DELTA AGRICULTURIST 16 (No. 1, 2024)
Published by Faculty of Agriculture, Rivers State University,
P. M. B. 5080, PORT HARCOURT, Nigeria Since 1981
Email: deltaagriculturist@gmail.com www.deltaagriculturist.com ISSN 1115-6813

Research Paper

Pp 41-63

EFFECT OF FILLING MEDIA ON THE CHEMICAL QUALITY OF RAW AND FRESHLY CANNED SHELLFISH – WHELK (*THAIS CALLIFERA*), OYSTER (*CRASSOSTREA GASAR*), PERIWINKLE (*TYMPANOSTONUS FUSCATUS*) AND CLAM (*MERCENARIA MERCENARIA*) CONSUMED IN THE NIGER DELTA, NIGERIA

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ABSTRACT

The study evaluated the chemical quality of fresh and canned whelk (Thais callifera), oyster (Crassostrea gasar), periwinkle (Tympanostonus fuscatus) and clam (Mercenaria mercenaria), as obtained from a seafood market in Victoria Island, Lagos, Nigeria. The fresh samples were analyzed for nutrient composition. The samples were canned using brine, vegetable oil and tomato sauce as filling media, sterilized and then evaluated for chemical quality. Results obtained for the raw samples showed that the oyster, whelk, clam and periwinkle samples respectively had 74.43%, 73.12%, 65.42% and 78.06% moisture, 15.11%, 16.09%, 12.65% and 9.72% protein, 6.01%, 1.56%, 2.35% and 3.53% fat, 2.15%, 2.52%, 18.94% and 7.44% ash, and 2.31%, 6.71%, 0.66% and 1.27% carbohydrate contents. The physicochemical properties of the canned samples had ranges 6.55 – 8.65 for pH, 0.020 – 0.990% for total titratable acidity, 0.052 – 2.68% for free fatty acid and 0.024 – 4.12 mEqO_2/kg for peroxide value. Negligible values were detected for all the samples canned with brine as the filling medium in FFA and PV. The physicochemical properties varied across the canning media and the shellfish species. The evaluated physicochemical properties were all still within acceptable thresholds. The canned products showed proximate composition of 51.59 – 76.15% moisture, 7.18 – 24.68% protein, 3.00 – 13.66% fat, 2.63 – 4.15% ash and 1.11 – 14.52% carbohydrate. The canned samples all had high moisture and protein contents, moderate ash and varying degrees of low fat and carbohydrate. Canning the shellfish in brine had the least deteriorative impact due to sterilization, showing brine the most preferred among the packing media evaluated.

Keywords: **Delta, mollusc, Seafood, Sterilization, Filling media, Shelf stability**

INTRODUCTION

Seafood is any form of sea life which constitutes an important food component for a large proportion of the world's population, especially those living in coastal areas (Edema *et al*., 2005; Akinrotimi *et al*., 2013) such as Niger Delta. Seafood is an excellent low-calorie, high protein food that promotes

general good health. Seafood is one of the important sources for food, nutrition, income and livelihoods and has been recommended to be consumed more frequently by nutritionists and health experts (Rahmaniya and Sekharan, 2018). Seafood is highly valued not only for its abundance of high quality protein, but also for the omega-3 polyunsaturated fatty acids (PUFAs), and other nutrients, such as minerals and vitamins (FAO, 2011). Seafoods are classified into molluscs such as oyster (*Crassosterea graser*), clam (*Anadora semillis*), periwinkle (*Tympanostomus fuscatus* and *Tympanostomus fuscatus var-radula*), and whelk (*Bucciumu undatum*), crustaceans and echinoderms (Ponder and Lindberg, 2008).

Shellfish are highly perishable due to their biological composition, hence, must be preserved just after catching or harvesting. This makes the preservation of seafood a critical issue in terms of quality and human health. They begin to go bad shortly after capture unless they are subjected to processing (Ashie *et al*., 1996). There are many different processing methods used across the world to keep shellfish longer. Canning is one of such. Canning is a well-established and conventional means of providing food which is stable at ambient temperatures, has long shelf life and in consequence is eminently suitable for worldwide distribution (Bratt, 2010). Canning is an important, safe method of food preservation when practiced properly. Apart from being convenient, canned foods are also practical and recommended for consumers to plan, prepare and add more nutrient-dense foods into their diet without compromising their budget (Kapica and Weiss, 2012). Shellfish are usually canned in different packing media. The medium added in the canning process would serve as a heat conductor and as a preservative, and may increase the degree of acidity. The medium would also serve to give taste to the final product (Xavier *et al*., 2015). Oil and brine are two of the most common packing media used in canning (Papadopulos and Boskou, 1991; Tsimidou *et al*., 1992). Biochemical and sensory changes are associated with the deterioration of seafood quality during handling, canning process and storage. It is therefore needful to conduct, among other tests, the chemical analyses of the canned shellfish to assess the quality of the products in the different media (Ryder *et al*., 1993). The general objective of this study was to evaluate the effects of different canning media used in thermal processing on the physicochemical properties and proximate composition of the canned shellfish.

MATERIALS AND METHODS

2.1. Materials collection

Oyster (*Crassostrea gasar*), Whelk (*Buccinum undatum*), Periwinkle (*Tympanostonus fuscatus* var) and Clams (*Mercenaria mercenaria*) freshly harvested from the source were obtained from a sea food market, Victoria Island, Lagos, and transported in an ice packed vessel to the Department of Fish & Fishery Product Processing Laboratory, Nigerian Institute of Oceanography and Marine Research (NIOMR) Lagos. All chemicals and reagents used were obtained from the same Department and were of analytical grade.

2.2. Sample preparation

The samples: oyster, whelk, periwinkle and clam were identified by physical inspection. For each shellfish species, a basket full weighing approximately 30 – 35 kg was purchased. The basketful yielded meat samples between 8.4 kg (periwinkle) and 9.6 kg (clam). The samples were prepared following the traditional method of processing the mollusc species in Rivers State, Nigeria (Kiin-Kabari and Obasi, 2020), as shown in Figure 1. After proper washing and boiling, the samples were drained in perforated basket and allowed to cool at room temperature (28 ± 2°C). The edible

portions (meats) were then removed from the shells using sterile pins in the case of the periwinkle and whelk and a sharp knife in the case of clams and oysters. The samples were frozen at – 20°C for subsequent use.

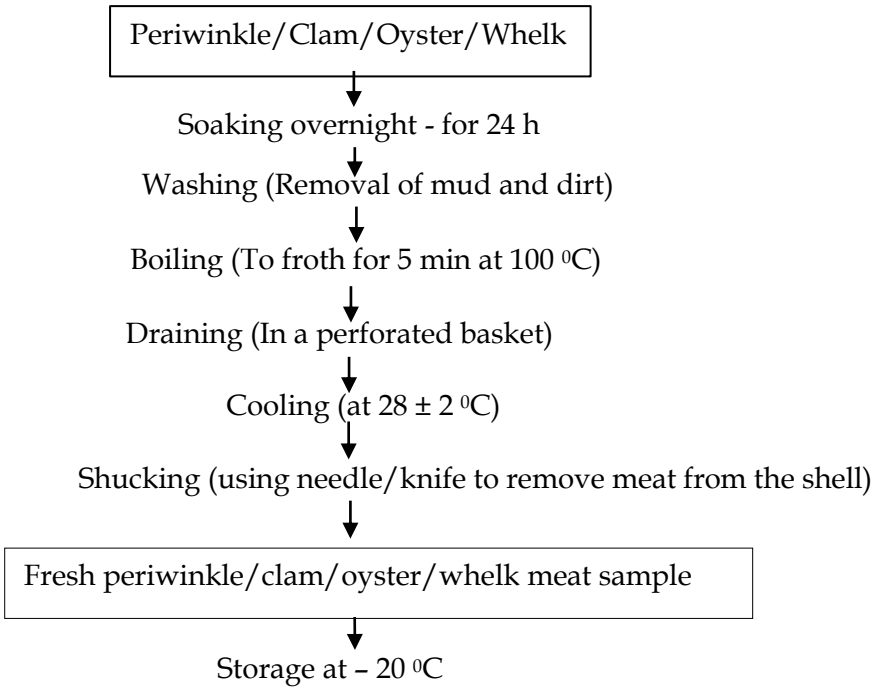

Figure 1: Traditional method of shellfish processing (Kiin-Kabari and Obasi, 2020)

Preparation of Filling Solutions; Canning Operation

a) Preparation of Brine:

Powdered oxidized salt bought from a local supermarket was used in making the saline solution food system. Distilled water was taken from a clean rinsed beaker and the amount of water weighed to make up 5% and 3% brine solution by adding the respective weights, 5g and 3g (Onwuka, 2018) of salt and also incorporating sodium tripoly-phosphate and citric acid into the solution. The solution was boiled to expel dissolved air and was allowed to cool down to room temperature in a water bath before being added to the module.

b) Preparation of Tomato sauce

Fresh tomatoes, pepper, onions were purchased, washed and chopped into pieces with a knife. The juice was mechanically extracted with the aid of a blender (Braun type: 4290 made in Germany). The extracted juice was blended followed by concentrating: frying in vegetable oil was followed with the addition of water and the tomato sauce was allowed to steam for 8 min followed by cooling. From the bulk preparation of the medium, a 100 mL portion was filled into each can as the packing medium.

Recipe for tomato sauce preparation

Fresh tomatoes	41 kg
Onions	3 kg
Fresh pepper	3 kg
Salt	1 kg
Concentrated tomato paste	2.2 kg
Vegetable oil	2 L
Water	2 L

c) Vegetable Oil

Refined groundnut oil (1500 mL) and 10 mL 2% sodium chloride was used in preparation of this filling medium. The filling solutions was mixed with 7.5 mL each of 0.1% citric

acid, 0.1% sodium benzoate, and 0.1% ascorbic acid and heated for 5 minutes before pouring.

d) Canning operation

The canning operation was performed by adopting the method of Cobas *et al*. (2022) with modification. The process followed the unit operations as shown in Figure 2. The pre-processed samples, having been frozen, were brought from the freezer, and thawed in a refrigerator (4 °C) for 12 h. Precisely, 130 g of the samples was placed in the 250 mL cans or glass jars and 100 mL of the canning media, brine, tomato sauce, refined groundnut, oil and brine was poured hot into the can. The cans were exhausted to remove the air and gases inside the filled cans using a clean stainless steel spatula and shaking the sample and swirling the can/jar. The cans were closed by placing the lids of the cans and closing or seaming the can – a process wherein the lid and the body of the can were tightly sealed. This was done by using the can seamer. The jars were sealed with a packaging machine (VP-430 Ramon Vac Line, Barcelona, Spain). The can closing was airtight, for preventing the exchange of gases between atmosphere and inside the can.

The cans containing the samples were thermally processed in an autoclave (Raypa AES-75, Barcelona, Spain) at 121 °C for 60 min before being cooled with potable water to about 40 °C. The cans were labeled and stored at room temperature for subsequent analyses. The samples were analyzed for sensory quality after canning, while the shelf stability was evaluated through the physicochemical properties and proximate composition.

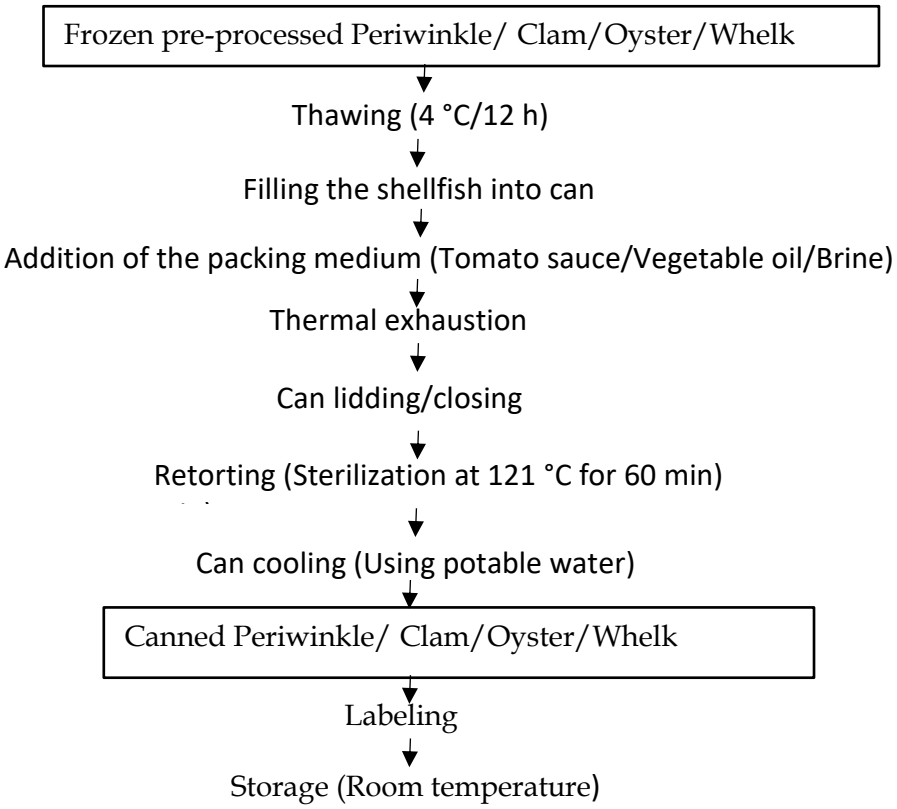

Figure 2: Canning procedure for periwinkle and clam (Cobas *et al*., 2022) modified.

Physicochemical properties of canned shellfish samples after storage

a) pH Determination

The pH of the canned samples was measured by potentiometer (Inolab, Weilheim, Germany) after calibration using standard buffers pH 6.0 and 9.0. The pH was recorded after the pH meter provided final reading.

b) Peroxide Value (PV)

Peroxide value was determined by using the method by AOAC (2012). Accurately, 5 g of oil was weighed into a 250 ml flask. Previously prepared acetic acid – chloroform solution (30 ml), saturated potassium iodide (0.5 ml), and distilled water (30ml) were added with occasional shaking. The mixture was titrated with 0.1N $Na_2S_20_3$ by shaking vigorously until yellow colour is almost gone. A 0.5 ml portion of 1% starch solution was added, and titration was continued with shaking vigorously to release all iodine from $CHC1_3$ layers until the blue colour disappeared. Peroxide value was calculated by using the following equation.

$$PV\ (mgO_2/kg\ fat) = \frac{S \times N \times 100}{W} \ldots \text{Eqn. 1}$$

where,

S = Vol (ml) $Na_2S_20_3$ (blank corrected)

N = Normality of $Na_2S_20_3$ solution

W = Weight of oil sample

c) Free fatty acid

This was determined according to the method described by Onwuka (2018). A portion (5 g) of the sample was weighed into a 250 ml flask and 50 mL distilled water was added and stirred with a magnetic stirrer. After stirring, 50 mL diethyl ether and 1 mL phenolphthalein indicator were added and shaken. The mixture was titrated with 0.1N NaOH with vigorous shaking until a permanent faint pink colour appeared and persisted for at least 1 min. The free-fatty acid content was calculated as percentage oleic acid according as follows.

$$\%\ FFA\ (as\ oleic\ acid) = \frac{V \times N \times 2.82}{W} \ldots \text{Eqn. 2}$$

Where;

W = Weight (g) of the sample

N = Normality of NaOH

V = Volume (ml) of NaOH used in the titration

d) Total titratable acidity (TTA)

The total titratable acidity value of the fresh and canned samples was determined according to the method by Shittu *et al.* (2005). A 10 g portion of the fresh or sterilized sample, as the case may be, was soaked in 50 mL of distilled H_2O for 30 minutes and intermittently stirred. A 10 mL aliquot of supernatant was collected and four drops of phenolphthalein were added as indicator and titrated with 0.1N NaOH to a pink colour end point. The TTA value was calculated as:

% TTA value = Titre value of the NaOH x 0.009 mg lactic acid. … Eqn. 3

Proximate analysis of fresh and canned shellfish samples

a) Moisture Content Determination

Moisture contents of the fresh and canned samples were determined in triplicate by hot air oven method, according to AOAC (2012). Each sample (2 g) was weighed into thoroughly washed previously dried dishes and in an oven at 100 – 105 °C for 3 hours. The dishes were cooled in a dessicator and weighed. Drying, cooling and weighing were continued until a constant weight was obtained. Thereafter the dry weight of the sample plus crucible were recorded and used to calculate moisture with the expression.

$$Moisture\ Content\ (\%) = \frac{A - B \times 100}{C} \ldots \text{Eqn. 4}$$

Where:

C = Sample weight in g

A = Weight of dish + sample before drying

B = Weight of dish + sample after drying

b) Crude Protein Determination

Crude protein of the fresh and canned samples was determined by kjeidahl method as described by AOAC (2012). Each sample (10g) was weighed into a kjeidahl flask and 3.0 g of hydrated cupric sulphate (catalyst), twenty (20) ml of sodium sulphate solution and 1.0 ml of concentrated sulphuric acid (H_2SO_4) was added to the sample in the flask. The flask was clamped and heated until the solution become colourless. The clear solution was cooled and diluted with distilled water to make up the volume to 100 ml. The (10) ml of the digest was mixed with 4ml of 40% sodium hydroxide solution in a distillation flask and distilled to release ammonia which was titrated with 0.1 mi hydrochloric acid (HCl). The titre value or end point at which the colour changed from green to pink was noted and the crude protein was calculated using the expression.

$$\% N_2 = \frac{V_s - V_b \times n_a \times 0.01401}{W} \times 100 \quad \ldots \text{Eqn. 5}$$

Where:

N_2 = Nitrogen

V_s = Volume (ml) of acid required to titrate sample

V_b = Volume (ml) of acid required to titrate blank

n_a = Normality of acid

W = Weight of samples in grams

% Crude protein = N_2 x conversion factor of 6.25

c) Crude Fibre Determination

The crude fibre content of the fresh and canned samples was determined using the method of AOAC (2012). The sample was first defatted with n-hexane, dried and then 2g was weighed (W_1) into a beaker, boiled for 30 min with 100 ml of H_2SO_4 then filtered through a filter paper. The residue was washed with boiling water until the washing was no longer acidic. The washed residue was boiled for another 30 min with 100 ml of 0.02M NaOH solution, filtered and washed with hot water for 3 min. The residue was transferred into a previously ignited, cooled in a desiccator and then weighed (W_2) using digital balance. The cooled sample was then ignited in a muffle furnace at 600 °C for 3 h, cooled and weighed (W_3) using digital balance. The percentage crude fibre was calculated with the expression.

$$\%\text{Crude fibre} = \frac{W_2 - W_3}{W_1} \times 100 \ldots \text{Eqn. 6}$$

Where

W_1 = Initial weight of sample; W_2 = Weight of sample + crucible; W_3 = Weight of the sample + crucible after incineration

d) Crude Fat Determination

The Soxhlet extraction method (AOAC, 2012) was used in determining fat content of the fresh and canned samples. The sample (2 g) was weighed in a digital balance and put in a cellulose thimble placed in the extraction tube of the soxhlet apparatus. A weighted round bottom flask was filled in about three quarter (¾) of its volume with petroleum ether (BP 40 – 60 °C) fitted to the extraction tube and set on a heating mantle. The sample was refluxed for 6 - 8 hours after which the (petroleum ether) was recovered and the extract oil in the flask was dried in the oven at 80 °C for 30 minutes to remove solvent traces, cooled in a desiccator and finally weighed using digital balance. The fat content was expressed as a percentage of the raw material, according to equation 7 below.

$$\text{Fat (\%)} = \frac{A - C}{W} \times 100 \quad \text{Eqn. 7}$$

Where A = Weight of flask + oil; B = Weight (g) of sample; C = Weight of empty flask

e) Ash Content Determination

The ash content of the fresh and canned samples was determined using the method of AOAC (2012). Each sample (2 g) was weighted into a silica dish previously washed heated to about 600 °C, cooled in a desiccator and then weighed using digital

weighing balance. The silica dish with the sample was heated in a muffle furnace at about 700 °C for 5 h. This temperature was maintained until whitish-grey coloured ash was obtained indicating that all the organic matter in the product has been destroyed. The dish was cooled in a desiccator and weighted using a digital balance. The percentage ash content was calculated as:

$$\% \text{ Ash} = \frac{B - A}{C} \times 100 \quad \ldots \text{Eqn. 8}$$

Where:

A = Weight of crucible; B = Weight of crucible + ash; C = Weight of original sample

f) Carbohydrates

The carbohydrate content of the canned samples determined by difference as:

Carbohydrates % = 100 – (Moisture + protein + ash + fat + fibre) %

Data analysis

All analysis was conducted in triplicate. Data collected was subjected to analysis of variance (one-way ANOVA) using Minitab®, version 16.0 software. Means of the results were reported, and Tukey's test was used to separate significant mean, with significance established at $p<0.05$.

RESULTS

Proximate composition of fresh shellfish samples

The proximate composition of fresh shellfish: oyster, whelk, periwinkle and clam are presented in Table 1. The moisture contents of the fresh aquatic gastropods studied were 74.43% for oyster, 73.12% for whelk, 65.42% for clam and 78.05% for periwinkle samples. The ash content of the samples had 2.15% for oyster, 2.52% for whelk, 18.93% for clam and 7.44% for periwinkle. The percentage fibre contents were low, as the fibre content detected in the shellfish samples evaluated ranged between 0.0098 and 0.0100%. The oyster contained 15.11% protein while whelk contained 16.09% protein, with clam and periwinkle having 12.64% and 9.72%, respectively. Values for protein content showed significant ($p<0.05$) difference. The fat contents of the fresh samples were 6.01% for oyster and 1.56% for whelk, as the highest and lowest values, respectively. Fat content results were 2.35% for clam and 3.52% for periwinkle, of which the two were not significantly ($p>0.05$) different, but were all significantly ($p<0.05$) less than the 6.01% for oyster. The carbohydrate content of the fresh oyster, whelk, clam and periwinkle showed that values were 2.30% in oyster, 6.70% in whelk, 0.65% in clam and 1.26% in periwinkle. Generally, the periwinkle sample had highest moisture and lowest protein contents; clam had highest content of ash but least carbohydrate, while whelk had highest contents of protein and carbohydrate.

Proximate composition of canned shellfish samples

The proximate composition of the canned sea food samples are presented in Table 2. The results showed the values varied with the filling media and between the sea food materials. The samples were generally high in moisture and low in carbohydrate. The samples had moisture contents of 51.59% to 76.74%. The ash content was 2.36% to 4.15%. The protein content of the canned samples showed 7.18% to 24.68%.

Table 1: *Proximate composition of fresh (raw) shellfish samples* (%)

Sample	Moisture	Ash	Fibre	Protein	Fat	Carbohydrate
Oyster	$74.43^{b}\pm0.37$	$2.15^{d}\pm0.01$	$0.0090^{b}\pm0.00$	$15.11^{a}\pm0.40$	$6.01^{a}\pm0.71$	$2.30^{b}\pm0.04$
Whelk	$73.12^{c}\pm0.14$	$2.52^{c}\pm0.18$	$0.0100^{a}\pm0.00$	$16.09^{a}\pm0.00$	$1.56^{c}\pm0.04$	$6.70^{a}\pm0.09$
Clam	$65.41^{d}\pm0.32$	$18.93^{a}\pm0.01$	$0.0098^{a}\pm0.00$	$12.64^{b}\pm0.57$	$2.35^{bc}\pm0.06$	$0.65^{c}\pm0.25$
Periwinkle	$78.05^{a}\pm0.11$	$7.44^{b}\pm0.01$	$0.0100^{a}\pm0.00$	$9.72^{c}\pm0.78$	$3.52^{b}\pm0.67$	$1.26^{bc}\pm0.77$

Values are mean ± standard deviation of replicate determinations (n=13). Means in the same column bearing different superscripts are significantly (p<0.05) different.

The periwinkle samples showed a generally lower range of values. Generally, whelk had higher protein content than other samples in all the packing media. The fat content of the canned samples packed in different media had range 3.00% to 13.66%. The fibre contents obtained in the samples canned in other media apart from tomato sauce were all ≤ 0.01%. Values recorded for samples canned in tomato sauce were 0.044%, 0.160%, 0.055% and 0.010% for oyster, whelk, clam and periwinkle, respectively. The carbohydrate content of the samples canned with different media had range of 1.11% to 14.52%.

Physicochemical properties of canned shellfish packed in different media

The physicochemical properties of the canned sea food samples are shown in Table 3. From the table, the physicochemical properties all varied across the packing media and the sea food samples. The oyster samples had pH values of 6.55 – 7.46. The whelk samples had pH values ranging from 7.65, for the tomato sauce packed samples to 8.06, for those filled with 3% brine. The clam samples had pH range of 6.55 for those immersed in vegetable oil to 7.01 for clam in 5% brine. Clam in tomato sauce had pH of 6.75. Periwinkle samples had pH range of 8.10 – 8.50. Periwinkle samples immersed in vegetable oil and tomato sauce had similar pH value of 8.10. There were significant ($p<0.05$) differences among the samples in the pH values obtained. The total titratable acidity (TTA) values for canned shellfish packed in brine were 0.900% for oyster, 0.090% for whelk, 0.315% for periwinkle and 0.020% for clam. TTA values for samples packed in vegetable oil were 0.100% for oyster, 0.090 for whelk, 0.990% for clam and 0.057% for periwinkle. Products based in tomato sauce medium had TTA values of 0.083% for oyster, 0.180% for whelk, 0.105% for clam and 0.445% for periwinkle. Generally, clam immersed in vegetable oil had the highest TTA value while clam in 5% brine had the lowest value. There were significant ($p<0.05$) differences in the values among the different shellfish and different canning media. The free fatty acid, FFA contents of the samples had values ranging from 0.52% for whelk in vegetable oil to 2.68% for oyster in vegetable oil. FFA values for the brined samples were reported as not more than 0.0020%, being yet detected in almost negligible amounts in all of the four shellfishes studied. The tomato sauce based samples had values reported for FFA ranging from 1.16% for periwinkle samples to 1.65% for oyster samples. The value for the oyster in vegetable oil sample was overall higher than others. The values were still acceptable, as the percentage FFA was not more than 1.5% stated for canned meat products and the likes (Mohammed, 2013). The peroxide value, PV of the vegetable oil filled canned shellfish was obtained to be 4.02 $mEqO_2/kg$ (highest) and 0.83 $mEqO_2/kg$ (lowest), respectively. Oyster in vegetable oil had the highest while clam in vegetable had the lowest PV in the oil-filled products. The peroxide value recorded for the samples

canned in brine medium was low, being ≤ 0.0011 $mEqO_2/kg$. It was not detected in the brined samples in considerable quantity, as was also the case with FFA, which suggested lipid oxidation. Peroxide values reported for the tomato sauce based samples were 0.89 $mEqO_2/kg$ for oyster and 0.49 $mEqO_2/kg$ for whelk, being significantly ($p<0.05$) different from each other. The 4.00 $mEqO_2/kg$ for clam and 0.24 $mEqO_2/kg$ for periwinkle were significantly different, being the highest and lowest values, respectively, for the tomato sauce-filled products. The PV were all lower than the Codex Alimentarius guidance acceptable level of 10 $mEqO_2/kg$ of peroxides in fats and oils for edible purpose and the maximum PV of 25 $mEqO_2/kg$ generally

Proximate composition of fresh shellfish samples

The values showed that the molluscs are high moisture samples, with periwinkle having the highest, oyster having more moisture than whelk, and clam having the least. The proximate composition of foods or food components is of interest in the food industry for product development, quality control, or regulatory purposes (Nielsen, 2006). The proximate composition of shellfish varies with genetic, food intakes, age, metabolism rate and reproductive cycles, and extrinsic such as temperature of the water, nutrient availability, habitat and seasons (Md Noordin *et al*., 2014). The samples have already been described by earlier studies as high moisture foods (Ogundiran and Fasakin, 2015; Tabakaeva *et al*., 2018). The results in this present study gave higher moisture for the whelk sample than the 67.1% reported by Md Noordin *et al*. (2014) for maculated or Babylonian whelk. Higher moisture contents of 73.72% and 84.80 % had earlier been reported for clam and periwinkle, respectively (Kiin-Kabari *et al*., 2017). Akinjogunla *et al*. (2017) reported moisture content of 83.34% for fresh mangrove oyster. The value was higher than those obtained in this study for oyster and clam, being fellow bivalves. The seasonal, maturity and environmental differences may have had a part in the reasons for the variation in results. Chaitanawisuti *et al*. (2011) reported value (73.37%) in for the juveniles of the *Babylonia areolata.* Glatt *et al*. (2003) obtained moisture contents of 73.35% for knob whelk and 79.86 – 83.80% for oyster from different locations. Studies on *Anadara broughtonii* and *Mactra chinensis* showed that the bivalve molluscs had moisture content of 78.55 – 82.32% (wet weight basis) and 10.04 – 13.64% (of dry mass) for different edible parts (Tabakaeva *et al*., 2018). Md Noordin *et al*. (2014) stated that a moisture content of 85.2% was documented in the National Nutrient database for oyster.

Table 2: *Proximate composition of canned shellfish samples* (%)

Sample	Moisture	Ash	Fibre	Protein	Fat	Carbohydrate
Oyster in 5% brine	75.80^{b}±0.23	2.34^{g}±0.28	0.011^{d}±0.00	10.29^{f}±0.14	7.05^{d}±0.03	4.51^{e}±0.18
Whelk in 3% brine	76.74^{a}±0.10	2.65^{ef}±0.07	0.010^{d}±0.00	12.98^{d}±0.00	5.16^{f}±0.09	2.48^{g}±0.06
Periwinkle in 5% brine	76.15^{b}±0.09	3.54^{c}±0.13	0.010^{d}±0.00	7.74^{h}±0.18	6.62^{d}±0.12	6.11^{d}±0.06
Clam in 5% brine	71.43^{e}±0.08	2.90^{de}±0.03	0.0098^{d}±0.00	11.41^{e}±0.21	3.00^{g}±0.02	11.28^{b}±0.13
Oyster in vegetable oil	68.03^{g}±0.06	4.15^{a}±0.09	0.010^{d}±0.00	14.01^{c}±0.06	10.62^{b}±0.04	3.21^{fg}±0.12
Whelk in vegetable oil	61.57^{h}±0.11	2.71^{ef}±0.23	0.0099^{d}±0.00	24.68^{a}±0.19	6.18^{de}±0.08	4.87^{e}±0.03
Periwinkle in vegetable oil	71.41^{e}±0.22	3.82^{b}±0.04	0.0099^{d}±0.00	7.18^{i}±0.05	9.08^{c}±0.09	8.52^{c}±0.13
Clam in vegetable oil	51.59^{i}±0.33	4.06^{ab}±0.07	0.010^{d}±0.00	16.18^{b}±0.19	13.66^{a}±1.28	14.52^{a}±1.22
Oyster in tomato sauce	72.27^{d}±0.21	3.84^{b}±0.04	0.044^{c}±0.000	16.18^{b}±0.06	6.61^{d}±0.18	1.11^{h}±0.00
Whelk in tomato sauce	71.96^{d}±0.21	2.49^{fg}±0.04	0.160^{a}±0.007	16.40^{b}±0.41	5.44^{ef}±0.05	3.54^{f}±0.27
Periwinkle in tomato sauce	74.99^{c}±0.06	3.03^{d}±0.03	0.010^{c}±0.000	9.51^{g}±0.09	8.86^{c}±0.02	3.62^{f}±0.04
Clam in tomato sauce	70.21^{f}±0.18	3.81^{b}±0.04	0.055^{b}±0.007	10.33^{f}±0.10	9.13^{c}±0.08	6.48^{d}±0.12

Values are mean ± standard deviation of duplicate determinations. Means in the same column bearing different superscripts are significantly ($p<0.05$) different.

Table 3: *Physicochemical properties of canned shellfish samples*

Sample	pH	TTA	FFA	PV
Oyster in 5% brine	6.55^{h}±0.07	0.900^{b}±0.000	0.0020^{g}±0.00	0.0011^{h} ±0.00
Whelk in 3% brine	8.65^{a}±0.07	0.090^{f}±0.000	0.0011^{h}±0.00	0.0010^{h} ±0.00
Periwinkle in 5% brine	8.50^{a}±0.00	0.315^{d}±0.064	0.0015^{g}±0.00	0.0010^{h} ±0.00
Clam in 5% brine	7.01^{f}±0.01	0.020^{g}±0.000	0.0020^{g}±0.00	0.0010^{h} ±0.00
Oyster in vegetable oil	7.46^{e}±0.06	0.100^{f}±0.014	2.68^{a}±0.04	4.12^{a}±0.04
Whelk in vegetable oil	7.90^{c}±0.00	0.090^{f}±0.000	0.52^{f}±0.06	1.04^{d}±0.06
Periwinkle in vegetable oil	8.10^{b}±0.14	0.057^{fg}±0.004	1.01^{e}±0.02	2.89^{c}±0.02
Clam in vegetable oil	6.55^{h}±0.07	0.990^{a}±0.00	1.18^{d}±0.03	0.83^{e}±0.05
Oyster in tomato sauce	6.69^{gh}±0.13	0.083^{f}±0.004	1.65^{b}±0.13	0.89^{e}±0.02
Whelk in tomato sauce	7.65^{d}±0.07	0.180^{e}±0.00	1.46^{c}±0.02	0.49^{f}±0.01
Periwinkle in tomato sauce	8.10^{b}±0.14	0.445^{c}±0.050	1.16^{de}±0.21	0.24^{g}±0.04
Clam in tomato sauce	6.75^{g}±0.07	0.105^{f}±0.007	1.51^{bc}±0.05	4.00^{b}±0.03

Values are mean ± standard deviation of replicate determinations (n=2). Means in the same column bearing different superscripts are significantly ($p<0.05$) different.

Proximate composition of fresh shellfish samples

The values showed that the molluscs are high moisture samples, with periwinkle having the highest, oyster having more moisture than whelk, and clam having the least. The proximate composition of foods or food components is of interest in the food industry for product development, quality control, or regulatory purposes (Nielsen, 2006). The proximate composition of shellfish varies with genetic, food intakes, age, metabolism rate and reproductive cycles, and extrinsic such as temperature of the water, nutrient availability, habitat and seasons (Md Noordin *et al*., 2014). The samples have already been described by earlier studies as high moisture foods (Ogundiran and Fasakin, 2015; Tabakaeva *et al*., 2018). The results in this present study gave higher moisture for the whelk sample than the 67.1% reported by Md Noordin *et al*. (2014) for maculated or Babylonian whelk. Higher moisture contents of 73.72% and 84.80 % had earlier been reported for clam and periwinkle, respectively (Kiin-Kabari *et al*., 2017). Akinjogunla *et al*. (2017) reported moisture content of 83.34% for fresh mangrove oyster. The value was higher than those obtained in this study for oyster and clam, being fellow bivalves. The seasonal, maturity and environmental differences may have had a part in the reasons for the variation in results. Chaitanawisuti *et al*. (2011) reported value (73.37%) in for the juveniles of the *Babylonia areolata.* Glatt *et al*. (2003) obtained moisture contents of 73.35% for knob whelk and 79.86 – 83.80% for oyster from different locations. Studies on *Anadara broughtonii* and *Mactra chinensis* showed that the bivalve molluscs had moisture content of 78.55 – 82.32% (wet weight basis) and 10.04 – 13.64% (of dry mass) for different edible parts (Tabakaeva *et al*., 2018). Md Noordin *et al*. (2014) stated that a moisture content of 85.2% was documented in the National Nutrient database for oyster.

The ash content of the samples had 2.15% for oyster as the least ash content and a remarkable 18.94% for clam. This can easily be traceable to the low moisture content of the sample, a situation that could be described or viewed as "concentration effect." There were significant ($p<0.05$) differences among the four values. The average value of ash content of fresh oyster meat was earlier reported by Chellappan (1989) to be 2.76%. Maculated ivory whelk (*Babylonia areolata*) showed to have ash content of 5.4% (Md Noordin *et al*., 2014). Chaitanawisuti *et al*. (2011) reported ash content of 2.91% in juveniles of same whelk species. Clam, another bivalve in this study, showed a considerably comparable value. *Anadara broughtonii* and *Mactra chinensis* showed ash contents of 0.95 – 1.89% (wet weight basis) and 4.53 – 9.45% (dry weight) in different edible parts (Tabakaeva *et al*., 2018). The values were lower than the 5.54% ash content reported for another closely related aquatic gastropod mollusc, fresh water snail (*Pila ampullacea*) (Obande *et al*., 2013). The results in this study however suggest the samples could be considered mildly rich in minerals. The ash of oysters contains, besides sodium chloride, probably almost every chemical element of sea water. Detailed analysis of the ash showed iodine and traces of bromine are present, as well as calcium and magnesium carbonates (Kontaminas *et al*., 2021). Ogungbenle and Omowole (2012) reported higher ash content of 9.56% for periwinkle. Ash content of 7.44 % obtained for periwinkle in this study was, however, higher than the 1.32 – 1.55% reported by Kiin-Kabari *et al*. (2021) and the 6.85% earlier reported by Kiin-Kabari *et al*. (2017). Similarly, ash content range of 2.52 – 4.23% reported for clam by Srilatha *et al*. (2013) was way lower than the result obtained in this study. Differences were probably due to species, environment, feeding habit and season of harvest. Differences in season, species, feeding and

environment, predominantly, water composition, may have influenced the difference in results (Davies and Jamabo, 2016; Srilatha *et al*., 2013). The fibre contents detected in the samples were not higher than 0.01%. Although Obande *et al*. (2013) reported a crude fibre content of 0.03% in fresh water snail (*Pila ampullacea*) and Akpang and Oscar (2018) reported close fibre contents of 0.05% for periwinkle and 0.04% for clam, many reports on the proximate composition of gastropod molluscs, especially, of aquatic origin, did not have fibre content. These included reports by Chellappan (1989), Glatt *et al*. (2003), Ogundiran and Fasakin (2015), Tabakaeva *et al*. (2018), Panayotova *et al*. (2019) and Kontaminas *et al*. (2021).

Protein in oyster contained 15.11% protein while whelk contained 16.09% protein. The values were, however, not significantly ($p>0.05$) different. They were, however, significantly ($p<0.05$) higher than the 12.65% and 9.72% recorded for clam and periwinkle, respectively. The values were typical of mollusc sea foods of the gastropod and bivalves nature (Ogundiran and Fasakin, 2015; Tabakaeva *et al*., 2018). The average value of the protein content of fresh oyster meat obtained by Chellappan (1989) was 11.188%. Oysters were earlier reported to contain up to 21% organic matter, in which protein constitutes 46.3% of the organic matter examined; glycogen being present to the extent of 4%, and the fat content is 4.7%. Maculated ivory whelk (*Babylonia areolata*) also known as ivory shell, spotted babylon, babylon snail or babylon shell showed to be high in protein (22.4%), according to Md Noordin *et al*. (2014). Chaitanawisuti *et al*. (2011) reported protein content of 18.11% in juveniles of same whelk specie. Protein content obtained by Glatt *et al*. (2003) was 59.95% (dry weight) for knob whelk and 46.50 – 48.87% (dry basis) for oyster from different locations. Values reported for the protein content of various dried oyster had 6.20 – 7.58%. Kiin-Kabari *et al*. (2021) earlier reported protein contents of 12.01% and 18.84% for periwinkle and clam, respectively. These values were higher than the respective 8.22% and 12.65 % in periwinkle and clam recorded here. However, they were comparable to the respective 9.97% and 13.97% protein reported for periwinkle and clam by Kiin-Kabari *et al*. (2017). The results of fat contents of the fresh samples were similar to those reported for similar and closely related samples. Generally, the samples could be judged to be low in fat content (especially the whelk), but high in protein. Mollusc meats are cheap and rich in protein and omega 3 fatty acid but low in fat content, making their low fat content still highly valuable (Saito, 2014). While the fat content of 2.35% obtained for clam corroborated the earlier reported range of 2.30 – 3.82% by Srilatha *et al*. (2013), Panayotova *et al*. (2019) reported that whelk had fat content of 0.5%. This was however lower than value recorded in this study. Ogungbenle and Omowole (2012) recorded a fat content of 1.32% for periwinkle (*Tympanotonus fuscatus* var. radula). Md Noordin *et al*. (2014) reported fat content of 2.7% in maculated ivory whelk, while Chaitanawisuti *et al*. (2011) reported 0.12% for juveniles of same whelk specie. In comparison, the value obtained for oyster was higher than the fat content of 2.0% in oyster documented in the National Nutrient Database 2012 (Md Noordin *et al*., 2014). Obande *et al*. (2013) reported a much lower fat content of 0.06% in Fresh water snail (*Pila ampullacea*), another aquatic gastropod mollusc close to the oyster, whelk and periwinkle collection in the shellfish artisanal fishing. Panayotova *et al*. (2019) reported that whelk (*Rapana venosa*) was characterized by low lipid content of 0.50% (wet weight) but with beneficial polyunsaturated fatty acid/saturated fatty acid ratio (PUFA/SFA) and omega-6/omega-

3 (n-6/n-3) ratio. Despite being low in fat content, oyster and whelk are not considered in the light of nutritional deficiency due to the fat content. The low fat content is rich in omega-3 fatty acid, making their low fat content still highly valuable (Kawashima and Ohnishi, 2014; Saito, 2014). Marine oils, rich in fatty acids bound to phospholipids, as with the lipids of shellfish, crustaceans and algae, have many advantages compared to fish oils since they are much more stable to oxidation (Panayotova *et al*., 2019). In addition, dietary phospholipids act as natural emulsifiers, which facilitate and improve the digestion of nutrients in the intestine (Mendis and Kim, 2011). The World Health Organization (WHO) recommended the replacement of high saturated fatty acids (SFA) intake with polyunsaturated fatty acids (PUFAs) or monounsaturated fatty acids (MUFAs), preferably from seafood origins (WHO, 2018). Whelk (*Rapana venosa*) has been reported to consistently show the same pattern of fatty acid composition (PUFA>SFA>MUFA), with PUFAs being the highest, despite the environmental factors, such as temperature, salinity, pollution and diet, which the fatty acids composition of lipids of the marine mollusks depend on (Popova *et al*., 2017). Panayotova *et al*. (2019) reported that whelk meat contains only 0.122 g SFA per 100 g edible portion, thus could be classified as low-saturated fat food (containing less than 1.5 g per 100 g). One hundred grams of whelk meat contained 246.8 mg of PUFA, with two-thirds of them being in the form of polar lipids. It is important, since phospholipids act as natural emulsifiers, easing digestion and absorption of nutrients in the gastrointestinal tract. Although whelk lipids are low, they are rich in very long-chain PUFA – eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n3) in particular. These PUFAs can reduce the platelet adhesion and aggregations, have blood pressure reducing properties and thus influencing positively cardiovascular diseases (CVD). DHA plays structural and functional roles in brain and retina tissues, therefore being important in optimum neural and visual functions (Popova *et al*., 2017; Prato *et al*., 2018).

The carbohydrate content of the fresh mollusc sea foods, 2.31% in oyster, 0.66% in clam, 1.27% in periwinkle and 6.71% in whelk, showed that there was significant difference ($p<0.05$) among the shellfish samples. Whelk had the highest value, while clam had the lowest. The values were within range reported for gastropod molluscs, which are usually low. Md Noordin *et al*. (2014) reported carbohydrate content of 2.4% in maculated ivory whelk, similar with the 2.0% documented for oyster, while Chaitanawisuti *et al*. (2011) reported 5.47% for juveniles of same whelk specie. They also stated that a carbohydrate content of 2.0% in oyster was documented in the National Nutrient Database of 2012. Carbohydrate content of 0.55% and 2.35% was reported by Kiin-Kabari *et al*. (2017) and Ahaotu *et al*. (2021), respectively, for periwinkle. The carbohydrate content of molluscs are said to be in the stored energy form, glycogen. A carbohydrate content of 5.60% was reported by Kontaminas *et al*. (2021) for oyster. This was higher than that obtained in this study. The flesh of molluscs differs from that of crustaceans and free-swimming fish in that it contains an appreciable amount of carbohydrates in the form of glycogen, hence, the reasonable involvement of glycolytic microbial species in the spoilage of mollusc sea foods (Kontaminas *et al*., 2021). It was reported that the carbohydrate glycogen is the substance the presence or absence of which makes oysters fat or lean. Carbohydrate content of 11.36–20.37% (dry weight) was reported for different edible portions of the molluscs *Anadara broughtonii* and *Mactra chinensis* (Tabakaeva *et al*., 2018). Generally, the carbohydrate contents of the

different shellfish species used were within previously reported findings.

Physicochemical properties of canned shellfish

The physicochemical properties of the canned aquatic molluscs all varied across the packing media and the sea food samples. There were significant ($p<0.05$) differences among the samples in the values obtained in this study. It was observed that, for every packing medium, there was significant ($p<0.05$) difference among the shellfish samples. The results showed that the sterilized samples were low in lipid oxidation. The pH of the canned shellfish samples ranged between 6.55 and 8.65, with oyster and whelk in brine having the lowest and highest pH values, respectively. While values obtained for whelk samples were all above 7.00, indicating a minimum of mild alkalinity, oyster and clam samples were mostly slightly acidic in the brine and tomato sauce media. The pH values obtained were typical of canned sea foods, which are always >4.5 and not counted as high acid foods (ElShehawy and Farag, 2019). Canning of sea foods in acidic medium such as tomato sauce has not proven to bring down the pH of sea foods to high acid. The pH values of canned shrimp products including those canned with tomato sauce were 6.48 – 6.61. The higher pH values observed in canned sea food samples may be due to the formation and accumulation of some dibasic amino acids and volatile basic nitrogenous compounds such as ammonia (NH_3) resulting from the breakdown and proteolysis of proteins during heat treatment (El Sherif, 2001). The pH is an important parameter in canning as it is often considered in determining the sterilization temperature (Conrad and Smith, 2013). It was noted by ElShehawy and Farag (2019) that when pH value of canned products is low, the preservative effect of thermal process increases. The probability of survival of spoilage organism during processing, or its growth in the product while in the shelf or during storage also largely depends on this physicochemical property. A significant change in pH may, therefore, indicate spoilage of canned foods (Evancho *et al*., 2010). The canned clam in tomato sauce and vegetable oil, and oyster in brine and tomato sauce had slightly acidic pH values, indicating that the products were typically low acid foods. Clam in brine could almost be considered neutral. At this pH, spore-forming organisms such as *Clostridium spp* may grow. This therefore suggests the canning operation needed sterilization treatment effective enough to destroy all bacteria spores, as opined by Nketia *et al*. (2020). The importance of the pH appears more pronounced when it comes to storage and shelf stability of the product. According to Ezeama (2007), pH value of food has much importance in the production of botulin toxin and the consequent food poisoning. An optimum pH is required for growth and synthesis of the toxin, more importantly, in foods with pH > 4.5. The psychro-tolerant and non-proteolytic *C. botulinum* group can grow and produce toxin at ~3 °C, with 5% NaCl and at pH of above 5.0 (Dalgaard, 2006). According to Hait (2012), *S. aureus* grows in pH range of 4.5 and 9.3, with an optimum between 7.0 and 7.5. The pH range of the samples is therefore such that can support the growth of these pathogens in all the shellfish samples studied here.

Clam in 5% brine had the least TTA value, while clam in vegetable oil had the highest acidity value. The generation of acidic organic acids would naturally lower the pH of the medium. Total acidity values obtained in this study were low, consistent with the high pH values. Total titratable acidity values reported by ElShehawy and Farag (2019) of different fish products canned in vegetable oil as the filling medium varied from 1.00% to 1.93%. The values were higher than those obtained here in this study. The

lower acidity values in the canned shellfish samples compared to the oyster samples could have been due to the formation and accumulation of some more dibasic amino acids and volatile basic nitrogenous compounds due to breakdown and proteolysis during heat treatment of the whelk than the oyster, thus, reducing the acidity (El Lahamy and Mohamed, 2020).

The FFA contents of the canned aquatic gastropods filled with vegetable oil canning medium were between 0.52 – 2.68%, while those filled with tomato sauce ranged between 1.01% and 1.65%. Low free fatty acids were detected in the brine filled samples. Detecting higher FFAs in the cans filled with vegetable oil and tomato sauce can obviously be attributed to the vegetable oil used in preparing those media. The value for the oyster sample was significantly ($p<0.05$) higher than the whelk sample. The outcome may have resulted due to the oxidizing effect of the moisture content, as both the processed and unprocessed oyster had higher moisture content than the whelk counterpart. High moisture can sometimes mediate oxidation and fatty acid generation. According to Lu (2018), in lipids degradation, hydrolysis usually precedes oxidation in the presence of water to produce free fatty acids. Another dimension to this might also be the lipids composition. It has been established that the quality of canned products has a very close relationship with their lipid content and composition (El Lahamy and Mohamed, 2020). The oyster sample may have been richer in the unstable (mono or poly) unsaturated fatty acids than other samples. This composition predisposes a lipid to high oxidation. Lipid oxidation involves the reaction of unsaturated fatty acids of fish triglycerides with atmospheric oxygen to form hydroperoxides (primary oxidation products) which are unstable and therefore decompose to carbonyl compounds such as aldehydes and ketones (secondary oxidation products), responsible for characteristic rancid off-flavors (Kontaminas *et al*., 2021). Other oxidation variables include individual fatty acid susceptibility, molecular structure of lipids, initiation reactions and presence of oxidized lipids and more (German, 1997). Furthermore, besides the degree of saturation, the fraction of the lipids bound to phospholipids matters. The higher the portion bound to phospholipids the more stable the lipid to oxidation (Mendis and Kim, 2011). This therefore suggests that whelk may be having greater portion of its lipids bound to phospholipids than oyster and clam do.

The peroxide value (PV) of the vegetable oil and tomato sauce filled canned shellfish was obtained to be 0.24 $mEqO_2/kg$ (periwinkle in tomato sauce) and 4.12 $mEqO_2/kg$ (oyster in vegetable oil), as the lowest and highest values, respectively. The peroxide values of the oyster and clam samples were significantly ($p<0.05$) higher than those of other samples in the vegetable oil and tomato sauce media, respectively. Apart from the set of values for the vegetable oil packed samples, the high PV was followed by values reported for samples canned with tomato sauce. Their values can all be attributed to the vegetable oil added to and used for the preparation of the sauce. For the tomato sauce packed samples, the periwinkle and whelk samples had very low concentration. This variation may be attributable to the fatty acid compositions of the two samples. Peroxide value is always evaluated as the basic index of primary oxidation. In food systems such as the filling medium in the sea food canning, fatty acid composition, the physical states of the lipids, content of tocopherols, and activity of transition metals have been implicated in factors controlling rates of lipid oxidation (Frankel *et al*., 2002). The peroxide value is a key indicator of lipid stability. PV is a measure of degree of oxidation of fat hence

termed as index of spoilage due to oxidative rancidity (Balachandran, 2001). The first compounds formed during oxidation process are peroxides, especially hydroperoxides; hence, their description as primary oxidation products. Lower values indicate better stability of the lipid to oxidation (Nwokocha and Adegbuyiro, 2017). The lower PV of the whelk sample therefore indicates better stability of the canned whelk to lipid oxidation than the oyster and clam samples. The low fat content in periwinkle may have also showed in its lowest value in tomato sauce. Peroxide value essentially indicates the primary oxidation stages of fats/oils in foods. When detected and found to be increasing in a product, it suggests the product's taste and odour are deteriorating, tending to rancidity (Jin *et al*., 2009). Although standards for peroxide values vary, Karibe (2018) reported that PV range of 3 – 20 $mEqO_2/kg$ is recommended for meat products, while Codex Alimentarius guidance accepts levels of about 10 $mEqO_2/kg$ of peroxides in fats and oils for edible purpose, according to acceptable limits of oxidation, criteria of wholesomeness, nutritional and safety values (Ahmed *et al*., 2016). Generally, however, a maximum peroxide value limit of 25 $mEqO_2/kg$ is allowed in foods (Evranuz, 1993; Karibe, 2018).

Proximate composition of canned shellfish samples

The proximate composition of the canned sea foods varied with the filling media and between the sea food materials. The samples were generally high in moisture and protein and low in carbohydrate. The fat content was as considerable affected by the canning medium. In the brine medium, the oyster and periwinkle samples had no significant ($p>0.05$) difference in moisture content. Similarly, there was no significant ($p>0.05$) difference between oyster and whelk in the tomato sauce-packed samples. The moisture content of the samples was within range reported for canned sea foods – shellfishes, molluscs. The moisture content of canned bivalve specie (clam) *Paphiaundulata* in tomato sauce ranged from 71.46% to 74.33% (Abd-El-Aziz, 2021). The moisture of canned product affects the quality of the product in different ways, including nutritional and sensory. According to Brown *et al*. (2008), moisture content in canned product is associated with some sensory attributes. Higher moisture content of canned abalone was associated with an increased tenderness. The moisture content of a food sample is important to its shelf life, as it affects the type of microorganism than can grow on the food sample and its proliferation potential (Ezeama, 2007) and the kind of physicochemical properties affected. The moisture content translates to water activity based on its level of availability for biochemical activities. The activity of microorganisms shows a definite limiting water activity below which the probability of microbial growth is insignificant or considered to be zero (Karel and Lund, 2003). The ash content of the canned molluscs ranged from 2.36% to 4.15%. Sample with the lowest ash content was the canned oyster in brine, while oyster in vegetable oil, on the other hand, had the highest ash content. Significant ($p<0.05$) differences existed among the samples. Oyster in the vegetable oil and tomato sauce packing media were significantly higher than the brine counterpart. The low value of the brine-based oyster may be attributed to its higher moisture content, which consequently, caused a probable dilution effect on the value. The difference in ash content of the brine-packed samples showed that the values may not be credited to the difference in strength of concentration of the brine solutions for oyster and clam than that of whelk (3%). The values are within values reported for various sea food samples. Onwuka (2018) stated that ash content gives

approximate information on the mineral content of the samples. The ash content of the samples was within the range of various values reported for canned molluscs. Ash content of 2.00% in oyster was reported by Kontaminas *et al*. (2021). The ash content of canned bivalve specie *Paphia undulata* canned in tomato sauce ranged from 8.68% to 19.59% (Abd-El-Aziz, 2021). Ash content of 10.82% was reported by Omorodion and Emmanuel *et al*. (2022) for processed periwinkle. That was a little higher than value obtained here for the three canning media.

The low fibre content result obtained was in line with results reported in earlier studies for canned gastropods such as oyster by Kontaminas *et al*. (2021). Molluscs muscles are not known to contain high fibre, based on their chemical constitution. However, Ahaotu *et al*. (2021) reported crude fibre contents of 6.87% in freshly harvested periwinkle and 4.64 – 6.69% in smoked periwinkle packaged in various forms. The higher value results obtained for tomato sauce-packed samples were largely attributed to the crude fibre from the tomato fruits, pepper and onion used in the sauce preparation. Whelk had higher protein content than oyster and periwinkle in all the media: the brine-packed, tomato sauce-filled and vegetable oil-packed samples. The values obtained were within range of results reported for the sample shellfish organisms. Balachandran *et al*. (1984) reported mean protein content of 12.26% for farmed oyster canned using 2% brine, vegetable oil and tomato sauce as the filling media, and 11.74% protein content in wild oyster meat canned using 2% brine and vegetable oil. The whelk sample showed similar result of increase after thermal processing. However, the results in this study rather showed some modest decrease in protein content of the fresh samples after sterilization. Protein content of 9.80% in oyster was reported by Kontaminas *et al*. (2021). Houcke *et al*. (2016) reported in earlier studies that the protein content of all investigated oyster samples ranged from 44.5% to 51.2% (dry weight basis). The highest fat content value of the vegetable oil-packed sample may be attributed to the vegetable oil in which the sample was packed. In a report, smoked oyster canned in oil had the result for the lipid content 7.19%, and was 52.9% more in the oil packed sample than in the tomato sauce pack at the same sampling period. Sample canned in brine had 4.46% (Chellappan, 1989). Fat content of 2.10% in oyster was reported by Kontaminas *et al*. (2021). The smoked oyster meat canned in tomato sauce had 5.29%. The fat content of the samples were low and typical of molluscs. The values were close to some canned sea foods – shellfishes, molluscs. The fat content of bivalve specie like oyster, *Paphia undulata* canned in tomato sauce ranged from 8.49% to 14.96% (Abd-El-Aziz, 2021). The results were higher than results for tomato sauce-filled samples recorded in this study. This may be attributed to species, location and possibly, maturity. It is well known that the fat of marine organisms, including bivalve molluscs, is rich in biologically active polyunsaturated fatty acids—eicosapentaenoic acid (EPA C20:5 n-3) and docosahexaenoic acid (DHA C22:6 n-3). This makes the lipids in the molluscs, despite their low content, valuable for the food industry (Fernández-Reiriz *et al*., 2006; Kawashima and Ohnishi, 2014; Saito, 2014). Fat is important in sensory perception, as it facilitates flavor and palatability of a product. This is however not popularized with mollusc meats. According to Brown *et al*. (2008), relatively less emphasis has been placed on the lipid profile of abalone meat and its relationship to taste. This was perhaps because of the low oil content of abalone, typically 1% to 2% of wet weight (Hatae *et al*. 1995, Dunstan *et al*. 1996). Hence, the low lipid contents of the oyster and

whelk samples may not, on their own, be considered in the light of significant influence on taste of the samples.

The lowest and highest values of carbohydrate content were observed in oyster in tomato sauce and clam in vegetable oil, respectively. The result for the clam in oil sample was much probably as a result of the low moisture content. Results observed in this study were within the range of values reported by earlier studies. Balachandran *et al*. (1984) reported that farmed oyster canned using 2% brine, vegetable oil and tomato sauce as the filling media, had a mean glycogen (the form of carbohydrate in molluscs) content of 2.66%, while 3.4% glycogen content was recorded in meat of oyster fished from the wild, canned using 2% brine and vegetable oil. Chellappan (1989) reported that the smoked oyster meat canned in oil had higher glycogen (carbohydrate) values and better stability than the same sample packed in oil. With value obtained for the sample in oil being 12.07%, sample canned in tomato sauce had glycogen (carbohydrate) content 1.8% more than for the oil packed meat of the same storage period. The values of glycogen for brine packed samples were found to have decreased from 7.638% to about 6.800%. After canning in brine the values decreased to 5.48%. The carbohydrate content of the tomato sauce may have contributed to its higher value. A carbohydrate content of 5.60% was reported by Kontaminas *et al*. (2021) for canned oyster. The carbohydrate content of canned bivalve specie, clam, *Paphia undulata* packed in tomato sauce ranged between 4.82% and 9.74% (Abd-El-Aziz, 2021). The difference with results obtained here may be attributed to species, location and possibly, maturity and harvesting time, according to some variables listed by Abd-El-Aziz (2021). Besides caloric value, the carbohydrate content of molluscs has been, however unpopular, linked with a sensory attribute. According to study, glycogen improved the characteristic taste of abalone, although tasteless itself. The contribution of glycogen to taste is however unclear (Brown *et al*., 2008). In scallop muscle, glycogen was reported to elevate ''continuity, fullness, complexity, and overall preference." However, Carefoot *et al*. (1993) found an Asian sensory panel could not discriminate between meats of a species of abalone, *Haliotis kamtschatkana* with low or high glycogen content.

CONCLUSION

The results of the chemical properties obtained after processing the samples into canned sea food products have shown that producing canned periwinkle, clam, oyster and whelk with different filling media without compromised chemical quality was achieved. The periwinkle, clam, oyster and whelk had high moisture, high protein and ash contents and low fat and carbohydrate contents. None of the samples had monopoly of richness in the macro nutrients. Canned shellfish samples are not high acid foods. Canning the shellfish in vegetable oil, tomato sauce and brine would deliver products with uncompromised chemical properties. However, brine medium offered the least impact and concerns of lipid oxidation. Considering the high consumption and enormous nutritional values of the samples, they should be produced into shelf-stable forms through canning.

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