that cooked meat is known to oxidise faster than raw meat. Igene et al. [19] reported that there appeared to be a very rapid onset of lipid oxidation during processing. Igene et al. [20] also reported that cooking significantly increased the amount of phospholipids and that non-heme iron is the major pro-oxidant in cooked meat and which is released from heme pigment (myoglobin) during cooking.

Analysis of variance shows that there was a significant difference (P<0.001) in the lipid oxidation values of the different products based on the treatment applied. Table 1 showed lipid oxidation of snail meat products in relation to treatments. The unseasoned-fried product had the lowest lipid oxidation values (0.04, 0.13 and 0.19mg malonaldehyde/kg meat) in all the storage periods 0-5, 10-20 and 25-30 d respectively. This could be attributed to the absence of salt in the product. Anderson and Skibsted [21] found that salt acts as a pro-oxidant at 1% inclusion in pork meat. King and Bosch [22] reported that at 2% inclusion level of salt, it was more pro-oxidant. Kanner and Rosenthal [2] stated that sodium chloride acts as a pro-oxidant by displacing the iron ions with sodium in the heme pigment of the muscle tissue, whereas others recognized the chloride ion acting upon the lipid as the source [23]. Salih [24] reported that the metal impurities particularly iron, within salt are also capable of causing lipid oxidation. [25] agreed with these results as they found that when different salt varieties at 2% inclusion level were used with added metal contaminants that include Cu, Fe, and Mg lipid oxidation occurred. Table 2 showed that freezer stored product had lower TBA value than refrigerated product. There was a significant difference (P<0.05) in the lipid oxidation of products stored for 10d (0.2565), 15days (0.3040) and 20 d (0.3548) Table 3. This showed that lipid oxidation increases with storage days.

Table 4 showed lipid oxidation of snail products in relation to processing methods and storage days. Lipid oxidation values increased with increasing storage days for all the products. There was no significant difference (P>0.05) in the lipid oxidation of seasoned oven-dried product (0.42 and 0.44) from seasoned smoke-dried product (0.44 and 0.46) at 25 and 30days respectively. The seasoned smoke-dried product had lower lipid values throughout the storage period than the seasoned fried product. This could be attributed to the component of smoke and constituents of the curing ingredients which possess known potency for retarding rancidity. Hence, the high level of lipid stability observed in the seasoned smoke-dried snail meat products was not unexpected. The phenolic component of smoke and the sodium tripolyphoshate, curry and ginger used in the cure are known for lowering TBA reactive substances production [26].

Tables 5 and 6 showed that lipid oxidation was lower in freezer stored product than refrigerated product at 0-20 d. This implies that freezer storage retards the development of lipid oxidation. This was similarly observed in Table 2 where freezer stored products had lower TBA value than refrigerated products.

Table 7 showed lipid oxidation of snail products in relation to processing methods, storage conditions and storage days. Seasoned fried product was significantly different (P<0.05) from other products; it possessed the highest value of lipid oxidation for all the different storage conditions throughout the storage days. These results reflect the severity of pressure cooking in the case of frying; the severity of frying must have resulted in higher proportion of phospholipids and lower level of triglycerides in the product. This must have been responsible for the elevated TBA value in the fried products. Besides, the oil used for frying increased the lipid in the product, which must have accelerated lipid oxidation. At 0-5days, the changes in TBA values were more pronounced during storage at ambient condition (28.5^{o}C) than during cold storage (refrigeration 9.5^{o}C and freezer -12.5^{o}C). The TBA value changes were least during frozen storage. Due to the low TBA values, snail meat products did not experience deterioration at 30 d. This is due to the fact that the TBA values were below the threshold value (1.56) for rancidity development as reported by Younathan and Watts [27]. This could be ascribed to proper packaging of products [28].

3.2 Sensory Evaluation of Snail Meat Products

Analysis of variance showed that there was a significant difference (P<0.001) in the sensory attribute (colour) of the different snail meat products based on the treatment applied (Processing methods, storage condition and storage days).

The colour changes due to the interaction between processing methods, storage conditions and storage days are shown in Table 8. Unseasoned fried product (3.950) and seasoned oven-dried products (3.800) had declined in colour quality at 20days freezer storage. There was no significant difference (P>0.05) between seasoned fried products and seasoned smoke-dried products under freezer condition throughout storage. Besides, freezer stored snail meat products were better shelf stable. This implies that seasonings and freezer storage prolong and maintain colour quality of meat products. This is in accordance with [29] who reported that cold storage of meat and meat products prolongs and maintains their quality over a reasonable period of time.

The analysis of variance showed that there was significant difference (P<0.001) in the flavour of products based on treatment applied (processing methods, storage conditions and storage days).

The interaction between processing methods, storage conditions and storage days of product's flavour are shown in Table 9. The result showed that seasoned smoke-dried product under freezer storage was ranked the highest score (5.000) at 30 days. This implies that smoke components impact and stabilise the flavour of meat products. Smoke generally tends to enhance the flavour of food. Arvanitoyannis and Kotsanopoulos [30 and 31] reported that the presence of certain phenolic compounds such as guaiacol and syringol in smoke play important role in the characteristic flavour of smoke-dried product.

The analysis of variance showed that there was significant difference (P<0.001) in the juiciness of products based on treatment applied (processing methods, storage conditions and storage days).

Table 10 showed juiciness changes as affected by the interaction between processing methods, storage conditions and storage days. The result showed that seasoned smoke-dried product under freezer storage was ranked the highest score (5.000) at 30 days in terms of juiciness. All the products under fridge and freezer initially increased in juiciness at the first few days of storage but decreased towards the end of storage periods. The decrease towards the end of storage could be attributed to the decrease in moisture content. Lawrie [32 and 33] reported that the principal sources of juiciness in meat are the intra muscular lipids and water content.

Table 11 showed the effect of interaction of processing methods, storage conditions and storage periods on product tenderness. The tenderness of the different refrigerated products increased with increasing storage periods (10-20 days). This implies that there was gradual increase of moisture in the refrigerated products. Forest [34] reported that loss of moisture contributes to the toughness of meat products.

Table 12 showed that at room storage (0day), there was no significant difference (P>0.05) among unseasoned fried product (4.000), seasoned fried product (4.400) and seasoned smoke-dried product (4.250) in terms of acceptability. Seasoned oven-dried product was the least preferred (2.950) for room storage. A similar trend was also observed at 5days storage at room condition. Before day 10 all the products under room storage were terminated based on obvious spoilage. Products under room temperature lasted for 6days. For all the storage conditions, seasoned smoke-dried product was preferred throughout the storage periods. This could be due to the impacted colour and flavour by smoke components which had a positive influence on the acceptance of the product. The primary purpose of smoking of meat is development of colour and flavour. Also, hardwoods are noted for giving off good quality smoke that enhances colour of meat products. Besides, the shelf life of processed meat could be extended by smoke-drying and curing without adverse effect on the quality and overall acceptance of meat [35]. In this work, charcoal from hardwood was used to generate the smoke. Skewing of the smoke-dried meat could also have added extra value to the product.

3.3 Relationship between TBA Number and Sensory Scores (Colour and Overall Acceptance)

Figs. 1 and 2 represent a plot of TBA numbers against panel sensory scores (colour and acceptability). These graphs demonstrate that the relationship between TBA values and panel scores (colour and acceptability) were linear but negative. The correlation coefficient between these measurements was -0.902 for colour and also -0.900 for acceptability which was statistically significant at P<0.05 and P<0.05 respectively and also negatively correlated. This shows that the TBA values were highly related to colour and overall acceptance. It also indicates that changes in TBA numbers accounted for over 80% of the variation in colour and acceptance. The regression curve for colour was a = 5.282 and b = -5.342 x while acceptability was a = 4.455, b = -3.438x. The relationship implies that TBA values give a strong estimate of colour and acceptability [19 and 28].

Table 1. Lipid oxidation of Snail Meat Products (processing methods)

Storage days	Treatments (processing methods)				
	Unseasoned/fried	**Seasoned/fried**	**Seasoned/oven -dried**	**Seasoned/smoke-dried**	**LSD**
0-5	0.0419[d]	0.2498[a]	0.2037[c]	0.2373[b]	0.0026
10-20	0.1286[d]	0.4001[a]	0.3301[c]	0.3617[b]	0.0037
25-30	0.1863[d]	0.5382[a]	0.4253[c]	0.4470[b]	0.0194

Means within storage day bracket having same superscript are not significantly different (p>0.05).

Table 2. Lipid oxidation of snail meat products (storage conditions)

Storage days	Treatments (storage conditions)			
	Room (28.5°C)	**Fridge (9.6°C)**	**Freezer (-12.5°C)**	**LSD**
0-5	0.2048[a]	0.1780[b]	0.1667[c]	0.0022
10-20	-	0.3361	0.2741	0.0026
25-30	-	-	-	-

Means within storage day bracket having same superscript are not significantly different (p>0.05).

Table 3. Lipid oxidation of snail meat products (storage days)

Storage days	Mean values	LSD
0	0.1523	0.0018
5	0.2140	
10	0.2565[c]	
15	0.3040[b]	0.0032
20	0.3548[a]	
25	0.3819	0.0137
30	0.4165	

Means with the same superscript are not significantly different (P>0.05)

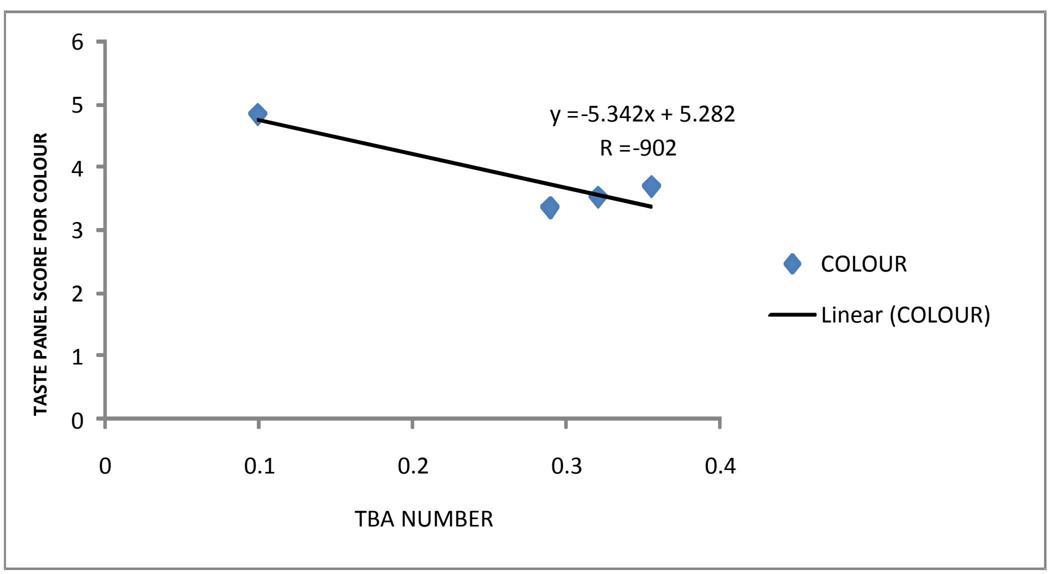

Fig. 1. Relationship between Lipid and Sensory Evaluation (Colour)

Table 4. Lipid oxidation of snail meat products (proceeding methods and storage days)

Products	Storage period (d)						
	0	**5**	**10**	**15**	**20**	**25**	**30**
311	0.0097^{h}	0.0741^{g}	0.0988^{j}	0.1330^{i}	0.1538^{h}	0.1830^{e}	0.1897^{e}
312	0.2073^{e}	0.2923^{a}	0.3298^{e}	0.4148^{b}	0.4557^{a}	0.4940^{b}	0.5823^{a}
412	0.1787^{f}	0.2287^{c}	0.2845^{g}	0.3145^{f}	0.3912^{c}	0.4153^{d}	0.4353^{cd}
512	0.2137	0.2609^{b}	0.3128^{f}	0.3537^{d}	0.4187^{b}	0.4353^{cd}	0.4587^{c}
SEM		0.013		0.0023			0.0091

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

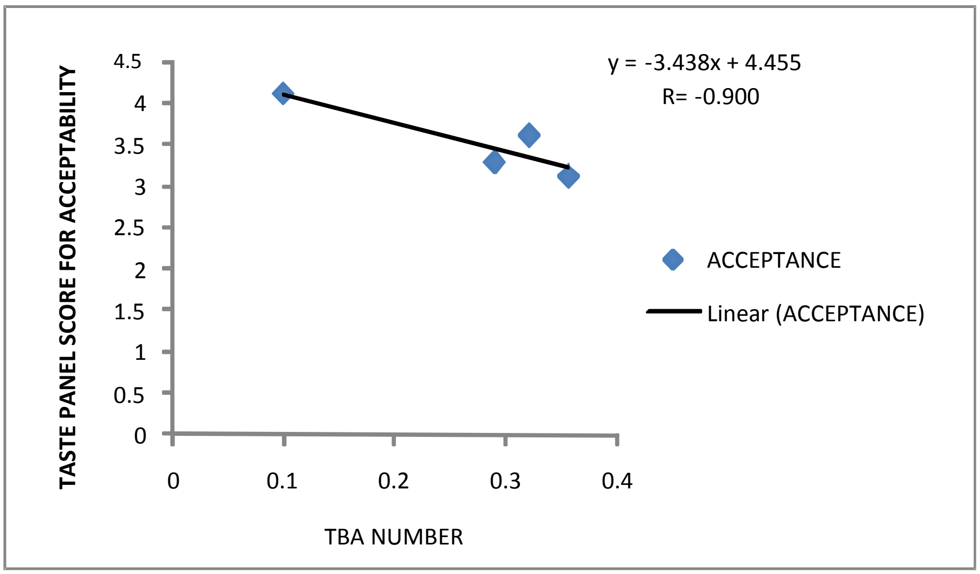

Fig. 2. Relationship between Lipid and Sensory Evaluation (Acceptance).

Table 5. Lipid oxidation of snail meat products (storage conditions and storage days)

Products	Storage period (d)						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Room	0.1523^{d}	0.2573^{a}	-	-	-	-	-
Fridge	0.1523^{d}	0.2036^{b}	0.2969^{c}	0.3378^{b}	0.3736^{a}	-	-
Freezer	0.1523^{d}	0.1811^{c}	0.2161^{e}	0.2703^{d}	0.3361^{b}	0.3819	0.4165
SEM		0.0011		0.0016		0.0048	

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05).

Table 6. Lipid oxidation of snail meat products (processing methods and storage conditions)

Products	Storage conditions		
	Fridge	**Freezer**	**Room**
0-5 d			
311	0.0338^{j}	0.0272^{k}	0.0647^{i}
312	0.2482^{c}	0.2357^{d}	0.2657^{a}
412	0.1978^{g}	0.1853^{h}	0.2278^{e}
512	0.2320^{de}	0.2187^{f}	0.2612^{b}
SEM	0.0016		

Products	Storage conditions		
	Fridge	Freezer	Room
10-20 d			
311	0.1591^{g}	0.980^{h}	-
312	0.4340^{a}	0.3662^{c}	-
412	0.3570d	0.3031^{f}	-
512	0.3942^{b}	0.3292^{e}	-
SEM		0.0018	
25-30 d			
311	-	0.1863^{d}	
312	-	0.5832a	-
412	-	0.4253^{c}	-
512	-	0.4470^{b}	-
SEM		0.0064	

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

Table 7. Lipid oxidation of snail meat products (processing methods, storage days and storage condition)

Products	Storage conditions	Storage period (days)						
		0	5	10	15	20	25	30
311	Freezer	0.0097^{o}	0.0447^{o}	0.0613^{t}	0.0947^{s}	0.1380^{r}	0.1830^{e}	0.1897^{e}
312	Freezer	0.2073^{i}	0.2640^{e}	0.2923^{n}	0.3890^{h}	0.4173^{d}	0.4940^{b}	0.5823^{a}
412	Freezer	0.1787^{k}	0.1920^{i}	0.2420^{p}	0.2853^{n}	0.3820^{h}	0.4153^{d}	0.4353^{d}
512	Freezer	0.2137^{hi}	0.2237^{g}	0.2687^{o}	0.3120^{m}	0.4070^{e}	0.4353^{d}	0.4587^{c}
311	Fridge	0.0097^{o}	0.0580^{m}	0.1363^{r}	0.1713^{q}	0.1697^{q}	-	-
312	Fridge	0.2073^{i}	0.2890^{c}	0.3673^{i}	0.4407^{b}	0.4940^{a}	-	-
412	Fridge	0.1787^{k}	0.2170^{h}	0.3270^{l}	0.3437^{k}	0.4003^{ef}	-	-
512	Fridge	0.2137^{hi}	0.2503^{f}	0.3570^{j}	0.3953^{fg}	0.4303^{c}	-	-
311	Room	0.0097^{o}	0.1197^{i}	-	-	-	-	-
312	Room	0.2073^{i}	0.3240^{a}	-	-	-	-	-
412	Room	0.1787^{k}	0.2770^{d}	-	-	-	-	-
512	Room	0.2137^{hi}	0.3087^{b}	-	-	-	-	-
SEM		0.0022			0.0032		0.0091	

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

Table 8. Colour of snail meat products (processing methods, storage days and storage conditions

Products	Storage conditions	Storage period (days)						
		0	5	10	15	20	25	30
311	Freezer	4.150^{abc}	4.500^{a}	4.300^{abcde}	4.650^{a}	3.950^{efg}	4.200^{c}	4.100^{c}
312	Freezer	4.250^{ab}	4.350^{a}	4.500$_{ab}$	4.450^{ab}	4.500^{ab}	4.500^{ab}	4.900^{a}
412	Freezer	3.450^{e}	3.656^{cde}	4.550$_{ab}$	4.600^{a}	3.800^{gh}	4.000^{c}	4.000^{c}
512	Freezer	4.050^{abcd}	4.400^{a}	4.550$_{ab}$	4.600^{a}	4.600^{a}	4.800^{a}	4.950^{a}
311	Fridge	4.150^{abc}	4.250^{ab}	4.00^{bcdef}	4.500^{ab}	2.850^{j}	-	-
312	Fridge	4.250^{ab}	4.150^{abc}	4.350^{abcd}	4.000^{defg}	3.850^{fgh}	-	-
412	Fridge	3.450^{e}	4.000^{abcd}	4.050^{cdefg}	3.900^{fgh}	3.600^{i}	-	-
512	Fridge	4.050^{abcd}	4.300^{a}	4.400^{abc}	3.700^{gh}	4.200^{bcdef}	-	-
311	Room	4.150^{abc}	3.550^{de}	-	-	-	-	-
312	Room	4.250^{ab}	3.700^{bcde}	-	-	-	-	-
412	Room	3.450^{e}	3.700^{bcde}	-	-	-	-	-
512	Room	4.050^{abcd}	3.650^{cde}	-	-	-	-	-
SEM			0.1670			0.1101		0.0784

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

Table 9. Flavour of snail meat products (processing methods, storage days and storage conditions

Products	Storage conditions	Storage period (days) 0	5	10	15	20	25	30
311	Freezer	3.950^{bc}	4.100^{b}	4.200^{def}	3.850^{fg}	3.800^{fghi}	3.750^{d}	4.250^{c}
312	Freezer	4.650^{a}	4.150^{ab}	4.350^{cde}	4.350^{cde}	4.450^{abcd}	4.450^{bc}	4.650^{b}
412	Freezer	3.200^{defg}	3.550^{cd}	3.350^{j}	3.500^{ghij}	3.950^{fg}	3.700^{d}	3.800^{d}
512	Freezer	4350^{ab}	4.200^{ab}	4.850^{ab}	4.650^{abc}	4.450^{abcd}	4.600^{b}	5.000^{a}
311	Fridge	3.950^{bc}	4.200^{a}	4.150^{def}	3.350^{ij}	2.350^{k}	-	-
312	Fridge	4.650^{a}	3.500^{cde}	4.200^{def}	4.050^{def}	3.550^{ghij}	-	-
412	Fridge	3.200^{defg}	4.000^{bc}	3.450^{hij}	3.400^{ij}	2.650^{k}	-	-
512	Fridge	4.350^{ab}	3.300^{def}	4.850^{a}	3.950^{fg}	4.400^{cd}	-	-
311	Room	3.950^{bc}	3.000^{efg}	-	-	-	-	-
312	Room	4.650^{a}	2.900^{fg}	-	-	-	-	-
412	Room	3.200^{defg}	2.750^{g}	-	-	-	-	-
512	Room	4.350^{ab}		-	-	-	-	-
SEM			0.1636		0.1347		0.1484	

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

Table 10. Juiciness of snail meat products (processing methods, storage days and storage conditions

Products	Storage conditions	Storage period (days) 0	5	10	15	20	25	30
311	Freezer	4.050^{b}	4.250^{ab}	4.450^{cde}	4.350^{de}	3.450^{gh}	3.750^{c}	4.250^{b}
312	Freezer	4.350^{ab}	4.200^{ab}	4.650^{abcd}	4.850^{abc}	4.700^{abcd}	4.300^{b}	4.750^{a}
412	Freezer	2.650^{de}	3.150^{cd}	3.200^{ij}	3.628^{gh}	2.950^{j}	3.200^{d}	3.550^{cd}
512	Freezer	4.200^{ab}	4.650^{a}	4.850^{abc}	4.850^{abc}	5.000^{a}	5.000^{a}	5.000^{a}
311	Fridge	4.050^{b}	4.100^{b}	4.500^{bcde}	3.850^{fg}	2.450k	-	-
312	Fridge	4.350^{ab}	4.200^{ab}	4.650^{abcd}	3.400^{i}	3.550^{gh}	-	-
412	Fridge	2.650^{de}	2.850^{cde}	3.200^{ij}	4.100^{ef}	2.900^{j}	-	-
512	Fridge	4.200^{ab}	4.400^{ab}	4.950^{ab}	4.100^{ef}	4.250^{def}	-	-
311	Room	4.050^{b}	2.700^{cde}	-	-	-	-	-
312	Room	4.350^{ab}	3.100^{cd}	-	-	-	-	-
412	Room	2.650^{de}	2.350^{e}	-	-	-	-	-
512	Room	4.200^{ab}	3.200^{c}	-	-	-	-	-
SEM			0.1640		0.1414		0.1787	

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

Table 11. Tenderness of snail meat products (processing methods, storage days and storage conditions

Products	Storage conditions	Storage period (days) 0	5	10	15	20	25	30
311	Freezer	4.250^{a}	4.200^{a}	3.900^{efg}	4.350^{bcd}	4.350^{bcd}	4.050^{d}	4.000^{de}
312	Freezer	4.550^{a}	4.250^{a}	4.450^{bc}	4.450^{bc}	4.200^{bcde}	4.400^{c}	4.000^{de}
412	Freezer	3.400^{c}	3.500^{c}	3.700^{g}	4.000^{defg}	3.850^{efg}	3.800^{e}	4.050^{d}
512	Freezer	4.350a	4.400^{a}	4.900^{a}	4.500^{ab}	4.900^{a}	4.700^{b}	5.000^{a}
311	Fridge	4.250^{a}	4.150^{ab}	2.550^{i}	3.650^{g}	4.350^{bcd}	-	-
312	Fridge	3.400^{c}	3.700^{bc}	3.250^{h}	4.100^{cdef}	4.200^{bcde}	-	-
412	Fridge	3.400^{c}	3.700^{bc}	2.750^{i}	3.750^{fg}	3.850^{efg}	-	-
512	Fridge	3.400^{c}	3.700^{bc}	4.800^{ab}	3.850^{efg}	4.900^{a}	-	-
311	Room	4.250^{a}	3.650^{c}	-	-	-	-	-
312	Room	4.550^{a}	3.550^{c}	-	-	-	-	-
412	Room	3.400^{c}	3.250^{c}	-	-	-	-	-
512	Room	4.350^{a}	3.400^{c}	-	-	-	-	-
SEM			0.1686		0.1136		0.1126	

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

Table 12. Acceptance of snail meat products (processing methods, storage days and storage conditions

Products	Storage conditions	Storage period (days)						
		0	5	10	15	20	25	30
311	Freezer	4.000^{a}	4.350^{a}	4.500^{bcd}	4.450^{bcd}	3.850^{fg}	3.900^{cd}	4.150^{bc}
312	Freezer	4.400^{a}	4.100^{a}	4.550^{bcd}	4.600^{bcd}	4.700^{abc}	4.400^{b}	4.750^{a}
412	Freezer	2.950^{c}	3.200^{bc}	3.450^{ij}	3.800^{fghi}	3.600^{ghij}	3.700^{d}	3.750^{d}
512	Freezer	4.250^{a}	4.500^{a}	5.000^{a}	4.800^{ab}	5.000^{a}	5.000^{a}	5.000^{a}
311	Fridge	4.000^{a}	4.050^{a}	4.500^{bcd}	3.950^{fg}	2.550^{l}	-	-
312	Fridge	4.400^{a}	4.300^{a}	4.550^{bcd}	4.000^{ef}	3.450^{ij}	-	-
412	Fridge	2.950^{c}	3.500^{b}	3.550^{hij}	3.550^{hij}	2.900^{k}	-	-
512	Fridge	4.250^{a}	4.400^{a}	5.000^{a}	4.300^{de}	4.400^{cd}	-	-
311	Room	4.000^{a}	3.400^{bc}	-	-	-	-	-
312	Room	4.400^{a}	3.350^{bc}	-	-	-	-	-
412	Room	2.950^{c}	2.400^{d}	-	-	-	-	-
512	Room	4.250^{a}	3.150^{bc}	-	-	-	-	-
SEM			0.1635		0.1159		0.0975	

Means within storage day bracket having same superscript along the row and down the column are not significantly different (P>0.05)

4. CONCLUSION

In this research work, it is evident that processing methods, cold storage and proper packaging retard the development of lipid oxidation in snail meat products. Smoke-drying with seasonings had lower lipid oxidation values than the seasoned fried product throughout the storage period. This could be attributed to the component of smoke and constituents of the curing ingredients which possess known potency for retarding rancidity. Hence, the high level of lipid stability observed in the seasoned smoke-dried snail meat products was not unexpected. The phenolic component of smoke and the sodium tripolyphoshate, curry and ginger used in the cure are known for lowering TBA reactive substances production. This study also showed that TBA number give a good estimate of colour and overall acceptance of processed and packaged snail meat product. Due to the low TBA values, snail meat products did not experience deterioration at 30 days storage. The TBA values were below the threshold value (1.56) for rancidity development. It, therefore, suggests that the use of antioxidant in snail processing is not relevant. Seasonings and freezer storage prolong and maintain the colour quality of meat products. The presence of certain phenolic compounds such as guaiacol and syringol in smoke play an important role in enhancing the flavour of the smoke-dried product. The shelf life of processed meat could be extended by smoke-drying and curing without adverse effect on the quality and overall acceptance of meat.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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