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Nutritional and functional attributes of raw and grilled crabmeat

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Abstract. *Crab is a good source of animal protein, eaten either as snacks or as part of main meal in Southern Nigeria. The effect of grilling on energy-providing nutrients and functional attributes of Cardiosoma armatum (Herklots, 1851) were determined. The comparison of the raw and grilled crabmeat showed that grilling had considerable effect on the quality of this species. Significant changes (p<0.05) in crude fiber (%), calcium (mg/100g), magnesium (mg/100g), potassium (mg/100g), sodium (mg/100g), and oil absorbing capacity (%) were observed after grilling. Utilizable energy due to protein (60% of protein energy utilization assumed) was comparable in both raw (9.36 kJ/9.27 kcal) and grilled samples (10.92 kJ/10.83 kcal). The ratio, Ca/Mg was high with a little variation between the two samples, having coefficient of variation percent of 12.94%. Only calcium had its Mineral Safety Index (MSI) greater than the standard value for both the raw samples (23.68>10.00) and the grilled samples (13.86>10.00). All the significant energy-providing nutrients have a positive correlation with the investigated minerals except magnesium. Grilling was found to be a suitable cooking process for C. armatum, since it conserved the main energy-providing nutrients and functional characteristics.*

Keywords: crab, meat texture, mineral content, nutritional quality, proximate composition

Introduction

The importation of crabmeat has increased steadily over the past 20 years, with over 300,000 tons of products worldwide (Dima et al., 2016). However, despite the abundance of crabs, the exploitation of this resource in Nigeria is still lagging behind due to lack of scientific and technical information for optimum industrial processing. One of the main ways of commercializing crabmeat is as frozen products. The first stage consists of a thermal treatment that allows the detachment of the meat from the exoskeleton and provides the product with the characteristic color and flavor, coupled to the denaturation of the myofibrillar proteins to determine adequate conditions for the detachment of the exoskeleton from the meat (Dima et al., 2012).

Burrowing crabs of the genus *Cardiosoma*, are important elements in the fauna composition of many tropical coastal ecosystems (Sanni et al., 2020). These crabs belong to the family Gecarcinidae, often large in size and commonly referred to as ‘land crabs’ (or ‚land-dwelling‘ crabs), based on the terrestrial habits shown by adults of most member species (Etchian et al., 2016). Several species actively forage on land and most have become semi-terrestrial (Moruf and Ojetayo, 2017). One of the most elusive (tending to evade grasp) crab species around the brackish environment in Nigeria is the gecarcinid land crab (*Cardiosoma armatun*, Herklots, 1851), which inhabits almost every microhabitat in the mangrove ecosystem. The species cohabit in the mangrove swamp of Abule-Agege Creek of Lagos where they are harvested by locals for domestic markets (Lawal-Are et al., 2019).

Although, most food sources for humans are provided from land animals, recently crabs have been successfully used as another source of food nutrients especially among coastal dwellers in southern parts of Nigeria. Several studies have indicated that crab is an excellent source of minerals, large range of polyunsaturated fatty acids and high quality proteins in their tissues, among other healthy components (Fagbuaro et al., 2013; Moruf and Lawal-Are, 2019; Oluwole et al., 2020). The biochemical analysis provides important information for facilitating the fattening, or processing of crabs and crab products (Baklouti et al., 2013; Wan Yusof et al., 2020).

One of the many relevant factors that influence the consumption of shellfish such as crab, is the quality of the meats (Moruf et al., 2020). More so, nutritional benefits from fin and shellfishes are limited by its rapidly perishable nature and vulnerability to spoilage (FAO, 2016; Amuneke et al., 2020). Different cooking methods such as boiling, grilling, baking, or frying were applied to improve the taste and flavour of food, inactivate pathogens, and increase the duration of preservation (Weber et al., 2008).

Studies of crabmeat quality in term of nutritional parameters such as proximate, mineral, lipid and functional characteristic are usually performed using data obtained from raw crab. Hence, there is limited data regarding the influence of cooking process on the nutritional quality of crab. This study provides new information on the nutritional quality of cooked crab for concerned local consumers.

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Studying the nutritional value of grilled crabs is important to reveal the major changes that may occur on their quantity and quality after cooking. In this work, comparative evaluation on the proximate and mineral composition, proportion of energy due to nutrients, mineral ratios and Mineral Safety Index (MSI) of raw and grilled meat of *Cardiosoma armatum* is reported.

Material and methods

Sample collection and preparation

A total of 120 specimens of the gercacinid crab, *C. armatum* (length: 51.89-62.54 mm; total weight: 21.39-44.47 g) were harvested using bait traps and hand-picked from the University of Lagos Lagoon Coast (6°31.228'N and 3°24.044'E) during 2019 wet season. The specimens were kept in ice-chest before being taken to Marine Sciences Department, University of Lagos, for further analysis. The crabs were thoroughly washed, measured, de-shelled and carapace region was discarded. Ten crabs from each capture were cooked by grilling while the others were kept raw. Specimens in the grilled process were prepared in a griddle with the thermostat set at 100°C. After the set temperature was attained, samples were grilled for 15-17 min. Claw, leg, and shoulder meat were picked by hand, and the muscle tissues from each treatment (grilled and raw meat) were blended to prepare homogenate samples. These samples were kept in polythene bags and frozen separately (−20°C) until analysis.

Samples analysis

The proximate composition was determined using the methods described by the AOAC (2006). Crude protein content was determined by Kjeldahl method with a conversion factor of 6.25 for the translation of total nitrogen to crude protein. Total lipids were isolated from raw and cooked crabmeat samples according to Bligh and Dyer's (1959) procedure. Carbohydrate was determined by difference, 100 % – (% Crude protein + % Crude fat + % Crude fibre + % Ash), while the calorific values were calculated by multiplying the crude fat, protein and carbohydrate by the Atwater factors of 37, 17 and 17, respectively (Adeyeye and Adubiaro, 2018).

The samples were digested in HNO_3 / HCl for mineral determination. Calcium (Ca), phosphorus (P), magnesium (Mg), sodium (Na) and potassium (K) were then calculated by the Buck Scientific 210 GVP model of the Varian Spectra Atomic Absorption Spectrophotometer (Santoso, 2006). Mineral Ratios and Mineral Safety Index - MSI (Equation 1) were calculated according to Watts (2010) and Hatcock (1985), respectively.

MSI = [TMSI (Standard) / RAI]. Rr, (1)

Where: MSI - Mineral Safety Index;

TMSI - Tabulated MSI;

RAI - Recommended Adult Intake;

Rr - Researh results.

Water absorption capacity (WAC) and oil absorption capacity (OAC) were determined following the method described by Brishti et al. (2017). The 0.25 g of specimen was mixed with 5 ml distilled water or oil in pre-weighed centrifuge tube for 30 secs using a vortex. Then, specimen was allowed to stand at room temperature (20-25°C) for 15 min and centrifuged at 3000 rpm for 15 min. After centrifugation, the supernatant was decanted, and the centrifuge tubes + precipitate were re-weighed. The WAC and OAC were expressed as grams of water/oil absorbed per gram of the sample. The WAC and OAC were calculated by using the following equation:

$$WAC \text{ or } OAC\ (g/g) = W_2 / W_1, \quad (2)$$

Where: W_1 = weight of the dry sample (g);

W_2 = weight of precipitate + centrifuge tube (g).

The modified methods reported by Souissi et al. (2007) were used to determine the emulsion stability. The foam formation and the foam stability were determined by optical measurements as described by Lawal-Are et al. (2020). The foams were produced with a homogenizer for 2 min at 17 500 rpm, in 3 ml of solution (50 mMTris-HCl – 0.5 M NaCl, pH 7.5), which contained 1.5% protein. The initial height of the solution and the foam height were recorded at intervals of 0, 2, 10, 20 and 30 min, using a caliper. The foaming capacity was expressed as the proportion of foam height at 0 min to solution height. The foaming stability (FS) was conveyed by the percentage of foam height at some time to 0 min. The measurement of the height was rapid and accurate to three digits after the decimal point.

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.

Results and discussion

Proximate composition of crabmeat

The proximate composition of raw and grilled crabmeat (*C. amartum*) is presented in Table 1. The result demonstrated that, the proportion of protein content was dominating over carbohydrates and lipid contents in both the raw and grilled crabmeat. After grilling, the moisture, crude protein and total ash decreased from 71.37±0.77% to 69.83±0.62%, 16.02±2.24% to 14.98±1.12% and 6.02±0.92% to 4.62±0.47%, respectively. Meanwhile, grilling increases the content of crude fat, crude fibre and carbohydrate by 0.23, 1.24 and 2.51%, respectively. A significant ($p<0.05$) higher crude fibre content characterized the raw samples (1.25±0.03%). The crude protein, ash, and moisture contents of raw and grilled C. *amartum* meat presented no significant differences. Regarding moisture and protein, Risso and Carelli (2012) reported significant differences ($p<0.05$) between raw and cooked Southern King Crab (*Lithodes santolla*). The protein content in the present study were lower than 78.55±0.76 and 75.96±0.62 g/100 g reported for raw and boiled cuttlefish, respectively (Lawal-Are et al., 2018b), but close to the value of 16.73 ±0.74 g/100 g in *Callinectes amnicola* from Epe Lagoon (Moruf et al., 2019).

Table 1. Proximate composition of raw and grilled crabmeat (*Cardiosoma amartum*)

Parameters, %	Raw	Grilled	*p*-value
Moisture	71.37±0.77 (69.91-72.5)	69.83±0.62 (68.7-70.82)	0.19
Crude protein	16.02±2.24 (12.81-20.34)	14.98±1.12 (12.96-16.83)	0.7
Crude fat	1.51±0.12 (1.39-1.74)	1.74±0.09 (1.58-1.87)	0.18
Crude fibre	0.01±0.00 (0.01-0.02)	1.25±0.01 (1.24-1.27)	0.00
Total ash	6.02±0.92 (5.08-7.85)	4.62±0.47 (3.71-5.25)	0.25
Carbohydrate	5.07±2.40 (0.32-8.03)	7.58±1.52 (5.67-10.58)	0.43

*Mean±SE (Range), $p<0.05$ indicate significant difference

Percentage energy contribution in crabmeat

The percentage energy as contributed by protein, carbohydrate and total lipid can be seen in Table 2. Higher metabolisable energy (TE) was observed in grilled crabmeat (457 kJ $100g^{-1}$, 108 kcal $100g^{-1}$) compared to raw crabmeat (395 kJ $100g^{-1}$, 93 kcal $100g^{-1}$). In both samples, the trend of energy contributions follows decreasing order of Proportion of total energy due to protein (PEP) > Proportion of total energy due to fat (PEF) > Proportion of total energy due to carbohydrate (PEC). The PEF was lower (3.8-4.3%) than recommended level of 30-35% (Adeyeye, 2014) for total fat energy intake, this is useful for people wishing to adopt the guidelines for a healthy diet.

Table 2. Energy value contributed by nutrients in raw and grilled crabmeat (*Cardisoma amartum*)

Parameter	Unit	Raw	Grilled	Mean	SD	CV, %
TE	kJ $100g^{-1}$	395	457	425.87	44.13	10.36
	kcal $100g^{-1}$	93	108	100.68	10.34	10.27
PEF	% (kJ $100g^{-1}$)	4.2 (64)	3.7 (56)	3.97	0.33	8.34
	% (kcal $100g^{-1}$)	4.3 (16)	3.8 (14)	4.06	0.33	8.23
PEC	% (kJ $100g^{-1}$)	6.1 (93)	8.6 (129)	7.35	1.77	24.09
	% (kcal $100g^{-1}$)	6 (22)	8.5 (30)	7.29	1.77	24.21
PEP	% (kJ $100g^{-1}$)	15.6 (238)	18.2 (272)	16.89	1.84	10.87
	% (kcal $100g^{-1}$)	15.4 (56)	18.1 (64)	16.75	1.84	10.99
UEDP, %	kJ	9.36	10.92	10.14	1.10	10.87
	kcal	9.27	10.83	10.05	1.10	10.99

*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, %).

Utilizable energy due to protein (UEDP, %) (assuming 60% of protein energy utilization) was similar in both raw (9.36 kJ/9.27 kcal) and grilled samples (10.92 kJ/10.83 kcal) while greater than the recommended safe level of 8% for an adult man who requires about 55 g protein per day with 60% utilization (Adeyeye and Adubiaro, 2018). This shows that the protein concentration in the crabmeat in terms of energy would be more than enough to prevent protein energy malnutrition in children and adults fed solely on the crab samples as main sources of protein.

Mineral content of crabmeat

Mineral content of raw and grilled crabmeat (*C. amartum*) determined in this study is summarized in Table 3. Raw sample has higher mg/100g levels of calcium, magnesium, potassium, phosphorus and sodium as follows: 2841.3±0.12, 78.77±1.01, 436.7±0.05, 368.3±0.05 and 306.66±0.09, respectively. With the exception of phosphorus, grilled samples had a significant decrease in mineral level. In contrast to the mineral contents of king crab (K: 204 and 262; P: 219 and 280; Ca: 46 and 59; Mg: 49 and 63 expressed in mg/100 g meat for raw and cooked meat, respectively (USDA, 2008), *C. amartum* contained considerably higher amounts of calcium, magnesium, potassium, phosphorus and sodium.

Table 3. Mineral contents of raw and grilled crabmeat (*Cardiosoma amartum*)

Parameters (mg/100g)	Raw	Grilled	*p*-value
Calcium (Ca)	2841.3±0.01 (2841.29-2841.31)	1663.17±0.02 (1663.15-1663.2)	0.00
Magnesium (Mg)	78.77±0.01 (78.76-78.79)	55.40±0.00 (55.39-55.41)	0.00
Potassium (K)	436.70±27.97 (380.78-465.92)	71.99±15.51 (51.56-102.43)	0.00
Phosphorus (P)	368.33±29.69 (312.56-413.88)	326.25±13.25 (311.83-352.71)	0.27
Sodium (Na)	306.66±2.93 (301.04-310.88)	57.60±8.20 (49.20-74.00)	0.00

*Mean±SE (Range), $p<0.05$ indicate significant difference

The calcium levels in both raw (2841.3±0.01 mg/100g) and grilled samples (1663.17±0.02 mg/100g) were far above the recommended daily allowance (RDA) level of 800 mg (Adeyeye et al., 2020). This high content of calcium in the crabmeat (*C. armatun*) suggests that its consumption can increase the calcium in the body and help in blood clotting process. If calcium is adequate enough in the diet, it can correct excessive amounts of sodium, magnesium or potassium present in the body. Magnesium, being the mineral with the lowest value in this study, is lower than the reported value (34.3±0.5 - 41.3±1.0 mg/100g) for Southern King Crab by Risso and Carelli (2012). According to Moruf and Akinjogunla (2018), magnesium is an activator of the enzyme system, which functions in the metabolism of carbohydrates to produce energy.

Both sodium and potassium contents in the present study were higher than those: 55.53±20.97 mg/100g of sodium and 33.33±1.76 mg/100g of potassium, reported for the periwinkle, *Tympanotonus fuscatus* var *radula* from Abule-Eledu Creek (Moruf and Akinjogunla, 2018). Sodium and potassium are essential in the regulation of pH, osmotic pressure, acid-base equilibrium, muscle and nerve irritability, control glucose absorption, and active transport of glucose/amino acids (Asuquo et al., 2004). The values of phosphorus in the investigated crabmeat compared favourably with the RDA level of 800 mg and were higher than 342.16±3.99 - 321.05±2.85 mg/100 g reported for cuttlefish, *Sepia officinalis* (Lawal-Are et al., 2018b). Phosphorus plays a vital part in the oxidation of nutrient in form of phosphate groups in ATP for energy and cell metabolism.

Mineral ratios in crabmeat

As ratios are more important than absolute quantities, Table 4 shows some significant mineral ratios in the raw and grilled crabmeat (*C. amartum*). Ideally, Ca/Mg should be a 7.0:1 ratio of calcium relative to magnesium with a range of 3.0 to 11.0 being acceptable. The sample results gave ratios of 5.00-6.01, which are within the ideal range. This means the meat of *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 et al., 2018). The study of Rosanoff et al. (2016) has shown that Ca/Mg ratio of approximately 2:1 is considered healthy, while ratios above 2.6:1 and below 2:1 can lead to heart disease and other conditions.

Table 4. Mineral ratios in raw and grilled crabmeat (*Cardisoma amartum*)

Ratio	Ideal	Acceptable ideal range	Raw	Grilled	Mean	SD	CV, %
Ca/Mg	7	3 to 11	6.01	5.00	5.51	0.71	12.94
Ca/K	4.2	2.2 to 6.2	6.51	23.1	14.8	11.74	79.27
Ca/P	2.6	1.5 to 3.6	7.71	5.1	6.41	1.85	28.88
Na/K	2.4	1.4 to 3.4	0.7	0.8	0.75	0.07	9.21
Na/Mg	4	2 to 6	3.89	1.04	2.47	2.02	81.81
[K/(Ca + Mg)]	2.2		0.41	0.31	0.36	0.08	21.1

Ca/P levels ranged between 5.10-7.71 in the grilled to raw crabmeat. 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). Food is considered ‘good’ if the Ca/P ratio is above 1.0 and ‘poor’ if the ratio is less than 0.5 (Adeyeye, 2014). Ca:P is an important determinant of calcium absorption and retention because of the regulatory mechanisms, which control calcium and phosphorus homeostasis within the body (Loughrill et al., 2017). Common practice is to have a Ca:P molar ratio between 1:1 and 2:1 (Koletzko et al., 2005). Hypothetically, low Ca:P may adversely affect calcium balance, which subsequently may increase the risk of bone fracture and osteoporosis.

The interaction of sodium and potassium is integral to maintaining healthy blood. The ratios Na/K (1.7-1.8), Na/Mg ratio (1.04-3.89) and the milliequivalent ratios of [K/(Ca+Mg)] (0.31-0.41) in the investigated samples fall within the recommended values of 2.4, 4.0 and 2.2, respectively. This is similar to the observations on the flesh of *Neopetrolisthes maculatus* (Adeyeye and Adubiaro, 2018). According to McDonough et al. (2017), raising dietary potassium to sodium ratio to recommended level helps reduce heart and kidney diseases. These selected mineral ratios revealed not only the important balance between these elements, but they also provided information regarding the many possible factors that may be represented by a disruption of their relationships, such as disease states, physiological and developmental factors, the effects of diet, drugs, would also predispose a person with parasympathetic dominance to certain health conditions if severe or chronic (Watt, 2010).

Mineral safety index of crabmeat

Table 5 shows the mineral safety index of some minerals in the crabmeat (*C. amartum*) whose standard comparisons were available from literature (Adeyeye and Adubigaro, 2018; Adeyeye et al., 2020). Only calcium had its MSI greater than the standard value for both the raw samples (23.68>10.00) and the grilled samples (13.86>10.00), thereby giving negative difference. The percentage difference (%D) in Ca MSI for the raw sample (-136.78%) and grilled samples (-38.60%) indicate that the raw crabmeat might overload the consumer to the tune of 136.78% and the grilled crabmeat to the tune of 38.60% of calcium. Similarly, Adeyeye and Adubiaro (2018) reported magnesium overloading to the tune of 45.69% in *N. maculatus*.

Table 5. Mineral safety index of raw and grilled crabmeat (*Cardisoma amartum*)

Mineral	RAI (mg)	MSItv	Raw			Grilled			Mean	SD	CV, %
			MSIcv	D	%D	MSIcv	D	%D			
Ca	1200	10	23.68	-13.68	-136.78	13.86	-3.86	-38.6	18.77	6.94	36.99
Mg	400	15	2.95	12.05	80.31	2.08	12.92	86.15	2.52	0.62	24.63
P	1200	10	3.07	6.93	69.31	2.72	7.28	72.81	2.89	0.25	8.57
Na	500	4.8	2.94	1.86	38.67	0.55	4.25	88.48	1.75	1.69	96.7

*Recommended adult intake (RAI) by the U.S. Department of Agriculture, MSI standard value (MSI_{sv}), MSI calculated value (MSI_{cv}), Difference between MSI_{sv} and MSI_{cv} (D), Percentage difference (%D), Standard deviation (SD), Coefficient of variation percent (CV, %).

The differences between the standard and calculated MSI values for all the other calculated mineral Mg, P and Na were being positive ($MSI_{Calculated} < MSI_{Table}$). This implied that the body might not be overloaded with these minerals by both the raw and grilled crabmeat; therefore the risk of secondary hypertension would be avoided (Ademola and Abioye, 2017). This is in line with the report made by Adeyeye et al. (2020) that Mg, P and Na beef jerky meat would not constitute mineral overload to the sample consumers.

Correlation between proximate and mineral compositions of crabmeat

The correlation coefficient between the proximate and mineral compositions of raw and grilled crabmeat (*C. amartum*) is shown in Table 6 and Table 7, respectively. In the raw sample, all the significant energy-providing nutrients; protein, crude fat and carbohydrate have a positive correlation with all the investigated minerals except Mg with a respective values of -0.813, 0.959 and -0.827. A similar result was observed in the grilled sample (Table 7), where positive relationships exist between the proximate and mineral compositions; except Mg with negative association. The result is comparable to the work of Lawal-Are et al. (2018a) who reported significant direct relationship among proximate/mineral compositions of whole and fillet of the Guinean Mantis Shrimp, *Squilla aculeata calmani* from Southwest Nigeria. 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 crabmeat. However, correlation does not mean that the changes in proximate composition actually cause the changes in the mineral content.

Table 6. Correlation coefficients between the proximate and mineral compositions of raw crabmeat

	Moisture	Protein	Crude fat	Crude fibre	Total ash	CHO	Ca	Mg	K	P	Na
Moisture	1										
Protein	-0.993	1									
Crude fat	-0.901	0.945	1								
Crude fiber	0.757	-0.827	-0.966	1							
Total ash	0.087	-0.202	-0.511	0.717	1						
CHO	-0.233	0.344	0.633	-0.812	-0.989	1					
Ca	-0.393	0.497	0.753	-0.899	-0.95	0.986	1				
Mg	0.74	-0.813	-0.959	1	0.735	-0.827	-0.909	1			
K	-0.774	0.842	0.972	-0.999	-0.699	0.797	0.887	-0.999	1		
P	-0.486	0.584	0.817	-0.939	-0.913	0.963	0.995	-0.948	0.93	1	
Na	-0.909	0.951	1	-0.961	-0.495	0.618	0.741	-0.953	0.967	0.806	1

Functional properties

The result as shown in Figure 1 revealed significantly higher percentage ($p<0.05$) of oil absorbing capacity (339.96±0.05%) and foam stability (10.02±0.01%) in grilled crabmeat, while emulsion stability (19.00±0.05%) and foam capacity (13.01±0.01%) were higher in the raw crabmeat ($p>0.05$). Water absorbing capacity is affected by pH and ionic strength (i.e. salt) reflecting the extent of denaturation of the protein (Butt and Batool, 2010). The high oil absorption capacity, which acts as a flavour retainer and enhances the mouth feel of food, reveals that crabmeat products would be good samples for this baking products better than cuttlefish with 197-220% as cited by Lawal-Are et al. (2018b). According to Lone et al. (2015), the oil absorption capacity depends on the amount of non-polar amino acids in the side chain and structure of the proteins.

Table 7. Correlation coefficients between the proximate and mineral compositions of grilled crabmeat

	Moisture	Protein	Crude fat	Crude fiber	Total ash	CHO	Ca	Mg	K	P	Na
Moisture	1										
Protein	0.999	1									
Crude fat	0.958	0.969	1								
Crude fiber	0.95	0.963	0.999	1							
Total ash	0.992	0.986	0.915	0.904	1						
CHO	0.986	0.993	0.992	0.988	0.959	1					
Ca	0.992	0.997	0.986	0.982	0.969	0.999	1				
Mg	-0.641	-0.674	-0.835	-0.849	-0.541	-0.758	-0.733	1			
K	0.993	0.997	0.986	0.981	0.97	0.999	0.999	-0.729	1		
P	0.965	0.976	1	0.999	0.925	0.995	0.99	-0.82	0.99	1	
Na	0.946	0.959	1	1	0.898	0.986	0.979	-0.856	0.978	0.998	1

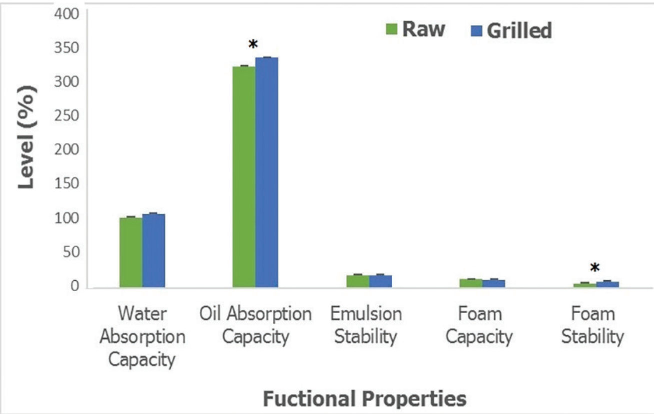

Figure 1. Functional attributes of raw and grilled crabmeat (*Cardiosoma amartum*)

Crabmeat in the present study had foam stability remaining uncollapsed after grilling; a quality of most commercial ingredients used in making baking products like cakes or whipping toppings. However, since the emulsion stability was generally low in both raw and grilled crabmeat, this meant that the samples would be of little use in products that depend on the formation of stable emulsions. The result is comparable with the emulsion stability value of 32.66±1.40% for boiled smooth swim crab, *Portunus validus* (Lawal-Are et al., 2020).

Conclusion

This study showed that crabmeat of *Cardiosoma armatum* has high protein content with good ratios and absolute quantities of mineral composition. The comparison of the raw and grilled crabmeat showed that grilling had considerable effect on the quality of this species. The grilled crabmeat had a lower crude protein content ($p>0.05$) when compared to raw crabmeat. Meanwhile, grilling increases the content of crude fat, crude fibre and carbohydrate while conserving the functional characteristic of the crabmeat. The positive relationship in the nutritional quality indicates that changes in proximate composition are associated with changes in mineral contents of the crabmeat. Finally, the crabmeat exhibited a non- collapsible foam stability after grilling; a quality of most commercial ingredients used in making baking products.

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