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Estimation of nutritional energy values, mineral ratio and mineral safety index in the Royal spiny lobster, *Panulirus regius* (De Brito Capello, 1864)

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ABSTRACT

Royal spiny lobster is a marine crustacean with a significant economic value as a popular consumer product. However, information on the energy-providing nutrients of lobster is scarce, especially on those living in the southern coast of Nigeria. This study provides information about the nutritional quality and metabolizable energy of flesh and shell of the Royal spiny lobster, *Panulirus regius*. Proximate and mineral compositions were analyzed, while energy contributions, mineral ratio and mineral safety index were estimated. Higher concentrations of moisture, crude protein and fat were recorded in flesh, while crude fibre, total ash, and nitrogen free extract were more in shell. The proximate with the highest values were crude protein (57.71 $g100g^{-1}$) and total ash (40.67 $g100g^{-1}$) in flesh and shell samples, respectively. The flesh had higher total metabolisable energy (1375 kJ $100g^{-1}$) and utilizable energy due to protein (38.62). The minerals, with the exception of Na, were concentrated more in the shell. In the flesh sample, Na/K and Na/Mg ratios were within the acceptable ideal range of 1.4 - 3.4 and 2 – 6, respectively, while other ratios were below ideal range. In shell samples, Ca/K (3.55) was within the ideal range of 2.2 - 6.2, while Ca/P (5.23) was higher than the reference balance of 2.6. Mg in shell sample was the only mineral whose safety index value (21.85) was higher than the table value (15) with negative difference (-6.85). K, P and Na showed negative relationships with all the proximate compositions except for the moisture and protein in shell sample, while only K showed positive relationships with moisture (r = 0.68), protein (r = 0.63), fat (r = 0.64) and nitrogen free extract (r = 0.17) in the flesh sample. The flesh and shell of the lobster will be good alternative sources of nutrients in human diet and animal feed, respectively.

Introduction

Lobsters are the focus of valuable fisheries worldwide; they are often regional icons and one of the most researched aquatic animals (Phillips et al., 2013). Lobster catches continued to be reported at more than 300,000 tonnes, following the highest catches of 316000 tonnes reported in 2016 (FAO, 2020). The Royal spiny lobster (*Panulirus regius*), a member of the family Palinuridae, is a marine species of lobsters that command a high commercial value in the Gulf of Guinea. In Nigeria, the species is caught as by-catch by trawlers. The genus *Panulirus* is of interest to biologists because of its high level of biodiversity and its wide geographic dispersal, while it is also important as a fisheries commodity in Nigeria (Lawal-Are et al., 2018a).
Crustaceans supply good quality proteins, lipids and essential dietary elements, which are beneficial in maintaining physio-biochemical activities in human

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being (Banu et al., 2016). Crustaceans gulp omega–3 fatty acids from their phytoplankton foods which serve as primary producers of fatty acids (Mili et al., 2013; Moruf and Akinjogunla, 2019). Polyunsaturated fatty acids such as docosahexaenoic acid, docosapentaenoic acid and eicosapentaenoic acid in the oil of aquatic animals, have been linked to the prevention of many cancerous and cardio vascular diseases (Marchioli, 2002; Sidhu, 2003). Royal spiny lobster as a proteinase crustacean has become one of the most favourite seafoods that commands a high price in the restaurants (Haryono et al., 2018). Lobster is a type of crustacean that is typically prepared by boiling or steaming. It can be eaten as a main course, enjoyed as a sandwich filler, or added to rich dishes like pasta, mashed potatoes, and eggs.

The potential use of *P. regius* is encouraged by the fact that it can be used for different purposes. Lobster species, in general, can be used to prepare diet supplements, to obtain chitin, and as a source of astaxanthin for aquaculture (García-López et al., 2016; Varisco et. al., 2020). Although nutritional status of different species of lobsters has been dealt with in various parts of the world (Floreto et. al., 2000; Ayanda et. al., 2018; Haryono et. al., 2018; Varisco et. al., 2020), details on energy-providing nutrients of *P. regius* are scarce. Therefore, the aim of this study was to analyse the proximate and mineral compositions, gross energy, proportion of energy due to nutrients, mineral ratio and mineral safety index (MSI) in flesh and shell of the Royal spiny lobster, *P. regius,* from the Lagos Harbour, Nigeria.

Materials and methods

Study area

The 2km wide Lagos Harbour with an average depth of 7.5 meters, has a global positioning system closed to Commodore Channel (6° 39' 16"N and 3° 40' 11" E) in Lagos State, Nigeria (Lawal-Are et al., 2018a). The Lagos Harbour, which is a marine environment, is an inlet from the Atlantic Ocean. The sampling station lies along the eastern part of the Lagos Harbour, the commodore channel which is at the mouth to the Atlantic Ocean.

Sample collection

Wet samples (60.6 g - 198.6 g) were obtained from commercial trawl catches at the landing site, between May and October 2019. To remove adhering contaminants, the lobsters were thoroughly washed with water and immediately brought to the Marine Science Laboratory, University of Lagos for identification and further analyses.

Laboratory procedure

After removing from freezer, samples were allowed to thaw for one hour, separated into fillet extract and shell. The various parts were dried at 105 °C and homogenised. The analyses of the moisture, ash, protein, fat and carbohydrate contents were determined using the methods described by AOAC (2006). Mineral components were evaluated from solution obtained by first wet-ashing the samples and dissolving the ash with de-ionized water and concentrated hydrochloride acid in standard flask. The solution was analyzed for mineral content using Atomic Absorption Spectrophotometer. Phosphorus was analyzed by employing the method of Vanado Molybate and read on colourimeter (Santoso, 2006).

Statistical data analysis

Results were expressed as means, standard deviations (SD) and coefficient of variation per cent (CV %). Each value was a mean of six (6) replications for proximate and mineral compositions. Pearson Correlation Coefficient was conducted to establish the relationships between the compositions at $p \leq 0.05$ level of significance. Data were analyzed using SPSS statistical software version 22. Mineral ratio and MSI were calculated according to formulae described by Santoso (2006) and Hatcock (1985), respectively.

Results and discussion

Aquatic animal foods have good quality proximate contents with highly digestible protein richer in essential amino acids and several peptides than in terrestrial meat proteins (Khalili and Sampels, 2018). Table 1 presents the proximate composition of the Royal spiny lobster, *P. regius,* on dry matter basis. Important results were (g/100 g): protein (11.67 - 57.71) having a CV% of 93.85; total ash (10.9 - 40.67) with CV% of 81.64; carbohydrate (6.01 - 26.55) with CV% of 89.21; moisture (13.01 - 15.01) with CV% of 10.09. Crude fibre of 2.47 - 7.27 g/100 g having 69.69 CV% while crude fat had the highest level of CV% (114.50) with mean of 4.36 g/100 g. The values of the CV% were generally high, ranging between 10.09 and 114.50, indicating heterogeneous relationships of proximate compositions of shell and flesh of the Royal spiny lobster.

Table 1. Proximate contents of shell and flesh of *Panulirus regius* on a dry matter basis

Parameters (g/100 g)	Shell	Flesh	Mean	SD	CV%	D	% D
Moisture	13.01	15.01	14.01	1.41	10.09	-2.00	-15.37
Protein	11.67	57.71	34.69	32.56	93.85	-46.04	-394.52
Crude Fat	0.83	7.89	4.36	4.99	114.50	-7.06	-850.60
Crude Fibre	7.27	2.47	4.87	3.39	69.69	4.80	66.02
Total Ash	40.67	10.90	25.79	21.05	81.64	29.77	73.20
Carbohydrate	26.55	6.01	16.28	14.52	89.21	20.54	77.36

Keys: Standard deviation (SD), Coefficient of variation per cent (CV%), Difference between shell and flesh (D), Percentage difference (D).

Table 2. Energy value contributed by nutrients in the shell and flesh of *Panulirus regius*

Energy	Unit	Shell	Flesh	Mean	SD	CV%
TE	kJ/100 g	680	1375	1027.5	491.44	47.83
	kcal 100 g	160	326	243	117.38	48.3
PEF	% (kJ/100 g)	2.1(31)	19.2(292)	10.65	12.09	113.54
	% kcal/100 g)	2.1(7)	19.6(71)	10.85	12.37	114.05
PEC	% (kJ/100 g)	30.2(451)	6.7(102)	18.45	16.62	90.07
	% kcal/100 g)	29.9(106)	6.6(24)	18.25	16.48	90.28
PEP	% (kJ/100 g)	13.3(198)	64.4(981)	38.85	36.13	93.01
	% (kcal/100 g)	13.1(47)	63.8(231)	38.45	35.85	93.24
UEDP%	kJ	7.95	38.62	23.29	21.69	93.14
	kcal	7.89	38.26	23.08	21.47	93.07

Keys: Total energy (TE), Proportion of total energy due to fat (PEF), Proportion of total energy due to carbohydrate (PEC), Proportion of total energy due to protein(PEP), utilization of energy value due to protein (UEDP%), Standard deviation (SD), Coefficient of variation per cent (CV%).

The flesh protein content in the present study is generally much higher compared with the five species of spiny lobsters in the same genus as reported by Haryono et al. (2015), where *P. versicolor* contained protein of 20.24 g/100 g, *P. ornatus* 22.34 g/100 g, *P. longipes* 22.83 g/100 g, *P. penicullatus* 23.81 g/100 g and *P. homarus* at 24.18 g/100 g. The same is not observed in the carbohydrate content as the value of flesh carbohydrate is much lower compared to values (g/100 g) of 50.73, 52.55, 55.08, 55.68 and 56.38 for *P. longipes, P. versicolor*, *P. penicullatus*, *P. homarus* and *P. ornatus,* respectively (Haryono et al., 2015).

In the present study, the mean crude fat (7.89 g/100 g) of the flesh sample can be considered as low fat nutritional source. Three proximate parameters (crude fibre, total ash and carbohydrate) were more positive towards the shell sample and the other three parameters (moisture, protein and crude fat) were more positive towards the flesh sample, similar to the report of Moruf et al. (2019) on the flesh and shell of *Callinectes amnicola* from the coastal waters of Lagos, Nigeria. The preponderance shows the nutrients abundance in different parts of the lobster.

The percentage energy contribution from nutrients is contained in Table 2. Total energy (metabolisable) ranged between 1680 and 1375 kJ/100 g (160 - 326 kcal/100 g). In the lobster's flesh, the proportion of energy from protein (PEP) was the highest (64.4%), while the least energy contribution was from carbohydrate (PEC = 6.7%). As for lobster's shell, PEC was the highest (30.2%), while the least contribution came from fat (PEF = 2.1%). Generally, CV% was high (47.83-114.05). Utilizable energy due to protein (UEDP %) (60% of protein energy utilization assumed) was higher in flesh (38.62) than in shell (7.95) in a multiple of five times. The values of total metabolisable energy were comparable to 1142 kJ/100 g reported for *Callinectes latimanus* (Adeyeye et al., 2014). In the lobster flesh, the trend of energy contributed, PEP% > PEF% > PEC% was similar to the trend in *Neopetrolisthes maculatus* (Adeyeye and Jegede, 2017).

Table 3 presents mineral contents of shell and flesh of the Royal spiny lobster, *P. regius*. The total mineral values were 2453.62 mg/100 g (shell) > 916.00 mg/100 g (flesh). The shell was higher in mineral content than the flesh with the exception of Na (188.33 - 327.85 mg/100 g). This result was in contrast to the mineral trend reported for *C. amnicola,* where crab flesh was Na > K > Ca > Mg, while the crab shell was Ca > Na > K > Mg; but comparable in mineral values, as the shell of the crab also had higher values than the flesh (Moruf et al., 2019). Differences in percentage values in the present study ranged from 5.28 - 94.44, where the least was from P and the highest from Ca. Four (4) of the parameters (Ca, Mg, K and P) had differences more positive towards shell, while a parameter (Na) had value more positive towards the flesh sample. According to Lawal-Are et al. (2018b), a number of factors, seasonality, biological differences, food source and body parts, influence mineral concentrations in shellfish.

Table 3. Mineral content of shell and flesh of the Royal spiny lobster, *Panulirus regius*

Mineral (mg/100 g)	Shell	Flesh	Mean	SD	CV%	D	% D
Ca	1142.23	63.51	602.87	762.77	126.52	1078.72	94.44
Mg	582.76	84.38	333.57	352.41	105.65	498.38	85.52
K	321.8	233.20	277.5	62.65	22.58	88.6	27.53
P	218.5	207.06	212.78	8.09	3.8	11.44	5.24
Na	188.33	327.85	258.09	98.66	38.23	-139.52	-74.08
Total	2453.62	916.00	1684.81	1087.26	64.53	1537.62	62.67

Keys: Standard deviation (SD), Coefficient of variation per cent (CV%), Difference between shell and flesh (D), Percentage difference (% D).

Table 4. Mineral ratio in shell and flesh of the Royal spiny lobster, *Panulirus regius*

Parameters	Ideal	Ideal range	Shell	Flesh	Mean	SD	CV%
Ca/Mg	7	3.0-11.0	1.96	0.75	1.36	0.85	62.94
Ca/P	2.6	1.5-3.6	5.23	0.31	2.77	3.48	125.75
Ca/K	4.2	2.2-6.2	3.55	0.27	1.91	2.32	121.27
Na/K	2.4	1.4-3.4	0.59	1.41	1.00	0.58	58.29
Na/Mg	4	2.0-6.0	0.32	3.89	2.10	2.52	119.70
[K/(Ca+Mg)]	2.2		0.45	1.84	1.15	0.98	85.84

Keys: SD: Standard deviation, CV%: Coefficient of variation per cent.

Table 5. Mineral safety index (MSI) in the shell and flesh of the Royal spiny lobster, *Panulirus regius*

Mineral	RAI (mg)	MSItv	Shell MSIcv	D	%D	Flesh MSIcv	D	%D	Mean	SD	CV%
Ca	1200	10	9.52	0.48	4.81	0.53	9.47	94.71	5.02	6.36	126.52
Mg	400	15	21.85	-6.85	-45.69	3.16	11.84	78.91	12.51	13.22	105.65
P	1200	10	1.82	8.18	81.79	1.73	8.27	82.75	1.77	0.07	3.80
Na	500	4.8	1.81	2.99	62.33	3.15	1.65	34.43	2.48	0.95	38.23

Keys: Recommended adult intake (RAI), MSI Table value (MSItv), MSI calculated value (MSIcv), Difference between MSItv and MSIcv (D), Percentage difference (% D), Standard deviation (SD), Coefficient of variation percent (CV%).

Determining the interrelationship between nutritional composition is much more than estimating the mineral concentrations only (Watts, 2010). The mineral ratio is presented in Table 4. In the flesh sample, Na/K and Na/Mg ratios were within acceptable ideal range of 1.4-3.4 and 2–6, respectively, while other ratios were below ideal range. In the shell samples, Ca/K (3.55) was within ideal range of 2.2-6.2, while Ca/P (5.23) was greater than the ideal of 2.6. All other significant ratios have their values less than the ideal range just as observed in *N. maculatus* (Adeyeye and Jegede, 2017).

Table 5 contains the mineral safety index (MSI) of the Royal spiny lobster. Mg in shell sample was the only mineral whose MSI value (21.85) was greater than the MSI tabulated (15), thereby having negative difference (-6.85), while other minerals gave positive differences. The negative difference (in shell) indicates overloading to the tune of 45.69%, comparable to high levels of Mg as observed for *N. maculatus* (Adeyeye and Jegede, 2017). MSI calculated < MSI tabulated/standard means mineral non-overload/non-toxic when the sample is consumed (Adeyeye and Adubiaro, 2018).

The relationship matrix showed some important correlations between the investigated proximate and mineral compositions. Table 6 showed the correlation for shell of Royal spiny lobster in which there were approximately perfect positive relationships between crude protein and Na (r = 0.96) and between crude fat and Ca (r = 0.97). Similar relationship was exhibited by fibre with Ca (r = 0.94), total ash with Mg (r = 0.98) and NFE with Ca (r = 0.94) with significance at 0.05 level. K, P and Na showed negative relationship with all the proximate parameters except for moisture and protein. In the flesh sample (Table 7), only K showed positive relationship with moisture (r = 0.68), protein (r = 0.63), fat (r = 0.64) and NFE (r = 0.17). All other minerals exhibited negative relationship with all the proximate parameters. The result is in contrast with Oluwole et al. (2020), who reported perfect positive relationships between proximate and mineral compositions of *Cardiosoma armatum*.

Table 6. Correlation coefficient between proximate and mineral compositions in the shell of Royal spiny lobster, *Panulirus regius*

	Moisture	*Protein*	*Fat*	*Fibre*	*Ash*	*NFE*	*Ca*	*Mg*	*K*	*P*	*Na*
Moisture	1										
Protein	0.99	1									
Fat	-0.99	-0.97	1								
Fiber	-0.98	-0.93	0.99	1							
Ash	-0.61	-0.47	0.65	0.76	1						
NFE	-0.98	-0.93	0.98	0.99	0.76	1					
Ca	-0.99	-0.99	0.97	0.94	0.49	0.94	1				
Mg	-0.44	-0.29	0.49	0.61	0.98	0.62	0.31	1			
K	0.93	0.86	-0.95	-0.99	-0.85	-0.98	-0.87	-0.73	1		
P	0.76	0.64	-0.79	-0.87	-0.98	-0.87	-0.65	-0.92	0.94	1	
Na	0.99	0.96	-0.99	-0.99	-0.69	-0.99	-0.97	-0.54	0.97	0.82	1

Table 7. Correlation coefficient between proximate and mineral compositions in the flesh of Royal spiny lobster, *Panulirus regius*

	Moisture	*Protein*	*Fat*	*Fibre*	*Ash*	*NFE*	*Ca*	*Mg*	*K*	*P*	*Na*
Moisture	1										
Protein	0.99	1									
Fat	0.99	0.99	1								
Fibre	0.69	0.74	0.73	1							
Ash	0.57	0.64	0.62	0.99	1						
NFE	0.84	0.88	0.87	0.97	0.93	1					
Ca	-0.50	-0.57	-0.55	-0.97	-0.99	-0.90	1				
Mg	-0.50	-0.57	-0.55	-0.97	-0.99	-0.90	1	1			
K	0.68	0.63	0.64	-0.06	-0.21	0.17	0.29	0.29	1		
P	-0.65	-0.71	-0.70	-0.99	-0.99	-0.96	0.98	0.98	0.11	1	
Na	-0.36	-0.43	-0.41	-0.92	-0.97	-0.81	0.99	0.99	0.44	0.95	1

Conclusion

The flesh sample of the Royal spiny lobster, *Panulirus regius,* was higher in important proximate parameters, while the shell sample was of higher mineral content. The Mg (shell) might give mineral overload if not properly balanced with other minerals in feed formulation. However, our findings revealed that the flesh and shell of the lobster will be good alternative sources of nutrients in human diet and animal feed, respectively. While our results are novel, further research is needed on the variations of other nutritional compositions like amino and fatty acids profile in this lobster.

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