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NUTRITIONAL COMPOSITION, BACTERIAL LOAD AND ORGANOLEPTIC QUALITY OF FARM-RAISED CATFISH (*Clarias gariepinus*, Burchell, 1822) FROM THE DORMAA MUNICIPALITY, GHANA.

BY

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DECLARATION

This dissertation is the result of research work undertaken by Kwame Issifu in the Department of Marine and Fisheries Sciences, University of Ghana, Legon, under the supervision of Dr. Samuel Addo and Dr. Winnie Sowah.

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ABSTRACT

The aim of this study was to evaluate the nutritional composition, bacterial load and organoleptic quality of farm-raised African catfish (*Clarias gariepinus*; Burchell, 1822) in the Dormaa Municipality. Thirty (30) specimen of freshly harvested fish *Clarias gariepinus* of average weight 912.78 ± 16.43 g obtained from a fish farm and an equal number of smoked farm-raised fish of average weight 769.19 ± 6.48 g were used for the study. Proximate analysis, bacterial and organoleptic quality assessments yielded the following results: The mean percent moisture, ash, fat, protein and total carbohydrate contents for fresh farmed fish were 77.4 ± 1.94%, 1.34 ± 0.26%, 0.57 ± 0.17%, 17.58±0.23% and 4.45 ± 1.55% respectively. The corresponding levels in smoked farm-raised fish were 11.63 ± 0.43%, 7.06 ± 0.66%, 9.31 ± 1.80%, 25.72 ± 1.51% and 53.34 ± 0.15% respectively. The mean total viable counts, total coliform counts, *Staphylococcus aureus* and *E. coli* for the fresh fish were respectively $2.2x10^5$ cfu/g, $8.7x10^2$ cfu/g, $5.5x10^3$ cfu/g and $2.3x10^3$ cfu/g. For the smoked fish, mean total viable counts, total coliform counts, *S. aureus* and *E. coli* were $4.2x10^5$ cfu/g, 0.0 cfu/g, $2.8x10^3$ cfu/g and $2.5x10^3$ cfu/g respectively. The overall acceptability of fresh and smoked farm-raised catfish ranged from 3.2 to 4.6 and 3.0 to 3.8 respectively. There were significant differences ($P < 0.05$) in the nutritional, bacterial and organoleptic qualities between the fresh and smoked catfish. Results from the study revealed higher nutritional composition in smoked catfish and lower bacterial loads in both fresh and smoked fish except *E. coli*, which must be of concern for consumer safety.

DEDICATION

I dedicate this work to my Supervisors, my family and work colleagues. I also dedicate this work to all those who helped in making this project work a success.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In Ghana, fish is considered the prime source of animal protein alluding to its relatively large scale of production and consumption in comparison with other protein source alternatives such as meat. The African Catfish in Ghana, otherwise known as (*Clarias gariepinus*, Burchell, 1822*)*, is an extremely vital freshwater fish and hence being the second most cultured freshwater fish in the country (FAO, 2016). Due to its distinctive taste, texture and flavour, it has largely been accepted in most parts of Ghana. An evidence of their wide acceptability has being shown in their extensive distribution and cultivation in most ponds nationwide. Being a major source of vitamins, proteins and minerals, fishes contain other important nutrients required to complement diets of both adults and infants (Abolagba *et al.*, 2015; Alao *et al.*, 2017).

Fishes, as observed in most African countries, are consumed fresh, preserved or processed dried or smoked in most cases and is considered by most as a much-appreciated delicacy irrespective of financial, religious, age and educational boundaries (Adebayo-Tayo *et al.*, 2008). African catfish is amongst the fish species of utmost significance, presently being cultured in and out of its natural range with regards to geographical location tropical and

subtropical (Adewolu *et al.*, 2008). Ghana places second to Nigeria in the West African sub-region in terms of production and consumption of this species of fish (FAO, 2016). Its possession of certain unique characteristics, some of which include high rates of fertility, easy production of larvae during captivity and high resistance with regards to diseases make it commercially viable in aquaculture (Haylor, 1991). It is of incredible significance since it develops rapidly, accomplishes a table size in a short time and is a consumable fish with limited flesh spines. It can endure an extensive variety of ecological conditions, as well as extreme temperatures, and low levels of oxygen. The significance of catfish to human diet can therefore not be exaggerated. As indicated by Anoop *et al.* (2009), it gives sustenance to the people, it permits enhanced protein nourishment since it contains a high biological value with regards to high protein retention in the body, higher protein absorption in comparison to alternative sources of protein, small cholesterol substance and a prime animal protein source when considering safety.

Research has shown that for newly harvested fish, the microbial flora accompanying it is essentially as a result of the surroundings within which the fish is harvested and not the type of fish; subsequently, the local microbial populaces of fish can differ considerably (Shewan, 1961). It further stated that owing largely to their delicate tissues and aquatic surroundings, fishes are particularly vulnerable to microbial pollution. Masses of bacteria, a considerable lot of them potential spoilers, are Despite the possession of typically sterile flesh, bacteria are available in the surface sludge, on the gills and in the digestive tracts of live fish. When alive, the natural defence barrier of fish stalls or inhibits the development and intrusion of bacteria yet after death the guard framework breaks down and the

microscopic organisms increase and attack the flesh (Abolagba and Uwagbai, 2011). Large amounts of fish spoilage have therefore been attributed to inappropriate postharvest technology, which includes handling, preservation and processing, all of which has the potential of negatively impacting fish wholesomeness unhealthy situation. In Nigeria, total fish landings have been associated with an approximation of 40% postharvest losses (Akande, 1996).

Consequently, it is essential to process and reserve a portion of the fish harvested in the time of plenty, in order to guarantee supply throughout the year. Processing and preservation will subsequently lessen losses incurred after harvesting, prolong fishes' shelf-life while ensuring a viable supply of fish all year round. In Ghana, a host of processing techniques aimed at ensuring the reasons named above, are in operation. Smoking is, however, the most prominent and probably the least difficult fish processing technique amongst a host of others as it does not necessitate complex tools or exceedingly resourced workers (Olayemi *et al.*, 2011).

In many third world countries, the oldest and most popular conservation technique is smoking (Kumolu-Johnson *et al.*, 2010). It is a conservation technique that incorporates the burning of wood which subsequently produces natural chemicals through a combination of drying and decomposition (Tobor, 2004). Through the process of wood burning (incomplete), smoke is produced which in turn gives fishes a unique colour and flavour.

Smoke contributes to fish preservation and shelf life by drying, cooking, acting as an effective antioxidant, bacteriostatic and bactericidal agent as well as by depositing natural wood–smoke chemicals like tars, phenols and aldehydes; all of which provide a protective film on the surface of smoked fish and have powerful bactericidal action and prevent the growth of other microorganisms on the flesh of the fish (Swastawati *et al*, 2000; Daramola *et al.*, 2013). A host of techniques are accessible for smoking fish and varied smoked items have been produced in different areas of the globe in connection to the properties of the locally existing raw materials and the overall level of expertise (Olley *et al.*, 1988). The most suitable smoke condensate for the elaboration of particular fish could be used to evaluate sensory value, as well as microbiological, chemical and safety point of view. In relation to consumer preferences, it is indicated that consumers do not like the same kind of products. For example, some people require a strong smoke odour and flavour, others want a specific "wood or smoke material (Cardinal *et al.*, 2006).

1.2 JUSTIFICATION

Consumers in recent times, have begun to comprehend that their choice of food can have a subsequent impact on their health (Franz and Nowak, 2010). A healthy diet has now become a trending topic attracting vast global consideration (Kaimakoudi *et al.*, 2013). Research indicates that modern consumers of varied age groups are well informed of the nutritional and health benefits derived from fish consumption (He, 2009). As a result of the nutritional value of fish, such as omega-3 fatty acids, vitamins and minerals coupled with its ease of digestion, fish consumption by all irrespective of age is encouraged. Owing to the consistent increment in the human populace and nutritional benefits of fish

consumption, the demand for fish has been on the rise (Claret *et al.*, 2014). This increase in the demand for fish has resulted in diminishing resource base of capture fisheries, owing largely to unsustainable fishing methods being employed which is adversely causing a reduction in wild fisheries contribution to fish food security (FAO, 2004). In an effort to address decreasing wild fish stock and an upsurge in the demand for fish by consumers, they are being given the viable option of farmed fish (Cahu *et al.*, 2004).

Catfish (particularly fresh wild catfish) has become an increasingly popular foodstuff in the Brong Ahafo region of Ghana, with significant production centred in five major districts including Dormaa Municipality, however, farmed catfish production in the municipal suffers post-harvest losses especially to small-scale fish farmers who are in the municipality. This is due to the plethora of factors including the presence of microorganisms, unhygienic handling of farmed fish as well as the absence of a ready market.

The presence of micro-organisms such as bacteria impairs the nutritional quality of fish and its organoleptic attributes. It is therefore important to establish baseline data on nutritional composition and also investigate the microbial load and organoleptic quality of farmed catfish both smoked and fresh. This could help educate small-scale farmers on good handling practices that would make their produce acceptable on the market.

1.3 OBJECTIVE OF THE STUDY

The study aimed at understanding the nutritional, bacterial and organoleptic quality of farm-raised African catfish, *Clarias gariepinus* in the Dormaa Municipality of the Brong Ahafo Region in Ghana.

The specific objectives were to:

- Determine the proximate composition of fresh and smoked farm-raised African catfish;
- Investigate the bacterial load of the fresh and smoked African catfish;
- Evaluate the organoleptic quality of the processed and unprocessed fish.

CHAPTER TWO

LITERATURE REVIEW

2.1 FISHERIES IN GHANA

The Ghanaian fishing industry makes up 5% of Ghana's agricultural Gross Domestic Product with the resources primarily obtained from freshwater (inland) and marine sources, lagoons dotted along coasts and aquaculture (FAO, 2007). The inland fishery in Ghana is predominantly carried out on the Volta Lake (FAO, 2007). The marine subsector, on the other hand, comprises four subsectors including artisanal fisheries, inshore fisheries (semi-industrial), industrial fisheries and the tuna fisheries. Vessel accounts by Amador *et al.* (2006) recorded 11,200 artisanal vessels, 230 semi-industrial vessels, 57 industrial vessels and 36 tuna vessels, along the Ghanaian coast. With respect to the landed weight of fish, artisanal fisheries account for approximately 70 to 80% of the national marine fish production and are thus the most important fisheries subsector in Ghana (FAO, 2007).

2.2 AQUACULTURE PRODUCTION IN GHANA

Aquaculture as a rising fishery subsector in Ghana, is controlled by the extensive, small-scale and subsistence systems. Reliance on this subsector has increased due to dwindling fisheries (marine and inland) production. In Ghana, aquaculture dominance is characterized by tilapia and catfish cultivation, in cage production (Antwi-Asare and Abbey, 2011). Systems employed range from earthen ponds to cage systems and pens in other cases.

Although actual production volumes are poorly documented, tilapia constitutes up to 80% of total production while the catfish species, *Clarias* spp, *Heterobranchus* spp and African bonytongue *(Heterotis niloticus*; Cuvier,1829) account for the remaining 20% (Antwi-Asare and Abbey, 2011). There is high internal demand for both fishes, thus there are virtually no exports of fresh tilapia or catfish in Ghana (Antwi-Asare and Abbey, 2011).

The African catfish, *Clarias gariepinus* much like tilapia has high moisture contents of up to 78% and fat as well as protein contents of 5.5% and 17% (fresh weight) respectively. High levels of moisture, proteins and fats in these fishes make them highly susceptible to microbial attack after harvest.

2.3 MERISTIC AND BIOLOGICAL FEATURES OF *CLARIAS GARIEPINUS*

Body firmly compacted towards caudal, colour differs from relatively dark to light brown, frequently patterned in shades of olive green and grey; bottom parts of the head and abdomen white, regularly with a red flush to margins of fins, particularly when spawning (Skelton, 1993). Head expansive and depressed, substantially boned and totally enclosed above. The species has 61–75 dorsal rays and 45–60 anal fin rays. Extending from the head almost to the basal part of the caudal fin is the dorsal fin. Also extending from the basal part of the anus to basal part of the caudal fin is the anal fin.

No adipose fin. Caudal fin rounded. Pectoral fin with barbed spine, used for defence or "walking" overland. Eyes small, lateral. Mouth large, subterminal, jaws with broadband of fine, pointed teeth. Vomerine band of similar teeth. Four pairs of long filamentous barbels;

maxillary barbels longest. First gill arch with numerous (24–110) close-set, slender gill rakers. A large chamber above gill arches contains the suprabranchial organs (multi-branched accessory air-breathing organs). These function like a lung and gives *Clarias sp*. the ability to respire out of water, hence, in circumstances of little dissolved oxygen, is able to acquire 80–90 per cent of oxygen it requires (Moreau, 1988). The species is an obligate air breather.

2.4 Reproduction of *Clarias gariepinus*

The species is gonochoristic. Size and age at first maturity vary greatly (150–750 mm total length between one and four years), although the average size at sexual maturity is around 300–350 mm total length. The elongate and pointed urinogenital papilla of the male and the more rounded papilla of the female are the only external features upon which the sexes can be distinguished from each other (Bruton, 1979). The fecundity relativity averages between 20,000 and 25,000 eggs/kg body weight. Being oviparous, parental care for offspring is normally absent, except for the choice of an appropriate site for egg and larval development.

2.5 Food and feeding habits of *Clarias gariepinus*

The species is euryphagous and largely considered an opportunistic, omnivorous predator. It can productively use as well as alternate between different sources of food that include plants and detritus when prey turns out to be rare (Potts *et al.,* 2008).

Typically, catfish are scavengers, nonetheless, their feeding behaviours are versatile and they periodically filter feed at the surface of the water in clutches. There are four recognized feeding modes, viz. individual foraging, individual shovelling, surface feeding and formation feeding. Adopting a feeding mode rests predominantly on the accessibility to food (Bruton, 1979). In ponds, catfish are normally seen snatching falling pellets before getting to the bottom, at that point, feed off the bottom and then surface to eat the gliding fines utilizing the gill rakers as a means of sieving out little particles (Hecht *et al.*, 1988). With a versatile feeding behaviour and the possession of certain features, the species feeds on a number of organisms stretching from phytoplankton to fish. It possesses an extensive, sub-terminal and transverse buccal cavity. To allow suction feeding, the mouth is able to open vertically to a sizeable extent. The teeth are many, little, cordiform and extend backwards (Teugels, 1986).

The premaxilla, mandibular and pharyngeal teeth are tapered and piercing, though the Vomerine band has mostly granular molar-like teeth with different quantities of cone-shaped teeth, typically on the distal margin. Pulverizing and grasping of prey occurs between the Vomerine teeth and the hyoid apparatus, that forms a tongue by swelling upwards. *Clarias gariepinus* has long gill rakers on the anterior borders of the five branchial arches, and additional gill rakers on the posterior margins of the third and fourth arches that interdigitate with those from the anterior row of the next arch.

The length of gill rakers influences their quantity, where an increase in length means an increase in number (Bruton, 1979). The mean width between gill rakers varies between

<0.1 and 0.6 mm, but this increases with length (Murray, 1975). Despite this, larger fish are known to filter feed on phytoplankton, zooplankton and surface scum (Bruton, 1979). The stomach is well-developed, and the digestive tract is thin-walled and moderately short, inferring a reliance on foods high in protein. The stomach in North African catfish becomes functional 5–6 d (11 mm total length) succeeding the exogenous feeding which begins at 27.5 °C (Verreth *et al.*, 1992).

2.6 GLOBAL CAPTURE PRODUCTION OF *CLARIAS GARIEPINUS*

The global capture production of *Clarias gariepinus* has been rising steadily across the years. In the year 2004, 46,859 metric tonnes were captured as compared to the 2014 record of 55,417 metric tonnes (FAO, 2018). Aquaculture production of the species, has seen a significantly higher rise between the same period. Global production figures have risen about seven folds from 35,400 metric tonnes in the year 2004 to 237,124 metric tonnes in 2014 (FAO, 2018). This is a clear indication that the aquaculture production of *Clarias gariepinus* is gaining grounds globally and especially in Nigeria, West Africa. In Ghana, well documented records of *Clarias spp* production is lacking and determined as a factor of local aquaculture production of about 200 tonnes for the cage system and about 70 tonnes for the pond system.

2.7 NUTRITIONAL QUALITY OF *CLARIAS GARIEPINUS*

A major component of the human diet is protein, a nutrient abundantly provided by fishes when added to the diet. Protein, oil, moisture and ash contents (proximate composition) are

customarily utilized as pointers of the nourishment derived from fish. According to Nnam and Njoku (2005), the significance of the nutritional value of fish rests on the principle that, fish tissues contain complex organic compounds that are effectively broken down into simple substances as "building blocks" and absorbed to rebuild severed tissues, maintain body and sources of energy to the consumer. Freshness and nutrient quality is collectively described as shelf life which is described as the maximum duration within which a product is considered wholesome for intake (Doyle, 2007). Spoilage of fresh fish also results in loss of freshness and nutrient quality (Makawa *et al.*, 2014).

The nutrients derived from these fishes might be distinctive because of the nutrient accessible in the surroundings and the capacity of the diverse types of fish to use and keep these nutrients in their body (Makawa *et al.*, 2014). Fawole *et al.* (2007) carried out research on the mineral and proximate structure of dried samples of fish, Babalola *et al.* (2011) based on proximate analysis, categorized *Clarias gariepinus* as having moderately normal protein and lipid content.

A study conducted by Ezeafulukwe *et al.* (2017) to determine the haematology of wild and pond-raised catfish to determine whether there is any distinction in their nutritional status which will assist consumers with making a decent decision in catfish intake showed that there was no critical contrast in wild and pond-raised catfish. This study agreed with Adeosun *et al.* (2015) who also observed no variation in pond raised and wild-caught catfish.

Proximate composition studies were carried out by Ukagwu *et al.* (2017) on wild-caught catfish samples from Oguta lake and pond reared catfish. The comparative study was done to determine if the fish behaviour could impact its nutritional make-up. Pond-raised catfish percentage crude protein was 60±1.30% and for the wild *Clarias gariepinus* crude protein percentage was 61 ± 1.20%. The study showed that there were significant differences between *C. gariepinus* raised in the pond and the one caught from the wild for all the nutrients analyzed.

This study indicated that wild reared *Clarias gariepinus* accumulates more crude protein, fat, ash, dry matter, crude fibre and energy than pond raised *Clarias gariepinus.* Ogbonnaya and Ibrahim (2009) stated that the drying procedures aside reducing the energy value, did not have negative impacts on the proximate and mineral qualities in catfish . This study was contrary to what Adeosun *et al.* (2014) found on the proximate composition of wild and pond-raised *Clarias gariepinus.* The pond-raised *C. gariepinus* had a higher lipid (6.30%) and protein content (20.00%) as compared to the wild caught ones which had a lipid and protein content of 4.48% and 18.05% respectively.

Abolagba *et al.* (2015) undertook a study that looked at the influence of smoking on the dietetic values of Mandi (*Synodontis clarias*; Linnaeus, 1758) and African sharptooth catfish *(Clarias gariepinus*; Burchell, 1822). The study revealed that *C. gariepinus* had a higher crude protein level of (66.5%) as compared to *S. clarias* (57.7%). The higher value crude protein recorded for *C. gariepinus* might be ascribed to more synthetic diet consumption (35-45% crude protein) compared to *Synodontis clarias* which feeds more on

plankton or waste produce which may likely not exceptionally contain much protein. This led Abolagba *et al.* (2015) to recommend *Clarias gariepinus* other than *Synodontis clarias* to processors based on consumer preference.

Proximate analysis of wild and pond-reared *Clarias gariepinus* was investigated by Ezeafulukwe *et al.* (2015) to determine if the fish behaviour could impact its nutritional make-up. The percentage crude protein was 13.36 ± 0.4 for the pond-raised catfish whiles that of the river-harvested catfish was 12.27 ± 0.87. It showed no significant differences ($P>0.05$) regarding the nutritional make-up between *Clarias gariepinus* from pond-raised and wild caught for most of the nutrients analyzed except for crude fat 10.94 ± 4.12% which was significantly higher ($P<0.05$) than 4.81 ± 0.06% recorded in pond-reared catfish. The findings showed that *Clarias gariepinus* from the wild accumulated more fat in comparison with ones from the pond. Proximate analysis various researchers (Osibona, *et al.,* 2010; Ayeloja *et al.,* 2011; Isah *et al.,* 2014) of African sharptooth catfish *(Clarias gariepinus*; Burchell, 1822) and Redbelly tilapia *(Coptodon zilli*; Gervais, 1848) all stated that the African catfish has a high crude protein content.

2.8 MICROBIAL QUALITY OF *CLARIAS GARIEPINUS*

Nutrient losses increase with decreasing freshness quality due to chemical changes as well as response to bacterial activity (Mchazime and Kapute, 2018). A fish when alive has its muscles void of microorganisms. Nonetheless, its surface mucus, digestive tracts and gills harbour a large group of microscopic organisms relying upon the surrounding where they are reaped. Once a fish dies, microbes will attack the fish tissue from within and the outside,

increasing quickly and prompting its deterioration (Adeosun *et al.*, 2015). Fish like all foodstuffs has the likelihood of causing consumer sickness provided mitigative actions are not put in place to stall contamination from pathogenic microbes, toxin or pollutants.

Fish safety as food is an exceedingly vital part of the need to protect fish consumers and guarantee the sustainability of the industry (Mchazime and Kapute, 2018). According to Adeosun *et al.* (2015), current food security and quality affirmation frameworks have as fundamental guideline, the need to demonstrate that precautionary measures are channelled towards protecting the consumer. The extensive international approval of food safety and quality affirmation frameworks which incorporate Hazard Analysis and Critical Control Point (HACCP) standards make these systems presently the choice of food production industries. An effective food safety and quality assurance system is an essential component in ensuring both the wellbeing of the consumer and the concerns of the industry.

Studies carried out by Adeosun *et al.* (2014) on iced wild and pond-reared catfish indicated a decrease in sensory features throughout storage with a concomitant increase in bacteria counts. The microbe bacilli were the most abundant. The amounts ranged from $11.5x10^2$ cfu/g to $15.4x10^2$ cfu/g for wild catfish and $9.7x10^2$ cfu/g to $11.1x10^2$ cfu/g for the pond reared catfish. This indicated that there were more bacteria counts recorded for the wild catfish as compared to the pond reared ones. Comparing the microbial enumeration for fish species smoked with cow dung and corn husks, cow dung recorded higher amounts of 1.81×10^5 as against 1.2×10^5 for corn husks (Ayuba *et al.*, 2015).

Adeosun *et al.*, (2015) evaluated the microbial content of smoked cultivated catfish *Clarias gariepinus* reared in dissimilar culture systems with the aim of evaluating its quality and period of wholesomeness considering surrounding temperatures. It was observed that the most astounding total viable count (TVC) in processed catfish from the two systems ($1.27x10^6$ cfu/g) were attained in the 36th week of storage indicating that the storage time had significant influence ($p<0.05$) on TVC. Also, smoked fish from the local fish processor (LFP) had maximum TVC $>10^7$cfu/g.

2.9 ORGANOLEPTIC ATTRIBUTES OF FARMED *CLARIAS GARIEPINUS*

Fish quality is an intricate attribute affected by various endogenous and exogenous variables (Grigorakis, 2007). Fish quality perception is affected by organoleptic properties, wholesome qualities and freshness. Also, changes in colour, odour and texture are very important to consumers (Tomić *et al.,* 2017). A consumer shows a high level of acceptability with respect to the sensory evaluation of fishery product and is only possible if the fishery product is handled under a strict sanitary condition in all the stages of production. However, overall acceptability decreased with storage time. (Abiodun et al., 2014)

Sensory assessment is a standout amongst the most imperative techniques for surveying freshness and quality in the fishing segment and in fish-examination administrations. Sensory techniques done legitimately are a fast and precise tool that gives exceptional data with regards to food (Hyldig *et al.* 2007). Much has been written on the analytical techniques developed to establish the nutritional and chemical composition of foods to

ensure their compliance with food law. Fish freshness/spoilage and quality may be investigated subjectively or objectively (Mchazime and Kapute, 2018).

According to Lakshmanan (2000), objective assessments of fish, are based on: Physical changes such as measurement of conductivity using the Torrymeter, Chemical and biochemical tests, including tests dependent on bacterial action such as estimation of trimethylamine (TMA); tests dependent on autolytic action such as enzymic assays of nucleotide breakdown products, for instance; hypoxanthine; tests dependent on fat oxidation, such as peroxide value estimation and bacteriological changes, for example: counting and identification of various microorganisms. Subjective tests are also based on a person's normal sentiments. For example, preference, desire, approval and esteem are unreservedly communicated. Due to individual appraisals commonly comprising the articulations of pleasures or degrees of it, they are frequently called hedonic.

A personal or hedonic appraisal is utilized as a part of product improvement and market survey and is to a great extent restricted to discovering what consistently users think about fish products (Hyldig *et al.,* 2007). In many ways, the quality requirements of the customer are more difficult to satisfy since the customer assesses the quality of a product mainly by subjective means, i.e. by sensory evaluation of a food's appearance, colour, odour, taste and texture, plus the visual appeal of its packaging and presentation. Sensory appreciation of food quality may be divided into the following categories: Appearance and colour, odour and taste and texture. The above three categories cannot be treated in isolation since sensory evaluation is often a combination of several overlapping factors, for instance,

'flavour' includes elements of odour, taste, texture and even the psychological effect of colour (Lofster and Schlang, 2010; Cahu *et al.*, 2004; Ruiter, 1979).

Sensory assessment can be carried out at various levels in fish processing such as after landing, arriving at the fish plant (whole), at the reception, or processing halls of fish factories; evaluation of raw/cold and cooked fillets at the reception, or processing halls of fish factories, or at auction sites, very common in Europe (Hyldig *et al.*, 2010). According to Martinsdóttir *et al.* (2001), the European fisheries research institutes, in collaboration with the seafood industry, built up another tool, whereby sensory evaluation can be done in an efficient and cautious manner with a target quality appraisal technique, known as the Quality Index Method (QIM) (Martinsdóttir *et al.*, 2001).

However, it must be remembered that objective measurements of food quality are preferable only if the objective tests can provide a precise measure of the subjective quality being considered (Alasalvar *et al.*, 2011). A lot of research has been done on the organoleptic value of fish. An organoleptic assessment conducted by Mchazime and Kapute (2018) on processed *Oreochromis shiranus* endemic to the Shire river indicated that the fish was liked by consumers for up to about twelve (12) hours. Through organoleptic studies by Ayuba *et al.* (2015), the appropriateness of cow dung and corn husks as probable replacements of fish smoking sources to the ordinary fuelwood was evaluated. It was revealed that fish smoked with corn husk and fuelwood had enhanced visual appeal, smell, flavour and texture when contrasted with those smoked utilizing cow dung.

An organoleptic evaluation carried out by Meenakshi *et al.* (2010) on *Cyprinus carpio* at different storage temperatures showed that the skin, looks and shading diminished in a period-dependent way. The body texture was loosed and the odour was amplified as a result of the increment in the duration of storage at room temperature. Studies carried out by Tomic *et al.* (2017) in Croatia on consumers' perceptions of wild-caught and farmed fish established that most consumers (almost 40%) commonly consume fresh fish in their various home.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

The research was done in the Dormaa Central Municipality, located in the Brong Ahafo region and adding up to the other twenty-six (26) administrative districts within the region. Formed under the Local Government Act of 1993 (Act 462), it remains one of the oldest districts situated in the west of the Brong Ahafo Region (GSS, 2014).

It is bound to the north by the Jaman South district and to the east by the Dormaa East district, to the south and south-east by Asunafo and Asutifi districts respectively, to the west and south-west by Dormaa West and to the west and north-west by the Ivory Coast. Situated approximately 80 kilometres west of Sunyani is Dormaa Ahenkro – the municipal capital. With an overall land cover of 1,210.28 square kilometres, the municipality makes up approximately three per cent of the region's total land area (Okoffo *et al.*, 2016).

The population of Dormaa Central Municipal based on the Population and Housing Census conducted in 2010 is 112,111, thus making up 4.9 per cent of the regional populace out of which females and males are 52.2 and 47.8 per cent respectively. About sixty-one per cent (61.0%) of the inhabitants reside in rural localities (GSS, 2014). The Dormaa Central Municipality has about 153 fish farmers within its jurisdiction.

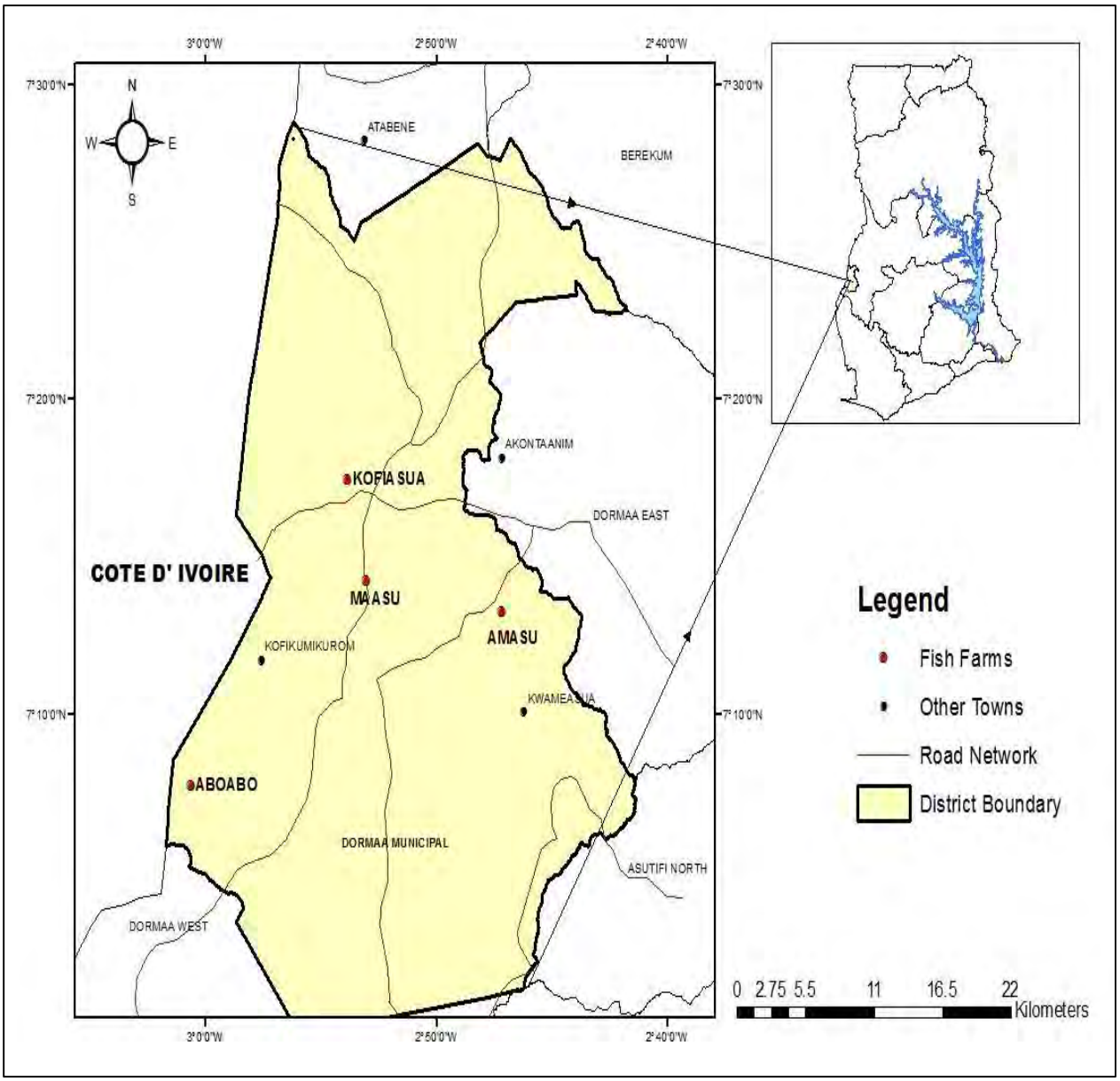

Figure 1: A map of Ghana showing the Dormaa Municipal Area

3.2 FIELD PROCEDURES

3.2.1 Samples of fresh fish

Thirty (30) samples of fresh fish of *Clarias gariepinus* were purchased from ten (10) randomly selected fish farms within the municipality. With the aid of a 1-metre measuring board and a weighing scale, their corresponding length and weight data were taken. Aseptic means were employed to avoid cross-contamination, and neatly packaged in sterile ziplock bags. They were then stored in a chest cooled with ice at about 4˚C, prior transport to the Nutrition and Food Sciences Laboratory, University of Ghana.

3.2.2 Smoked fish samples

Purposive random sampling was employed for the selection of thirty (30) smoked farm-raised *Clarias gariepinus* from market women in the Dormaa Central Municipality. Fish samples were packaged aseptically, labelled accordingly and transported to the Nutrition and Food Sciences Laboratory, University of Ghana.

3.3 PROXIMATE ANALYSIS OF FISH

The fish samples were sorted and grouped into ten (10) individual farms for both fresh fish and smoked fish samples. Each grouping of the fish was blended and homogenized and samples kept for analysis under aseptic conditions. Analysis of the samples was done in triplicates for protein, fat, fibre and ash contents based on procedures defined by the Association of Official Analytical Chemists, AOAC (2005).

3.3.1 Moisture Content

Using the method of A.O.A.C (1999), the amount of moisture was deduced by evaluating the pre and post-evaporation masses of the fish. The fish samples' moisture content was determined by measuring the initial mass ($M_{INITIAL}$) of the sample using a digital weighing scale. The samples were then dried in an oven at 105 ºC overnight till they reached a steady mass and the mass recorded as dried mass (M_{DRIED}). Using the formula below, the amount of moisture in percentage was then determined:

$$\%\text{Moisture} = \frac{M_{INITIAL} - M_{DRIED}}{M_{INITIAL}} \times 100$$

The fish samples were then grounded in porcelain can until homogenized samples were obtained. Approximately 2g each of the homogenized samples was weighed to determine the proximate composition (Adeosun *et al.*, 2014).

3.3.2 Crude protein

The Kjeldahl technique – determines a sample's overall amounts of nitrogen once digested using a catalyst in sulphuric acid – was used to deduce the crude protein of the samples. The samples were digested with 15mls of concentrated Sulphuric acid (H_2SO_4) in combination with a catalyst (a mixture of potassium sulphate and copper sulphate) for about one and half hours and allowed to cool for about 15 min. The resulting digestate was distilled in the presence of strong alkali, sodium hydroxide (NaOH). The ammonia released was collected in an aqueous solution of boric acid and titrated against 0.01M HCl. The blank was determined following the same procedure. Based on the determined ammonia,

equivalent nitrogen was calculated. To determine the crude protein in percentage, a factor of 6.25 was multiplied against the percentage of nitrogen of the sample (AOAC, 2005).

3.3.3 Ash content

The amount of ash contained in a sample is the white-coloured remains of the sample retained when ashed in a muffle furnace at approximately 550-600°C. The amount of Ash was determined by burning about 2g of each fish sample in a muffle furnace at 600°C for 2 hrs. The percentage remains weighed was regarded as ash content (AOAC, 2005).

3.3.4 Fat content

The amount of fat was determined by oven-drying samples at 50^0C prior to removing the crude fat with petroleum ether in a Soxhlet extractor for 4 hours (Kumolu-Johnson *et al.*, 2010).

3.3.5 Total carbohydrate

Carbohydrates were deduced from the difference between 100% and the sum of ash, protein, moisture and fat contents and results recorded.

3.4 MICROBIOLOGICAL ANALYSIS OF FISH

3.4.1 Enumeration of Total Viable Aerobic Count

Total viable aerobic bacteria of fish was enumerated by standard plate count (SPC) procedure (Maturin and Peeler, 2001). For enumeration of TVAC, 10 g sample was added to 90mL sterilized 0.1% peptone water, out of which an aliquot of 1mL was aseptically

decanted into duplicate sterile Petri plate and sterile melted (around 40–45^{O}C). Plate Count Agar was poured over it, rotated clockwise-anticlockwise, left to harden, then kept warm at an inverted position at 37^{O}C for 24–48 hours.

After incubation, the plates having well-spaced colonies (30–300) were used for counting and the colonies were counted by a colony counter (Stuart Scientific, UK). Total viable aerobic count per mL or per g was calculated by multiplying the average number of colonies per plate by reciprocal of the dilution and expressed as colony forming units(cfu) per milligram of the sample (AOAC, 1995).

3.4.2 Total coliform count

The total coliform count was determined on violet red bile agar (Oxoid) using pour plate technique and an overlay with the same agar after solidifying. Plates were aerobically incubated in inverted positions at 37ºC for 24–48 h.

3.4.3 *Staphylococcus* aureus

Staphylococcus aureus was determined on Baird Parker Agar (Oxoid CM 275) supplemented by egg yolk tellurite at 37°C for 24–48 hours. Typical black colonies with zones around and atypical black colonies were considered as *Staphylococcus* species.

3.4.4 *Escherichia coli*

Escherichia coli were enumerated on EMB agar medium (Oxoid). At a temperature of 25°C, plates were kept warm aerobically upright for 48 hours.

3.5 ORGANOLEPTIC ASSESSMENT OF FISH

A nine-point Hedonic scale as described by Sugri *et al.* (2010) was used to score samples for eye colour, odour/smell, skin feel/texture, skin colour and overall acceptability (Appendix 1). Blindly Coded samples were served to each member of 20 panellists for their sensory evaluation.

3.6 STATISTICAL ANALYSIS

Data attained after the microbiological and proximate analysis were laid open to descriptive statistics to estimate the mean, maximum and medium values. Further to this, the sample T-test was employed to test whether or not there were differences regarding significance in proximate structure between the fresh and farmed catfish samples. The output of the test is provided in Appendix VI-IX. The level of significance (P-values) used was 0.05.

Organoleptic properties obtained from respondents were analyzed with the Social Package for Statistical Software (SPSS). Purposive random sampling used in selecting the respondents for the organoleptic studies. Data cleaning in SPSS was done to ensure that values for the right codes were entered before analysis proceeded.

CHAPTER FOUR

RESULTS

4.1 NUTRITIONAL COMPOSITION

Figure 2 shows the concentration of nutrients for both smoked and fresh farmed catfish from proximate analysis. From Figure 2, the mean concentration of moisture in the smoked farmed catfish was 11.63 ± 0.43% while in the fresh farmed catfish, the value was 77.40 ± 1.94%. Using the T-test analysis, the difference in total concentration for the assessed fish samples was significant ($p < 0.05$) as shown in Appendix 2. The mean ash concentration in the smoked farmed catfish was 7.06 ± 0.61% while in the fresh farmed catfish, the value was 1.34 ± 0.26%. Using the T-test analysis, the difference in total concentration for the assessed fish samples was significant ($p < 0.05$) as shown in Appendix 3.

The mean fat concentration in the smoked farmed catfish was significantly higher (9.31 ± 1.80%) than the fresh farmed catfish (0.57 ± 0.17%) ($p < 0.05$). Mean per cent protein in the smoked fish was 25.72 ± 1.51% while in the fresh fish, it was 17.58 ± 0.23%. There was significant difference ($p < 0.05$) (Appendix 4). Total carbohydrate mean values in the smoked and fresh farmed catfish were 53. 34 ± 0.15 and 4.45 ± 1.55 respectively. This showed a significant difference in total concentration for the assessed fish samples (Appendix 5).

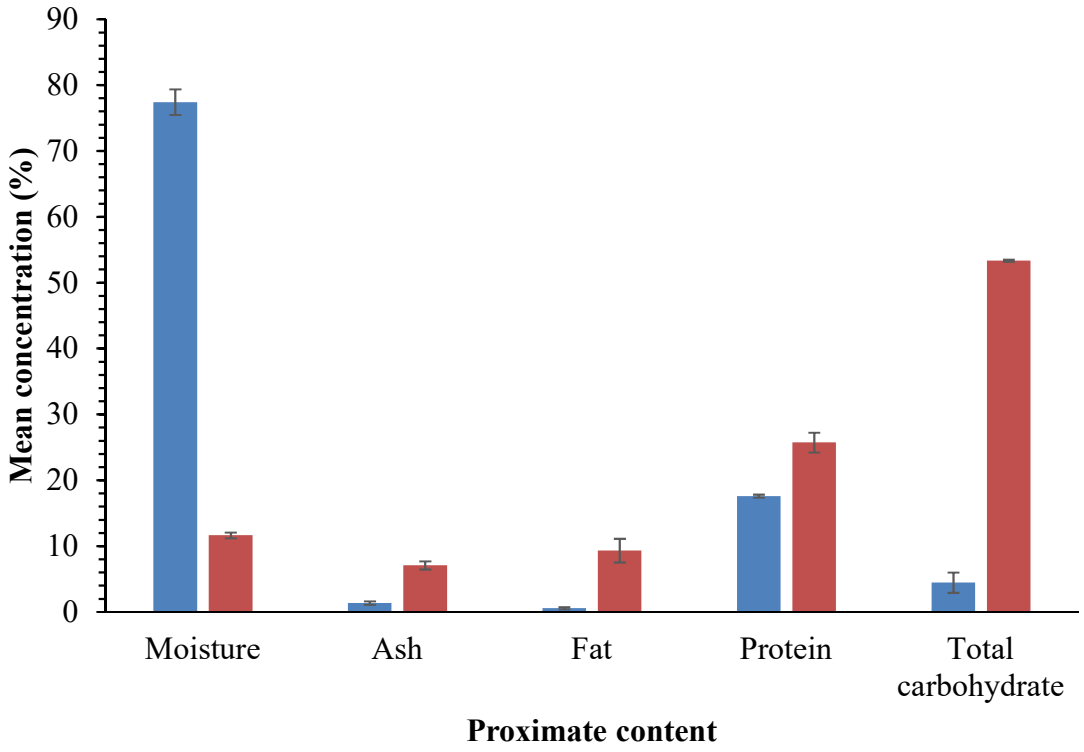

Figure 2: Nutritional composition of fresh and farm-raised catfish from the Dormaa Municipality

4.2 MICROBIOLOGICAL ANALYSIS

Table 1 provides the microbial content for both smoked and fresh farmed catfish. The mean amount of Total Viable Count in the smoked catfish was 4.2 x 10^5 CFU/g while in the fresh fish, the value was 2.2 x 10^5 CFU/g. These values depicted no significant difference ($p > 0.05$). The mean count of Total Coliform in the smoked fish was 0.0 CFU/g while that of the fresh fish was 8.7 x 10^2 CFU/g. The mean count of *Staphylococcus aureus* in the smoked and fresh fish were 2.8 x 10^3 CFU/g and 5.5 x 10^3 CFU/g respectively, showing insignificant difference ($p > 0.05$). The mean colony counts of *E. coli* in the smoked catfish

was 2.5 x 10^3 CFU/g while in the fresh fish, the value was 2.3 x 10^3 CFU/g without significant difference ($p > 0.05$). Except for *E. coli*, the observed values were below the standards from the Ghana Standard Authority (GSA) and the International Commission on Microbiological Specifications for Foods (ICMSF) standards (1.0×10^7 cfu/g for TVC; 1.0×10^4 cfu/g for *Staphylococcus aureus* and 1.0×10^2 cfu/g for *E. coli*) (ICMSF, 1988).

Table 1: Microbial content of assessed smoked and fresh catfish from the Dormaa Municipality

	Mean Colony Counts (CFU/g)		
Parameter	**Fresh**	**Smoked**	**P value**
Total Viable Count	2.2 x 10^5	4.2 x 10^5	0.22
Total Coliform Count	8.7 x 10^2	0.0	0.34
Staphylococcus aureus	5.5 x 10^3	2.8 x 10^3	0.06
Escherichia coli	2.3 x 10^3	2.5 x 10^3	0.95

4.3 ORGANOLEPTIC PROPERTIES

The results from the sensory evaluation of farmed fresh catfish are shown in Figure 3 and Table 2. Eye colour, skin colour, texture, odour and overall acceptability scored 3.2 ± 0.1, 3.8 ± 0.1, 4.0 ± 0.2, 3.17± 0.2 and 4.6 ± 0.1 correspondingly. From the five sensory attributes, overall acceptability scored the highest, followed by texture with odour scoring the least.

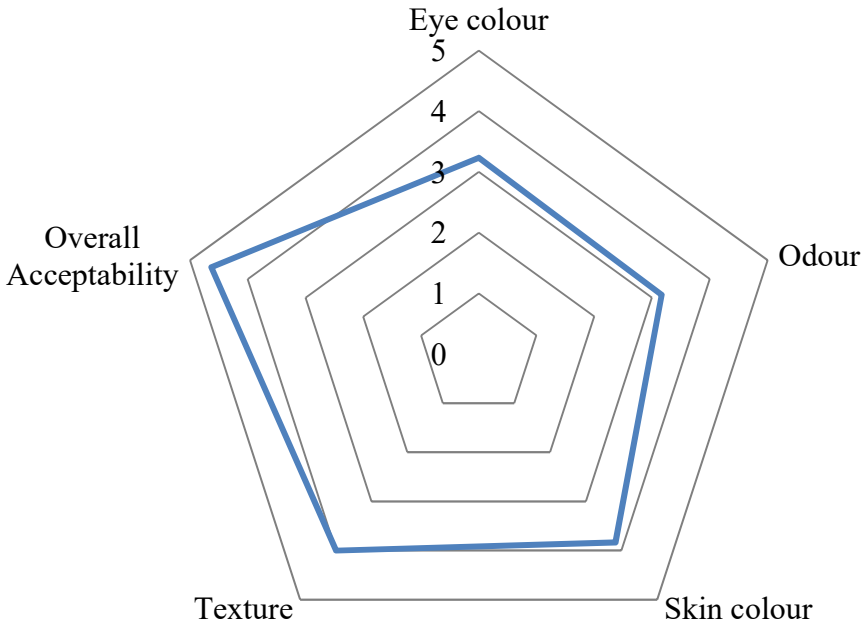

Figure 3: Organoleptic properties of fresh farm-raised catfish.

Figure 4 shows the results from the sensory evaluation of smoked farm-raised catfish. From the five sensory attributes, overall acceptability and eye colour scored the highest with texture scoring the least. Eye colour, skin colour, texture, odour and overall acceptability scored 3.8 ± 0.2, 3.3 ± 0.1, 3.0 ± 0.2, 3.70 ± 0.1 and 3.8 ± 0.1 respectively (Table 2).

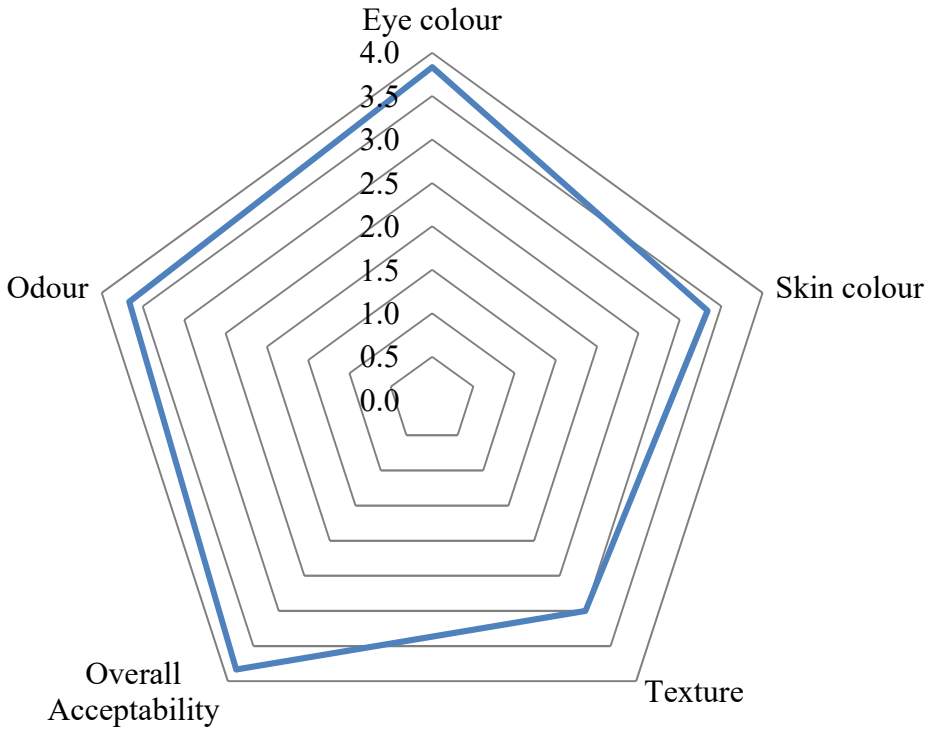

Figure 4: Organoleptic properties of smoked farm-raised catfish.

Organoleptic properties including eye and skin colour, texture, odour as well as overall acceptability between fresh and smoked catfish as listed in Table 2, showed a significant difference ($p < 0.05$).

Table 2: Organoleptic attributes of fresh and smoked farm-raised catfish

Attributes	Fresh	Smoked	P value
Eye colour	3.23	3.8	0.02
Skin colour	3.83	3.3	0.02
Odour	3.17	3.7	0.00
Texture	4.00	3.8	0.00
Overall acceptability	4.63	3.8	0.00

CHAPTER FIVE

DISCUSSION

5.1 NUTRITIONAL COMPOSITION

The significant moisture reduction found in the smoked African catfish, *Clarias gariepinus* in relation to fresh catfish is due to the heat the fish samples were subjected to during the hot smoking process. Ikeme (1991) reported a moisture content range between 7 and 15% for smoked catfish, which corroborates The moisture content of 11% from this study, indicates that such relatively low moisture content of smoked catfish could have comparatively prolonged storage duration (3 – 9 months) than fresh catfish. This is because the conditions are not conducive for the growth of bacteria responsible for spoilage (Daramola *et al.*, 2014).

The percentage crude protein values were comparatively higher in smoked fish than fresh fishes. This observation followed the general rule of inverse relationship that exists between moisture and protein as well as moisture and fat. Okereke *et al.* (2014) in their studies on the comparative nutritional composition of smoked catfish (*Clarias gariepinus*) produced from NIOMR Smoking Kiln and Local Cut Drum Oven found similar observation in smoked and *fresh* catfish. The increase in protein might be because of fish dryness which intensified the proteins through the heat treatment of the fish, subsequently increasing the catfish's nutritional value. Furthermore, high crude protein value obtained

for smoked *Clarias gariepinus* implies that it is a good source of pure protein, hence can aid in the adequate prevention of malnourishment in children, and necessary for the growing population in Ghana and other third world countries that depend on fish as their prime protein source.

The smoked fish's significant ash content increase as compared to the *fresh* fish could be assigned to dry matter increments for every unit of weight after the processes of drying and smoking (Adeyeye *et al.*, 2015). The high amount of ash in the smoked catfish according to the study (ash content = 7.06) was in the range of 5.4 – 15 as reported by Ikeme (1991). This high amount of ash could be assigned to the loss of humidity.

The relatively high level of fats in smoked catfish than in fresh catfish from the present study was at variance with studies by Sesugh *et al.* (2012). These researchers who studied 'Proximate analysis of smoked and *fresh* fish (cat and tilapia) in Ombi River Lafia Nasarawa State Nigeria' reported a higher level of fats and proteins in *fresh* catfish than smoked catfish. This variation in observation maybe linked to the species environment condition, sex of species, and method of preservation. Generally, the significant changes in the proximate composition of the smoked catfish as compared to the fresh catfish may be attributed to the action of the heat from the smoke oven used.

5.2 MICROBIOLOGICAL QUALITY

Bacterial development is the fundamental driver of fish waste; hence, it is reasonable to utilize bacterial count as a key of fish wholesomeness (Nahid *et al.*, 2016). The use of mild smoking treatment which does not achieve complete elimination of microbial load in smoked fish may have accounted for the presence of high bacterial growth in smoked catfish than in *fresh* catfish (Alao *et al.*, 2017). Nonetheless, the values of TVC derived for both *fresh* and smoked catfish fell within ICMSF's (1986) recommended microbiological limits for fish and other related products.

The commended TVC limit for fish intake falls between 6 and 7 log cfu/g (ICMSF, 1988). Thus, smoked and *fresh* catfish from the study are of good quality. The high coliform count in the fresh farmed sampled recorded in the present study might be as a result of pollution arising from fertilizing ponds with animal waste (Daramola *et al.*, 2014). Thus, the use fresh farmed fish with little or no processing, necessitates a suitable percentage use of a selected antimicrobial agent.

However, the absence of coliform in the smoked farmed fish could be attached to the processing technique (smoking). Swatawatsi (2008) in his studies on quality and safety of smoked catfish *(Aries talassinus*) using paddy chaff and coconut shell liquid smoke found that the lower amount of coliform in smoked catfish was as a result of the smoking processing. Studies by Nahid *et al.* (2016) on the quality and safety aspect of four types of smoke-dried Chapila (*Gudusia chapra*; Hamilton-Buchanan, 1822) fish in Dhaka also reported that smoke-drying process reduces bacterial load in fish.

Also, Edris *et al.* (2017) who investigated microbiological assessment of some heat-treated fish products in Egyptian markets stated that the presence of coliform in food is largely dependent on inadequate hygienic measure and mishandling.

The low level of pathogen including *Staphylococcus aureus* from the study of the smoked catfish may be due to the presence of low moisture content in the smoked catfish. It has been documented that high moisture content levels in the fish samples encourage the growth of microorganisms (Olaleye and Abegunde, 2015). Adeyeye *et al.* (2015) in their studies on Assessment of Microbial Safety and Quality of Traditional Smoked Bonga Shad (*Ethmalosa frimbriata*) Fish from Lagos State, Nigeria attributed the presence of *Staphylococcus aureus* to post-processing contamination.

The presence of *Escherichia coli* which is indicative organism representing contamination by microorganisms from enteric origin may be due to the ineffectiveness of the smoking kiln (Olayemi *et al.*, 2013). The ineffectiveness of smoking was reliant on allowing contact between fish smokers and the fish during smoking, thus accounting for the relatively high amount of *Escherichia coli* in smoked fish than in fresh farmed fish from the study. Adeyeye *et al.* (2015) stated that the occurrence of *Escherichia coli* may serve as the presence of indicator organisms for faecal contamination of foods which precipitates from non-adherence to good management practices (GMPs).

5.3 ORGANOLEPTIC QUALITY

A similar observation was made by Yakubu and Ngueku (2015) who investigated smoked-dried fish for their organoleptic properties from five Lafia markets in Nigeria. From their studies, they observed that the odour and texture attributes of smoked fishes were low due to poor handling. Furthermore, the low level of the score for texture in the smoked farmed fish could be due to case hardening which causes checking, cracking and wrapping in smoked fishes. However, Achanta and Okos (1996) indicated that moisture lost from the surface of fish can be adequately slowed down at a drying rate that allows sufficient replacement from inside the fish to prevent crust formation.

Modifications in muscle structure due to heating include coagulation of the perimysial and endomysial connective tissue, sarcomere shortening, myofibrillar fragmentation, and coagulation of sarcoplasmic proteins and detachment of the myofibrils from the muscle fibre bundles in smoked fish may have accounted for the low score than observed for fresh farmed catfish (Rahman, 2007).

Fish colour is a prime consumer appeal feature and smoke determines it. The smoked dark colour as compared to the slimy shiny dark colour of fresh farmed catfish could be due to the high temperature and type of fuelwood used (Toldra, 2010). This high temperature increases the concentration of the components of the dispersing phase of smoke and the rate of the carbonyl-amino reactions and polymerization of various components. Rahman (2007) mentioned that during smoking, the fish colour becomes apparent when the temperature of the fish surface gets to 54.4°C–60°C.

Furthermore, the colour of the smoked catfish maybe due to the type of fuelwood used in smoking (Toldra, 2010). For instance, to impart the colour of the smoked product, resins and carbohydrate-rich wood (e.g., bagasse [sugarcane], beet refuse from sugar making, or coconut husks) is utilized. Nahid *et al.* (2016) stated that the colour varies from shades of black and brown to dirty white.

According to Ziemba (1969) and Ruiter (1979), development of the colour of smoked products come from the reactions of carbonyl compounds, mainly glycolaldehyde and methylglyoxal available primarily in the vapour phase of the smoke, with the amino groups of proteins and nonprotein nitrogen compounds. The smoke phenols form stable colours in reactions with proteins at weak alkaline conditions. Additionally, the concentration of the smoked product's colour is basically in relation to the smoke's visual thickness and the duration of smoking.

Therefore, increasing the velocity and temperature of smoke quickens colour development by intensifying the concentration of the components of the dispersing phase of smoke and the rate of the carbonyl-amino reactions and polymerization of several constituents (Toldra, 2010). The high overall acceptability for fresh catfish by the panellist could be due to the consumer food habits and preference. Similarly, Giullén and Manzanos (2002) mentioned that consumers' food habit, as well as cultural attachments to traditional food, has an effect on consumer's preference. Further to this, high level of textural changes and colour coupled with limited cooking options for smoked fish may have accounted for the high overall acceptability for fresh farmed fish.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the research, the nutritional profile of the smoked (processed) catfish was significantly higher than the fresh (unprocessed) catfish, which means that the consumption of smoked catfish would be more beneficial.

Micobiological assessments, i.e. *E. coli* counts were higher in both smoked and fresh fish, with levels beyond internationally acceptable limits and this is a threat to safe consumption.

Organoleptically, fresh catfish appeared more acceptable than smoked fish, connoting that consumers may prefer buying fresh rather than processed fish on the market.

6.2 RECOMMENDATIONS

In reference to the results and objectives of the research, the following are recommended:

1. Consumers within the Dormaa Municipality should be sensitized to consume more smoked catfish due to its comparatively higher nutritional value;

2. Catfish processors and traders' association in the Municipality need to be trained by the Fisheries Commission on efficient fish handling, processing and packaging for consumer safety and sustainability of their businesses and livelihoods;

3. Research into the development of effective smoking oven (one which will reduce the frequency of contact between fish processors and the fish products) is strongly advocated. This will help reduce the level of *E. coli* in the final smoked products

4. A study should be conducted on consumer preference for the form (whether processed or unprocessed) of African catfish in the Dormaa Municipality since the organoleptic quality appeared to favour unprocessed fish.

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APPENDICES

Appendix 1: A five-point Hedonic scale for organoleptic studies

SCORE	REMARKS
1.0-1.9	Unacceptable
2.0-2.9	Fairly acceptable
3.0-3.9	Moderately acceptable
4.0-4.9	Acceptable
5.0-5.9	Highly acceptable

Appendix 2: Sample T-test for biochemical composition of fresh and smoked farmed catfish.

Moisture	*Fresh*	*Smoked*
Mean	77.39674208	11.6283
Variance	15.03089209	0.753148
Observations	4	4
Hypothesized Mean Difference	0	
df	3	
t Stat	33.10841941	
P(T<=t) one-tail	3.02831E-05	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.00	
t Critical two-tail	3.182446305	

Ash	*Fresh*	*Smoked*
Mean	1.335837984	7.060760188
Variance	0.278406431	1.492880748
Observations	4	4
Hypothesized Mean Difference	0	
df	4	
t Stat	-8.603102466	
P(T<=t) one-tail	0.000501604	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.001003208	
t Critical two-tail	2.776445105	

Fats	*Fresh*	*Smoked*
Mean	0.568944288	9.309488861
Variance	0.11316559	12.99471403
Observations	4	4
Hypothesized Mean Difference	0	
df	3	
t Stat	-4.828389151	
P(T<=t) one-tail	0.008466998	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.016933996	
t Critical two-tail	3.182446305	

Proteins	*Fresh*	*Smoked*
Mean	17.58118596	25.72279861
Variance	0.207257199	9.104457699
Observations	4	4
Hypothesized Mean Difference	0	
df	3	
t Stat	-5.33612011	
P(T<=t) one-tail	0.006432953	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.012865907	
t Critical two-tail	3.182446305	

Total Carbohydrates	*Fresh*	*Smoked*
Mean	4.453127665	53.33941079
Variance	9.657861001	0.095176835
Observations	4	4
Hypothesized Mean Difference	0	
df	3	
t Stat	-31.30740417	
P(T<=t) one-tail	0.0000358	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.0000716	
t Critical two-tail	3.182446305	

Appendix 3: Sample T-test for microbiology characteristics of fresh and smoked farmed catfish.

Total Viable Count	*Fresh*	*Smoked*
Mean	2.2	4.15
Variance	0.18	0.845
Observations	2	2
Hypothesized Mean Difference	0	
df	1	
t Stat	-2.723878154	
P(T<=t) one-tail	0.111996548	
t Critical one-tail	6.313751515	
P(T<=t) two-tail	0.223993095	
t Critical two-tail	12.70620474	

Total Coliform Count	*Fresh*	*Smoked*
Mean	8.65	0
Variance	51.005	0
Observations	2	2
Hypothesized Mean Difference	0	
df	1	
t Stat	1.712871	
P(T<=t) one-tail	0.168206	
t Critical one-tail	6.313752	
P(T<=t) two-tail	0.336411	
t Critical two-tail	12.7062	

Staphylococcus aureus count (10^3)	*Fresh*	*Smoked*
Mean	5.5	2.8
Variance	0	0.08
Observations	2	2
Hypothesized Mean Difference	0	
df	1	
t Stat	13.5	
P(T<=t) one-tail	0.023536	
t Critical one-tail	6.313752	
P(T<=t) two-tail	0.047071	
t Critical two-tail	12.7062	

E. coli	*Fresh*	*Smoked*
Mean	2.3	2.5
Variance	2.88	12.5
Observations	2	2
Hypothesized Mean Difference	0	
df	1	
t Stat	-0.07212	
P(T<=t) one-tail	0.477083	
t Critical one-tail	6.313752	
P(T<=t) two-tail	0.954165	
t Critical two-tail	12.7062	

Appendix 4: Sample T-test for sensory characteristics of fresh and smoked farmed catfish.

Overall Acceptability	Fresh	Smoked
Mean	4.6	3.833333333
Variance	0.248275862	0.488505747
Observations	30	30
Hypothesized Mean Difference	0	
df	52	
t Stat	4.892128097	
P(T<=t) one-tail	5.01652E-06	
t Critical one-tail	1.674689154	
P(T<=t) two-tail	1.0033E-05	
t Critical two-tail	2.006646805	

	Texture	Texture
Mean	4	3
Variance	1.24137931	1.034482759
Observations	30	30
Hypothesized Mean Difference	0	
df	58	
t Stat	3.630677372	
P(T<=t) one-tail	0.000299695	
t Critical one-tail	1.671552762	
P(T<=t) two-tail	0.00059939	
t Critical two-tail	2.001717484	

	Skin colour	Skin colour
Mean	3.833333333	3.333333333
Variance	0.626436782	0.574712644
Observations	30	30
Hypothesized Mean Difference	0	
df	58	
t Stat	2.498803541	
P(T<=t) one-tail	0.007657864	
t Critical one-tail	1.671552762	
P(T<=t) two-tail	0.015315727	
t Critical two-tail	2.001717484	

	Eye colour	Eye colour
Mean	3.233333333	3.8333333
Variance	0.667816092	1.1781609
Observations	30	30
Hypothesized Mean Difference	0	
df	54	
t Stat	-2.41879317	
P(T<=t) one-tail	0.00948623	
t Critical one-tail	1.673564906	
P(T<=t) two-tail	0.018972461	
t Critical two-tail	2.004879288	