CHAPTER 4

RESULTS AND DISCUSSION

4.1 Chemical Composition

Chemical composition values of wild-caught (Sungai Skudai, Johor Bahru) and farm- raised catfish from pond A (Lanchang, Pahang), pond B (Simpang Renggam, Johor), and pond C (Sungai Buloh, Selangor) were listed in Table 4.1. Catfish samples from Pond A and pond C were fed by fish pellets while catfish from pond B were fed with chicken offal. Generally, protein, fat, and ash contents of farm-raised samples of catfish were higher in percentages than those wild-caught catfish. Conversely, moisture content of wild-caught catfish showed the highest value among the samples (80.93%) indicating that it contains more water than the farmed-raised catfish.

Table 4.1: Chemical Composition of Wild-caught and Farm-raised Catfish

Parameter (%)	Wild- caught sample	Farm-raised sample		
		Pond A	Pond B	Pond C
Moisture (%)	$80.93^{A} \pm 0.29$	$75.02^{B} \pm 0.69$	$70.40^{C} \pm 1.81$	$65.39^{D} \pm 1.46$
Protein (%)	$15.59^{B} \pm 0.71$	$15.59^{B} \pm 0.81$	$20.94^{A} \pm 1.45$	$16.84^{B} \pm 1.72$
Fat (%)	$4.96^{AB} \pm 1.72$	$5.36^{AB} \pm 0.42$	$6.59^{A} \pm 1.28$	$3.10^{B} \pm 0.30$
Ash (%)	$1.27^{B} \pm 0.03$	$1.83^{A} \pm 0.07$	$1.35^{B} \pm 0.08$	$1.32^{B} \pm 0.05$

Regarding results from Table 4.1, the values are mean ± standard deviation (SD) of the mean (n=12) samples and are significantly different at ($p<0.05$).

Moisture content of wild-caught samples (80.93%) was significantly (P<0.05) higher in value as compared to the farm-raised samples from pond A (75.03%), pond B (65.39%), and pond C (70.40%). Ukagwu et. al. (2017) reported that external causes including catfish habitat, lifestyle and feeding source influenced the moisture content of catfish. Several studies stated that catfish muscle, moisture, and ash content decreased in values with an increase in fats and protein contents and vice versa (Shahid et al., 2019). The increase in moisture content is due to decreasing fat and protein contents in the fish body (Shahid et al., 2019).

On the other hand, protein content in the farm-raised samples of catfish from pond A (Lanchang, Pahang) (15.59%), pond B (Simpang Renggam, Johor) (20.93%), and pond C (Sungai Buloh, Selangor) (16.83%) were higher than wild-caught catfish samples (15.59%). Among these samples, catfish caught from pond B were found to have the highest protein percentage with the significant difference (p<0.05). The feed of chicken offal may contribute to the high protein content in catfish obtained from pond B. According to Omole and co-researchers (2006), chicken offal contains approximately 65.8% protein, and this data agrees to the current finding of high protein content in catfish fed with chicken offal in this study (Omole et al., 2006)

From Table 4.1, the high fat content of farm-raised catfish from pond A (Lanchang, Pahang) and pond B (Simpang Renggam, Johor) is due to the types of feed given were wheat bran pellet and chicken stomach. In another research of wheat bran pallet and chicken stomach are rich in fat content with the percentage of 5.5- 5.6% and 0.81-4.53% respectively (Koirala et al., 2017; Raghu Babu et al., 2018).

This statement may support the present study finding that the fat content of farm-raised catfish from pond A and pond B were higher than catfish fed by pellet only which is catfish from pond C. As result, catfish pond C (Sungai Buloh, Selangor) has low fat percentage of 3.10% due to the fish pellet having balance and least content of fat for preventing excessive fat deposition in the liver can decrease catfish health and quality (Steven Craig, 2017). These findings showed that the types of feed given to the farm-raised catfish are highly influenced by the fat content of the catfish caught. Wild-caught catfish are normally algae- and detritus-eating organisms. Therefore, the low-fat content of those wild-caught catfish is probably due to these eating habits. Furthermore, the more lipid deposition in farm- raised samples adipose tissue probably due to lack of moving of catfish in the earthen pond may also contribute to the high fat content in those catfish rather than wild-caught catfish.

Ash content was significantly ($P<0.05$) higher in the farm-raised (1.49%) than (1.27%) in the wild-caught samples respectively and showed farm-raised samples as a good mineral source nutritionally. Fish pellet that was consumed by catfish from pond C usually balance content of mineral for maintaining catfish health from bone mineralization, skeletal deformities, and fin erosion of farm-raised catfish due to mineral deficiency (Lall & Kaushik SJ, 2021). Comparison between the farm-raised and wild- caught samples of catfish showed higher levels of protein, fat, and ash content recorded in the farm-raised samples, while higher levels of moisture were noticed in the wild samples of catfish.

4.2 Fatty Acid Composition

The profile and percentage composition of up to 25 different fatty acids identified from the wild-caught and farm-raised catfish oil were presented in Table 4.2. The composition of fatty acids such as palmitic acid in wild-caught catfish samples was higher than farm-raised catfish from pond B and C while lower of stearic and oleic acids. Regardless of the diets, docohexaenoic acid and linoleic acid were the dominant polyunsaturated fatty acid (PUFA) detected in farm-raised catfish sample fillets from pond A (4.51%) and pond C (31.85%) respectively. Oleic acid in farm- raised from pond B (29.26%) and C (29.29%) higher than wild-caught sample but from sample pond A (10.84%) was the lowest. The high content of oleic acid may be attributed to the type of feed fed to the fish. Few studies stated that higher content of specific n-3 fatty acid such linoleic acid and docohexanoic acid (DHA) may cause increase of 'fishy' flavour of cooked fillet (Meadus W. J et al., 2013; Nhu, 2003; Zhang et al., 2021). Based on the statement and this study fatty acid composition result proved that commonly people do not like catfish due to having significantly 'fishy' flavour as well as mackerel and herring. Dieting of fish had a major effect on the fatty acid composition of lipid (Satoh. et al., 1989). For example, fish fed a diet high in omega-3 fatty acids will have a higher proportion of omega-3 fatty acids in their lipid than fish fed a diet high in omega-6 fatty acids. This is because the type of fatty acids that fish consume is incorporated into their lipid.

As in Table 4.2, DHA content in farm-raised catfish from pond A (4.51%) significantly higher than other sample may cause the catfish pond A live in waters that are rich in algae, which are also a good source of DHA. This means that catfish have a steady supply of DHA in their diet, which contributes to their high levels of this fatty acid.

Linoleic acid was one of the dominant polyunsaturated fatty acids in farm-raised sample of catfish which can prevent insulin resistance by decreasing Alpha-Tumor Necrosis factor (TNF –α) level and possibly by enhancing adiponectin levels while the oleic acid was another major fatty acid in farm- raised catfish due to the fed source was from chicken offal (Clarke, 2004). This is not surprising as chicken fat is demonstrated to be a predominant source of oleic acid.

Table 4.2: Fatty Acid Composition of Wild-caught and Farm-raised Catfish

Fatty Acid names	Wild- caught sample (%)	Farm-raised samples (%)		
		Pond A	Pond B	Pond C
Dodecanoic acid	$1.55^{A} \pm 0.02$	$1.53^{A} \pm 0.01$	$0.08^{B} \pm 0.00$	$0.10^{B} \pm 0.003$
Tetradecanoic acid/ mystric acid	$3.37^{A} \pm 0.02$	$3.13^{B} \pm 0.02$	$0.62^{C} \pm 0.01$	$0.66^{C} \pm 0.008$
Myristoleic acid (cis-9)	$2.32^{A} \pm 0.02$	$0.37^{B} \pm 0.02$	$0.12^{C} \pm 0.01$	$0.11^{C} \pm 0.009$
Pentadecanoic acid	$1.00^{A} \pm 0.02$	$1.12^{A} \pm 0.01$	$0.44^{B} \pm 0.00$	$0.31^{B} \pm 0.008$
Palmitic acid	$24.53^{A} \pm 0.07$	$19.65^{B} \pm 0.49$	$16.14^{C} \pm 0.06$	$12.35^{D} \pm 0.021$
Palmitoleic acid (cis-9)	$5.64^{B} \pm 0.02$	$1.98^{D} \pm 0.01$	$4.08^{C} \pm 0.03$	$6.77^{A} \pm 0.02$
Margaric acid	$1.15^{A} \pm 0.00$	$0.82^{B} \pm 0.02$	$0.33^{C} \pm 0.01$	$0.27^{C} \pm 0.01$
Cis-10-heptadecenoic acid (cis-10)	$0.21^{C} \pm 0.00$	$0.2^{C} \pm 0.02$	$0.32^{B} \pm 0.01$	$0.42^{A} \pm 0.01$
Stearic acid	$8.39^{B} \pm 0.01$	$10.04^{A} \pm 0.03$	$6.41^{C} \pm 0.03$	$5.20^{D} \pm 0.02$
Oleic acid (cis-9)	$20.84^{B} \pm 0.06$	$10.84^{C} \pm 0.07$	$29.26^{A} \pm 0.13$	$29.29^{A} \pm 0.09$
Linoleic acid (cis-9,12)	$13.44^{D} \pm 0.01$	$15.32^{C} \pm 0.06$	$22.56^{B} \pm 0.03$	$31.85^{A} \pm 0.07$
Arachidic acid	$0.28^{A} \pm 0.01$	$0.27^{A} \pm 0.01$	$0.13^{B} \pm 0.00$	$0.10^{B} \pm 0.00$
ɤ-Linolenic acid (GLA) (CIS-6,9,12)	$1.12^{C} \pm 0.02$	$0.60^{D} \pm 0.01$	$2.47^{A} \pm 0.02$	$1.75^{B} \pm 0.01$
Gadoleic acid (cis-11)	$0.82^{B} \pm 0.02$	$1.10^{A} \pm 0.03$	$0.89^{B} \pm 0.01$	$0.69^{B} \pm 0.03$
A-Linolenic acid (CIS-9,12,15)	$0.81^{B} \pm 0.01$	$0.78^{BC} \pm 0.02$	$0.60^{C} \pm 0.01$	$1.62^{A} \pm 0.01$
Heneicosanoic acid	$2.10^{A} \pm 0.03$	$0.57^{B} \pm 0.03$	$0.54^{B} \pm 0.00$	$0.33^{C} \pm 0.02$
Cis-11,14 eicosadienoic acid (cis-11,14)	$4.78^{C} \pm 0.04$	$18.03^{A} \pm 0.30$	$10.71^{B} \pm 0.01$	$4.01^{D} \pm 0.03$
Behenic acid	$0.49^{D} \pm 0.02$	$2.81^{A} \pm 0.08$	$1.00^{B} \pm 0.03$	$0.52^{C} \pm 0.02$
Cis-11,14 eicosatrienoic acid (cis-8,11,14)	$1.62^{B} \pm 0.01$	$2.56^{A} \pm 0.03$	$1.00^{C} \pm 0.02$	$0.83^{D} \pm 0.01$
Erucic acid (cis-13)	$0.18^{A} \pm 0.03$	$0.22^{A} \pm 0.02$	$0.18^{A} \pm 0.01$	$0.11^{A} \pm 0.01$
Cis-8,11,14 eicosatrienoic acid	$0.18^{C} \pm 0.04$	$0.38^{B} \pm 0.01$	$0.61^{A} \pm 0.03$	$0.16^{C} \pm 0.05$
Tricosanoic acid	$3.44^{A} \pm 0.01$	$0.76^{C} \pm 0.01$	$0.64^{C} \pm 0.02$	$1.18^{B} \pm 0.02$
Cis-13,16 docosadienoic acid	$0.15^{B} \pm 0.00$	$0.72^{A} \pm 0.02$	$0.23^{B} \pm 0.01$	$0.01^{C} \pm 0.00$
Lignoceric acid	$0.24^{B} \pm 0.01$	$0.55^{A} \pm 0.00$	$0.18^{B} \pm 0.02$	$0.18^{B} \pm 0.00$
Nervonic acid	$0.74^{B} \pm 0.00$	$1.06^{A} \pm 0.08$	$0.13^{C} \pm 0.01$	$0.13^{C} \pm 0.04$
Docosahexaenoic acid (DHA)	$0.60^{B} \pm 0.02$	$4.51^{A} \pm 0.04$	$0.23^{B} \pm 0.01$	$0.78^{B} \pm 0.01$

4.3 Texture Analysis

Regarding Table 4.3, wild-caught and farm-raised catfish flesh were determined for their texture profile analysis by using texture analyzer (Basmal, 2021). Hardness is a measure of force to compress the catfish fillet between the flat-cylindrical probe during the first compression was significantly greater for the cooked farm-raised catfish from pond B than cooked farm-raised from pond A, C, and wild-caught catfish. Cohesiveness was measured as the ratio of the positive force during the second compression to the positive force during the first compression of catfish fillet samples. Springiness was defined as the ratio of the time or distance from the start of the second area of catfish fillet to the second probe reversal over the distance or the time between the start of the first area and the first probe reversal.

Table 4.3: Texture Analysis of Wild-caught and Farm-raised Catfish

Parameter	Wild-caught sample		Farm-raised samples					
			Pond A		Pond B		Pond C	
	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw
Hardness	$5.53^{B} \pm 0.02$	$6.03^{b} \pm 0.02$	$3.14^{D} \pm 0.01$	$4.91^{c} \pm 0.03$	$6.64^{B} \pm 0.01$	$6.28^{a} \pm 0.48$	$4.89^{C} \pm 0.01$	$3.18^{d} \pm 0.01$
Springiness	$0.74^{A} \pm 0.08$	$0.62^{b} \pm 0.06$	$0.84^{A} \pm 0.03$	$0.69^{b} \pm 0.00$	$0.82^{A} \pm 0.02$	$0.64^{b} \pm 0.07$	$0.83^{A} \pm 0.03$	$0.86^{a} \pm 0.02$
Cohesiveness	$0.39^{C} \pm 0.03$	$0.47^{c} \pm 0.03$	$0.49^{A} \pm 0.02$	$0.59^{a} \pm 0.00$	$0.56^{A} \pm 0.03$	0.53 ± 0.06	$0.53^{AB} \pm 0.01$	$0.54^{ab} \pm 0.05$
Chewiness	$1.56^{D} \pm 0.09$	$1.69^{c} \pm 0.08$	$3.44^{A} \pm 0.02$	$1.98^{b} \pm 0.38$	$3.09^{C} \pm 0.02$	$2.14^{a} \pm 0.55$	$3.27^{B} \pm 0.05$	$1.55^{d} \pm 0.03$
Resilience	$0.12^{B} \pm 0.03$	$0.18^{b} \pm 0.02$	$0.22^{A} \pm 0.03$	$0.17^{b} \pm 0.03$	$0.17^{AB} \pm 0.01$	$0.18^{b} \pm 0.03$	$0.18^{AB} \pm 0.04$	$0.32^{a} \pm 0.02$

Raw wild-caught sample showed the hardness (6.03), cohesiveness (0.47), and resilience values (0.18) that slightly higher ($p<0.05$) than cooked wild-caught catfish flesh while the cooked farm-raised catfish from pond A and pond C samples had significantly ($p<0.05$) higher than cooked wild-caught sample. Resilience is a measurement of quantity; sample deformation recovery rate is seen in terms of speed and power. The resilience value is obtained from the comparison between the area before the peak and the area after the peak in the first compression. Resilience describes the product's ability to return to its original position immediately after experiencing the first compression before the second compression occurs. The resilience value was also greater in raw farm-raised catfish than wild-caught samples. However, the cohesiveness value of raw farm-raised catfish from pond A, B, and C were slightly greater than wild-caught catfish samples. The residual cohesiveness was also greater in raw farm-raised samples than wild-caught.

Springiness value was higher in cooked wild-caught and farm-raised catfish from pond A, B, and C than wild-caught and all farm-raised catfish raw samples, indicating cooked catfish samples could spring back upon compression better than the raw catfish sample. The residual springiness that was standardized to the fillet thickness was also greater in the both cooked wild-caught and all farm-raised catfish. This indicates that the added water holding compounds resulted in the flesh being less springy. The chewiness value was greater in the cooked farm-raised catfish. This indicated that cooked catfish takes longer to chew and has slower breakdown during chewing.

The texture analysis result showed that farm-raised catfish are more firm and not easy to mash especially after cooked as they are harder, springer, and chewy than wild-caught catfish.

Based on Table 4.3, the small letter indicates raw catfish sample while capital letter is used to show cooked catfish. Values in table are mean ± standard deviation (SD) of the mean (n=24) samples and are significantly different at ($p < 0.05$).

4.4 Sensory Analysis

According to Table 4.4, the sensory evaluation results of wild-caught and farm-raised catfish showed the values are mean ± standard deviation (SD) of the mean (n=12) samples and are significantly different at ($p<0.05$). The table showed odour value of wild-caught catfish samples particularly on 'grassy' were recorded highest while for attribute 'muddy earthy' were slightly lower than farm-raised catfish. The definition of 'grassy' odour attribute has mild, slightly earthy odour with a hint of leafy green vegetable (Martine van der Ploeg, 1991). The attribute of 'muddy earthy' was defined smells that may be described as fishy, soil-like, or musky are most likely natural smells and some species of aquatic actinomycetes, and blue-green algae are generally indicated as sources of muddy odour in natural waters. These organisms can produce the muddy-smelling compounds geosmin and 2- methylisoborneol (Persson, 1980). Therefore, wild-caught catfish have a lower muddy earthy odour than others due to fish living in flowing water such as rivers while farm- raised catfish live in stagnant water.

Waste from aquaculture is not flowing out of the pond resulting in the muddy earthy odour to the latter fish. Clearly, if not by chance it implies that the culture environment may influence the odour of fish evaluated by consumers. Johnsen & Carol A. Kelly (1990) indicated that aroma (odour or smell) gives an indication of the degree of attraction or repulsion of consumers to food substances.

Consumers of a seafood-based product are attracted or repelled to it by means of its odour. Pleasing aromas attract consumers while irritating odour repels them (Agbolosu et al., 2014).

Table 4.4: Sensory Evaluation of Wild-caught and Farm-raised Catfish

Attributes		Wild-caught	Farm-raised		
			Pond A	Pond B	Pond C
Odour	Grassy	$11.22^{A} \pm 1.67$	$10.79^{A} \pm 0.88$	$7.71^{B} \pm 1.38$	$2.95^{C} \pm 0.46$
	Muddy-earthy	$2.87^{B} \pm 0.93$	$2.86^{B} \pm 0.97$	$3.68^{A} \pm 3.22$	$3.25^{AB} \pm 0.66$
Appearance	Colour on top (Light to dark)	$11.55^{A} \pm 0.54$	$11.95^{A} \pm 1.74$	$11.63^{A} \pm 1.66$	$10.77^{B} \pm 1.33$
	Underneath (Brown to grey)	$9.39^{A} \pm 1.8$	$9.39^{A} \pm 1.8$	$9.3^{A} \pm 1.46$	$9.3^{A} \pm 1.88$
	Black threads	$0.9^{A} \pm 0.73$	$1.18^{A} \pm 1.01$	$0.9^{A} \pm 0.73$	$0.9^{A} \pm 0.73$
Juiciness	Moisture release	$4.98^{B} \pm 2.76$	$4.86^{B} \pm 2.76$	$5.75^{A} \pm 1.3$	$3.87^{C} \pm 1.34$
	Moisture retention	$6.48^{A} \pm 1.39$	$6.77^{A} \pm 1.67$	$6.73^{A} \pm 1.39$	$6.93^{A} \pm 0.91$
	Pasty/ Soft	$11.12^{BC} \pm 1.14$	$10.37^{C} \pm 1.14$	$12.36^{A} \pm 1.14$	$11.75^{AB} \pm 0.9$
Texture	Firm	$11.08^{A} \pm 1.85$	$7.4^{AB} \pm 1.28$	$6.43^{BC} \pm 0.76$	$4.4^{C} \pm 0.78$
	Fibrous	$9.64^{B} \pm 1.81$	$12.23^{A} \pm 0.9$	$7.17^{D} \pm 0.79$	$7.98^{C} \pm 0.89$
	Flakiness	$11.64^{D} \pm 0.95$	$12.14^{C} \pm 1.4$	$12.51^{B} \pm 0.83$	$12.85^{A} \pm 0.78$
Taste	Charred	$3.92^{A} \pm 0.92$	$3.11^{A} \pm 1.03$	$3.73^{A} \pm 0.85$	$3.87^{A} \pm 0.42$
	Sweet	$3.95^{B} \pm 0.76$	$6.72^{A} \pm 1.35$	$6.33^{A} \pm 1.14$	$6.93^{A} \pm 0.44$
	Metallic	$4.65^{A} \pm 1.56$	$2.92^{B} \pm 1.11$	$4.03^{A} \pm 0.61$	$1.75^{C} \pm 0.87$

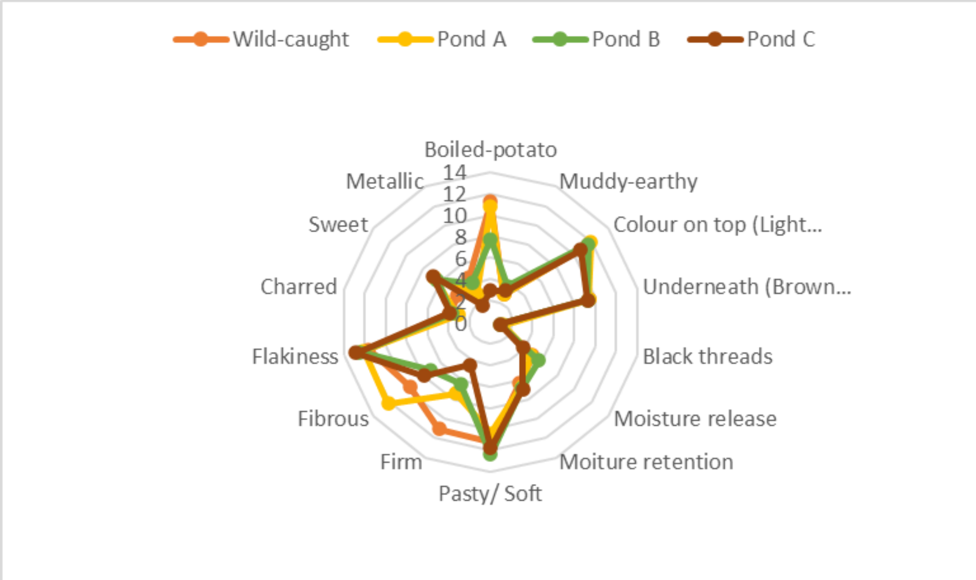

Figure 4.1: Qualitative Descriptive Analysis between wild-caught and farm-raised catfish

Colour is an important factor impacting consumer's acceptability. In general, the values of colour for both farm-raised and wild-caught catfish were slightly different for attribute descriptions of 'colour on top', 'colour underneath', and 'black thread'. The sensory attribute of 'colour on top' for farm-raised from pond A and B was darker than wild-caught samples. The results in this study provide indications that the culture environments do not negatively affect the colour of fish meat. There are several factors that can influence the colour of catfish, including genetics, diet, water quality, and lighting. Diet can also affect color, as certain pigments or nutrients may be required for certain colours to develop (Copatti et al., 2011). Water quality, including pH and temperature, can also play a role in coloration of fish (Akhter, F. et al., 2021). For example, some fish produce darker pigment in acidic and warm water, while others produce more yellow pigment in alkaline and cold water.

Furthermore, farm-raised catfish often have darker colour than wild-caught catfish because of their diet rich in protein such as soybean and grains also usually living in crowded conditions. Wild catfish, on the other hand, are typically fed a diet of insects, worms, and other small creatures, which gives their flesh a lighter color. They also tend to have less muscle fiber, as they do not get as much exercise.

The darker color and black thread look of the farm-raised catfish is not necessarily a bad thing. In fact, some people prefer the taste of farm-raised catfish over wild catfish. However, it is important to note that the darker color and black thread look are not indicative of the quality of the fish. The flesh of both farm-raised and wild catfish can be equally delicious.

As in Table 4.4 indicated, 'muddy-earthy' aroma of farm-raised catfish from pond B was higher value than farm-raised catfish pond A, C, and wild-caught catfish. This showed the specific characteristics of the pond B environment, including factors such as low water quality, presence of organic matter, or potential changes in microbial activity, could contribute to the difference in odor between pond B and other samples. This could be attributed to the level of maturity and nutrition of the diet eaten or provided. Catfish in the wild have the liberty to forage on what they need farm-raised catfishes on the other hand would have to depend on what is being provided. Flavour considers all the compounds in food that have taste, the interaction between these compounds and the effect on human senses. Farm-raised catfish had a better flavour than its wild counterpart. The reasons for varied flavours in both fishes cannot be explained within the context of this work. There may be the need to further investigate the chemical compounds in these fishes to establish the bare facts.

Farm-raised catfish from earth pond A, earth pond C and wild-caught catfish were less intense in moisture release than those obtained from earth pond B. It indicates that catfish from pond B produces a juicier taste than the other three samples as moisture release attribute was evaluated upon chewiness of the product. On the other hand, the moisture retention of farm-raised catfish from earth pond C was the highest among the other samples. In this study the texture attribute of earth pond-raised samples was revealed as less firm, softer, and flakier than wild-caught catfish. The firmness attribute of wild-caught samples was given a higher score than farm-raised catfish by the trained panelists. The differences in firmness ratings were attributed to reasons such as the lipid content and amount of exercise. This is probably the important factor to high degree of liking for wild-caught catfish.

Wild-caught catfish were the least sweet taste and more metallic taste than earth pond-raised samples. Wild-caught catfish can have a metallic taste due to the presence of higher levels of minerals and metals in their natural environment, such as iron and zinc. These minerals can accumulate in the catfish's flesh and lead to a metallic taste (Kasumyan AO, 2019). Additionally, catfish are known to feed on a wide variety of prey, including crustaceans, mollusks, and other fish, which can also contribute to the metallic taste (Kasumyan AO, 2001). Farmed catfish, on the other hand, are typically raised in controlled environments and are fed a specific diet, which can reduce the levels of minerals and metals in the fish, resulting in a milder taste.