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Product Quality and Safety

Functional potential of the edible portion in wild and cultured crabs

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Abstract. *Crab proteins can be utilized as additives in baking items, as well as contributing to the nutritional content of dishes. The edible portion's functional potential in wild and cultivated crabs (Cardisoma armatum) was determined using standard methods. In addition to water absorption capacity, both wild and cultivated female crabs had an encouragingly high swelling power of 269.30±24.26% and 238.78±3.25%, respectively. In combined sexes, there were higher percentages (%) of water absorption capacity (135.46), oil absorption capacity (74.27), emulsion stability (42.90), foam capacity (5.32), foam stability (40.25), dispersibility (10.01), swelling power (269.93) and solubility (3.33) in the edible portion of wild C. armatum. The cultured crabs showed higher values of packed bulk density (0.83 g.ml^{-1}), loose bulk density (0.47 g.ml^{-1}) and specific gravity (0.49 g.ml^{-1}) while the wild crabs had better emulsion capacity (1.94 ml.g^{-1}). The functional potential of the edible portion in wild and cultured crabs showed no significant differences ($p<0.05$). High functional solubility of the crab edible portion indicates potential applications in formulated food systems by providing attractive appearance and smooth mouthfeel to the product.*

Keywords: *Cardisoma armatum*, crab, crustacean, functional characteristics, Nigeria

Introduction

Consumers have favoured seafood over red meat in recent decades; since red meat production has been endangered by a number of crises and challenges, seafood products such as crab cuisines have emerged as the greatest alternative. Worldwide crabmeat imports have increased steadily over the past 20 years, with over 300,000 tons of products (Dima et al., 2016). Despite the great acceptability of crabmeat, Nigeria's exploitation of this resource is lacking due to a lack of scientific and nutritional information for optimal use. Many studies have demonstrated the benefits of consuming crabmeat for human health (Moruf et al., 2019; Oluwole et al., 2020; Lawal-Are et al., 2021). In fact, edible crabs are known for their high nutritional value, as they are rich in protein, essential n-3 acids (especially polyunsaturated fatty acids: eicosapentaenoic and docosahexaenoic), amino acids, and essential elements (Moruf and Lawal-Are, 2019; Moruf et al., 2020). Thus, crabs are considered as a healthy food in several dietary regimes.

Due to different consumption habits, various edible portions including the crabmeats (abdomen, claw, and leg meat), hepatopancreas, and gonad are individually popular. However, in Nigeria, flesh and gonad are preferred by consumers for their unique aromas and nutritional value. Crab proteins possess the essential requisite functional properties for successful utilization in various food products (Lawal-Are et al., 2020). Gelation, emulsion capacity, activities and stability are important functional properties of food ingredients. Other paramount functionalities are proteins solubility, water and fat absorption capacity, foam capacity and stability and bulk density. In present time, the best means to obtain the benefits of crab-consumption is to utilize its components as ingredients, such as crab protein isolates. The successful use of such protein ingredients depends upon their abilities to fulfill one or more functional requirements, e.g. good solubility, emulsion/foam stabilization, or gel formation. When compared to native unhydrolyzed proteins, enzymatic modification of proteins

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is a beneficial technique for improving functionality (Hall et al., 2017; Akharume et al., 2021).

There are few studies on crabmeat with respect to functional characteristics and compositions (Dima et al., 2016; Lawal-Are et al., 2020; Moruf et al., 2021). Furthermore, it is unclear if cultured or farmed crustaceans have the same functional profile as their wild counterparts. Though the nutrient content of farmed fish is more uniform than that of wild (Venugopal and Gopakumar, 2017; Isangedighi, 2017). Despite the apparent nutritional, economic, environmental, and health benefits of crab, empirical study evidence demonstrating crab functional values in Nigeria is limited.

The purpose of this comparison study was to provide empirical data on the functional potential of the edible portion in wild and cultured crab (*Cardisoma armatum*, Herklots 1851) from the mangrove swamp of Lagos Lagoon in Nigeria.

Material and methods

Sample collection and preparation

A total of 120 live crabs (C. *armatum*) were harvested using bait traps and hand-picked from the University of Lagos Lagoon Coast (6°31.228'N and 3°24.044'E) (Figure 1) during 2019 wet season. 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 (25±0.05 g) at the Department of Marine Sciences, University of Lagos. The juveniles were then selected and randomly stocked into eight small plastic tanks (8 m × 8 m × 1.5 m) 4 crabs per tank, while allowed to acclimatize for a week before the commencement of the experiment (Oluwole et al., 2020). 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 tank. A water depth of 20 cm was maintained with 50% lagoon water in each plastic tank, exchanged every 3 days over the period of the 3 months' experiment when the crabs attained a similar body weight of the wild-caught crabs. The sexes were distinguished by making use of the species conspicuous external morphological features, male by a T-shaped abdomen and females with their triangular or rounded aprons (FAO, 1990). The subjects were anesthetized, dissected, and their muscle tissues were weighed. The proportions of total edible portions yield (EPY %) were calculated as:

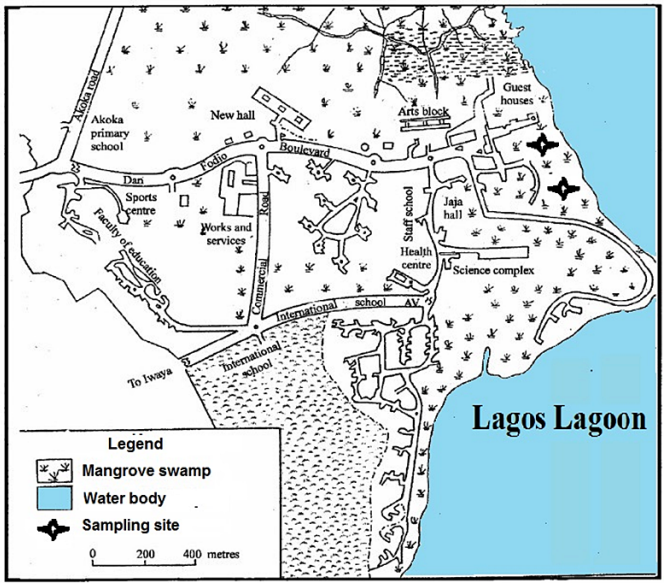

Figure 1. Map of Unilag Lagoon Front showing the study sites (Source: Moruf, 2020)

$$\text{EPY\%} = \frac{We}{Wt} x\ 100$$

Where: *We* is the weight of total raw edible portions;

We is the weight of whole raw crab.

Each sample was freeze-dried, separately homogenized, and separately stored at −20°C for further analysis.

Laboratory analysis

For the extraction of protein, four grams of minced crab edible portion were homogenized with 80 ml of ice-cooled buffered solution in a homogenizing tube placed in ice for 4 min. The homogenates solutions were centrifuged using SiGmA 3-18k Sartorius centrifuge machine (India) at 10,000 g for 1 hour at 4°C. After centrifugation, the protein isolate obtained from the resultant supernatants was used for the determination of protein (Nahar et al., 2014).

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 (USA) as described by Ratnawati (2019). 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:

$$WAC\ or\ OAC\ (g/g) = \frac{W2}{W1} \qquad (1)$$

Where: W1 = weight of the dry sample (g);

W2 = weight of precipitate + centrifuge tube (g).

The standard methods reported by Souissi et al. (2007) were used to determine the emulsion capacity and 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 of the protein was measured as the amount of interfacial area that can be created by whipping the protein. Foam stability was measured as the time required to lose either 50% of the liquid or 50% of the volume from the foam. Specific gravity was determined according to weight under water method as described by Solaiman et al. (2015) while bulking density was analyzed following the method of Eltayeb et al. (2011) and calculated using the below equation:

$$Bulking\ density = \frac{Weight\ of\ sample\ (g)}{Volume\ of\ sample\ (ml)} \quad (2)$$

The dispersibility of specimens was evaluated according to Lee and Lian (2002) as the ease of dispersing the thawed mince (300 g) during mixing for 1 min in a kitchen-aid bowl mixer at a setting of "5" (1 very difficult - 9 very easy to mix). Swelling power and solubility were determined by following the method described by Pranoto et al. (2014) with slight modification. A sample (0.2 g) was put in a pre-weighed centrifuge tube, added with 10 mL distilled water and mixed using vortex. The sample was allowed to stand at room temperature (20-25˚C) for 5 min and then put in a water bath at 95˚C for 30 min. After that, it was cooled at 20-25˚C for 10 min. The sample was centrifuged at 3000 rpm for 15 min to separate gel and supernatant. The gel after separating from supernatant was expressed as swelling power. The supernatant was placed on a plate that has been known to weigh and then dried in an oven to a constant weight. Swelling power and solubility were calculated by using the following equations:

$$Swelling\ power\ (g/g) = \frac{W2-W1}{W0} \quad (3)$$

Where: W0 = weight of the dry sample (g);
W1 = weight of the dry sample + centrifuge tube (g);
W2 = weight of gel + centrifuge tube (g).

$$Solubility\ (\%) = \frac{W2}{W1} X100\% \quad (4)$$

Where: W1 = weight of the dry sample (g);
W2 = dry weight of supernatant (g).

Data analysis

With the aid of SPSS statistical software version 22, mean and standard error were derived by subjecting data to descriptive analysis. Each value was a mean of six (6) replications for wild and cultured crabs. Statistical significances were tested at P<0.05 level of significance.

Results and discussion

Proportion of total edible portion

Figure 2 shows the proportions of total edible portion of wild and cultured *C. armatum*. The proportions were approximately 16 to 23% with the male wild crab having the highest yield. The wild crabs had higher total edible portion yield than the cultured crabs, which got the same results with other researches on Chinese mitten crab; 20 to 25% reported by Wu and Wang (2017), but higher than the 8 to 11% reported by He et al. (2014).

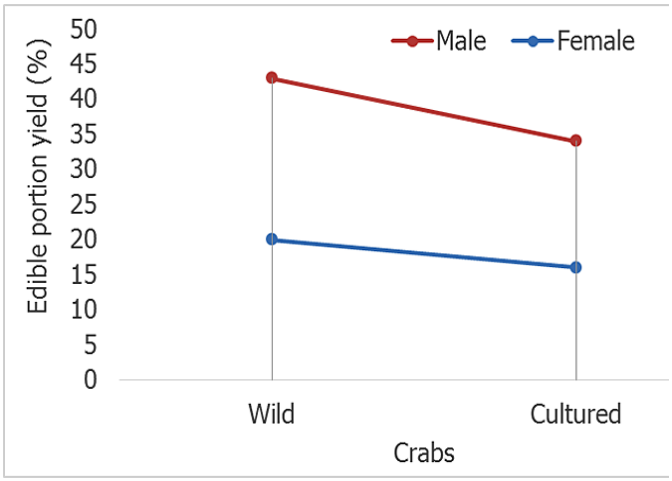

Figure 2. Edible portion yield (%) of wild and cultured crab, *Cardisoma armatum*

Functional potential by sex-based differences

Functional potentials of the edible portion of wild and cultured female *C. armatum* are shown in Table 1. There were significant differences (P<0.05) of water absorption capacity, emulsion capacity, and foam stability between wild and cultured female crabs. In addition to water absorption capacity, swelling power of both wild and cultured female crabs showed encouragingly high value of 269.30±24.26% and 238.78±3.25%, respectively, which were relatively comparable with that of jumbo lump of the berried Smooth swim crab (277.30±0.44%) (Lawal-Are et al., 2020). Low emulsion stability can be attributed to increased interactions between the emulsified droplets. As the pH increased, the subsequent increase in repulsion between neighbouring droplets and increased hydration of the charged protein molecules may lower interfacial energy and retard droplet coalescence (Sanni et al., 2019). The relatively high emulsion stability (33.48 - 51.95%) in this study indicated that crabmeats may be useful as an additive for the stabilization of fat emulsions in production of sausages, soups and cakes.

Table 1. Functional potential of edible portion in wild and cultured *Cardisoma armatum* (Female)

Parameters	Wild	Cultured	*P*- value
Water Absorption Capacity (%)	138.16±20.60 (89.02-185.37)	81.72±0.76 (78.97-83.35)	0.02
Oil Absorption Capacity (%)	72.11±12.42 (43.47-101.95)	51.08±1.76 (44.72-56.42)	0.12
Emulsion Capacity (ml/g)	2.15±0.08 (1.89-2.37)	1.95±0.04 (1.81-2.07)	0.04
Emulsion Stability (%)	42.80±3.85 (33.48-51.95)	37.95±0.49 (36.23-39.45)	0.24
Foam Capacity (%)	5.30±0.98 (2.37-7.46)	3.54±0.15 (3.19-3.88)	0.11
Foam Stability (%)	41.75±2.21 (36.91-48.13)	36.00±1.11 (31.71-39.13)	0.04
Packed Bulk Density (g ml^{-1})	0.75±0.03 (0.64-0.85)	0.85±0.07 (0.60-1.08)	0.26
Loose Bulk Density (g ml^{-1})	0.40±0.03 (0.33-0.51)	0.46±0.07 (0.30-0.62)	0.47
Specific Gravity (g ml^{-1})	0.45±0.03 (0.34-0.55)	0.50±0.03 (0.39-0.60)	0.29
Dispersibility (%)	9.99±0.92 (7.87-12.69)	8.85±0.32 (7.71-9.77)	0.27
Swelling Power (%)	269.30±24.26 (210.61-327.63)	238.78±3.25 (227.18-248.98)	0.24
Solubility (%)	3.32±0.56 (1.88-5.09)	2.95±0.67 (0.76-4.12)	0.68

In Table 2, functional potentials of the edible portion in wild and cultured male *C. armatum* are shown. There were no significant differences (P<0.05) in all measured functional properties of the edible portions between wild and cultured male crabs. However, the cultured crabs showed slightly lower values of emulsion stability (42.05±1.06%), packed bulk density (0.81±0.08 g.ml^{-1}), specific gravity (0.48±0.02 g.ml^{-1}), dispersibility (9.81±0.29%) and swelling power (264.58±8.40%). This is higher than the swelling power (80.4%) reported for keropok fish cracker (Cheow et al., 2004). High swelling power in this study indicates that the edible portion of the wild male crab can be applied to improve the characteristics of baked products. Such phenomenon was reported by Lawal-Are et al. (2020) and was attributed to additional interactions between nutrient and other components in the muscle tissues of the crab.

Table 2. Functional potential of edible portion in wild and cultured *Cardisoma armatum* (Male)

Parameters	Wild	Cultured	*P*- value
Water Absorption Capacity (%)	132.76±17.29 (92.25-174.176)	133.26±21.93 (82.56-185.06)	0.99
Oil Absorption Capacity (%)	76.42±9.34 (55.58-100.24)	77.25±8.04 (57.50-98.10)	0.95
Emulsion Capacity (ml/g)	1.73±0.13 (1.35-2.00)	1.73±0.06 (1.60-1.85)	1.00
Emulsion Stability (%)	43.00±2.46 (37.29-48.96)	42.05±1.06 (39.28-44.86)	0.73
Foam Capacity (%)	5.35±1.02 (2.67-7.61)	5.53±0.64 (4.09-6.96)	0.89
Foam Stability (%)	38.75±1.44 (35.96-44.80)	41.90±2.31 (35.20-49.80)	0.27
Packed Bulk Density (g. ml^{-1})	0.83±0.06 (0.65-1.00)	0.81±0.08 (0.62-1.11)	0.86
Loose Bulk Density (g. ml^{-1})	0.44±0.05 (0.33-0.59)	0.49±0.07 (0.33-0.65)	0.60
Specific Gravity (g. ml^{-1})	0.49±0.05 (0.40-0.75)	0.48±0.02 (0.43-0.54)	0.86
Dispersibility (%)	10.03±0.58 (8.65-11.75)	9.81±0.29 (8.83-10.8)	0.74
Swelling Power (%)	270.56±15.92 (234.05-321.56)	264.58±8.40 (241.39-295.76)	0.75
Solubility (%)	3.34±0.33 (2.76-4.86)	3.34±0.39 (2.08-4.54)	0.89

Functional potential by population-based differences

These functional properties are intrinsic physicochemical characteristics, which affect the behaviour of properties in food systems during processing, manufacturing, storage and preparation (Eltayeb et al., 2011). The result as shown in Figure 3 revealed non-significant (p<0.05) higher percentages (%) of water absorption capacity (135.46), oil absorption capacity (74.27), emulsion stability (42.90), foam capacity (5.32), foam stability (40.25), dispersibility (10.01), swelling power (269.93) and solubility (3.33) in the edible portion of wild *C. armatum* when compared with that of the cultured crabs. According to Butt and Batool (2010), water absorbing capacity is affected by pH and ionic strength (i.e. salt), reflecting the extent of denaturation of the protein while oil absorption capacity acts as a flavour retainer and enhances the mouth feel of food. The better emulsion stability in the wild crabmeat will confer ability to resist changes in its physicochemical properties over time. The high condition of the crab foaming capacity and foam stability clarify the potential of its proteins for application in certain food systems, where aeration and overrun is needed, e.g., whipped toppings, baked foods, and ice-cream mixes (Shevkani et al., 2015). The dispersibility recorded in the crabmeat is an important quality requirement for the ease

of mixing with other ingredients during formulation (Lawal-Are et al., 2020). Swelling power and solubility patterns of fish meat-based fried snacks have been used to provide evidence for associative binding force within the granules (Nawaz et al., 2019). The solubility of the investigated crabmeat is comparable with what was reported for hake protein powder (4%) by Pires et al. (2012). According to Nahar et al. (2014), solubility of sarcoplasmic protein was significantly affected by the interaction between classes of meat and storage.

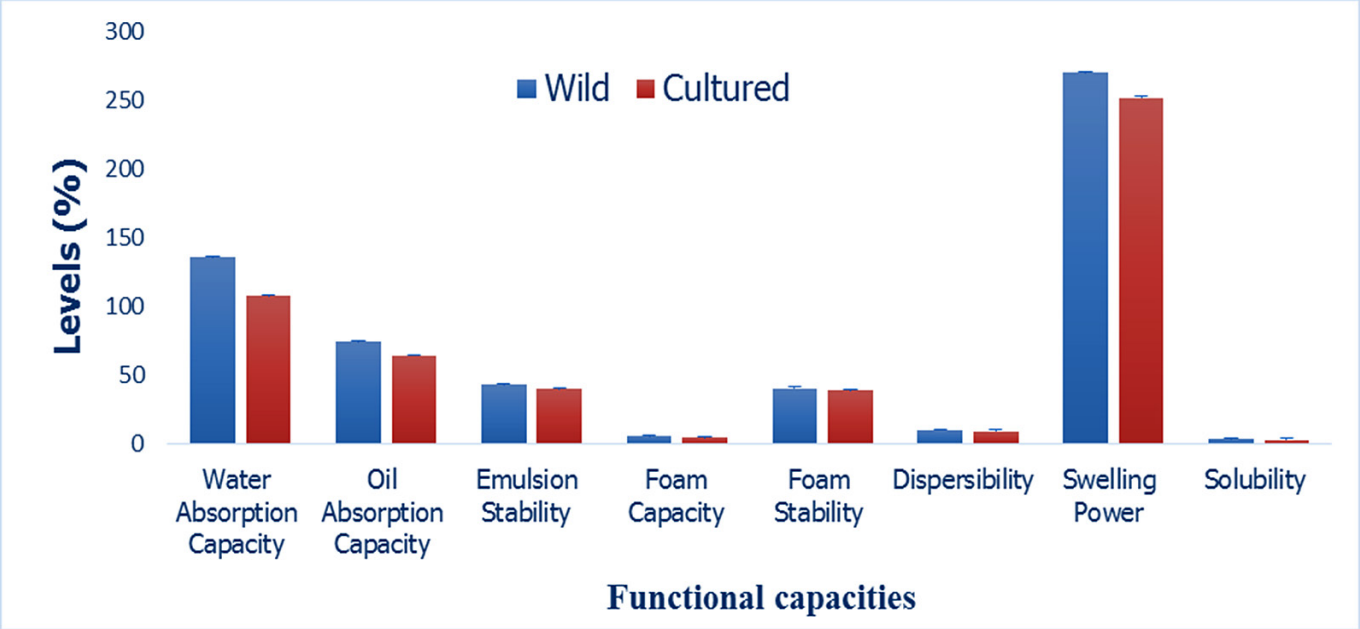

Figure 3. Functional capacities of edible portion in wild and cultured crab, *Cardisoma amartum*

In Figure 4, the functional densities of the edible portion in wild and cultured crabs showed no significant differences ($p<0.05$). Cultured crabs showed higher values of packed bulk density (0.83 $g.ml^{-1}$), loose bulk density (0.47 $g.ml^{-1}$) and specific gravity (0.49 $g.ml^{-1}$) while the wild crabs had better emulsion capacity (1.94 $ml.g^{-1}$). The bulk density in the present study were higher than those reported for salmon protein powder (0.49 $g.ml^{-1}$) and herring protein powders (0.59 $g.ml^{-1}$) (Abdollahi and Undeland, 2018). According to Shao et al. (2014), bulk density depends on the combined effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and number of contact points. High bulk density indicates that the product can function as a good thickener in food products as well as their suitability for use in processed foods (Appiah et al., 2011). The lower bulk density in the edible portion of wild crabs can be related to its lower protein content compared with cultured crabs. The emulsion capacity in the present study defines crab protein potential for application in a wide range of emulsion-based food products. Emulsion capacity of protein will depend on their ability to adsorb on the oil-water interface (Shaviklo et al., 2012). Once absorbed, the emulsifying agent protects dispersed phase droplets from coalescence by forming a film at the oil water interface and by reducing the interfacial tension (Abdollahi and Undeland, 2018). Higher swelling power in this study indicates that crab edible portion especially from the wild crabs can be applied to improve the characteristics of baked products. Such phenomenon was reported by Lawal-Are et al. (2020) and was possibly attributed to additional interactions between nutrient and other components in relation to heating temperature.

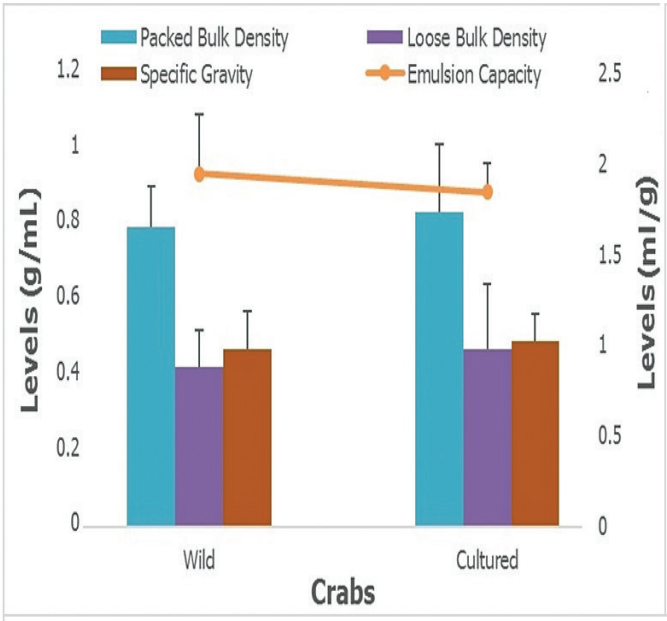

Figure 4. Functional densities of edible portion in wild and cultured crab, *Cardisoma amartum*

Conclusion

This study shows significant differences ($P<0.05$) in water absorption capacity, emulsion capacity, and foam stability between wild and cultured female crabs. There were no significant differences ($P>0.05$) in all measured functional properties of the edible portions between wild and cultured male crabs. Furthermore, there was no significant difference in the functional properties of the edible portion in wild and cultured *C. armatum*. High functional solubility of the crab edible portion indicates potential applications in formulated food systems by providing attractive appearance and smooth mouthfeel to the product. Studies on edible crab consumption could help to change food systems away from large animals.

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