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Nutrient compositional variation and interrelationship in the muscle of wild and plastic-reared brachyuran

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ABSTRACT. Edible brachyurans are recognized as a popular source of food due to their delicious taste and nutritional quality. This study investigated the nutrient compositional variation and interrelationship in the muscle of wild and plastic-reared *Cardisoma armatum*. The plastic-reared crab had 27.81 ± 2.29 g 100 g^{-1} protein while crab from the wild contained 22.45 ± 2.65 g 100 g^{-1} protein. The difference in protein content of plastic-reared and its counterpart from the mangrove swamp was not significantly different ($p > 0.05$). This is also true of other proximate composition except that wild crabs were slightly higher in both crude fat (2.68 ± 0.35 g 100 g^{-1}) and carbohydrate (5.89 ± 3.05 g 100 g^{-1}). Generally, the total energy contributed due to protein, carbohydrate and fat in the tissues of both wild and plastic-reared *C. armatum* are similar. In the wild crab, contents of calcium (16083.27 ± 2127.90 mg 100 g^{-1}) and phosphorus (1191.42 ± 199.21) were relatively higher, while contents of magnesium (368.69 ± 111.05 mg 100 g^{-1}), sodium (125.30 ± 11.18 mg 100 g^{-1}) and potassium (87.36 ± 7.27 mg 100 g^{-1}) were relatively higher in plastic-reared crabs. All significant mineral ratios in wild and plastic-reared *C. amartum* fall within acceptable range. The positive relationship in the nutritional quality indicates that changes in proximate composition are associated with changes in mineral contents of the crab tissue.

Keywords: crab; crustacean; culture; nutritional quality; Lagos lagoon.

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Introduction

Brachyurans (true crabs) have flourished predominantly in the invertebrate fauna due to its ubiquitous existence in almost all part of the world oceans, fresh water, and even on land (Lawal-Are, Moruf, Oluseye-Are, & Isola, 2019a). Many species actively forage on land and several species have become semi-terrestrial. Among the semi-terrestrial brachyurans, the burrowing crabs are possibly one of the most important components of mangrove fauna not only because of their burrowing activities which can affect nutrient cycling and forest productivity but also their role as a link in the food web in mangrove ecosystems (Moruf & Ojetayo, 2017; Sanni, Moruf, & Lawal-Are, 2020).

As burrowing crabs, the genus *Cardisoma* show significant behavioural, morphological, physiological and biochemical adaptations permitting extended activities out of water (Moruf, Durojaiye, & Taiwo, 2021a). *Cardisoma* could feed on leaves, fruits and grasses collected near the vicinity of their burrows. These crabs will also feed on insects, worms and are sometimes cannibalistic. The population of this genus is heavily influenced by water temperature in areas where water temperature falls below 20°C in winter; larval survival is affected (Oluwole, Moruf & Lawal-Are, 2020). The Land Crab, *Cardisoma armatum* cohabits in the mangrove swamp of Abule-Agege Creek of Lagos where they are harvested by locals for domestic markets (Lawal-Are, Moruf, Akubueze & Adewole, 2019b).

In Nigeria, a number of brachyuran species are present for human consumption and a tremendous variety of species are popular food source because of their delicious taste, unique and pleasant aroma, and nutritional quality (Moruf, Saba, Chukwu-Osazuwa, & Elegbede, 2019; Moruf & Lawal-Are, 2019; Lawal-Are, Moruf, Sanni, & Chukwujindu, 2020; Moruf, Ogunbambo & Moruf, 2020). As living standards improve, people start to pay more attention to the nutritional value and quality of food. Typically, there is a large difference in nutrient contents between wild and farmed aquatic animals consumed by humans, owing to environmental and dietary factors (He et al., 2017). Several studies have reported these differences in wild and farmed crabs (Kong et al., 2012; Wu et al., 2020). However, there is no detailed information about the nutrient compositional variation of the wild-caught and cage-cultured brachyurans in Nigeria. Hence, the present study was planned to quantify the nutrient differences in market-size wild-caught and plastic-reared *C. armatum*, in order to provide useful nutritional information to crab consumers and crab farmers.

Material and methods

Sample preparation

Live crabs (*C. armatum*) were obtained for four weeks in February 2020 from Abule-Agege Mangrove Swamp (Latitude of 6°26"N and 6°39"N and Longitude of 3°29"E and 3°50"E) in Lagos State, Nigeria. The specimens were divided into market-size group and juvenile group. The market-size specimens (80 ± 0.07 g) were taken to the laboratory as wild-caught, while culture experiment was conducted on the juveniles at the Department of Marine Sciences, University of Lagos. The juveniles were then selected and randomly stocked into eight small plastic tank (length × width × depth = 8 m × 8 m × 1.5 m) at a 4 crabs per tank, while allowed to acclimatize for a week before the commencement of the experiment. The crabs were fed with Trash Fish (*Sardinella aurita*) once daily, the amount of which was approximately 2.2 % of the total weight of crabs held in the plastic. A water depth of 20 cm was maintained with 50 % water in each plastic, exchanged every 3 days over the period of the 3 months experiment when the crabs attain a similar body weight of the wild-caught crabs. The subjects were dissected, and their muscle tissues were weighed. Each sample was freeze-dried, separately homogenized, and separately stored at −20°C for further analysis.

Laboratory analysis

The analyses of moisture, ash, protein, fat and carbohydrate contents were determined as described by Association of Official Analytical Chemists (AOAC, 2006). The calorific values were calculated by multiplying the crude fat, protein and carbohydrate by the Atwater factors of 37, 17 and 17 respectively (Merrill & Watt, 1955). For the mineral determination, the samples were digested in HNO_3/HCl while some elemental parameters namely Ca, P, Mg, Na and K were measured by a Varian Spectra Atomic absorption spectrophotometer (AAS), Buck Scientific 210 GVP model following the procedure reported by Santoso, Yoshie-Stark and Suzuki (2006). Mineral ratio was calculated according to Watts (2010).

Statistical analysis

With the aid of SPSS statistical software version 22, mean and standard error were derived by subjecting data to descriptive analysis while Pearson Correlation Coefficient was used to find the relation between the variables at significant level of $p \leqslant 0.05$.

Results and discussion

The proximate composition of wild and plastic-reared brachyuran (*C. armatum*) is presented in Table 1. The plastic-reared crab had 27.81 ± 2.29 g 100 g^{-1} protein while the same crab from the wild contained 22.45 ± 2.65 g 100 g^{-1} protein. The difference in protein content of plastic-reared and its counterpart from the wild was not significantly different ($p = 0.20$, $p > 0.05$). This is also true of fat. Plastic-reared crab had a crude fat of 2.50 ± 0.66 g 100 g^{-1} while in wild crab, crude fat was slightly higher (2.68 ± 0.35 g 100 g^{-1}). For crude fiber, plastic-reared crab had 0.16 ± 0.08 g 100 g^{-1} as against 0.10 ± 0.08 g 100 g^{-1} in wild crab. The difference was insignificant ($p > 0.05$). This is also true of total ash content, of which a value of 8.71 ± 3.67 g 100 g^{-1} was found in crab from the plastic as against 6.35 ± 2.47 g 100 g^{-1} from wild, which does not differ statistically. Plastic-reared crab had a carbohydrate of 4.95 ± 2.52 g 100 g^{-1} while in wild crab, crude fat was slightly higher (5.89 ± 3.05 g 100 g^{-1}) with insignificant difference. This result is comparable to the report of Ezeafulukwe et al. (2015), which states that the proximate composition of wild and pond reared *Clarias gariepinus* varied significantly only in terms of fat. The result does not however support the findings of He et al. (2017), on nutritional quality of three edible tissues of the wild-caught and pond-reared swimming crab (*Portunus trituberculatus*). Moreover, differences in proximate chemical composition between the wild-caught and pond-reared *P. trituberculatus* crabs were mainly observed in hepatopancreas and ovary, performing higher protein but lower lipid contents in three tissues of pond-reared crab. The difference might be as a result of variety of factors including size, species, weight and types of food. Wild-caught crab mainly eats debris, plankton and small benthos, whereas pond-reared crab is mostly fed with man-made diets and trash fish. The result of the present study has revealed that environment does not significantly change the proximate composition of *C. armatum*.

Table 1. Proximate composition in wild and plastic-reared *Cardisoma armatum*.

Parameter (%)	Wild	Plastic-reared	*p*-value
Moisture	62.55 ± 6.03 (50.80-70.8)	55.88 ± 6.83 (42.70-65.56)	0.50
Crude Protein	22.45 ± 2.65 (17.26-25.95)	27.81 ± 2.29 (23.50-31.31)	0.20
Crude Fat	2.68 ± 0.35 (2.00-3.18)	2.50 ± 0.66 (1.20-3.30)	0.82
Crude Fiber	0.10 ± 0.08 (0.00-0.25)	0.16 ± 0.08 (0.06-0.31)	0.59
Total Ash	6.35 ± 2.47 (1.85-10.35)	8.71 ± 3.67 (2.11-14.80)	0.62
Carbohydrate	5.89 ± 3.05 (0.37-10.9)	4.95 ± 2.52 (0.36-9.04)	0.82

Generally, the total energy (TE) as contributed by the proportion of total energy due to protein (PEP), proportion of total energy due to carbohydrate (PEC) and proportion of total energy due to fat (PEF) in the tissues of both wild and plastic-reared *C. armatum* are similar (Figure 1). In addition, non-significant differences ($p > 0.05$) were observed between wild and plastic-reared crabs. However, wild crab was slightly higher in PEF (99.04 kJ 100 g^{-1}) and PEC (100.07 kJ 100 g^{-1}), but lower in PEP (381.59 kJ 100 g^{-1}) and TE (580.70 kJ 100 g^{-1}) compared to plastic-reared crab. The higher PEP (472.71 kJ 100 g^{-1}) in plastic-reared *C. armatum* indicates that protein concentration in terms of energy would be more than enough to prevent protein energy malnutrition in children and adults fed solely on the plastic-reared crabs as main source of dietary protein. The energy values found in this present study are comparable to the range of 309.11- 344.94 kJ 100 g^{-1} for imported shellfish species (Lawal-Are, Moruf, Ojeah, Taiwo, & Aligbeh, 2021).

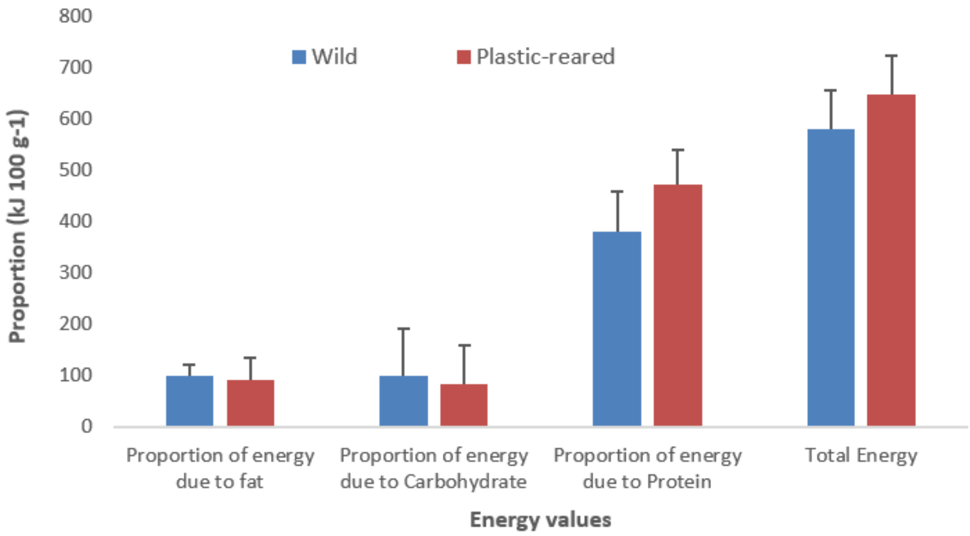

Figure 1. Energy values in wild and plastic-reared *Cardisoma armatum*.

Mineral content in both wild and plastic-reared *C. armatum* is shown in Table 2. In wild crab, contents of calcium (16083.27 ± 2127.90 mg 100 g^{-1}) and phosphorus (1191.42 ± 199.21) were relatively higher, while contents of magnesium (368.69 ± 111.05 mg 100 g^{-1}), sodium (125.30 ± 11.18 mg 100 g^{-1}) and potassium (87.36 ± 7.27 mg 100g^{-1}) were relatively higher in plastic-reared crab. The difference in mineral content of plastic-reared crab and its counterpart from the wild was not significantly different ($p > 0.05$). The results agree well with the report of Oluwole et al. (2020) on the mineral profile of *C. armatum* fattened with trash fish and formulated diet.

Table 3 shows some significant mineral ratios in wild and plastic-reared *C. amartum*. Ideally, Ca/Mg should be a 7:1 ratio of calcium relative to magnesium. In other words, there should be found 7 times more calcium relative to magnesium found in the diet. However, the ideal or preferred range can vary from 3.0 to 11.0. The sample results gave respective ratios of 9.63 and 3.00 for wild and plastic-reared crabs, which are within the ideal range. This means that both wild and plastic-reared *C. amartum* can stand as the only source of calcium in a diet. Calcium and magnesium appear to have a synergistic relationship in the body. Each can affect both the absorption and excretion of the other. According to Nadler et al. (2018), magnesium deficiency alters the cellular calcium levels in animal system. Also, the negative calcium balance in the body can be reversed by consuming more magnesium (Kelly, Gilman, & Ilich, 2018).

Table 2. Mineral content of wild and plastic-reared *Cardisoma armatum*.

Parameters (mg 100 g^{-1})	Wild	Plastic-reared	p-value
Calcium	16083.27 ± 2127.90 (12334.12-19701.91)	14676.73 ± 421.45 (13890.30-15332.65)	0.55
Magnesium	260.98 ± 57.34 (179.16-371.48)	368.69 ± 111.05 (480.28-479.19)	0.44
Sodium	93.59 ± 13.05 (67.50-106.69)	125.30 ± 11.18 (134.44-138.40)	0.14
Potassium	74.93 ± 5.15 (68.13-85.03)	87.36 ± 7.27 (91.37-97.46)	0.24
Phosphorus	1191.42 ± 199.21 (809.21-1479.93)	1145.02 ± 151.50 (1347.71-1238.72)	0.86

Table 3. Mineral ratio in wild and plastic-reared *Cardisoma armatum*.

Parameter	(Ref. balance)	Acceptable ideal range	Wild	Plastic-reared
Ca/Mg	7	3 to 11	9.63	3.00
Ca/P	2.6	1.5 to 3.6	2.11	0.97
Na/K	2.4	1.4 to 3.4	3.87	2.60
Na/Mg	4	2 to 6	3.04	2.24

In the present study, Ca/P of wild crab (2.11) falls within the acceptable range of 1.5 to 3.6 while 0.96 value of plastic-reared crab was slightly below the ideal range. However, these values were much higher than 0.5, which is the minimum requirement for favourable Ca absorption in the intestine and for bone formation (Adeyeye, 2014). Ca:P is an important determinant of calcium absorption and retention due to the regulatory mechanisms, which control calcium and phosphorus homeostasis within the body (Loughrill, Wray, Christides, & Zand, 2017). Hypothetically, high calcium/phosphorus intake ratio might be needed to the optimal bone health.

The ratios Na/K (2.60-3.87) and Na/Mg (2.24-3.04) in the investigated samples fall within the recommended values of 1.4 - 3.4 and 2-6 respectively. This is similar to the observations on the flesh of the Royal Spiny Lobster, *Panulirus regius* (Moruf, Afolayan, Taiwo, & Ogunbambo, 2021b). Na is regulated by the adrenal hormones and an elevated ratio indicates increased adrenal cortical activity. Mg deficiency is known to increase the stress response. The stage of stress can be determined when viewing the Na/K ratio in relation to the Na/Mg ratio. Heavy metals such as cadmium and lead can affect the Na/K relationship due to their affect upon renal function (Watts, 2010). The nutritional minerals such as calcium, phosphorus, copper, iron, manganese, magnesium and others will impact the Na/K ratio as well. According to McDonough, Veiras, Guevara and Ralph (2017), raising dietary potassium to sodium ratio to recommended level helps reduce heart and kidney diseases.

The correlation coefficient between the proximate and mineral compositions of wild and plastic-reared *C. amartum* are shown in Table 4 and Table 5 respectively. In the wild crab, protein had positive correlation with all the investigated minerals except Ca (-0.73) and Mg (-0.36). The same is true of crude fat. Similar result was observed in the plastic-reared crab, where positive relationships exist between the proximate and mineral compositions with the exception of Ca, which exhibited negative association with crude protein (-0.52) and crude fat (-0.85). Total ash and carbohydrate had a negative association with all the minerals (except Ca) in the plastic-reared crab. This result does not agree well with Lawal-Are, Moruf and Afolayan (2018) who reported a positive correlation between total ash and mineral elements in whole and fillet of the Guinean Mantis Shrimp, *Squilla aculeata calmani* harvested from Lagos Lagoon. In the present study, the positive relationship in the nutritional quality indicates that changes in proximate composition are associated with changes in mineral contents of the crab tissue. However, correlation does not mean that the changes in proximate composition actually cause the changes in the mineral content.

Table 4. Correlations for wild *Cardisoma armatum*.

	Moisture	Crude Protein	Crude Fat	Crude Fiber	Total Ash	CHO	Ca	Mg	Na	K	P
Moisture	1										
Crude Protein	0.91	1									
Crude Fat	0.88	0.99	1								
Crude Fiber	0.14	0.54	0.60	1							
Total Ash	-0.92	-0.68	-0.62	0.24	1						
CHO	-0.93	-0.69	-0.64	0.23	0.99	1					
Ca	-0.95	-0.73	-0.68	0.18	1.00	1.00	1				
Mg	0.54	0.84	0.88	0.91	-0.16	-0.19	-0.24	1			
Na	-0.68	-0.32	-0.24	0.63	0.91	0.90	0.88	0.25	1		
K	0.10	0.50	0.57	1.00	0.29	0.28	0.23	0.89	0.66	1	
P	0.10	0.88	0.85	0.09	-0.94	-0.95	-0.96	0.49	-0.72	0.04	1

Table 5. Correlations for plastic-reared *Cardisoma armatum*.

	Moisture	Crude Protein	Crude Fat	Crude Fiber	Total Ash	CHO	Ca	Mg	Na	K	P
Moisture	1										
Crude Protein	0.82	1									
Crude Fat	0.99	0.89	1								
Crude Fiber	0.07	0.63	0.20	1							
Total Ash	-0.95	-0.59	-0.90	0.26	1						
CHO	-0.94	-0.57	-0.88	0.27	0.99	1					
Ca	-0.92	-0.52	-0.85	0.34	1.00	1.00	1				
Mg	0.97	0.94	0.99	0.33	-0.83	-0.81	-0.78	1			
Na	0.93	0.97	0.97	0.42	-0.77	-0.75	-0.71	1.00	1		
K	0.87	1.00	0.93	0.55	-0.67	-0.65	-0.60	0.97	0.99	1	
P	0.99	0.85	1.00	0.12	-0.93	-0.92	-0.89	0.98	0.95	0.90	1

Conclusion

The results of the present study have revealed that food ecology does not significantly change the proximate composition and mineral content of *C. armatum.*, which might be as a result of like diets used in the experiment. The higher PEP (472.71 kJ 100 g^{-1}) in plastic-reared *C. armatum* indicates that protein concentration in terms of energy would be more than enough to prevent protein energy malnutrition in children and adults fed solely on the plastic-reared crabs as main source of dietary protein. The difference in mineral content of plastic-reared crabs and its counterpart from the mangrove swamp was not significantly different ($p > 0.05$). Overall, both crab types showed good nutritional quality suitable for human dietary needs. In addition, the nutritional quality of wild *C. armatum* can be retained if Trash Fish (*Sardinella aurita*) is used as the culture diet.

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