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Utilization of Fish Feed Waste by Freshwater Mussels (Freshwater Mussels of *Aspatharia chaiziana* and *Aspatharia marnoi* (Family: *Iridinidae*) in Integrated Multi-Trophic Aquaculture (IMTA) System

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Abstract: This study was conducted to investigate the potential utilization of fish feed particulate waste by freshwater mussels of *Aspatharia chaiziana* and *Aspatharia marnoi* (Family: *Iridinidae*) cultured in an integrated multi-trophic aquaculture (IMTA) system. The utilization of fish feed waste was assessed using some indicators related to growth performance and proximate composition, to evaluate if co-cultured freshwater mussels enhanced their IMTA system. Physical properties data for several cooked forms and processing methods of mussels was evaluated. The results showed that the net biomass production of Nile tilapia, Nile catfish, thin-lipped grey mullet, prawn and freshwater mussels in IMTA system are 327.63, 273.8, 96.76, 19.67 and 188 kg/6 month. The combination of Nile tilapia and catfish with thin-lipped grey mullet and prawn as detritivorous fish, increases dietary nitrogen (N) and phosphorous (P) utilization efficiency to 17.49 and 24.44%, respectively. By Added freshwater mussels in the system as herbivore consumption, increased dietary efficiency of N and P by 12.67 and 19.89%, respectively. Finally, dietary N and P efficiency increased by addition hydroponic systems (HS) by 35.76 and 44.31%, respectively. In the present study, Metals bioaccumulation in the flesh mussels did not exceed the permissible limits set for heavy metals. Therefore, these mussels in this study did not pose any threat to human upon their consumption. Concerning the effect of applied cooking methods (boiled, fried, steaming and France sauce, respectively), on mussel's values contents of Trimethylamine-nitrogen (TMA-N), total volatile basic nitrogen (TVB-N) and thiobarbituric acid (TBA) was decreased. Appearance scores for all cooked methods samples slightly increased than taste scores; while the odor and tenderness of the boiled and steaming mussel samples received a lower score than other cooked methods. The limit of acceptability (score lower than 6) for juiciness was recorded for fried mussel samples only. This result indicates that IMTA as a bio-integrated food production system is not only a successful method for biomass production as food crops, but also a useful system to recycle aquaculture wastewater and it is applicable to desert, rural and urban area in development countries.

Key words: Feed waste · Freshwater mussels · Aquaponic · Hydroponic · Integrated multi-trophic aquaculture (IMTA) system · Processing methods

INTRODUCTION

Nowadays, an increasing concern with regard to the negative environmental impacts associated mainly with fish culture systems. The effects of discharge suspended solids including undigested feed and feces, dissolved nutrients and organic matter enrich recipient water are the main issues restraining the expansion and sustainable development of fish culture [1-6]. Therefore, selecting and applying best practice system could minimize and reduced the negative environmental impacts associated with fish farms waste discharges effluents load waste discharges effluents load and maximize its potential to mitigate food insecurity [7].

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The synergistic cultures of mussels in close proximity of fish farms to utilize organic and inorganic nutrients released and simultaneously increase the growth of the extractive species at lower trophic levels is known as Integrated Multi-Trophic Aquaculture (IMTA). IMTA is a specialized form of the age-old practice of aquatic polyculture, promotes economic and environmental sustainability by converting by-products and uneaten feed released from aquaculture (fish and shrimp) with inorganic extractive (microalgae and seaweeds) and organic extractive (e.g. mussels) aquaculture to create balanced systems for environment remediation, economic diversity and better management practices [8-12]. In this way, IMTA may contribute to a more sustainable aquaculture production [13, 14].

Freshwater mussels are invertebrates that can be divided into two main families namely - *Sphaeriidae* (small freshwater mussels) and *Unionidae* (large freshwater mussels). Freshwater mussel is found adequately in freshwater sources like ponds, lakes and rivers. The Size of freshwater mussel ranges from 1" to 2" across the shell. There are various species of freshwater mussels according to the temperature and the pH level of the water.

Several studies used suspension feeder such as bivalves to improve water quality by removing suspended particles through filter feeding and the production of feces and pseudo-feces [15- 20]. Both processes reduce the turbidity of the water [21]. Generally, clearance rates of marine bivalves are correlated with rates of water flow, food concentration and water temperature [22]. Clearance rates of bivalves range from 0.4 to 4.1 h g^{-1} dry weight of bivalve. About 32% of the nitrogen is lost as participates such as feces, pseudo-feces and uneaten feed that sink to the bottom. Daily filtration rates of oysters and clams using fishpond efficient average 3.24×10^{-4} g^{-1} N-nitrogen g^{-1} wet weight of bivalve and assimilation efficiency ranges between 18-26% [23]. No such data are available for freshwater Mussels.

Mussels have great scientific value as biological indicators of environmental health. A sudden kill of freshwater mussels is a reliable indicator of toxic contamination in flowing and standing waters. The gradual disappearance of freshwater mussels usually indicates chronic water pollution problems. Moreover, biologists can measure the amount of pollutants found in mussels' tissue to determine the type and extent of water pollution in streams and lakes.

Humans have used marine mussels as food for thousands of years and until now. There are many ways of the world renowned in the preparation, cooking and consumed Marine mussels such as French fries or bread, often mixed with other seafood, or eaten with pasta, covered with flour and fried on shishs, or filled with rice. Marine mussels can be smoked, boiled, steamed, or fried in batter. In Belgium, mussels are often served with fresh herbs and flavorful vegetables in a stock of butter. In Netherlands, mussels are sometimes served fried in batter or breadcrumbs, particularly at take-out food outlets or informal settings. Such data related to freshwater mussels is scare. Generally, fresh water mussels have little value as human food and so far no potential use of it as food human source. In Egypt, the freshwater mussels are not be utilized either for human or animal foods.

In the present study, a freshwater Integrated Multi-Trophic Aquaculture (IMTA) for the land-based culture of Nile tilapia, Nile catfish, thin-lipped grey mullet, freshwater prawn, freshwater mussels and two separate hydroponic systems (Nutrient Film Technique, NFT and Floating Raft System, FRS) was established compared to traditional plant cultivation using a solar energy system. The culture efficacy was evaluated based on a 2-year field experiment covering two growing seasons. Therefore, the present study was conducted to investigated the potential utilization of fish feed particulate waste by freshwater mussels of *Aspatharia chaiziana* and *Aspatharia marnoi* (Family: *Iridinidae*) cultured in an integrated multi-trophic aquaculture (IMTA) system. The utilization of fish feed waste was assessed using some biological- indicators related to growth performance and proximate composition, to evaluate if co-cultured freshwater mussels enhanced their IMTA system. Physical properties data for several cooked forms and processing methods of mussels was evaluated.

MATERIALS AND METHODS

Experiments were conducted at the El-Kanater El-Khayria, National Institute of Oceanography and Fisheries (NIOF), Egypt in the fish greenhouse glazing consisted of double layer polyethylene plastics.

Experimental Design: The integrated multi-trophic aquaculture (IMTA) freshwater system was constructed based on the technical innovative aspects known in scientific literature. In this system, aquatic animals are cultured separately in an aquatic modular system, which allow the conversion of discharged nutrients into valuable products.

Three separate experimental aquaponic IMTA systems using a solar energy module were tested (Fig. 1) : a) An Integrated Multi-Trophic Aquaculture (IMTA)

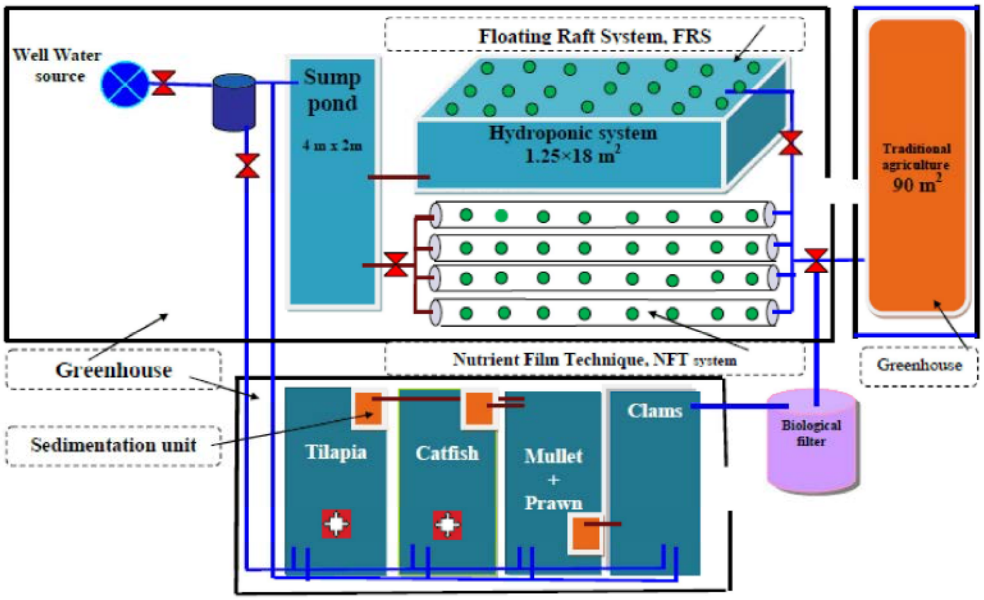

Fig. 1: Schematic Diagram of the IMTA system

of Nile tilapia, Nile catfish, thin lipped grey mullet, freshwater prawn, freshwater mussels and with Nutrient Film Technique (NFT) hydroponic system; b) IMTA and Floating Raft System, (FRS) hydroponic system; c) IMTA and Traditional soil plant cultivation (TSC).

The total area used for planted with economic vegetables in the IMTA-NFT, IMTA-FR, NT-FR and IMTA-TSC, are 122 m^2, 122 m^2, 122 m and 122 m^2, respectively. In the IMTA only tilapia and catfish are fed with a commercial diet then the water discharge from the tilapia and catfish ponds carried out all dissolved and particulate excreted by fish are pumped to the rest of the system modules, respectively to control of nutrient flow and uptake. In all experimental systems, the water was recycled again from the end of hydroponic system to aquatic animal ponds. In the present study, criteria for evaluating the culture performance efficacy and control of nutrient flow and uptake were evaluated based on a 2-year field experiment covering two growing seasons.

Experimental Aquatic Organisms Cultures: The initial body weight of all experimental aquatic organisms stocked in mid-June 2012, at various concrete ponds allocated to them in the aquatic raising greenhouse as follows: Fingerlings of Nile tilapia, *Oreochromis niloticus* (L.) (25.4± 0.2 g) was stocked into concrete pond (40 m^3) at stocking rates of 15 fish/ m^3. African catfish *Clarias gariepinus* (Burchell, 1822) (173.27±5.64 g) was stocked into a concrete pond (40 m^3) at a stocking rate of five fish m^3. Thin Lipped Grey Mullet *(Liza ramada)* fry and *Macrobrachium rosenbergii (de Man 1879)* post-larvae (PL) with an initial body weight of (0.2±0.04 g and 0.28±0.2 g, respectively) were stocked into a concrete pond (40 m^3) in polyculture manner at stocking rate of 50 fry m^3 and 84 prawn PL m^2, respectively. A total of 250kg from the freshwater clams *Aspatharia chaiziana* and *Aspatharia marnoi* (Family *Iridinidae*) (130.18 ± 15.22 g, for each individual mussel) were stocked into a concrete pond (40 m^3) based on the pond bottom area (40 m^2) at 2.5 kg^{-1} m^2.

A floating test diet (3-mm floating pellet) was formulated containing 35% CP and 12.32 MJ gross energy kg^{-1}. The diet was processed in NIOF fish feed mill in El-Max Research Station. Two strong air blowers aerated the ponds. Sampling of cultured fish, prawn and freshwater mussels to determine weight gain were conducted using a small seine net to sample the populations. The first sampling was conducted on the 30th day after stocking and each 15-days interval thereafter. The quantity of daily diet was adjusted accordingly.

Analytical Methods: The proximate composition of the diet and whole body were at the beginning and termination of the experimental periods was determined according to AOAC procedures [24]. Sample was oven-dried at 105°C for 24h to determine the moisture content. Ash content was determined by incineration at 550°C for 12 h. Crude protein was determined by micro-Kjeldhal method, (using a Kjeltech autoanalyzer, Model 1030, Tecator, Sweden) and crude fat by soxhlet extraction with diethyl ether (40-60°C). Trimethylamine-nitrogen (TMA-N), was determined as described in the AOAC [25]. Total volatile basic nitrogen (TVB-N) was determined by macro-distillation method proposed by] Pearson [26]. The thiobarbituric acid (TBA) value was determined as mentioned by] Pearson [26]. Iron (Fe), manganese (Mn), cadmium (Cd), copper (Cu), zinc (Zn) and lead (Pb) concentrations were determined using atomic absorption (model GBC Savant AA AAS) with GF 5000 graphite furnace. These metals were chosen because at higher concentrations there might be toxic to mussels or humans as food. Gross energy content of diet and whole body samples were calculated according to the gross caloric values by applying the factor 23.63 kJ g^{-1}, 39.52 kJ g^{-1} and 17.15 kJ g^{-1} of crude protein, crude fat and total carbohydrate, respectively [27].

Water Analysis: Water quality experiments on ponds and different hydroponic water system samples either inflow or outlets points were collected at the seventh day for every week from each separate aquatic animals modules. Ammonia (NH_4), nitrite (NO_2) and nitrate (NO_3), orthophosphate and total phosphorus, were determined as described in APHA [28].

Nitrogen (N) and Phosphorus (P) Calculation Parameters: The Nitrogen (N) and Phosphorus (P) balance for fish-culture ponds and different experimental hydroponic systems were calculated from the mass balance by following general equations:

Nutrient discharge = Dietary nutrients - aquatic animals body deposition nutrients.

Total N (P) gain = Tissue N (P) gain x Total biomass production (g wet weight).

N (P) intake = Feed N (P) x Total feed intake (mg dry weight).

Total N (P) discharge = N (P) in feed – N (P) gain (g wet weight).

N (P) gain in fish (g) = (Final wet weight x final N (P) content) – (Initial weight wt x initial N (P) content).

The following equations were used to determine the predicted computational (estimated) N and P balance for mullets, prawn and mussels:

N (P) gain biomass (kg) (mullets, prawn, mussels) = aquatic animals gain biomass × aquatic animals nitrogen content (%).

N (P) discharge (kg) (mullets) = N (P) discharge for Nile tilapia + nitrogen discharge for catfish) - N (P) discharge for mullets (kg).

N (P) discharge (kg) (prawn) = N (P) discharge for mullets (kg) - N (P) discharge for prawn (kg).

N (P) discharge (kg) (mussels) = N (P) discharge for mussels (kg) - N (P) discharge for mussels (kg).

Freshwater Mussels Processing: Three samples of mussels (20 kg for each sample with an average body weight of 300 - 350 g for each individual mussel) was collected from IMTA system and transported immediately to fish technology and processing laboratory. Mussels washed by tap water, soaked in water for 30 minutes at 30°C to essay dressing and then again washed by tap water to remove the sand from meat.

Four processing methods were used on mussels (fried, boiled, steaming and France sauce methods). In fried method, mussels sample was coated by flower and fried for 10 min in sunflower oil at 170°C. In boiled method, mussels sample was mixed with spices and salt then boiled with water for 10 minutes at 100°C. For steaming method, mussels sample treated by steaming for 30 min, then chilled to room temperature (25°C) for 5 min. In France sauce method, a component of vinegar (as the muscular foot of a mussel) and lemon juice, oil, salt and pepper was mixed with mussels sample for 1 h at 5°C. The Ingredients used for cooking (Sunflower oil- flower-black pepper - Sodium chloride- Lemon juice - vinegar - Onion – Garlic) were purchased from a local market.

Sensory Assessment: Sensory evaluation was carried out according to the procedure of [29]. A ten member-trained panel evaluated the sensory quality of cooked mussels. Mussel samples (140 g) were cooked with different four methods individually and immediately presented to the panelists (each panelist evaluating ca 20 g of mussel sample). Samples were presented to each panelist in plastic cups covered with a lid in random order. Panelists were asked to score odour, taste and appearance of cooked mussel and appearance of raw mussels using a 0–10 acceptability scale, where a score of 10 was defined as excellent. For each sensory attribute, a score of 6 (recorded by at least 50% of the judges) was considered to be the lower limit of acceptability, implying that shelf-life was terminated when this score was obtained.

Statistical Analysis: Data were statistically analyzed by analysis of variance using MSTAT-C Version 4 software [30]. Duncan's multiple range test was used to compare differences between treatment means when significant F values were observed [31], at $P \leq 0.05$ level.

RESULTS & DISCUSSION

IMTA System Production: The results showed that the net biomass production (6 month) of Nile tilapia, Nile catfish, thin lipped grey mullet, prawn and freshwater mussels in IMTA system are 327.63, 273.8, 96.76, 19.67 and 188 kg (Table 1). The results showed that the net biomass production (6 month) of Nile tilapia, Nile catfish, thin lipped grey mullet, prawn and freshwater mussels in IMTA system are 327.63, 273.8, 96.76, 19.67 and 188 kg (Table 1). Nile tilapia consumed a total of 509.24 kg of feed, containing 22.89 and 5.25, nitrogen (N) and phosphorous (P) kg, respectively and gains of 5.52 kg N and 3.22 kg P, representing 24.11 and 61.33 % of dietary N and P retention, respectively (Table 2). Similar, catfish consumed a total of 205.35 kg of feed, containing 9.23 nitrogen (N) and 2.12 kg phosphorous (P), respectively. Catfish gain of 2.76 kg N and 0.92 kg P, representing 29.90 and 43.39 % of dietary N and P retention, respectively (Table 2).

The combination of Nile tilapia and catfish with thin lipped grey mullet and prawn as detritivorous fish increased dietary N and P utilization efficiency to 13.04 and 24.44%, respectively and with addition freshwater mussels to the system as herbivore consumption, N and P efficiency increased to 9.44 and 19.89%, respectively (Table 3). Finally, dietary N and P efficiency increased by addition hydroponic systems (HS) by 9.53 and 44.31%, respectively (Table 2). This result indicates that IMTA as a bio-integrated food production system is not only a successful method for biomass production as food crops, but also a useful system to recycle aquaculture wastewater and it is applicable to desert, rural and urban area in development countries.

Heavy Metals Concentrations of Raw Freshwater Mussels: The bioaccumulation of heavy metals in living organisms and biomagnifications describes the processes and path- ways of pollutants from one trophic level to another. Heavy metal can be incorporated into food chains and absorbed by aquatic organisms to a level that might affects their physiological state. Trace metals such as Zn, Cu and Fe play a biochemical role in the life processes of all aquatic plants and animals; therefore, they are essential in the aquatic environment in trace amounts. High level of heavy metals has apparent lethal and chronic effects on fishes [32]. Thus, fish not only indicates the pollution status of aquatic ecosystem but also, have significant impact on the food web [33]. It is one of the main sources of protein-enriched food all over the world [34]. Consumption of contaminated fish with heavy metals can result hazardous effects on human health [35]. In the present study, the lowest heavy metals concentration of flesh mussels (Table 3) from Fe (0.86 mg g^{-1}), Mn (0.223 mg g^{-1}), Zn (0.110 mg g^{-1}) were recorded compared permissible limits (mg day^{-1}) of [36] (43, 2.9 and 40 mg g^{-1}, respectively). The same trend was observed for Cu (0.015 mg g^{-1}), Pb (0.001mg g^{-1}) and Cd (0.001 mg g^{-1}) and it was below the lower residue concentrations in mussels samples. Based on the above results, it can be concluded that metals bioaccumulation in the flesh mussels study did not exceeds the permissible limits set for heavy metals by FAO/WHO [36]. Therefore, these mussels did not pose any threat to human upon their consumption.

Proximate Composition of Freshwater Mussels: Moisture content had a downward pattern of change in all clam samples (Table 4). It was 72.22 % in raw sample and reached 51.47 after fried process at 170 °C for 10 min. with a loss of 20.75%. Changed in protein content of processed samples were also given in Table (5). Crude protein of fresh sample was 58.29% reduced to 52.84, 56.84, 56.86 and 56.56 % in the fried, boiled, steaming and France sauce samples, respectively. The initial fat content of fresh clam samples was 6.26% (on dry weight basis), increased to 12.30% after frying process. An apparent increased cleared in fat content, could be attributed to loss of moisture content. In this trial, cooking of samples would tend to cause a significant fat increase, Anthony [37] observed similar trend. Moreover, a slight increase was observed in ash content as affected by all processing treatments except fried samples showed a slight increase.

Quality Changes Induces of Freshwater Mussels: The effects of different applied cooking methods on quality criteria of mussels' samples are shown in Table (4). TVB-N content of fresh mussels sample (34.13 mg TVB-N $100g^{-1}$ dry^{-1}) is more realistic limit values for mussels (22– 25 mg TVB-N $100g^{-1}$ dry^{-1}) as compared with the value of (35 mg TVB-N $100g^{-1}$ dry^{-1}) proposed for fish [38]. Concerning the effect of applied cooking methods, TVB-N mussel's values content was decrease in all cooking methods (boiled, fried, steaming and France sauce, respectively). A possible reason for a relatively low TVB-N content after cooking methods may be that in natural condition mussels undergo a general acidification

Table 1: Growth performance of different aquatic species culture; Nile tilapia, Catfish, Mullets, Prawn and Mussels in aquaponic system

	IBW	FBW	WG	SGR	FI
Nile tilapia (g)*	25.4 ±4.7	231.33±2.31	205.93±2.32	1.38±0.28	346.95±13.3
Catfish (g) *	173.27±17.6	705.65±60.24	532.38±61.1	0.88±0.14	1058.48±143.2
Mullets (g)*	0.20±0.01	96.76±1.88	96.56±1.69	3.86±0.24	-
Prawn (g)*	0.28±0.01	19.67±0.87	19.39±0.68	2.66±0.28	-
Mussels(g) *§	130.18 ±15.2	415.33±60.95	285.15±61.24	0.73±0.83	-

* IMTA-NFT: integrated multi-trophic aquaculture (IMTA) - Nutrient Film Technique (NFT) or

IMTA-FRS system: integrated multi-trophic aquaculture (IMTA) – Floating Raft System, (FRS) § An estimate values

□S (%) = Survival

Table 2: Overall N and P budgets for IMTA system

	Kg-N 40 m^3	% of N-gain Intake^{-1}
Total N intake for Nile tilapia and catfish	32.12	100.00
Total N gain for Nile tilapia and catfish	8.28	25.53
Total N discharge from Nile tilapia and catfish	23.93	74.74
Total N gain for mullet	2.68	11.20
Total N gain for prawn	0.44	1.84
Total N gain for clams	2.26	9.44
Total N gain for plants in hydroponic	2.28	9.53
Total N remaining from the system	16.18	42.21
Total P intake for Nile tilapia and catfish	4.09	100.00

Table 3: Heavy metals concentrations (mg g^{-1}) in raw freshwater mussels

	Heavy Metals					
	Fe	Mn	Zn	Cu	Pb	Cd
Permissible Limits (mg g^{-1} wet-weight)*	0.100	0.001	0.040	0.030	0.0005	0.0005
Flesh mussels in the present study (mg g^{-1} dry- weight)	43	2.9	40	30	0.214	0.1

* According to FAO/WHO [36]

Table 4: Proximate composition analysis and quality induces of freshwater mussels

	Experimental cooking treatment				
	Raw	Fried	Boiled	Steaming	France Sauce
Moisture %	72.28±0.99	51.47±0.56	59.54±0.58	60.68±1.09	70.58±2.08
Protein %	58.29±0.33	52.84±1.20	56.84±0.51	56.86±1.21	56.56±2.20
Fat %	6.26±0.17	12.30±0.23	10.05±0.49	10.73±0.30	7.50±0.25
Ash %	34.62±0.40	35.30±0.53	33.27±0.88	31.40±0.61	33.23±1.10
TVB-N mg 100g^{-1}	34.13±1.71	10.90±0.97	10.21±0.89	13.22±0.90	23.33±1.12
TMA-N mg 100g^{-1}	14.87±1.98	5.41±0.62	6.77±0.42	9.37±0.57	11.94±1.45
TBA mg kg^{-1}	1.55±0.04	1.60±0.55	0.57±0.26	1.22±0.25	1.43±0.38

Data are expressed as mean ± SD from the three replicates.

Different superscript letters mean significant differences between samples ($p \leq 0.05$)

Table 5: Sensory scores of freshwater mussels

	Experimental cooking treatment			
Sensory property	Fried	Boiled	Steaming	France Sauce
Appearance	8.0±0.22	8.5±0.35	8.8±0.45	8.3±0.45
Color	7.7±0.45	7.9±0.55	8.3±0.22	7.6±0.45
Tenderness	7.5±0.22	6.8±0.45	6.9±0.45	7.0±0.45
Juiciness	5.9±0.45^{c}	6.5±0.55^{c}	6.9±0.55^{b}	7.9±0.45^{a}
Taste	7.1±0.22	7.1±0.67	7.0±0.45	7.4±0.55
Mouth Feeling	7.3±0.45	7.3±0.55^{a}	7.5±0.55	8.0±0.45
Odor	8.0±0.35	7.8±0.55	7.5±0.55	8.5±0.45
Overall acceptability	6.7±0.55^{b}	6.7±1.00^{b}	6.7±0.50^{b}	7.7±0.45^{a}

Data are expressed as mean ± SD from the three replicates for ten independent panelists.

Different superscript letters mean significant differences between samples ($p \leq 0.05$)

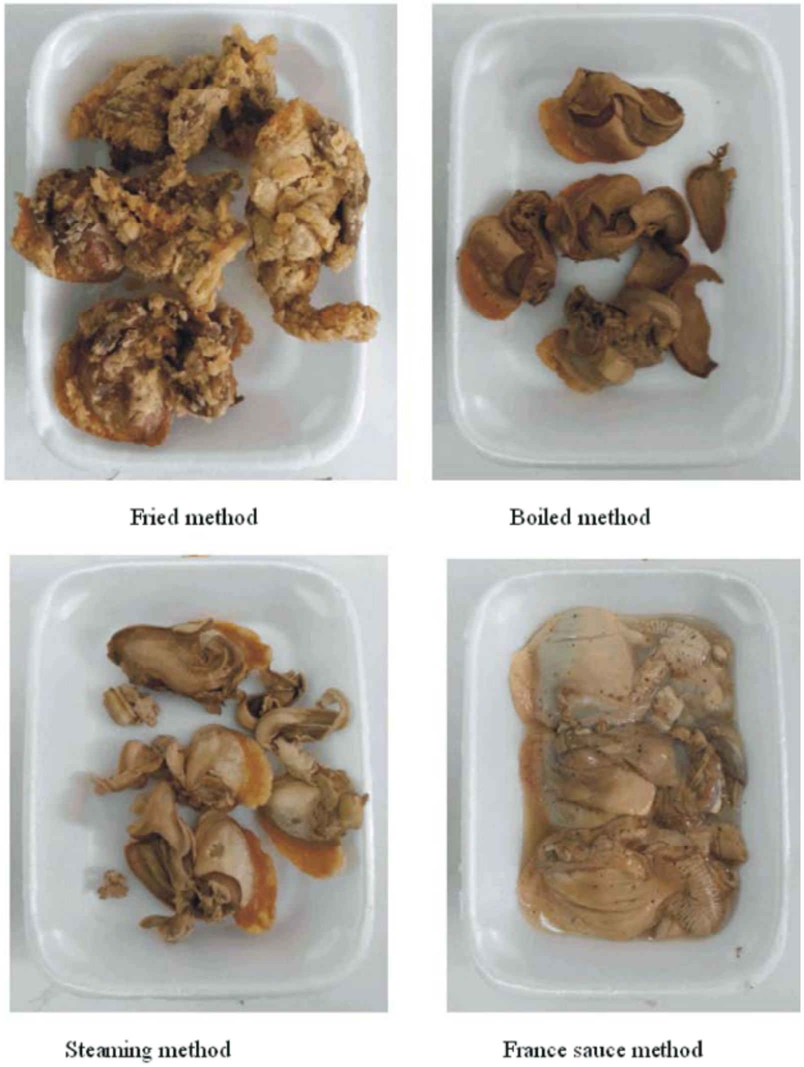

Fig. 2: Several cooked forms and processing methods of mussels

because of their high glycogen content, which is converted to lactic acid [39]. TVB-N value is the result of titration with HCl, the lactic acid produced neutralized part of the base (TVB-N) and thus reduced the calculated TVB-N values. According to Orban *et al*. [40], the glycogen content of mussels, *Mytilus galloprovincialis* is 12.7–24.8% on a dry basis.

The initial TMA-N content of fresh samples was 14.87 mg TMA-N $100g^{-1}$ dry matter. Concerning the effect of applied cooking methods, TMA-N mussel's values content was decrease in all cooking methods. TMA is produced by the decomposition of TMAO caused by bacterial action and possibly through the action of intrinsic enzymes [38 and 41]. Lower TMA-N values in mussel's can be attributed to bacterial growth inhibition after cooking. The same trend was observed for TBA value except for slightly increase occurred in fried sample. The TBA index is a measure of malondialdehyde (MDA), one of the degradation products of lipid hydroperoxides, formed from PUFA [42].TBA values of all mussel samples (0.57–1.60 mg malondialdehyde (MDA) kg^{-1} dry matter) did not exceed the value of 1–2 mg MDA kg^{-1} dry matter), As for this limit is beyond which mussels will normally develop an objectionable odour/taste [38, 43].

Sensory Test Scores of Freshwater Mussels: Table (5) shows sensory evaluation of mussels for different applied cooking methods (Fig. 2). There is a significant difference between France sauce sample and other samples in juiciness and overall acceptability parameters. These variations occurred in the organoleptic parameters depends mainly on the effect of heating conditions of each cooking method. The results showed that appearance scores for all cooked methods samples slightly increased than taste scores. In general, the odor of the boiled and steaming mussel samples received a lower score than other cooked methods. The same trend was observed for tenderness score. The limit of acceptability (score 6) for juiciness were recorded for fried mussel samples only.

Conflict of Interest: There is no conflict of interest.

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