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State of the Art and Contribution to the Documentation on Fishing, Aquaculture and on the Microbiological Profile of Clarias Gariepinus and Oreochromis Niloticus Two Species of Fish Reared in the Whedos of the Upper Ouémé Delta in the Republic of Benin

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Abstract

Fish is an important source of animal protein in Africa and is used in the composition of several national dishes. This literature review examines fishing, aquaculture and fish reared in the whèdos of the upper Ouémé delta

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in Benin. It addresses socio-economic aspects, nutritional importance and traditional fish preservation technology. The sources of information used are publications, books, reports of dissertations and theses and technical notes. It was found that Clarias gariepinus and Oreochromis niloticus, among others, are two species of fish most often raised in the whèdos of the Ouémé River in Benin. These fish adapt to large variations of ecological factors of the aquatic environment found everywhere in Africa and reproduce easily in captivity, which favors their breeding in ponds. These species present multiple fish farming qualities: resistance to high densities, resistance to diseases and low oxygen levels, easy adaptation to artificial feeding and high growth. Microbiological contamination of fish flesh occurs only after capture and can be endogenous or exogenous contamination. Generally, several processes are used to overcome this problem of contamination of fish. Hot smoking and drying are very often used. The lack of hygiene in the traditional technology of smoking fish sometimes favor a considerable microbial contamination of the obtained products. Thus, contaminated fish can be the cause of foodborne diseases such as food poisoning. Most of the pathogenic strains responsible for these diseases are resistant to certain antibiotics.

Keywords: Whèdos, fishing, fish, microbiological profile, antibiotic resistance

1. Introduction

The development of fisheries must be accompanied nowadays by a diversification of fish species to be promoted with the domestication of indigenous species of the concerned farming areas (Houenou, 2019). As for fish farming, it should be developed by modifying and improving existing traditional extensive systems such as fish hole systems called in traditional language Whédos and Acadja (Toko et *al*., 2011; Kalikoski et *al*., 2018). Unlike acadjas, traditional fish holes inspire admiration and deserve to be developed and improved taking into account local realities (Elegbe et *al*., 2015).

In Benin, the practice of extensive fish farming in traditional fish holes or traditional ponds, based on the succession of floods and floods in the plains, has been developed for decades by the population (Elegbe et *al*., 2015). Its adoption has certainly increased production and made fish a little cheaper for consumers. According to FAO data, the total amount of fish available in Benin in 2019 is 79.84 million tons and are all destined for food with a consumption of 6.77 kg per person per year and a protein availability of 2 g per person per day (FAO, 2022). Fish farming, particularly of *Clarias gariepinus* and *Oreochromis niloticus*, is gaining momentum because of the hardiness of these species as well as the quality of their flesh, which is

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highly appreciated by the Beninese population (Kpoguè et *al*., 2012; Houenou, 2019). Therefore, it is advisable to pay special attention to these species and to identify the aggressions and factors that can hinder their breeding (Kpoguè et *al*., 2012; Kalikoski, 2018; Houenou, 2019).

According to Kpadonou et *al* (2012), fish farming in traditional holes called whédos generates regular income that not only mitigates farmers' vulnerability to climate risks, but also finances agricultural activities. These climatic risks result in post-capture losses and seriously affect the quality of the fish (Kpadonou et *al*., 2012; Hambrey, 2017). Smoking, which is a processing operation, is then the only means likely to alleviate this problem in order to preserve the nutritional quality of these fish (Degnon, 2014; Gamané, 2017). It has been practiced for generations in many regions of the world, for the preservation of several perishable products and for food diversification (INRAB, 2012; FAO, 2018). Smoking is often combined with cooking, drying and/or salting (Rivier et *al*., 2009; Nyebe et *al*., 2014).

It is therefore with the aim of drawing up an inventory of the level of development of fishing, aquaculture and the conditions and constraints of traditional farming of *Clarias gariepinus* and *Oreochromis niloticus*, two species of fish farmed in the whedos of the upper Ouémé delta in Benin, that the present work has been written. It also presents the microbiological profile of these fish and discusses the resistance of pathogenic strains isolated from them to antibiotics.

3. General information on fisheries and aquaculture

3.1. Fisheries and Aquaculture in the world

Capture fisheries and aquaculture in the world provide about 143 million tons of fish for human consumption (FAO, 2012). Aquaculture alone provides 76% of global freshwater fish production (FAO, 2008). The fisheries and aquaculture sector is also a source of employment and income, providing livelihoods for 10-12% of the world's population (FAO, 2014; Hambrey, 2017). Global capture fisheries and aquaculture provided 167.2 million tons in 2014, of which 93.4% was produced by capture fisheries and aquaculture (FAO, 2008; Kalikoski et *al*., 2018). Other data estimate that over 90% of global production is for human consumption (FAO, 2018). Global trade in fish and fishery products has grown considerably in recent decades, with the quantities traded increasing from over 245% in 1976 to 515% in 2014 if only trade in fish for human consumption is considered (FAO, 2014; Hoag, 2017). Figure 1 show the per capita fish consumption per year worldwide from 2013 to 2015.

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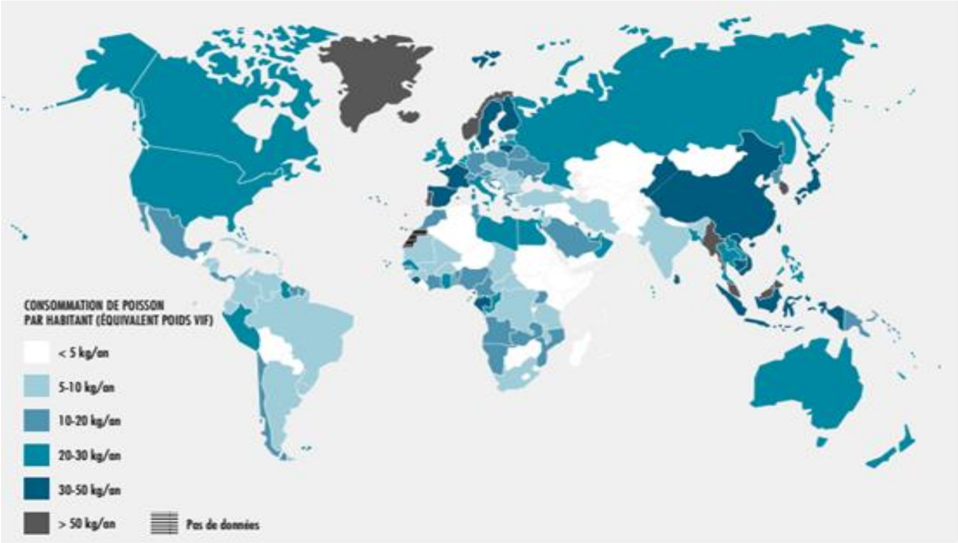

Figure 1. Fish consumption per person/year worldwide from 2013 to 2015 (FAO, 2018)

In 2016, the total number of people suffering from chronic undernourishment reached 815 million, compared to 777 million in 2015 (FAO, 2018). These data are nevertheless down from the year 2000, whose value was 900 million. The highest figures and percentages were recorded in Asia and Africa (Kolding et *al*., 2016; FAO, 2018). In 2012, employment in this sector grew faster than the global population and nearly 60 million people were working in the primary sector. Also, 90% of this population were artisanal fishers and 15% of them were women. In post-capture activities such as smoking, on the other hand, women can make up to 90% of the workforce (FAO, 2012; Kalikoski et *al*., 2018). Smoking is performed on gutted fish, opened and then placed on a wire mesh 30 cm from the embers (Ndrianaivo et *al*., 2016). Whole smoked and dried fish are used to make broth or sauce to accompany rice. Storage conditions partly determine the shelf life of the products and thus the acceptability of the product. Although smoked and dried fish are consumed by most low-income households, they are less valued than fresh fish (Ndrianaivo et *al*., 2016). Trade plays a major role in the fisheries and aquaculture sector as an employment creator, income generator, and driver of economic growth and development, as well as food and nutrition security. Fish and fishery products are one of the most heavily traded segments of the global food sector, with an estimated 78% of edible seafood products subject to international trade competition (Kurien and Lopez, 2013). Exports of fish and fishery products are critical to the economies of many countries and coastal, riverine, island, and continental regions (FAO, 2016). Expressed in value terms, global trade in fish and fishery products has also grown

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significantly, as the value of exports increased from USD 8 billion in 1976 to USD 148 billion in 2014, representing an annual growth of 8.0% in nominal terms and 4.6% in real terms. Many developing countries experienced an increase in demand and imports in 2009. In the following two years, trade rebounded strongly, with overall growth of 15 percent in 2010 and 17 percent in 2011, reaching a value of US$130 billion. Global commodity exports have grown strongly over the past 20 years, reaching USD 18 trillion in 2014, nearly four times the value recorded in 1995 (FAO, 2012). Artisanal fisheries contribute to the fight against poverty and food and nutrition insecurity and, are increasingly recognized for their value (Kurien and Lopez, 2013; FAO, 2014; Singleton et *al*., 2017). Table 1 describes fish consumption by continent in 2015.

Table 1. Fish consumption by continent in 2015 (FAO, 2018).

Region/economic grouping	Total fish consumption (millions of tons)	Fish consumption per capita (Kg/year)
Worldwide	148,8	20,2
World (excluding China)	92,9	15,5
Africa	11,7	9,9
North America	7,7	21,6
Latin America and Caribbean	6,2	9,8
Asia	105,6	24,0
Europe	16,6	22,5
Oceania	1,0	25,0
Developed countries	31,4	24,9
Least developed countries	12,0	12,6
Other developing countries	105,4	20,5
Low income countries	20,8	7,7

3.2. Fisheries and aquaculture in Africa

The African continent's fisheries production was estimated at over 9.7 million tons in 2012, or nearly 6% of global production (FAO, 2016). Africa's contribution to global fish production has increased over the past decade from 1.2% to 2.2%, largely due to the rapid development of freshwater aquaculture in sub-Saharan Africa (FAO, 2012; Kolding et *al*., 2016). Africa has considerable opportunities to develop aquaculture but has not exploited this technology to any significant extent. Less than 5% of Africa's aquaculture potential has been exploited (World Fish Centre, 2005; Kolding et *al*., 2016). The proportion of smoked fish in Africa is higher than the global average, at 14% of total global production (Kolding et *al*., 2016).

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Total domestic catches decreased by 0.3 million tons in Asia, while they increased by 0.1 million tons across all African countries (FAO, 2012). In African countries, as in many countries around the world, fisheries and aquaculture play an important role in providing animal protein for food (Keita, 2005; FAO, 2008). More than 200 million Africans regularly consume fish either fresh, or most often smoked or dried (World Fish Centre, 2005; Yvette et *al.*, 2016). In Africa, a distinction is made between artisanal and industrial fishing. Indeed, artisanal fisheries contribute to poverty alleviation and food and nutritional security (FAO, 2014). Africa is currently experiencing a crisis in the availability of fish while it is the region of the world with the lowest per capita consumption of fish. This decline is mainly due to stagnant catches while the population continues to grow. To maintain the current level of fish availability in sub-Saharan Africa (6.6 kg/person/year), production (capture fisheries and aquaculture) will have to increase by 27.7 percent by 2015. This percentage was calculated based on an average annual population growth rate of 1.9% over the period 2002 to 2015 (World Fish Centre, 2005). Total domestic catches decreased by 0.3 million tons in Asia, while they increased by 0.1 million tons across all African countries (FAO, 2012; Kolding et *al.*, 2016). About 12.3 million people living from fishing in Africa are in the artisanal fishing sector with more than 7.53 million fishermen and 2.3 million women. This artisanal activity therefore constitutes a means of living and above all a livelihood for millions of families in Africa (CAOPA, 2015).

3.3. Post-catch losses in the fishery

Post-catch losses are a recognized problem in the subregion. In Sub-Saharan Africa, about 25% of fish is lost due to lack of effective means of conservation and processing (FAO, 2018). Some estimates give post-harvest losses of between 20-25%, and as high as 50%, with quality degradation accounting for up to 70% of these losses (Akande and Diei-Ouadi, 2010). Dried fish products frequently suffer severe losses due to fly infestation, which contributes to the degradation of the fish flesh. Dried fish contaminated with both insects and harmful insecticides accounts for about 80% of total dried products which could cause a public health problem for consumers (Shiv et *al.*, 2018).

3.4. Fishing and aquaculture in Benin

3.4.1. History and evolution of fishing in Benin

Fishing in Benin is divided into two main areas :

- ❖ Inland fishing (lakes, lagoons, rivers etc....) represents about 79% of the national fisheries production with a value of 38,706 tons in 2011 (INRAB, 2012). According to the DIPA program (2016), artisanal

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fishing is practiced from 80 camps scattered in the three coastal departments of Benin including 51 camps for Atlantic; 23 for Mono and 6 for Ouémé. The face of artisanal fishing has changed significantly between 2012 and 2016. The boats operating on the Beninese coast are all made of wood, monoxies or improved monoxies of the Ghanaian type. Depending on the size and use of the boat, the hull is raised by an additional planking attached to the upper part of the hull. They can be classified into four main categories:

- The pirogues used by Fanti fishermen with bottom-set gillnets. They are between 4 and 8 m in length overall, 0.80 to 1 m wide and 50 to 60 cm deep. Most of them are propelled by paddle or square sail. The rare outboard motors used have a power of 8 horsepower.
- The pirogues used for hand-line fishing, with an overall length of 8 to 12 m and a width of 1 to 1.25 m for a depth of 50 to 80 cm. These pirogues are equipped with removable isothermal containers for the conservation of the catches on board during the whole tide (one week). They are propelled by outboard motors of 1 5 to 25 horsepower.
- The pirogues fishing with sardinella nets, beach seines or shark nets are 9 to 14 m in length overall, with a width of 1.25 to 1.60 cm and a depth of 60 to 80 cm. The commonly observed propulsion method is the outboard motor of 25 to 40 horsepower.

Semi-decked pirogues using the "washa" rotating and sliding seine, with a length of 12 to 16 rn by a width of 1.25 to 1.65 m for a depth of 80 to 90 cm. They are equipped with 40 horsepower outboard motors. They can be equipped with isothermal containers for hand-line fishing and/or bottom-set gillnet fishing.

Continental fishing is of particular importance in Benin. It is practiced in the numerous bodies of water in the south where a traditional fish farming technique called "Acadja" has also been developed. At all levels, inland fishing exceeds maritime fishing (artisanal and industrial). There are nearly 49,000 fishermen operating on more than 26,700 monoxyle canoes. Production is currently around 37,500 tons, of which 6,000 tons come from Acadja. The majority of the vessels currently operating are from Nigeria. The funds exploited are practically the same as in maritime artisanal fishing, i.e., the area within 5 nautical miles of the coast.

- ❖ Maritime fishing (21%) of the national fisheries production which is characterized by industrial maritime fishing (10% catches at sea) and artisanal maritime fishing (90% catches at sea) (INRAB, 2012). Industrial fishing in Benin is very little developed. The fishing effort

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hardly exceeds 40 trips in a year; the annual production, on average 630 tons over the last eleven years, represents only 8% of the total marine fishery (DIPA, 2016). The majority of the vessels currently operating are from Nigeria. The funds exploited are practically the same as in maritime artisanal fishing, i.e., the area within 5 nautical miles of the coast.

3.4.2. Fishing in Lake Nokoué

Lake Nokoué is one of the largest inland water bodies in Benin. Located north of the city of Cotonou, it covers 150 km2. It is limited to the west by the city of Abomey-Calavi, to the east by the lagoon of Porto-Novo to which it is connected by a channel, to the north by the floodplain of the rivers Ouémé and So and to the south by the city of Cotonou and connected to the Atlantic Ocean by a channel.

Lake Nokoué benefits from the humid tropical climate of southern Benin. The temperature of its waters, which are alternately fresh and brackish, varies between 27 and 29° C. Although it is fished all year round, its waters are most productive during the low water period, from November to June. The catches of Lake Nokoué are multispecific with largely sedentary species to which are added two migratory species thanks to its connection to the ocean through the channel. They have been increasing continuously for the last 3 to 4 years. Three groups of species are dominant (about 85% of the catches): cichlidae, clupeidae and crustaceans. In the absence of a series of reliable statistical data, it is difficult to make a statement on the state of the resources of Lake Nokoué. It can only be stated that the increase in the number of fishermen observed over the last few years is putting these resources under strong pressure. Currently, the lake is exploited by nearly 12,000 fishermen belonging to the Toffin (the majority of the population living in the lake villages), Xwlah, Pédah and Aïzo ethnic groups (in the peripheral villages): More than 10,000 pirogues are active in the area; For the fishermen living on the lake, fishing as the main activity is supplemented in increasingly considerable proportions by trade with Nigeria by lake route. Those living around the lake combine fishing, farming and trading (DIPA, 2016).

Fishermen use simple but diverse techniques that can be grouped into five categories: set nets, cast nets, acadja, pots, and longlines. These techniques are used by fishermen individually or in small teams (2 to 3 people). Another traditional fish farming technique called fish hole is practiced in the area.

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3.4.3. Fishing in other water bodies

In 2012, Lake Ahémé witnessed the development of acadja parks and dams that occupy 80% of the surface area of the water body. The entire population is practically occupied by these activities, with the poorest fishermen no longer finding room to operate with other gear preferring to work in the parks as laborers for a better income. Despite the large number of boats with a figure of nearly 9,200 and fishermen with about 8,500 people, production is low and has shown a slight decline between 2011 and 2012, from 4,800 tons to 3,700 tons.

The Ouémé River flows into Lake Nokoué and the Porto-Novo lagoon which serve as a relay to the sea. Production increased from 2,000 t in 2011 to 2,800 t in 2012. Due to its length, depth and fishery resources, it lends itself to the exploitation of acadja and fish holes, the use of longlines, pots, traps and landing nets. During the flood, its overflow enriches the floodplains. Almost all species can be found there with considerable fluctuation.

In the Porto-Novo lagoon (35 km2), some fishermen have abandoned fishing in favor of the exploitation of the lagoon's gravel and smuggling, which continues to grow. Nevertheless, we note the entry into the profession of new people, the fishing gear has become numerous, the parks cover the majority of the surface area of the water body. Between 2011 and 2012, production increased by almost 60%. It is mainly shrimp and crabs that are caught in the coastal lagoon. Fishermen are forced to head to the channel to catch medium-sized fish. The flooding enriches the lagoon with freshwater species such as clariidae, synodontis, schilbeictae, heterotis and machrobrachium. On Lake Doukonta, the regular presence of the hippopotamus prevents fishermen from staying in the water for long. In Lake Togbadji, many fishermen continue to use prohibited gear bringing in small species.

The Toho lagoon and Lake Hlan are covered with floating vegetation that tears nets and lets fish escape, even if they have already been removed. The areas covered by vegetation are sometimes abandoned by the fishermen, allowing the fish hidden under the vegetation to grow. Fishermen now spend much more time on field work given the low level of production (DIPA, 2016).

3.4.4. Study fish species

In the Beninese lake systems, several species of freshwater fish are encountered. However, certain species such as Tilapia or Carp (*Oreochromis niloticus*), and African Catfish (*Clarias sp*) are predominant. These fish species are widely abundant and the most processed in Benin and many African countries (Gamané, 2017).

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- Tilapia (*Oreochromis niloticus*)

Now renamed *Oreochromis niloticus*, Tilapia (Figure 2) is a species of fish native to the warm waters of Africa that lives exclusively in freshwater. It belongs, like all other tilapias, to the family *Cichlidae*. It is found everywhere in Africa. Its habitat is limited only by the water temperature (18 °C minimum). This species is very undemanding in terms of food and living conditions. Indeed, many field and laboratory studies have shown that *Tilapia nilotica* is a species that adapts relatively to large variations in ecological factors of the aquatic environment and colonizes extremely varied environments. Tilapia represents the major species of African fish farming and, well beyond the tropical world (PRODEPECHE, 2009 ; Abert, 2018).

Figure 2. Tilapia nilotica (*Oreochromis niloticus*)

- **African catfish (*Clarias gariepinus*)**

This species of fish belongs to the large family Clariidae. They are part of the order Cypriniformes and the suborder Siluroidei which includes 12 families characterized externally by a naked skin and by oral barbels. For West Africa, eight (8) families comprising twenty four (24) genera and one hundred and twenty four (124) species. The genus Clarias includes several large African species including *Clarias lazera* and *Clarias senegalensis* (Abert, 2018).

The African catfish (Figure 3), is widely distributed in Africa. It lives in tropical swamps, lakes and rivers and its production in Africa in 2000 was 131,819 tons (Abert, 2018). It is a fish that reproduces easily in captivity which favors its breeding in ponds. This species presents multiple fish farming qualities: resistance to high densities, resistance to diseases and low oxygen levels, easy adaptation to artificial feeding and high growth.

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Figure 3. *Clarias gariepinus* (Catfish)

3.5. General information on fish holes or wharfs in the Ouémé delta

Fish holes represent a form of extensive fish farming encountered in Benin and are exploited by the peasant-fish farmers. They are traditional pond that used to be the most important method of fish production. There are two types of fish holes:

- Ahlos are channels dug on the banks of streams that have permanent communication with the stream. They are constructed perpendicular to the stream plane and are fed by tidal movement. According to Toko (2007), Ahlos are deep trenches covered with floating vegetation but are less developed in the Ouémé delta despite the quality of their water and their better fish yield.
- The whédos are excavations made near water bodies or in the flood plains of rivers. They fill up during floods and are naturally colonized by fish that remain trapped there at the time of the flood. However, they are different from the "ahlos", on the one hand, by the absence of communication with the channel of the river and on the other hand, by the water supply carried out through the flood caused during the overflow of the river. They can reach more than 1 km long, 3 to 5 m wide and 0.5 to 1.5 m deep. Like the "ahlos", they are covered by floating plants before their exploitation and therefore have a very low oxygen content.

3.5.2. Origin and history of fish holes

According to Houenou (2019), "whedo" type fish holes are initially either natural depressions or holes, ponds or ditches made in floodplains to trap fish during flooding. They are located in marshes where water can still be retained during the dry season. This innovation probably began during

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the 19th century in the Ouémé Valley and, over time, has become increasingly popular. The "Ahlos" type fish holes were developed later after the "whédos" from 1945. These infrastructures allow a very intensive use of the floodplains by promoting the fishing of fish in the trenches and the practice of irrigated crops. From the sixties, nets are used to carry out the fishing in these infrastructures instead of the previously used branches. In 1975, a major project for the management of the plains, which was to build canals that could be used by the "Ahlos", began, but few canals were built due to poor management. In 1980, methods of attracting fish in fish holes were developed. In addition, since 2000, in order to adapt to climatic changes, the realization of off-season crops on the dikes of the fish holes was developed. The first experiments of profitability of these infrastructures through the realization of a second harvest by a 2nd cycle of production began in 2005.

3.5.3. Advantages and disadvantages of extensive fish farming

Extensive fish farming systems are second-tier users of the water resource, i.e. they do not consume enough water as do intensive and semi-intensive systems that require water to be added at regular intervals. These systems have no impact on water availability for human consumption and crop development. They do not require technical skills or heavy investments. They do not involve the use of feed, but use the primary production of the water bodies, unlike semi-intensive and intensive systems that use fertilizers or artificial feed. Thus, these systems modify the environment little and can, in some cases, create natural conditions favorable to the repopulation of natural populations. This system increases the availability of native species. In sum, extensive fish farming is a more environmentally friendly activity, capable of producing organic fish. It is a less expensive and less polluting alternative to other forms of fish farming existing today. Therefore, extensive systems can have three objectives: (i) restocking of natural populations that have been reduced by environmental alterations, including degradation of critical habitats for reproduction; (ii) acclimatization of exotic species or populations to create new stocks that are more interesting than the native ones; (iii) simple rearing of a stock by rearing from the natural environment, often leading to overcrowding. However, extensive fish farming is dependent on the climate and could therefore not be controlled by the producers. The production from the activity may be in surplus as harvesting can take place in a considerable amount of time in a considerable number of water bodies; this would create a market disposal problem (Houenou, 2019).

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4. Importance and technology of fish conservation

4.1. Nutritional importance of fish

Fish remains a source of animal protein with high nutritional value (Abelrahim et *al.*, 2012; Oladipo et *al.*, 2013; Kurien and Lopez, 2013). The protein content of fish exceeds that of beef, pork, and poultry meat. It is highly digestible and contains essential amino acids such as lysine, leucine, valine, arginine, methionine, tryptophan and histidine. It also contains polyunsaturated fatty acids of the n-3 series, precursors of prostanoids with an antithrombotic effect (Oladipo et *al*., 2013). Fish is an important source of vitamins and minerals (Abdullahi et *al*., 2001; Amiengheme, 2005). Over the past 50 years, the global supply of fish for human consumption has increased faster than the population. Over the period 1961 to 2013, it grew by an average of 3.2% per year, double the population growth, resulting in an increase in average per capita availability (Kurien and Lopez, 2013; FAO, 2016). Fish could play an important role in improving food security and nutritional status in Africa. It is an important source of protein and minerals for rural communities in all forms of consumption: fresh, dried or powdered (Tossougbo, 2017). Fish products are rich in vitamins. Fish has long been the only source of vitamin D and remains a notable supplement of B vitamins (B1, B2, B6, B12) for many communities. It contains vitamin A stored as retinol in the liver, intestines, pancreas and kidneys. The distribution of vitamin A between the liver and the viscera varies considerably from one species to another. Vitamins E and K are also present in fish flesh (Bourgeois, 2003; Oladipo et *al*., 2013). Fish consumption is particularly valuable during pregnancy and then during the first two years of a child (the first 1,000 days) (FAO, 2014). In addition, its fats are excellent for health because they contain polyunsaturated fatty acids with the property of promoting the lowering of cholesterol levels. Fish is therefore recommended in the diet for the prevention of cardiovascular diseases. It contains interesting levels of phosphorus, calcium, magnesium and iodine (Ogbannaga et *al*., 2009; Tossougbo, 2017). Micronutrient deficiencies affect hundreds of millions of people, particularly women and children in developing countries. More than 250 million children worldwide are at risk of vitamin A deficiency, 200 million people have goiter (20 million of whom have learning disabilities due to iodine deficiency), 2 billion (more than 30% of the world's population) lack iron, and 800,000 child deaths per year can be attributed to zinc deficiency. Fish could solve its micronutrient deficiency problems (FAO, 2014; Martin et *al*., 2018). Processed fish is part of the staple diet in many tropical countries (FAO, 2016). Artisanal fish processing remains the most widely used method of fish preservation in Africa, despite several attempts to introduce freezing systems in these areas (Kéita, 2005). Traditional methods of processing fish

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for direct consumption by drying, smoking or fermenting are still practiced in developing countries where good manufacturing and hygiene practices are respected. Smoking and drying, accounted for only 8.9 percent of the total volume of fish for human consumption in 2010, down from 10.9 percent in 2000 (Olsen et *al*., 2014; FAO, 2018). The FAO estimates that fish constitutes 22% of the protein ration in sub-Saharan Africa. However, in the poorest countries, this rate is reportedly higher than 50%, especially when other animal protein sources are inaccessible. In the coastal states of West Africa, where fish is important, the proportion of animal protein from fish is extremely high: 47 percent in Senegal, 62 percent in The Gambia, and 63 percent in Sierra Leone and Ghana (FAO, 2012; Kolding et *al*., 2016). Table 2 shows the nutrient composition of catfish per 100 g.

Table 2. Nutrient composition of catfish per 100 g (FAO, 2012)

Nutrients	Quantity	Unit
Protein	18,2	G
Iron	0,82	Mg
Calcium	9,0	Mg
Iodine	0,1	Mg
Potassium	32,1	Mg
Vitamin A	0,02	Mg
Vitamin B2	0,1	Mg
Vitamin B6	0,2	Mg

4.2. Socio-economic importance of fish

The added value of fish production averaged 21,564 billion CFA francs between 2000 and 2005, with 4,607 billion CFA francs coming from fresh fish and the remainder, approximately 16,956 billion CFA francs, from dried and smoked fish. Due to the lack of reliable statistics on the fishing sector in the national accounts, between 2000 and 2005 the contribution of fishing in value to GDP remained low. The average contribution to GDP over the six-year period is around 1.30 percent according to national accounts estimates. In the primary sector, also because of the strong contribution of food and industrial agriculture, its contribution remains low; it is around 3 percent of the primary sector. On the other hand, trend production figures seem to be fixed, although fishing activity is so widespread that it is carried out on a part-time basis by occasional fishermen who fish, consume and resell part of the product of their fishing (FAO, 2008).

4.2. Preservation of fish

Preservation is a means of stabilizing food, allowing it to be stored longer. The human diet depends on products of plant and animal origin. Preservation should be seen as a means of storing the surplus food available

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at certain times for consumption during periods when food is scarce. Processed fish is part of the staple diet in many tropical countries. Thus, artisanal processing remains the most widely used method of fish preservation in Africa, despite several attempts to introduce freezing systems in these areas (FAO, 2008). Fish is a highly perishable commodity. It must be caught or purchased and quickly transported under good conditions and processed in efficient storage, processing and packaging facilities before being marketed. In particular, a number of very precise hygiene rules must be respected to preserve the nutritional quality and extend the shelf life of the products, to limit the action of bacteria responsible for their degradation and to avoid losses due to bad handling practices. Fish is usually distributed in one of the following forms: live, fresh, chilled, frozen, heat-treated, fermented, dried, smoked, salted, pickled, boiled, fried, freeze-dried, minced, powdered or canned. Some of these techniques are lacking in the Sahelian zone (FAO, 2012; Singleton et *al*., 2017). In developing countries, less elaborate processing techniques such as: filleting, salting, canning, drying, and fermentation continue to be used. Over the past decade, fish processing has evolved, including in many developing countries, with a trend towards higher value-added products. Processing can range from preliminary operations (gutting, heading) or presentation in steaks to more elaborate methods of adding value such as breading, cooking or freezing of individual portions, depending on the product and its commercial value. Smoking, salting and drying are the main artisanal processing methods applied alone or in combination. Artisanal processing is a post-capture activity of the fishery, it remains a necessity to ensure animal protein coverage in developing countries (Oladipo et *al*., 2013; Kurien and Lopez, 2013).

4.3. Smoking and drying technology for fish

Smoking consists of impregnating a foodstuff with the volatile principles constituting the smoke obtained during the combustion of wood by giving it a particular taste and color (Abdoullahi, 2019). Smoking has three main purposes:

- obtaining a color ranging from yellow to dark brown ;
- obtaining a characteristic taste of the smoked products ;
- prolonged preservation of the product due to the antioxidant and bacteriostatic action of the smoke (Degnon et *al*.,2013; Abdoullahi, 2019).

4.3.1. Role, principle and importance of smoking

Smoking of fish is one of the most widespread conservation methods in Africa and is done in a traditional way (Degnon et *al*., 2013). It affects the

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color and provides a desirable flavor for the consumer (Ida and Nwankwo, 2013). Smoking encompasses different types of methods which, in tropical countries and in Africa in particular, do not necessarily correspond to true smoking but to cooking-smoking-drying. It allows fish to be preserved in areas where other techniques are not very effective because of high humidity. This method is mainly found in Africa, notably in Congo, Benin, Côte d'Ivoire, Chad and Senegal (FAO, 2008). In Benin, smoking is the most widespread artisanal fish processing technique (PRODEPECHE, 2009; INRAB, 2012). It concerns both fresh fish from the national artisanal fishery and it is estimated that about 50% of the fish processed by this method (PRODEPECHE, 2009).

4.3.2. Inputs, smoking materials and smoke characteristics

Different types of fuel are used to smoke fish in Benin, namely firewood. Thus, several species of tree are used, namely *Acacia nilotica*, which is abundant in almost all regions of Benin; other species of wood can also be used, notably *Balanites egyptiaca*, but the women processors consider that this species is likely to cause oedemas in the consumer and to give the product a bitter taste. Other women use *Salvadora persica*, *Acacia siberiana* and *Hephaenea thebaïca* palm nuts as fuel. For processors, the best fuel remains *Acacia siberina* (PRODEPECHE, 2009).

The smoke contains a significant amount of compounds from the incomplete pyrogenation at variable temperatures of the polyoses and lignin that constitute the wood. The polyoses are represented primarily by cellulose and hemicellulose 2 which form the "flesh" of the tree (Jean-Pierre, 2012). Wood consists of organic matter, mainly in the form of cellulose (about 50%), lignin (20-30%) and hemicellulose (15-25%) as well as mineral elements in very small quantities (1%) (Collet, 2000). Four elements contribute mainly to its chemical composition: carbon, oxygen, hydrogen, and nitrogen in much smaller proportions. The proportion of each element varies slightly depending on the wood species (Rogaume, 2009). Smoke contains hydrogen, carbon monoxide, carbonic acid, alcohols (methyl and ethyl), aldehydes (formic aldehydes), acetic acid and its counterparts (propionic, butyric valeric acids), ketones, cresols, guaiacols, tars, and creosote oils (Abdoullahi, 2019; Depo et *al.*, 2019).

4.3.3. Types of smoking

There are generally three types of smoking (Abdoullahi, 2019; Depo et *al.*, 2019).

Cold smoking: is the process of smoking fish at a temperature and time that does not cause significant coagulation of the proteins in the fish flesh, but will allow some reduction in water activity (Codex alimentarius, 2018). The temperature generally does not exceed 28°C. The fish does not

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undergo any cooking (Pôle, 2010). Cold-smoked fish is more tender than hot-smoked fish, however this process does not allow a destruction of parasites possibly present in the product (FAO, 2016). In addition, this type of smoking requires a fairly long time. The low smoking temperature will not be able to destroy as effectively the microorganisms contained in the fish. The main bacteriological hazards associated with cold-smoked fish are pathogenic bacteria capable of growing under refrigeration temperatures, such as *Listeria monocytogenes* and *Clostridium botulinum* (Diop et *al*., 2010). In addition, cold-smoked fish must be refrigerated and does not last much longer than fresh fish. This process cannot be recommended as a method of preserving fish or meat in tropical or subtropical regions, as it only partially reduces the risk of bacteriological contamination (Werlich, 2001). Regardless of the type of smoking practiced, the quality of smoked fish depends on the nature of the wood used, the temperature of combustion of the wood, the molecules that compose the smoke, as well as the processing time, relative humidity, and ventilation (Nicolle, 2017; Razanamanampy, 2018)

Hot smoking: is the process of smoking fish for an appropriate time and at a temperature sufficient to cause complete coagulation of the proteins in the fish flesh. The smoked fish is more or less cooked (60 -120 °C). Hot smoking is usually sufficient to kill parasites, destroy all non-spore forming bacterial pathogens and damage spores detrimental to human health (Abotchi, 2010; FAO, 2016; Codex alimentarius, 2018). Smoking is performed in conjunction with cooking. A gradual rise in temperature of the products is usually performed, which can reach 70-80°C at the end of the cycle. The texture of hot-smoked products is firmer than that of cold-smoked products (Pôle, 2010). This type of smoking is practiced in Benin and other tropical countries as well as in some European countries and the United States (Varlet, 2007; Abotchi, 2010; Salifou et *al*., 2020).

Smoking-drying: the product is smoked while hot, i.e. it is cooked, and then dried by continuing the smoking process; temperatures vary between 45 and 85°C. To do this, a slow-burning fire is first lit, using damp wood (at about 45°C). This produces a lot of smoke and forms a wet layer on the surface of the product, which accelerates the absorption of the smoke particles. The temperature is gradually increased (up to 85°C) by adding more and more oxygen. For fish, do not increase the temperature too quickly as the skin may tear and harden. Hardening can also occur when smoking meat. The product should then be cooked at about 85°C for a short period of time (2 to 4 hours). It must be taken into account that at these temperatures, the fat leaches out of the products and is lost. The fat content of the finished product will therefore be lower. After 2 to 4 hours at high temperatures, smoking is extended for a few hours at low temperatures

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(50°C) and the product continues to dry slowly. Lower the temperature of the smoke by letting in less oxygen. Smoke the products at this low temperature until they are well dried. A cheaper solution is to use all or part of the solar heat. The finished product, smoked and dried, should be distinctly brown, well dried and have a hard structure. A well-dried product can be stored for several months.

4.3.4. Smoking stages

Artisanal smoking is done in three stages: pre-smoking (low fire), smoking (high fire) and drying (fire-smoked in the sun). These smoked fish are highly nutritious and contain unsaturated fatty acids, fat-soluble vitamins, essential minerals as well as proteins containing essential amino acids useful for humans (Ozogul and Balikci, 2013). There are generally two crucial steps in fish smoking processes. These are cooking and smoking itself. These steps follow each other in the traditional fish smoking technology diagram.

- **Cooking :** It consists in firming up the flesh. The height of the flames is maintained at a level that prevents the product from burning. Then, the fire is increased so as to obtain a high fire (at least 85%) for one to two hours (Bleu, 2006). The fish can also be preserved for two or three days by cooking in salt water. In this case, it is necessary to reheat from time to time to avoid the proliferation of bacteria. The cooked fish can be separated from the bones and dried, then ground into flour or made into pellets (Brigitte, 2007).
- **Smoking :** Smoking consists of producing smoke. It is often necessary to turn the fish to obtain a homogeneous product. The fire must be moderate (60°C) to continue the drying process. This is the most important phase from a technological point of view. It can last up to two days, depending on how long the product is to be kept. The longer it lasts, the drier the product will be and the later the quality deterioration will be. However, a product that is too dry will be brittle and crumble easily (Djinou, 2001). Figure 4 presents the technological diagram of traditional fish smoking

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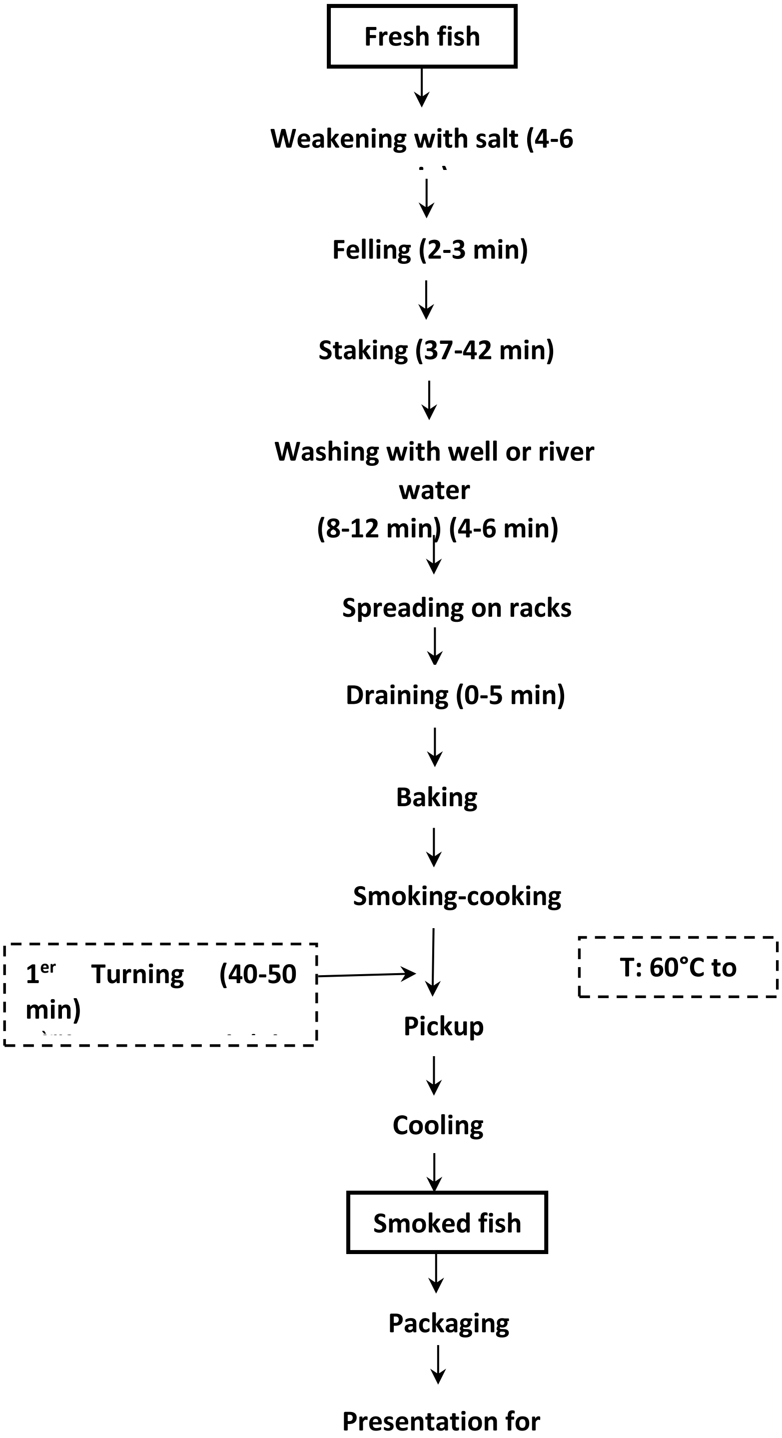

Figure 4. Fish smoking technology diagram (Depo *et al.*, 2019)

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4.3.5. Preservative effects of smoking

Smoking has two types of action that affect the hygienic, organoleptic and nutritional qualities of the smoked product.

- **Antioxidant action**

It results in delaying the oxidative degradation of lipids in the case of cold smoking. After a certain storage time, the oxidation of the lipids increases the faster the smoking temperature and the final humidity have been high, hence the shorter shelf life of the smoked products.

- **Bacteriostatic action**

The low-boiling phenolic fraction would have an inhibitory action by prolonging the latency phase of microorganisms. The high boiling phenolic fraction would act as an antioxidant. The bacterial action is however selective. Indeed, some salmonella survive and the smoke has no effect on staphylococci. Nevertheless, the effect is more marked on *Clostridium batulinum* (Momar, 2007). The smoking of fish consists therefore in impregnating the fish with the components of the smoke in order to give it a specific taste and smell (flavour) highly sought after, due to certain substances such as carnosine, anserine, creatine and carbonyl compounds (phenol). Smoke is obtained by burning wood in general (Bleu, 2006).

- **Toxic effects of smoke**

Smoke consists of more than 300 substances that are very important for the preservation of fish and meat. Some of them are carcinogenic, such as benzo-a-pyrene, phenol, formaldehyde, nitrosamine (Guissou and Ilboudo, 2013).

5. Microbiological profile of strains isolated from fish reared in Benin

Normally, fish flesh is sterile. The contaminated areas are the mucus covering the skin, the gills and the digestive tract. Bacterial contamination of the flesh occurs only after capture. The sources of this contamination are diverse and can be divided into two groups (Razanamanampy, 2018).

5.1. Endogenous or primary contamination

This contamination takes place during the life of the animal. It is done via breathing, feeding and during movement. The composition and quantity of this bacterial flora depends on the origin, water temperature, feeding etc. (Levoi, 2002). Some work has shown a predominance of Gram-negative bacteria in the initial flora of fishes from temperate waters while a high proportion of Gram-positive cockles and Bacillus spp. are found in some fishes from warm seas and tropical waters (Gram and Dalgaard, 2002; Degnon et *al*., 2013). Bacteria of endogenous origin can be subdivided into 3 classes:

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Typically aquatic germs

They generally belong to the genera *Pseudomonas*, *Vibrio*, *Flavobacterium*, *Acinetobacterium*, *Micrococcus*, *Corybacterium*, *Aeromonas*, *Morexella*, (Levoi, 2002).

- **Germs of terrestrial origin**

These are spore-forming bacteria, in particular the genera *Clostridium* and *Bacillus*. Their dissemination in aquatic environments is ensured by runoff and rainwater.

- **Germs of human or animal origin**

These germs come from the digestive tract of humans and animals. They are found in aquatic environments through pollution by poorly or untreated wastewater.

5.2. Exogenous or secondary contamination

After capture, the fish is subject to numerous manipulations that are at the origin of bacterial contamination. Generally, it is a contamination by personnel, equipment and the environment. Humans are the most important source of exogenous contamination of food of animal origin (Abotchi, 2010). The germs brought by this secondary contamination are *salmonella*, *thermotolerant coliforms*, presumptive pathogenic *Staphylococcus*, *sulfite-reducing anaerobic* bacteria, yeasts and molds, *total aerobic mesophilic flora* (Razanamanampy, 2018). Table 3 presents some of the microbial loads found in smoked fish according to various smoking systems in West Africa.

Table 3. Microbial load found in traditional smoked fish according to various smoking systems in West Africa.

Microorganisms	**Traditional smoked fish**
Flore Aérobie Mésophile Totale	$0.89.10^7$ - $4.50.10^6$ CFU/g (Abdoullahi, 2019)
Coliformes totaux	$1,5.10^2$ CFU /g (Degnon *et al.*, 2013)
Levures	$3.17.10^3$-$9.26.10^3$ CFU/g (Farougou *et al.*, 2011)
Staphylococcus aureus	$2.6.10^2$ CFU /g (Degnon *et al.*, 2013)
Salmonella sp.	Presence in 66.7% of fish analyzed (Gamané *et al.*, 2018)
Moisissures	$2.22.10^2$-$8.27.10^2$ CFU /g (Farougou *et al.*, 2011)

CFU/g: Colony Forming Unit per gram

- **Indicator germs of the microbiological quality of smoked fish**

The main indicator germs of the quality of smoked fish are Total Aerobic Mesophilic Flora (TAMF), Total Coliforms, Yeast and Mold, *Staphylococcus aureus*, *Listeria monocytogenes*, *Escherichia coli*, *Salmonella* sp, (Degnon *et al*., 2013).

6. Use of antibiotics in the control of microorganisms

Most microorganisms isolated from food products such as fruits, vegetables, meats and fish, are resistant to certain groups of antibiotics (Moussé, 2016; Ahouandjinou, 2016; Abdoullahi, 2019). Recent research on fresh and smoked fish has revealed the presence of a number of pathogenic microorganisms (Farougou et *al*., 2011; Degnon et *al*., 2013; Moussé, 2016; Ahouandjinou, 2016; Gamané et *al*., 2018; Abdoullahi, 2019). These have been subjected to antibiotics and have shown notable resistance. The mechanisms by which bacteria resist antibiotics have been highlighted by several authors (Sina, 2012; Moussé, 2016; Ahouandjinou, 2016). Thus, research work conducted by Moussé (2016), revealed Imipenem as the best antibiotic against infections due to isolated germs (*E. coli*, *K. pneumoniae* and *Pseudomonas spp*.) from street foods, vegetable products and irrigation water. According to Ahouandjinou (2016), *S. aureus* strains isolated from beef, were 90% resistant to oxacillin, cefoxitin and penicillin G. Also, it showed that the coagulase-negative strains isolated were highly resistant to oxytetracycline (73.6%) and penicillin G (64.6%). Most E. coli strains are penicillinase producers (97.12%) and are resistant to several families of antibiotics. They have several genes of resistance to ß-lactam and are able to secrete verotoxins which confer resistance properties.

It is therefore intended to study the groups of antibiotics on which this work has been carried out and to try other groups of antibiotics to see their effects on microorganisms isolated from fish reared in wherries, especially bacteria which constitute a serious threat to public health.

6.1. Classification of antibiotics

An antibiotic is defined as any chemical compound, elaborated by a living organism or synthetic product, with a high chemotherapeutic coefficient whose therapeutic activity is manifested at very low doses in a specific way, by the inhibition of certain vital processes, towards viruses, microorganisms or even some multi-cellular beings (Sina, 2012). Antibiotics can be synthetic products, but most of them are produced naturally by microorganisms to regulate their growth, or when subjected to particular conditions. The bacteriostatic or bactericidal properties of antibiotics come from their ability to block a step in a mechanism that is essential to the multiplication or survival of bacteria (Ahouandjinou, 2016). To do this, they aim at a specific target of the bacterial cell, thus presenting a selective toxicity that at the doses used, they affect only certain bacteria and not the infected host. The classification of antibiotics is often made on the basis of their natural or synthetic origin, their chemical nature, their mechanism of action on the bacteria, modality (bactericidal or

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bacteriostatic) and spectrum of action. The main mechanisms of action that can be encountered differ according to the molecule considered. Each antibiotic family has its own site of action (Sina, 2012; Moussé, 2016).

6.1.1. Antibiotics acting on the membrane

They may act on the outer wall membrane of Gram (-) bacteria or the cytoplasmic membrane of Gram (+) bacteria. Others act on the integrity of the bacterial plasma membrane, which allows it to retain the elements necessary for its survival in the cytoplasm, and to maintain a chemo-osmotic gradient (Opatowski, 2020). It has a positive charge and acts as surfactants. Some antibiotics bind to bacterial membranes, particularly the outer membrane of bacteria, and disrupt them by combining with, in particular, the phospholipids that constitute them (Ahouandjinou, 2016). These are Polymycins (Colistin) and Nitrofurans (nifurzide, nifuroxazide).

6.1.2. Antibiotics acting on peptidoglycan synthesis

According to Nauciel and Vildé (2005), peptidoglycan is a cross-linked polymer made of polysaccharide chains linked by peptides. This molecule exists only in bacteria and ensures the rigidity of the wall. When bacteria are in growth phase, there are simultaneously phenomena of synthesis and destruction of peptidoglycan. The balance between these two phenomena is disrupted by antibiotics that inhibit the synthesis of peptidoglycan by blocking the final phase of polymerization. The result is an alteration of the wall with a lethal effect for the bacteria. These families of antibiotics have: The β lactams, glycopeptides and fosfomycins. In this family, all molecules have in common the beta-lactam cycle.
This family includes :

- Penicillins (Penicilin G, M, A, Carboxy-penicillin, Ureido-penicillin, Amidino-penicillin and sulfone penicillins). They act on peptidoglycan synthesis by inhibiting penicillin-binding proteins (PLPs). PLPs have transpeptidase, carboxypeptidase and transglycolase activity. Inhibition of PLPs results in inhibition of the formation of pentacyclic bridges responsible for the cross-linked structure of the wall. This results in bizaroid forms (round or filamentous) which lead to bacterial lysis.
- Cephalosporins 1st generation: Cefalotin and Cefadroxil, 2nd generation: Cefoxitin, Cefuroxime, 3rd generation: Ceftazidim, Cefotaxime, Ceftriaxone, Cefixime).
- Glycopeptides: Vancomycin and Teicoplanin are bactericidal and act only on Gram-positive cocci bacteria by blocking the polymerization of peptidoglycan by a complex mechanism (Rabaud and May, 2007) and finally Fosfomycin. Fosfomycin is bactericidal

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and acts by inhibiting the synthesis of peptidoglycan precursors. It is active on *Streptococcus pneumoniae, Staphylococcus sp*. (Cattoir, 2006).

6.1.3. Antibiotics inhibiting protein synthesis

They act on the synthesis of proteins, essential to the survival of the cell. The antibiotic penetrates the cell, and blocks the bacterial ribosome, a structure in the cytoplasm necessary for protein synthesis (Poyart, 2006; Moussé, 2016). Several families of antibiotics can inhibit, by different mechanisms, the elongation of the polypeptide chain in bacteria. Among these, we have :

- Aminosides (Sisomycin), Streptomycin, Gentamicin, Kanamycin, Netilmicin, Anikacin and Tobramycin ;
- Tetracyclines (Chloranphenicol and Thiamphenicol) ;
- Macrolides (Erythromycin, Azithromycin), Lincosamides (lincomycin, clindamycin), Streptogramines and Oxazolidones (Leclercq, 2006; Ahouandjinou, 2016; Opatowski, 2020).

6.1.4. Antibiotics acting on nucleic acids

This group includes Sulfonamides and Trimethoprim often used in combination (cotrimoxazole) inhibiting folate synthesis and in addition it interacts with dihydrofolate reductase to inhibit tetrahydrofolic acid synthesis (Adam and Drouillard, 2003). Quinolones interfere with the topological state of bacterial DNA by inhibiting topoisomerases or DNA-gyrase, enzymes involved in DNA conformation (nalidixic acid, ofloxacin, ciprofloxacin, pefloxacin). Like nalidixic acid, they inhibit DNA synthesis by blocking the activity of the alpha subunit of DNA gyrase.

To these two, we must add the Nitro-imidazoles, whose activity involves a reduction in vivo of their nitro group (-NO2). They bind to the DNA at the level of the adenine and thymine-rich regions, causing strand breaks and uncoiling of the DNA, and the Rifamycins, which inhibit RNA polymerase, stopping the synthesis of messenger RNA at the initiation stage (Opatowski, 2020).

6.2. Mechanisms of resistance of bacteria to antibiotics

Antibiotics, in the presence of bacteria exert a selection pressure that favors the selection of mutants with the ability to survive in the presence of the antibiotic in question (Sina, 2012; Moussé, 2016). One of the main characteristics of an antibiotic is its spectrum of activity. Indeed, since the successive introduction in therapeutics of different antibiotics, the sensitivity of bacteria to these drugs has evolved a lot, so that the percentage of resistant strains in different pathogenic species is currently significant.

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Besides natural resistance, which is a characteristic of all strains of a bacterial species, there is an acquired resistance of strains within the theoretically sensitive species. It is due to genetic modification: mutation or contribution of foreign genetic material (plasmids - transposons).Three main mechanisms are responsible for antibiotic resistance (Sina, 2012; Moussé, 2016; Opatowski, 2020). These mechanisms are:

- Modification of the antibiotic target;
- Synthesis of antibiotic-inactivating enzymes;
- Decreased bacterial permeability to antibiotics.

A bacterial species can be resistant to multiple antibiotics by different mechanisms (Moussé, 2016; Opatowski, 2020).

6.2.1. Modification of the target of antibiotics

This resistance mechanism is described for almost all antibiotics but more importantly for penicillins, glycopeptides and MLS for Gram-positive and for quinolones whatever the Gram. When the target of the antibiotic is modified or replaced, the antibacterial agent loses its affinity for it and can no longer exert its activity on the bacteria. The modification can occur through the acquisition of new genetic material encoding an enzyme that alters the target or through a mutation within the nucleotide sequence of the target (Mangin, 2016; Opatowski, 2020).

6.2.2. Synthesis of antibiotic-inactivating enzymes

This is one of the most widespread and effective mechanisms for bacteria, which consists of secreting an enzyme capable of inactivating the antibiotic even before it has penetrated the bacteria. It is well elucidated by the enzymatic hydrolysis of the betalactam ring supporting the activity of betalactams (Mangin, 2016). In Gram (-) bacteria, the enzyme once produced remains in the periplasmic space. It then protects only the bacterium that synthesizes it. In Gram (+) bacteria, the enzyme produced spreads all around the bacterium. It can then protect bacteria that do not produce it. Some examples of enzymes and their specific targets are :

- acetyltransferases, adenyltransferases, phosphotransferases which hydrolise aminosides
- nucleotidyltransferases active on lincosamines.

6.2.3. Decreased bacterial permeability to antibiotics

This mode of resistance is found in Gram-negative bacteria because of their more complex outer envelope. Indeed, the antibiotic can only penetrate intracellularly through transmembrane protein channels, the porins. This passive phenomenon allows small, neutral and hydrophilic molecules to pass through more easily. Any modification of these porins (mutation of the coding genes, loss, decrease in their size or expression) confers a low level of resistance to many antibiotics. This resistance mechanism can apply to several families of antibiotics when they use the same porin or be specific when the channel is specific to a family; the acquired resistance of *P. aeruginosa* for imipenem by loss of the carbapenem porin (OprD) is an example (Jehl et *al*., 2012; Mangin, 2016; Moussé, 2016).

This mechanism alone is not very efficient as in most cases increasing the antibiotic concentration is sufficient to cope with it, so it is often combined with two mechanisms (active efflux, β-lactamase production) (Fosseprez, 2013).

- Alteration of membrane proteins

These are porins that become refractory to the passage of the antibiotic across the membrane. This mechanism can affect antibiotics such as betalactams, quinolones, chloramphenicol, tetracyclines, trimethoprim, sulfonamides, and polymixins. The typical example of this mechanism is given by the gonococcus with respect to penicillin G.

- Active efflux of the antibiotic

This is a new mechanism found in certain bacteria capable of actively transporting the antibiotic from inside to outside the cell. Bacteria are equipped with systems that allow them to expel foreign metabolites or toxic compounds such as antibiotics into the outside environment. This active efflux requires energy in the form of ATP (Adenosine Tri Phosphate) or a transmembrane electrochemical gradient, used by efflux pumps or active transporters that reduce the intracellular concentration of the antibiotic limiting access to its target (Mangin, 2016; Opatowski, 2020). This mechanism may involve tetracyclines, lincosamines, quinolones, and erythromycin.

Conclusion

Benin has assets, albeit modest, for an integrated development of the fisheries and aquaculture sector. Among these assets are the fish holes called whedos exploited by fishermen at the time of flooding. The fish holes of the Ouémé valley, although they are ancestral practices, are very productive. The difference in productivity between this traditional fish production technique and improved pond production techniques is mainly related to the management method. The fish most commonly raised in these wherries are *Clarias gariepinus* and *Oreochromis niloticus*, among others. These fish are an excellent source of protein and minerals for their consumers. After capture, the conservation of these fish is difficult due to the highly perishable nature of this product and the lack of adequate conservation facilities. Smoking is the most used conservation process for generations to

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remedy this problem that undermines the sector. The non-observance of good hygiene and manufacturing practices at the smoking sites leads to microbial contamination of the finished product after smoking, which causes diseases such as food poisoning manifested by diarrhea, headaches, nausea, fever and others. These index microorganisms are resistant to certain antibiotics by several mechanisms including enzymatic inhibition, reduction of cell permeability, alteration of the binding sites targeted by the antibiotic and production of efflux pumps. This information proves that the health of fish consumers is threatened, will play a great role in the improvement of public health and will allow the best development of the fishing and aquaculture sector in Benin.

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References:

1. Abdoullahi, H. O. (2019). Caractéristiques microbiologiques et procedés de transformation des poissons fumés et sechés du Tchad : cas des espèces Clarias spp (Silure) et Oreochromis Niloticus (Tilapia). Thèse unique de doctorat en Microbiologie et Technologie Alimentaire à l'Université Joseph KI-ZERBO, 1-220p.
2. Abdullahi, S.A., Abolude, D.S. & Andega, R.A. (2001). Nutrient quality of four oven dried fresh water catfish in northern nigeria. j. trop. biosci., vol. 1(1), 70-76p. DOI: 10.12691/ajmr-6-5-1
3. Abert, T. N. (2018). Contribution à la promotion de la pisciculture intégrée de tilapia du Nil (Oreochromis niloticus, Linnaeus, 1758) par la valorisation des sous-produits agro-industriels et l'utilisation rationnelle des fertilisants animaux en République Démocratique du Congo. Doctorat en Sciences Animales, Université LAVAL Canada, 205p.
4. Abotchi, K. (2010). Evaluation de la qualité microbiologique des poissons fumés artisanalement au Togo. Mémoire de Master en qualité des aliments de l'homme à l'école interétats des sciences et médecine vétérinaires (EISMV) de Dakar (Sénégal), 42p

5. Adam, F. & Drouillard, I. (2003). Sulfamides et associations. Encycl Méd Chir, Maladies infectieuses, 8-004-A-10, 9p.
6. Ahouandjinou, S. H. S. (2016). Qualite microbiologique, antibioresistance des souches de staphylococcus spp. et d'escherichia coli isolees des carcasses bovines au benin. Thèse unique en science de la vie : microbiologie et biologie moléculaire à la faculté des sciences et techniques de l'Université d'Abomey-Calavi ; 65-68p.
7. Akande, G. & Diei-Ouadi, Y. (2010). Post-harvest losses in small-scale fisheries. FAO fisheries and aquaculture technical paper, pages 1-89.
8. Amiengheme, P. (2005). The importance of fish in human nutrition. A paper delivered at a fish culture forum. Federal department of fish farmers, Abuja, 21p.
9. Bleu, B. G. (2006). Contribution à l'étude de l'évolution de la qualité microbiologique du poisson fumé en Côte d'Ivoire et destine à l'exportation. Docteur en médecine vétérinaire, Université Cheik Anta Diop de Dakar, École Inter-états des sciences et médecine vétérinaires. 137p.
10. Bourgeois, C. (2003). Les Vitamines dans les industries agroalimentaires. (collection sciences et technique agroalimentaires). Ed. Tec & doc Lavoisier, 153 p.
11. Brigitte, M. B., Brigiet, V. B. & Carolien, H. (2007). La conservation du poisson et de la viande. marja de goffau – markusse, 2eédition, 47 p.
12. Cattoir, V. (2006). Chloramphénicol, fosfomycine, acide fusidique et Polymixines 2ième édition, 349-364p.
13. Codex alimentarius (2018). Norme pour le poisson fumé, le poisson aromatisé à la fumée et le poisson fumé séché. FAO/OMS. 10 p
14. Collet, S. (2000). Facteurs d'émission. emissions de dioxines, de furanes et d'autres polluants liées à la combustion du bois naturel et adjuvanté ; rapport ineris, ineris-drc n°00/60-mapa-sco-25420, 68 p.
15. Conférence Africaine des Organisations Professionelles de la Peche Artisanale (CAOPA). (2015). Paidoyer pour une année africaine de la peche artisanale, 10 p.
16. Degnon, R.G., Agossou, V.E., Adjou, E.S., Dahouenon-Ahoussi, E., Soumanou, M. M. & Sohounhloue D. C. (2013). Évaluation de la qualité microbiologique du chinchard (Trachurus trachurus) au cours du processus de fumage traditionnel. Journal of Applied Biosciences, 67, 5210-5218p. DOI:10.4314/jab.v67i0.95042
17. Degnon, R. G., Faton, A-N, Adjou, E. S., Tchobo, F. P., Dahouenon-Ahoussi, E., Soumanou, M. M. & Sohounhloue, D. C.K. (2014). Efficacité comparée des huiles essentielles de deux plantes

aromatiques dans la conservation post-fumage du Chinchard (Trachurus trachurus). Journal of Animal et Plant Sciences, Vol.19, Issue 1: 2831-2839p

18. Depo, A., Dossou, J. & Anihouvi, V. (2019). Itinéraire technique et évaluation de la qualité du poisson-chat, Clarias gariepinus (Siluriformes, Clariidae) fumé et commercialisé au Bénin. Science de la vie, de la terre et agronomie ; rev. ramres - vol.07, ISSN 2424-7235; 32p
19. Diop, M.B. Destain, J., Tine, E. & Thonart, P. (2010). Les produits de la mer au Sénégal et le potentiel des bactéries lactiques et des bactériocines pour la conservation. Biotechnol. Agron. Soc. Environ., 14 (2), 341-350p.
20. Djinou, H. P. A. B. (2001). Etude de la qualité microbiologique du poisson fumé artisanalement en côte d'ivoire et destiné à l'exportation. thèse : méd. vét : Dakar, 96p.
21. Elegbe, H. A., Toko, I. I., Agbohessi, P., Ble, C., Banag, A., Chikou, A., Tomedi, E. M. & Laleye, P. (2015). Co-culture Clarias gariepinus-Oreochromis niloticus : quels avantages pour l'amélioration des performances zootechniques et économiques des poissons élevés dans les « whedos » du delta de l'Ouémé au Bénin. Int. J. Biol. Chem. Sci. 9(4), 1937-1949p. DOI : 10.4314/ijbcs.v9i4.19
22. Farougou, S., Hounkpe, E., Sessou, P., Yehouenou, B. & Sohounhloue, D. (2011). Evaluation de la qualité microbiologique du poisson Trachurus trachurus fumé et vendu dans les marchés de la commune d'Abomey-Calavi. Conférence: Actes du 3ème colloque des Sciences, Cultures et Technologies de l'UAC-Bénin. At ; University of Abomey-Calavi.337-348p
23. FAO (2008). Vue générale du secteur des pêches national de la république du Tchad, profils des pêches et de l'aquaculture par pays. 18 p.
24. FAO. (2012). La situation mondiale de pêche et de l'aquaculture, première partie, organisation des nations unies pour l'alimentation et l'agriculture, département des pêches et de l'aquaculture de la FAO, Rome 229 p.
25. FAO. (2014). La situation mondiale de pêche et de l'aquaculture, première partie, organisation des nations unies pour l'alimentation et l'agriculture, département des pêches et de l'aquaculture de la FAO, Rome. 229p
26. FAO (2016). La situation mondiale des pêches et de l'aquaculture 2016. Contribuer à la sécurité alimentaire et à la nutrition de tous. Rome. 224 p.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

27. FAO (2018) (Food and Agriculture Organization of the United Nations) (2018). World Aquaculture Performance Indicators (WAPI)-Fish Consumption Module (WAPI-FISHCSP v.2018.1). In: FAO Fisheries and Aquaculture Department [online]. Rome, Italy ; 112p.
28. FAO (2022). FAOSTAT Database. Food and Agriculture Organization, Roma, Italy. Available online at URL: www.fao.org.
29. Fosseprez, P. (2013). Antibiothérapie en pratique de ville : Constat et réflexions sur le rôle du pharmacien d'officine dans la lutte contre l'antibiorésistance. [Nancy]: Faculté de Pharmacie ; 124p.
30. Gamané, K. A., Tidjani, A. & Micha, J.C. (2018). Qualité hygiénique du poisson transformé et commercialisé au Tchad. 9p.
31. Gamané, K. A. (2017). Evaluation physique des pertes post capture des produits de la pêche avec les communautés de mitteriné lac Tchad, institut avd-Tchad, mémoire pour la licence professionnelle en gestion de l'environnement, 63p.
32. Guissou, R. & Ilboudo, F. (2013). Analyse des incitations et pénalisations pour l'huile de coton au Burkina Faso. Monitoring africain food and agricultural policies- suivi des politiques agricoles et alimentation en Afrique, 1-37p.
33. Gram, L. & Dalgaard, P. (2002). Problèmes et solutions des bactéries d'altération du poisson. Opinion actuelle en biotechnologie, 13, 262-266p.
34. Hambrey, J. (2017). The 2030 Agenda and the sustainable development: the challenge for aquaculture development and management. Circulaire de la FAO sur les pêches et l'aquaculture (1141), Rome, FAO 49p.
35. Hoag, H. (2017). Nations agree to ban fishing in Arctic Ocean for at least 16 years. Science [en ligne]. Le 1er décembre, 89p.
36. Houenou, S. D. M. M. V. (2019). Métazoaires parasites de Clarias gariepinus et Oreochromis niloticus, poissons des whédos du haut delta de l'Ouémé au Bénin. Thèse unique en Parasitologie dans le Faculté des Sciences Techniques sur le Campus d'Abomey-Calavi au Bénin, 36p.
37. Ida, P. A. & Nwankwo, I. (2013). Effects of smokedrying temperatures and time on physical and nutritional quality parameters of Tilapia (Oreochromis niloticus). International Journal of Fisheries and Aquaculture, Vol. 5(3), Pages 29-34. DOI: 10.5897/IJFA12.078,
38. INRAB (2012). La pêche artisanale au sud bénin face aux défis des changements climatiques. Pages 1-21.
39. Jean-pierre, S. (2012). La combustion du bois et ses impacts sur la qualité de l'air. Air Pur,(8), 1 -16p.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

40. Jehl, F., Chomarat, M., Tankovic, J., Gérard, A., Schrenzel, J. & Gutmann, L. (2012). De l'antibiogramme à la prescription. Marcy-l'Étoile: BioMérieux; 122p.
41. Kalikoski, D. C., Jentoft, S., Charles, A., Salazar Herrera, D., Cook, K., Béné, C. & Allison, E. H. (2018). Understanding the impacts of climate change for fisheries and aquaculture: applying a poverty lens. Dans M. Barange, T. Bahri, M. Beveridge, K. Cochrane, S. Funge-Smith.15p.
42. Keita, D. (2005). Contribution à l'étude de la qualité des poissons transformés (Fumés, Séchés) A Bamako, Mopti, Niono et Sélingué, Diplôme D'Etat, Mémoire pour obtenir le grade de docteur en Pharmacie, Université de Bamako, Faculté de Médecine de Pharmacie et d'Odonto-Stomatologie, 139 p.
43. Kolding, J., van Zwieten, P., Marttin, F. & Poulain, F. (2016). La pêche dans les zones arides d'afrique subsaharienne. «Le poisson vient avec la pluie». Favoriser la résilience dans les zones arides pour la sécurité alimentaire et la nutrition des populations qui dépendent de la pêche. Circulaire de la FAO sur les pêches et l'aquaculture n° 1118. Rome, FAO, 147p.
44. Kpadonou, R.A.B., Adégbola, P.Y. & Tovignan, S.D. (2012). Local knowledge and adaptation to climate change in ouémé valley, benin. African Crop Science Journal, Vol. 20, 181-192p.
45. Kpogue, D. N. S., Mensah, G. A. & Fiogbe, E. D. (2012). A review of biology, ecology and prospect for aquaculture of Parachanna obscura. Rev Fish Biol Fisheries, 1-12p. DOI 10.1007/s11160-012-9281-7.
46. Kurien, J. & López Ríos, J. (2013). Flavouring fish into food security. SF-FAO/2013/14. Ebene (Maurice), FAO-Smart Fish Programme de la Commission de l'océan Indien, 60 p.
47. Leclercq, R. (2006). Macrolides- lincosamides-streptogramines. 2ième édition ; 299-324p.
48. Levoi, F. (2002). La microbiologie du saumon fumé à froid: aspects hygiéniques et qualité. Revue générale du froid (1028): 35 – 40p.
49. Mangin, L. (2016). Antibiotiques et résistances : enquête sur les connaissances et les comportements du grand public. Thèse unique en Faculté de pharmacie de l'Université de Lorraine ; 21-27p.
50. Martin, C. L., William, K., Mangani, K. & Placid, M. (2018). Microbiological quality of traditional and improved kiln smoked catfish (Clarias Gariepinus; Pisces; Clariidae) In Lake Chilwa Basin, The Authors. Food Science & Nutrition Published By Wiley Periodicals, Inc. J. Food Sci Nutr,4 (7), 281–286p.
51. Momar, Y. D. (2007). Seminaire de formation en groupe sur les techniques améliorées de traitement de conservation et de

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

transformation du poisson et des produits halieutiques, Kayar du 1er au 02 Février 2007, Saint Louis du 05 Au 06 Février 2007,16p.
52. Mousse A. W. (2016). Profil toxinogénique et production de BLSE des souches de Escherichia coli , Klebsiella pneumoniae et Pseudomonas spp. fluorescents isolées des aliments de rue et des produits maraîchers au Sud du Bénin. Thèse unique de doctorat en Biochimie, Microbiologie et Biologie Moléculaire dans la faculté des sciences et techniques à l'université d'Abomey-Calavi, 28-37p.
53. Nauciel, C. & Vildé, J-L (2005). Bactériologie médicale 2ième édition. Ed : Masson, Pages 1-272.
54. Ndrianaivo, E. N., Cornet, J., Cardinal, M., Razanamparany, L. & Berge, J-P. (2016). Stockage des poissons fumés et ou séchés : cas de Oreochromis niloticus " Fiha saly " Malgache. Afrique Science 12(2) 254 – 265p.
55. Nicolle, J. (2017). Technologie de fumage. Application au Saumon. Nattes : institut scientifique et technique des pêches maritimes (ISTPM).
56. Nyebe, I. G., Meutchieye, F. & Fon, D. (2014). Expériences de la fumaison et de la commercialisation du poisson dans l'environnement urbain de Douala qualifie l'activité de hautement rentable. Agriculture familiale et lutte contre la pauvreté 30 (3): 25–26p.
57. Ogbannaga, C. (2009). Influences of drying methods on nutritional properties of tilapia fish (Oreochromis Nilotieus), World. J. Agri. Sci, 3 (5), 256-258p.
58. Oladipo, I. C. & Bankole, S. O. (2013). Nutritional and microbial quality of fish and dried, Clarias Gariepinus and Orachrumis Niloticus. International Journal Applied. Microbiology and Biotechnology, (3), 1-6p.
59. Olsen, R. L., Toppe, J. & Karunasagar, I. (2014). Challenges and realistic opportunities in the use of by products from processing of fish and shellfish. Trends in Food Science et Technology, 36 (2), 144 – 151p. DOI:10.1016/j.tifs.2014.01.007
60. Opatowski, M. (2020). Résistance bactérienne aux antibiotiques, apport su système national des données de santé. Thèse unique en santé publique : santé publique- épidémiologie de l'université Paris-saclay ; 16-20p.
61. Pôle, A. (2010). Le fumage du poisson, Procédé de transformation et conservation, Technologie. 12 p.
62. Poyart, C. (2006). Tétracyclines. 2ième édition ; 325-334p.
63. Projet de développement de la pêche (PRODEPECHE). (2009). Étude sur l'état des lieux de la zone d'intervention et étude du rapport efficacité / coût des fours améliorés, des claies de séchage et des

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

conteneurs isothermes disponibles dans la région ainsi que la qualité des produits livrés par ces matériels et leur commercialisation, Commission Economique du Bétail, de la Viande et des Ressources Halieutiques (CEBEVIRHA- CEMAC), rapport final, 122p.
64. Programme pour le Développement Intégré des Pêches artisanales en Afrique de l'Ouest (DIPA). (2016). Revue sectorielle de la pêche artisanale au Bénin. Pages 1-76.
65. Rabaud, C. & May, T. (2007). Glycopeptides. Encycl méd chir, maladies infectieuses, 8-004-J-20, 7p.
66. Razanamanampy, T. S. (2018). Qualités nutritionnelle et hygiénique du thon fumé prêt à la consommation dans la ville d'Antananarivo. Mémoire de Master, Faculté des Sciences, Université d'Antananarivo. 99 p.
67. Rivier, M., Kebe, F. & Goli, T. (2009). Fumage de poissons en Afrique de l'Ouest pour les marchés locaux et d'exportation. Rapport intermédiaire, 19p.
68. Rogaume, Y. (2009). La Combustion du bois et de la biomasse, pollution atmosphérique, numéro spécial/le bois énergie : enjeux écologiques et de santé environnementale, 66-81p.
69. Salifou, C.F.A., Ahounou, S.G., Kiki, P.S., Hogbonouto, E.B., Gade, K.A.I. & Youssao, A.K.I. (2020). Caractérisation des techniques de fumage des poissons au sud-Bénin. J. Interdiscip. la Rech. Sci., 1 (2), 41-47p.
70. Shiv, M. S., Siddhnath, R. B., Abdul, Aziz, S.P., Bhagchand, C. & Narinder, K. (2018). Insect infestation in dried, fishes, Journal of Entomology and Zoology Studie, 6 (2), 2720-2725p.
71. Sina, H. (2012). Antibiorésistance et variabilité de la production des facteurs de virulence produits par les souches de Staphylococcus aureus d'origines clinique et alimentaire. Thèse unique en science de la vie : biochimie, biologie moléculaire et Microbiologie à la faculté des sciences et techniques de l'Université d'Abomey-Calavi ; 39-41p.
72. Singleton, R. L., Allison, E. H., Le Billon, P. & Sumaila, U. R. (2017). Conservation and the right to fish: international conservation NGOs and the implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries. Marine Policy, (84), 22-32p.
73. Toko, I. I., Attakpa, E. Y., Baco, M. N. & Gouda, A-I. (2011). Analyse des systèmes piscicoles dans la Vallée du Niger (Nord Bénin). Int. J. Biol. Chem. Sci. 5(5) pages: 1993-2003p.
74. Toko, I. I. (2007). Amélioration de la production halieutique des trous traditionnels à poissons (whedos) du delta de l'Ouémé (sud Bénin) par la promotion de l'élevage des poissons chats Clarias gariepinus et

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Heterobranchus longifilis. Thèse unique en Faculté Universitaires Notre -Dame de la Paix dans le Département de Biologie. 1-129p.
75. Tossougbo, H. D. C. (2017). Système technique de production, caractérisation microbiologique et physico-chimique des poissons fumés commercialisés au carrefour de Djèffa dans la commune de Sèmè-Podji. Mémoire de master en en normes et contrôle de qualite des produits agroalimentaires à la faculté des sciences agronomiques dans l'université d'Abomey-Calavi, 1-87p.
76. Varlet, V., Prost, C., Sérot, T. (2007). Volatile aldehydes in smoked fish: Analysis methods, occurrence and mechanisms of formation. Food Chemistry, Analytical, Nutritional and Clinical Methods, 105:1536-1556p.
77. Werlich, M. (2001). Fumage du poisson et fours de fumage. Infogate, GTZ. 17 p.
78. World Fish Centre. (2005). Le Poisson et la sécurité alimentaire en afrique. egypte. 2p.
79. Yvette, D.O., Boris, K. S., Frieda, A. O., Ycouba, O., Kissem, B. & Illia, R. (2016). Renforcement de la performance des systèmes post-capture et du commerce régional en pêche artisanale: cas de la réduction des pertes post-capture des pays riverains du bassin de la volta, pays impliqués: Bénin, Burkina-Faso, Côte d'Ivoire, Ghana, Mali, Togo, FAO, Circulaire sur les pêches et l'aquaculture n° 1105, 1-80p.