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(REVIEW ARTICLE)

Improvement of smoked and fermented dried fish processing and application of essential oils as their natural preservatives.

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Abstract

A key factor limiting fish utilization is its extreme perishability due, especially, to microbial and autolytic spoilage during processing and storage. Thus, various traditional techniques are used to limit post-capture losses, in particular in West Africa where techniques such as drying, salting, smoking and fermentation are used individually or in combination for the conservation of fresh fish. Unfortunately, these techniques have long been handcrafted and influence the quality and shelf life of manufactured products. In other hand, recently the disappearance of many active synthetic substances in foods protection has resulted to a renewed interest in naturally occurring substances. In parallel to these disappearances, the regulatory environment incites strongly to increase the use of alternative methods to chemical control. In this review, we have summarized the innovations suggested in the literature for the improvement of fish processing techniques in order to ensure the manufactured product quality. Results show that several innovations have been proposed. This mainly concerns the invention of smoking and drying devices, the development of starters and the use of essential oils for fish preservation.

Keywords: Improvement; Fish processing; Essential oils; Preservation

1. Introduction

Hunger and malnutrition remain the major problems of our societies, in particular, populations in developing countries where the concept of food security remains a luxury. To contribute to the fight against food insecurity, we should increase agricultural production and promote the valorization local products through the judicious use of technical knowledge [1].

The agricultural sector has capital importance for the strengthening of the Beninese economy because it contributes 32.5% on average to the GDP, 75% to the export receipts, 15% to the receipts of the State and provides about 70 % jobs. It is therefore considered to be the sector whose much potential must be judiciously exploited to support national economic growth and thus contribute to the effective fight against poverty [2]. Amon agricultural products are prominently products such as fish, milk and their respective derivatives.

Fish and fish products play a significant role in the diet of West African populations [3]. Fish is a foodstuff of high nutritional value but very perishable. It is also a valuable supplement in diets poor in proteins, vitamins and essential

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mineral salts. In Benin, fishing occupies a relatively important place in the national socio-economic balance because it supports around 500,000 people and contributes 3% to the GDP [4]. However, the conservation of fish, particularly in hot countries, is difficult due to the lack of adequate conservation infrastructure and due to the climatic and environmental conditions which contribute to its degradation in a few hours [5]. In Benin, and like other countries in the western sub-region, post-harvest losses are estimated at around 20% [5]. To limit these losses, smoking is one of the main methods of preserving fish and is still done in the traditional way [6]. For a few years, the safety of fish has been a public health problem, since pathogenic germs and / or chemical contaminants present in smoked fish have posed serious threats to the health of consumers [7]. Other concerns may arise from contamination of this commodity by molds, anaerobic sulfo-reducers and Staphylococci which, under certain conditions, can secrete toxins with hepatotoxic power [8,9].

Chemical preservatives such as benzoates, sulphites, a-tocopherol, calcium chloride and citric acid were usually used for food preservation in general and especially drinks [6]. However, at short or long-term, these synthetic chemical products could be very toxic, with risks of mutagenicity, chromosomal aberrations and cancer [10, 11]. Due to the resurgence of the harmful effects of these chemical substances on the human health, the use of essential oils generally recognized as safe (GRAS) as bioconservatives agents of Fish and fish products could be a credible alternative. Indeed, essential oils possess antimicrobial activities and are without major effects on the environment and human health [12]. This article aims primarily to summarizing the research results on improvement of fish processing and application of plant extracts as essential oils for their conservation.

2. Brief evidence on fish processing

Fish processing definition may include various procedures like sorting, grading, gutting, deskinning, filleting, fermentation, drying and trimming. Furthermore, other processing procedures such as thermal processing (cooking, smoking etc.) can be applied to make product edible, to increase the price of the product on the market or to protect product against different spoilage and pathogen microorganisms [13]. In this study, we focused on improvement suggested for fish smoking, fermentation and drying (Table1).

3. Description and manufacturing process of smoked fish

3.1. Description

The smoking process has been used for hundreds of years either to preserve and extend the shelf-life of foods or to give them specific organoleptic characteristics (taste, flavour). In developed countries, fish smoking is applied by means of mechanical smokers [14]. Fish smoking process can be divided in two basic categories: cold smoking and hot smoking. The cold smoking processing is referred to the smoking of the product at a temperature up to 33 °C. In this way, the intense thermal processing is avoided and nutrients' structure is preserved. As a consequence, cold smoking does not provide adequate protection against harmful microorganisms and further processing is required prior to consumption. The only exception to this rule is the smoked salmon, which is consumed raw. Hot smoking is referred to smoking of the product at a temperature that may reach up to 70–80 °C. The above process results in cooking of the fish thus making it suitable for direct consumption [15].

3.2. Improvement of manufacturing process of smoked fish

Depending on the type of fish, there are two smoking technologies. The first in which the fish is subjected to a large fire to reduce its moisture content before being subjected to smoke is used for lean fish such ensure a long shelf life ranging from 2 to 6 weeks. Regarding the second variant it is used for oily fish such as skate, catfish and others (Figure 1). The fish are subjected to the simultaneous action of smoke and fire for 2 to 6 hours of time depending on the species of fish. The shelf life of these is 2 to 3 days at most. To ensure their preservation and avoid putrefaction, processors heat up and package using cement paper and baskets every night after the market if all their stocks of smoked fat fish are not finished.

Several studies have investigated the influence of smoking on the quality of the fish and the possibilities for improving the process. According to Varlet et al [16], Phenolic compounds generated by the combustion combined with the temperature and the conditions of smoking can reduce the microbiological development and the oxidation. Products smoked by an indirect technique using external smoke generators have low polycyclic aromatic hydrocarbons and benzo[a]pyrene levels that are well below the maximum level of 5.0 mg/kg [17]. Roth et al [18] investigated the effectiveness of smoking on the quality preservation of stunned and pumped or live chilled of Atlantic salmon (*Salmo salar*). Fishes remained on ice during a period of 1 week and then were dry-salted (18 h, 3–4 °C, pure NaCl) and smoked

(Bastramat C1500, chamber temperature 1.4 °C, relative humidity 61±7%, air velocity 0.5–1.0 ms−1). A drying device invented by Dossou-yovo et al. [19] protects fermented fish from infestations. Fish dried by this device have a firmer texture without an aggressive odor and have a relatively low relative humidity (42.64%) to be kept longer. According to Chabi et al. [20], traditional method of smoking exposes producers to smoking which has consequences on their health on 40 fish smokers. The results also revealed that smoked fish by improved furnace (Chorkor) are microbiological and nutritional better than smoked fish by traditional furnace.

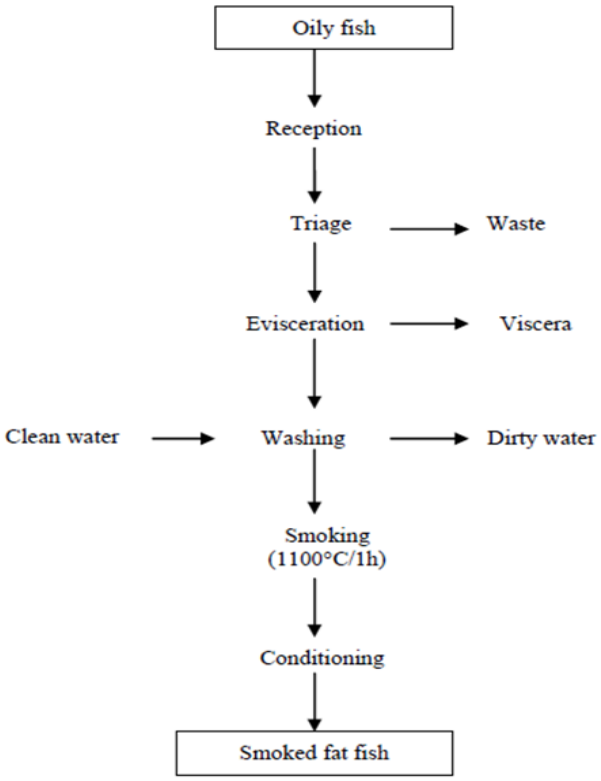

Figure 1 Manufacturing process of smoked fat fish [21].

4. Definition and manufacturing process of *lanhouin*

4.1. Definition

Lanhouin, a traditional fermented fish-based condiment is processed in the coastal areas of West African countries including Benin, Togo, Ghana, Nigeria and Côte-d'Ivoire. It is mostly used as taste enhancer and flavouring agent in many types of dishes [5, 22]. The raw materials used for *Lanhouin* production include the fish and the salt, and the fermentation is spontaneous and uncontrolled [23]. The product which is similar in color, taste and smell to that of other fermented fish products such as *momone* which retain their original texture is widely used as taste enhancer in many traditional dishes and low coast meat substitute [24].

4.2. Improvement of manufacturing process of *lanhoin*

For traditional processing of *lanhouin*, the fish is scaled, gutted and sometimes cut into pieces and then left overnight at ambient temperature in fly free enclosure. The next day, the seemingly spoiled fish is washed. Dry salt is rubbed into gills, the belly cavity and on the surface. After this first salting, the fish is arranged in a basket, a can or a hole, covered with old cement paper bag and old clothes and allowed to ferment for 3 to 8 days at room temperature (28 to 30°C) before being removed, washed slightly and sun dried [5].

These last years, several works have brought improvements to *lanhouin* processing method. This work mainly suggested the improvement of processing equipment, the use of plant extracts such as essential oils for the control of microorganisms in *lanhouin* or the development of starters for its fermentation [24, 25, 26, 19]. Figure 2 shows improved *lanhouin* manufacturing process.

Table 1 Summary of suggested improvements in fish processing

Fish species investigated	Suggested improvement	References
Trachurus trachurus	Identification of potential sources of contamination and suggestions for avoiding contamination.	[28]
	Use of clove essential oil (*Syzigium aromaticum* L.) in the post-smoking preservation of mackerel.	[29]
	Use of *Pimenta racemosa* and *Ocimum gratissimum* in post-smoking conservation.	[24]
Ethmalosa fimbriata	Production of flours for their use as a dietary supplement	[30]
Galeoides decadactylus	Fermentation and drying for its use as food supplement.	[31]
	Improvement of fermented fish flour quality using essential oil extracted from *Pimenta racemosa.*	[25]
Manta birostris, Marcusenius Senegalensis, Liza falcipinis, Hydrocynus brebis, Elops lacerta valvercienne, Silurus linnaeus, Silurus glanis, Arius africanus, Heterotis niloticus, Strongylura senegalensis valenciennes, Ethmalosa finbriata, Gymnocranius griseus and Ameiurus melas	Evaluation of occurrence of Microbial Loads in Smoked Fishes Marketed in the Lakeside Village of Guezin (Southern Benin) to decrease associated microbiological hazards.	[32]
Caranx hippos	Use of ice-salt mixture for fish conservation.	[33]
-	Potential use of *Cymbopogon citratus* essential oil to control Aspergillus Species from fermented fish products of Southern Benin.	[26]
Manta birostris Liza falcipinis, Silurus Linnaeus, Elops lacerta valvercienne, (Arius africanus, Ethmalosa finbriata, Ameiurus melas,Oreochromis alcalia, Caranx latus	Evaluation of the Microbiological Quality of Smoked Fish Taken at Lake Ahémé of Benin for risk control.	[21]
Galeoides decadactylus	Development of an improved device for drying fermented fish called *lanhouin* in Benin.	[19]
-	Survey of the improvement of fish fermentation for *lanhouin* production in Benin.	[34]
-	Use of *Lactobacillus plantarum* from fermented maize dough hydrolysate to improve *lanhouin*	[27]
-	Construction of an improved smoking device (Chorkor furnace) to improve the quality of smoked fish.	[20]
Scomber scombrus, Trachurus trachurus	Evaluation of the impact of break in cold chain on the technological and organoleptic qualities.	[35]
Scomber scombrus Trachurus Trachurus	Improvement of technological quality and sensory by the quality of smoking.	[36]
Clarias gariepinus	Optimization of the salt dose to preserve Biochemical characteristics of fermented, Salty and Dried Catfish.	[37]
-	Use of cinderblock ovens as solutions for the sustainable management of mangrove wood resources.	[19]

Pseudotolithus sp	Identification of predominant organisms during naturally fermented of cassava fish for *lanhouin* production for improving fermentation.	[38]
Pseudotolithus sp	Investigation on biochemical changes and aroma development during the spontaneous fermentation of Cassava fish into *Lanhouin* and their influence on product acceptability.	[39]
Pseudotolithus sp	Use of starter cultures of Bacillus and Staphylococcus in the controlled fermentation of *Lanhouin*.	[23]
Pseudotolithus sp	development of a ferment for the artisanal production of *Lanhouin.*	[40]

-: Unspecified

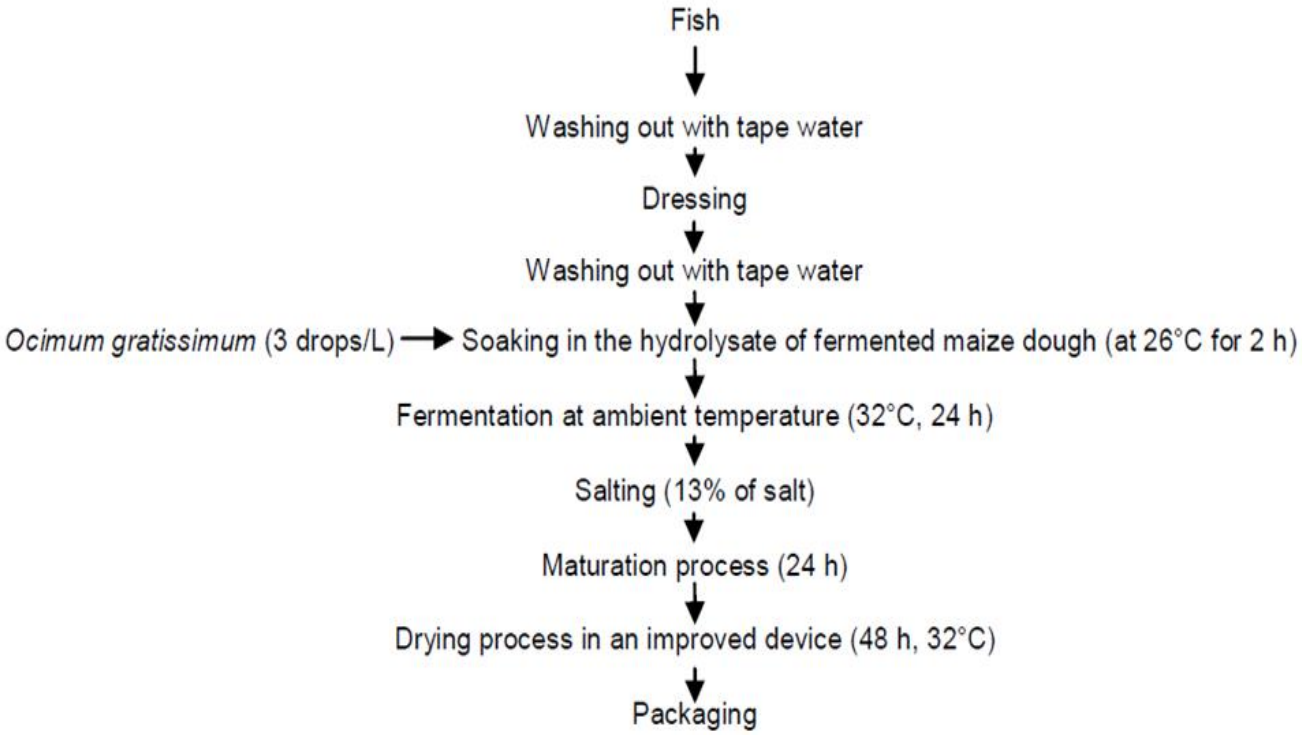

Figure 2 Flow chart of improved *lanhouin* production [27]

5. Essential oils: their antimicrobial properties and potential applications in fish processing

5.1. Essential oils extraction and chemical analysis

Essential oils are products, generally, of rather complex composition comprising the volatile principles contained in the plants, and more or less modified during the preparation process. They are essentially obtained by hydrodistillation where the plant material is heated in two to three times its weight of water with indirect steam from outside the still. Chemical analysis of essential oils is generally using GC (quantitative analysis) and GC/MS (qualitative analysis). Identification of the main components is carried out by the comparison of both the GC retention times and MS data against those of the reference standards (with known source) [41, 42].

Table 2 Major components and susceptible microorganisms to investigated essential oils.

Plant species used	Countries	Identified Major components (%)	Essential oil active against	References
Syzigium aromaticum	Benin	Eugenol (91.3), Trans-β-caryophyllene (4.4), eugenyl acetate (2.4)	*A. candidus, P. camemberti*	[29]
	Benin	Eugenol (60.4), Trans-β-caryophyllene (24.0), eugenyl acetate (10.0)	-	[46]
	Indonesia	eugenol (70.43%), β-caryophyllene (16.79%), α-humulene (3.05%), caryophyllene oxide (2.07%), tetratetracontane (3.12%).	-	[47]
Pimenta racemosa	Benin	Eugenol (51.1), Limonene (3.0), 1,8-cineole (2.7)	*A. candidus, P. camemberti*	[48]
		myrcene (25.1), chavicol (7.5) and eugenol (51.1).	-	[49]
	Jamaica	Eugenol (45.60), Myrcene (24.97), Chavicol (9.31).	-	[48]
	Spain	-	*K. pneumoniae, S. marcescens, S. thyphimurium, E. coli*	[49]
Ocimum gratissimum	Benin	Thymol (26.9), γ-terpinene (20.0), p-cymene (17.6), α-thujene (8.2), myrcene (6.4).	*A. candidus, P. camemberti, E. coli, S. aureus, A. niger, F. graminearum, F. oxysporum, F. poae*	[24, 50]
	Benin	Thymol (30), γ-Terpinene (27), p-Cymene (16,4)	-	[51]
	Kenya	Eugenol (68.81), Methyl eugenol (13.21), cis-Ocimene (7.47), Germacrene-D (4.25).	*S. aureus, K. pneumonia, P. mirabilis, P. aeruginosae, E. coli, C. albicans, Salmonella Enterica, Serovar Typhi*	[52]
Cymbopogon citratus	Benin	Geranial (41.3), neral (33.0), myrcene (10.4), and geraniol (6.6)	*A. ochraceus, A. oryzae, A. fumigatus, A. parasiticus*	[26]
		Myrcene (10.4), Neral (33,0), Geranial (41.3).	*E. coli TCC 25922, S. aureus TCC25923, A. niger, F. oxysporum, P. camembertii*	[42]
	Togo	Neral (31.36%), Geranial (43.15), Myrcene (10.65%).	*C. albicans, C. neoformans, M. pachydermatis, A. fumigatus, P. aeruginosa V5667, S. intermedius IP81.60*	[53]
	Cameroon	E-Citral/Geranial (37.7); Z-Citral/Neral (21.2-80).	*Penicillium expansum, P. verrucosum, A. ochraceus, A. flavus, L. monocytogenes, Salmonella*	[54]

5.2. Antimicrobial activity of essential oils in fish systems

Several studies have evaluated the chemical composition of essential oils as well as their antimicrobial power (Table 2). Spices and herbs can be used as an alternative preservative and pathogen-control method in food materials. Indeed, according to studies by Burt [43], essential oil of *Mentha piperita* had been recognized as bio preservatives for fish dishes and vegetables. Mint oil in the high fat products pâte´ and fish roe salad exhibited little antibacterial effect against *L. monocytogenes* and *S. enteritidis*, whereas in cucumber and yoghurt salad (low fat) the same essential oil was much more effective. The spreading of essential oils on the surface of whole fish or using essential oils in a coating for shrimps appears effective in inhibiting the respective natural spoil [44]. According to Degnon et al. [29] the microbial flora associated with smoked fish are coliforms, staphylococci and molds such as *Penicillium camemberti* and *Aspergillus candidus*, which is relation to the low level of hygiene applied in the production of that food. In vitro antimicrobial tests indicated that essential oil of *Syzygium aromaticum* has a pronounced antimicrobial activity against spoilage flora. The preservation of smoked fish by incorporation essential oil increased the shelf life of the product. However, this protection is not for a long time due to the volatile property of the essential oil.

Antifungal agents such as essential oils kill the fungal cell via binding primarily to ergosterol, the major sterol found in fungal cellular membrane. This binding destroys the osmotic integrity of the membrane, and this is followed by leakage of intracellular potassium, magnesium, sugars, and metabolites and finally by cellular death. Lipid characteristics of essential oils act via the same mechanism. It has been suggested that oxidative damage due to essential oil may also contribute to its antifungal activity against Candida [42, 45].

6. Perspectives for research

In the near future, it would be interesting with regard to the fermented salted and dried *lanhouin* fish to evaluate the cumulative effectiveness of the starters developed, the essential oils investigated as well as the invented improved drying devices. It could be also important to test the cumulative effect of improved funace such as the chokor oven and essential oils. Finally, it will be necessary to assess the acceptability of the improved finished products at the consumer level.

7. Conclusion

Several artisanal treatments reduce post-capture losses of fish. However, nowadays, the smoking and fermentation of fish became one of the mostly conservation methods. Despite the social importance and the nutritious nature of smoking and fermented fish, several problems are remained related to their hygienic quality as well as their suitability for conservations. In this review we highlighted the improvements suggested in recent years to the smoking and fish fermentation processes in Africa. The results show that several innovations have been proposed. This mainly concerns the invention of smoking and drying devices, the development of starters and the use of aromatic plant extracts in the conservation of fish. However, it would be interesting to assess the cumulative effectiveness of its innovations.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors agree no conflict of interest.

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