International Journal of Engineering & Technology, 12 (2) (2023) 88-101

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Review on the design, production and study of the intelligent smoke dryer

Alphonse Sawalda Guidzavaï [1] *, Ngasop Ndjiya [1], Nicolas Njintang [2], Hilaire Tchami [1], Aslain Brisco Ngnassi Djami [3], Ulrich Ngnassi Nguelcheu [4]

[1] *Department of Electrical Engineering, Energy and Automation, National School of Agro-Industrial Sciences, University of Ngaoundere, Ngaoundere, Cameroon*
[2] *Department of Food Sciences and Nutrition, National School of Agro-Industrial Sciences, University of Ngaoundere, Ngaoundere, Cameroon*
[3] *Department of Fundamental Sciences and Techniques of Engineer, Chemical Engineering and Mineral Industries School, University of Ngaoundere, Ngaoundere, Cameroon*
[4] *Department of Physics, Faculty of Science, University of Ngaoundere, Ngaoundere, Cameroon*
**Corresponding author E-mail: sawaldito@gmail.com*

Abstract

Smoking and drying are widely used techniques for preserving food to reduce losses and ensure availability of food in all seasons in developing countries where cost and high technology are out of reach. The effectiveness of ancestral know-how and techniques of these conservation methods being indisputable, it is desirable to improve practices due to the arduousness, health problems of processors and consumers, loss of materials and resources; the irregularity of the quality of the finished product and the loss of time are always perceived. Added to these disadvantages is the lack of information on the evolution of the transformation process which impacts the quality of the finished product. This review aims to take stock of the scientific bases of smoking and drying, the processes and equipment for preserving meat products as well as the laws on the marketing and consumption of these products. It emerges from this study that a device for smoking and drying meat products, and its process making it possible to guarantee food safety, user safety, retaining all nutrients, ergonomic, using fewer resources, fast, adaptable to any type and size of smoking products is not yet present in our markets.

Keywords: *Drying; Meat Products; Process; Smoking; Smoking-Drying.*

1. Introduction

The world population is experiencing rapid urban growth, which represents a strong demand for meat products, the supply of which is constantly increasing to meet demand. But its conservation for later use in order to satisfy demand, especially in times of scarcity, remains a subject of research which has not yet found satisfaction. Indeed, huge losses have been recorded in the meat product sector because they are highly perishable due to their very high protein and water content. These losses are estimated at 50 % for fish in Africa (FAO, 2016). Until now, several traditional processing and preservation techniques have been used, including smoking, salting, fermentation, drying, frying, refrigeration and freezing (Anihouvi and al., 2006; Depo and al., 2019) and also equipment integrating these processes has emerged (Knockaert, 1995; Ahmat, 2015; Fabrice, 2020). Among all these techniques, that of using cold is the most used. In addition to being energy consuming, there are also the intensive cuts by the electricity supplier which contribute to the deterioration of the quality of the finished product during cold storage. However, the need for a reasonable quantity of energy can allow long-term preservation while improving the quality of the finished product by applying smoking and/or drying. In addition, the finished product obtained by this method is more appreciated than the finished product obtained by other methods because of its perfume and its color.
Difficulty in implementing the process, lack of control over the process and safety standards, loss of time, loss of resources, loss of materials, respiratory problems, back pain and visual impairment are common. in smokers. Cancer among consumers is just as many disadvantages which mean that not everyone adheres to this technique (Akakpo and al., 2020; Ahmat, 2015). Several works have been carried out in order to overcome these disadvantages. In order to give an overview of the current state of research and the characteristics of future smokehouse dryers, it will be a question for us in this article to present the scientific laws which govern smoking and drying, the processes and equipment of the smoking and drying that exist there. Without forgetting the legal laws of meat products as well as the difficulties and needs of those involved in smoking and drying.

2. Bases of smoking and drying

Smoking is a processing operation practiced for generations in many regions of the world, for the preservation of products (meat, fish or cheese) and food diversification (to impart flavor). It is often associated with cooking, drying and/or salting. The preservative, flavoring and coloring functions are well correlated with the intake of smoke, but we also know that smoke carries polycyclic aromatic hydrocarbons (PAH), known for several decades for their carcinogenic potential in humans.

2.1. Smoking and drying method

There are several smoking methods, namely: cold smoking, hot smoking, smoking-drying, electrostatic smoking, smoking and smoking with liquid smoke (Centre technique of aquatic products Haliomer, 2010).
Cold smoking has a maximum temperature of 30°C. The hot smoking temperature varies between 65°C and 100°C. That of smoking-drying varies between 45°C and 85°C. (Brigitte and al., 2005). In the electrostatic smoking process, the particles that make up the smoke are subjected to a magnetic field which ionizes them. Arranged on a trolley, the product is placed between two electrodes: the electric current which passes through the product carries the ionized particles of the smoke into its flesh (smoking method patented by Ifremer and Cirad under number FR 2693351 (B1)). Liquid smoke smoking, well established in the meat industry, is obtained by condensation of smoke produced by wood pyrolysis. The condensate obtained is treated by filtration and decantation in order to eliminate residues of tar and 3-4 benzopyrene. Three methods of applying liquid smoking exist, namely immersion, sprinkling and atomization (or even revaporization) (Centre technique for aquatic products Haliomer, 2010).
Regarding drying, two mechanisms can be implemented to evaporate water from a product: boiling and/or entrainment. The drying operation can be done in several ways. We distinguish among others: conduction drying, convective drying, infrared drying, microwave drying, freeze-drying, solar drying. (Ahmat, 2015). The simplest idea is to bring the product to the boiling temperature of water, which then vaporizes. Whatever the drying method, it is the water vapor pressure in the product which determines the exchanges between the air and the product (Fabrice, 2020).
Entrainment drying takes place when a wet product is placed in a stream of gas (most often air) that is sufficiently hot and dry. A difference in temperature and partial pressure is established such that: The gas provides the product with at least part of the energy necessary for vaporization; The water is evaporated without boiling under the effect of the water partial pressure gradient; The water vapor is transferred by conduction and convection from the product into the ambient environment and is then entrained by the gas; The product spontaneously reaches a temperature such that heat transfer allows the evaporation of a flow of water equal to that capable of crossing the boundary layer.
Boiling occurs when the temperature of the product is raised (by conduction on a hot surface, by radiation, by superheated water vapor, by immersion in hot oil) to a value such as the vapor pressure of water of this product is equal to the total ambient pressure:

$$p = pt \qquad (1)$$

It follows from this definition that the boiling temperature depends on the total pressure (it is lower under vacuum than at atmospheric pressure) and on the water activity of the product (it increases when a w decreases), according to the formula:

$$p=aw.p'\theta=pt \qquad (2)$$

2.2. Suspension mode for smoking and drying

To dry or smoke a product, it can be hung in several ways as shown in Fig. 1. The hanging method on horizontal sticks allows free circulation of air around it. pieces of meat. Drying on mesh or bamboo racks has the disadvantage of the risk of drying the product poorly, that is to say of remaining damp in the places where it is in contact with the sticks and the fence. For Brigitte (2005), the best is to use a string passed around tail or hook. This hanging method allows free circulation of air around pieces of meat. This way, the product dries more quickly and more uniformly.

a) Suspension of meat on horizontal stick **b) Hanging strips of meat on hooks and strings** **c) Racks with horizontal and inclined drying surface**

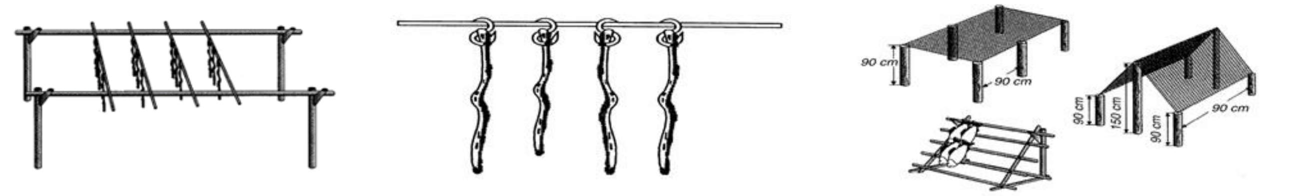


Fig. 1: Suspension Modes for Smoking and Drying (Brigitte and Al., 2005).

2.3. Smoke

Smoke is a gaseous product released from burning bodies. It has a beneficial effect (preservation, flavoring, coloring) and also a disadvantage (deposition of carcinogenic components) for products exposed in its field. (Rivier and al., 2009).

2.3.1. Action, undesirable effects of smoke and influence of sawdust hygrometry

Regarding the actions of smoke on food products, we can classify them according to chemical, organoleptic and bacteriostatic action. As for the organoleptic action, it concerns aroma, taste and colour. And as for the chemical action, these are phenols which can have an anti-oxygen action which delays oxidation. Regarding the bacteriostatic action, acids and phenolic derivatives have a slight antiseptic action on the smoked product.

In smoked products, there are two families of chemical contaminants: polycyclic aromatic hydrocarbons (PAHs) and N-nitroso compounds (Knockaert, 1995).
According to Ruiter (1979), the humidity of the wood influences the levels of glycolic aldehydes and methylglyoxal's in the smoke and therefore the colouring of the product. The optimum seems to be a humidity of 17 to 20% in the sawdust (Sainclivier, 1985).

2.3.2. Factors influencing smoke deposition and penetration

Several factors such as density, temperature, humidity, speed favor or not the deposition and penetration of smoke on the product.

- Smoke density

Density is an important factor that determines the rate of smoke deposition. Empirically, it had been established that opaque smoke (of high density) gave the fish a marked colouring and gave it a longer shelf life, probably due to a high bactericidal power. It is therefore based on the opacity that we regulate the smoking. Foster in 1961 highlights the relationship between the quantity of smoke retained and the optical density (Do) of the smoke:

$$Do = \log (Io/Ii) \quad (3)$$

- Smoke temperature

Generally, the rate and extent of smoke absorption by product fabrics increases with increasing temperature. However, at temperatures that are too high, the amount of substances absorbed decreases. Raising the temperature too high therefore risks drying out the product excessively (Sainclivier, 1985). It is also necessary to avoid that the temperature of the smoke entering the smokehouse at the start of smoking is lower than that of the product to be smoked because the humidity in the smoke would condense and deposit water droplets on the surface of the product (Sainclivier, 1985). Likewise, during smoking, a drop in temperature can not only cause the same phenomenon, but lower the content of volatile products in the gas phase and slow down the absorption of smoke (Clifford, 1980).

- Smoke and product humidity

The best relative humidity percentage for cold smoking, at a temperature of 29°C, is between 60 and 70% (Anonymous, 1972). Above this, the subsequent conservation of the smoked product would be defective. On the other hand, at a humidity below 60%, drying would be too rapid and therefore smoke absorption too low. The humidity of the product surface also influences the smoke deposition process: the absorption rate increases with humidity. (Sainclivier, 1983).

- Smoke hygrometry

If you want to complete the drying during smoking, a humidity of 55 to 65% is optimal for a temperature of 22°C (Knockaert, 1990). If we completely differentiate the drying phase from the smoking phase, the relative humidity is greater than 65% and there is an optimal relative humidity value for each smoking temperature.

- Air introduction

High velocity of air-smoke flow in the smokehouse results in greater absorption and penetration of smoke compounds. However, the speed of 2 m/s at product level is optimum.

- Smoke models

Ifremer in 2002 offered us different models of smoke including:

- The geometric models (the geometry of trays, the geometry of beams out of phase according to the layers, the geometry of paving stones with a symmetrical arrangement according to the height and the geometry of paving blocks out of phase according to the height) of which the choice of a model is made on several criteria namely the techniques (the possibility of generating a mesh according to the criteria and the means of calculation) and the practice (the guarantee of consistency in the distribution and of course according to the different possible arrangements on the grid);
- Physical models such as the conservative Euler system for air (which is the basis of any numerical simulation of gas flow), the passive scalar model (used to account for a dilute phase acting as a scalar passive), the passive scalar model with deposition (a flow of particles due to particle wall interaction is added to the transport equation in the form of a source term), the Euler-Euler model (used for flows loaded with fine particles. With this model we can take into account the particle phase like the gas phase of the smoke using a system based on the number of particles or in volume fraction of volatile compounds), the Euler model- Euler with coalescence and deposition (It takes into account the work of the cohesion forces (particles-particles walls-particles) and the resulting dissipation.) and the Euler-Lagrange model (whose interest in relation to the Eulerian approach lies above all in the finer modelling of the liquid phase (smoke particles) in a two-phase flow);
- And turbulence models which consist of simulating small-scale speed fluctuations. Among these models, we find the model based on turbulent viscosity, the model k-ε, the model k-ω and the model at Reynolds tensions.

2.3.3. Fuels

Wood is most used by processors for smoking products including: neem (Azadirachta indica), mango tree (Mangifera indica), teak (Tectona grandis), and grape (Lannea acida) (Akakpo and al., 2020). Other plant materials are also used including: coconut husks, sawdust, dried corn husks and cobs, sugar cane bagasse and cardboard. The best smoke is obtained with a fire of wood chips and pieces of hardwood (smothered combustion). The downside to smoking is that it requires a lot of wood. We present in Table 1 the list of woods for smoking and their different flavors:

Table 1: Different Types of Wood for Smoking with Their Scent

Drink	Perfumes	Choice of meat
Almond	Soft and subtle	Perfect for all meats
Apple tree	Gives a smoke with a fruity scent, the strongest essence of all fruit tree woods.	Good with red meats, poultry, wild birds, pork and wild boar.
Ash	Burns quickly	Very good combination with pork and poultry
Mulberry	Soft and delicate	Ideal for cooking and cooking poultry and wild birds like quail
wild cherry	Sweet, soft and delicate	Good for all meats, especially poultry whose skin turns brown during cooking
Lemon and other citrus trees	Not too powerful, with a slight fruity accent	Beef, bison, venison, pork, wild boar and poultry

plum tree	Light fragrance	Most chicken, turkey, pork and fish meats
Sassafras	Sweet and mild musky smoke	Beef, pork and poultry

2.4. Modelling of matter and heat transfer phenomena

During drying, heat and material transfer phenomena take place and are localized both outside and inside the product.

2.4.1. Energy balance during drying

The equation (4) is generally speaking, the thermal power model (or heat flow) noted φ and the equation (5) is that of the energy balance in a system (Fabrice, 2020):

$$\varphi=K.S.\Delta T \quad (4)$$

$$\varphi_e+\varphi_g=\varphi_s+\varphi_{st} \quad (5)$$

φ_e heat flow entering the system can be one of three forms of heat transfer (convection, conduction, or radiation). The equation (6) represents Fourier's equation, formulated in 1822, also called the equation of heat in a product, is expressed in a three-dimensional system as follows:

$$\frac{\partial}{\partial x}\left(\lambda_x\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(\lambda_y\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(\lambda_z\frac{\partial T}{\partial z}\right)+q=\rho c\frac{\partial T}{\partial t} \quad (6)$$

2.4.2. Transfer of matter and heat

Drying is a complex operation which involves coupled transfers of material (mainly water) and heat, accompanied by physico-chemical modifications and structure of the material.

- Internal transfers
- Material transfer

Water migrates from the interior to the surface of the product under the action of various mechanisms which can combine. The equation (7) is that of the evolution of water content which is expressed as a function of the water content gradient and an overall diffusivity which brings together the different transport phenomena, in a law analogous to Fick's second law:

$$\frac{\partial X}{\partial t}=D_{app}.\nabla^2X \quad (7)$$

The diffusivity of water, depending on temperature, could be observed as following the Arrhenius relationship (Meisami-asl and al., 2010):

$$D=D_0e^{\left(-\frac{E_a}{RT_a}\right)} \quad (8)$$

- Heat transfer

For Fabrice (2020), heat diffuses into the product under the effect of the temperature gradient. The equation (9) is Fourier's law, which characterizes the diffusion of heat in an immobile medium (which requires neglecting the effect of water migration, or convection, on this transfer).

$$\frac{\partial\theta}{\partial t}=D_t.\nabla^2\theta \quad (9)$$

- Heat transfer by conduction

Conduction is the transfer of heat within a solid. The flow is calculated by the equation (10):

$$\varphi_x=-\lambda_x.S\frac{\partial T}{\partial x} \quad (10)$$

Considering the homogeneous medium, we have:

$$\varphi=-\lambda.S\frac{\Delta T}{e} \quad (11)$$

- Heat transfer by convection

Fabrice (2020) recalls that it is essentially the phenomenon of heat transfer in fluids. The equation (12) represents the heat flow between a fluid and a wall.

$$\varphi=h.S.(T_f-T_p) \quad (12)$$

$$h_{air}=5,7+3,8.V_{air} \quad (13)$$

- Mass transfer

Mass transfer is governed by Fick's first law which is represented by the equation (14):

$$\varphi_m=\rho_{ms}D\frac{dX}{dx} \quad (14)$$

- External transfers

During strip drying, water vapor is removed from the product surface by convection. The heat is transferred by convection of the air towards the surface, and possibly by radiation (infrared or microwave) or by conduction (if the product is placed on a plate or on a heating mat).
In practice, the air most often follows a turbulent regime in the dryer and a boundary layer is established (with a thickness of around a tenth of a millimetre) in the immediate vicinity of the product. Inside this boundary layer, the air flow is approximately laminar and the air in contact with the product (A*) is considered immobile and in temperature and humidity equilibrium with the surface. of the product. This balance is reflected by the equations (15), (16), (17), (18) et (19).

$$\theta^* = \theta_s \quad (15)$$

$$\varphi^* = a_{ws} \text{ either } P^* = P_s = P'\theta_s a_{ws} \quad (16)$$

$$\dot{Q} = Ah(\theta - \theta^*) = Ah(\theta - \theta_s) \quad (17)$$

$$\dot{m} = Ak_p(p^* - p) = Ak_p(p - p_s) = Ak_p(p'\theta_s . a_{ws} - p) \quad (18)$$

$$\frac{h}{K_p . \Delta H_v} \approx 65 \text{ Pa/°C} \quad (19)$$

2.5. Empirical models of drying kinetics

Drying kinetics is a curve which illustrates the evolution of the water content of a product over time. The models, for the most part, are based on Fick's diffusion law (Meisami-asl and al., 2010).

$$\frac{\partial M}{\partial t} = \nabla[D_{eff}(\nabla M)] \quad (20)$$

For Yves (2006) and Ahmat (2015), these laws are not the most suitable models for products with a high-water content. Yves instead advocates the use of empirical models for these products.

Table 2: Empirical Laws of Drying Kinetics (Ahmat, 2015; Fabrice, 2020)

Model Name	Equations	Description
Lewis	$\frac{W-W_e}{W_0-W_e}=e^{(-kt)}$ (21)	This model only considers diffusion based on water migration.
Page	$\frac{W-W_e}{W_0-W_e}=e^{(-kt^n)}$ (21)	Page (1949) modified the Lewis model by adding an empirical dimensionless constant (n).
Pabis model	$\frac{W-W_e}{W_0-W_e}=a.e^{(-k_1t)}+b.e^{(-k_2t)}$ (23)	Henderson and Pabis (1962) improved the drying model using Fick's second law of diffusion.
Midilli model	$\frac{W-W_e}{W_0-W_e}=a.e^{(-kt)}+b.t$ (24)	Midilli and al., (2002) proposed a new model with the addition of an additional empirical term integrating time t to the Henderson and Pabis model.
Kaleemullah Model	$\frac{W-W_e}{W_0-W_e}=e^{(-cT)}+b.t^{(pT+n)}$ (25)	Kaleemullah (2002) created an empirical model that included MR, T and t.

- Influence of air parameters on the drying kinetics

The drying air temperature significantly affects the drying rate as shown in Fig. 2. The effect of drying air temperature has been studied by many researchers who found that drying time decreased with increasing the drying temperature.

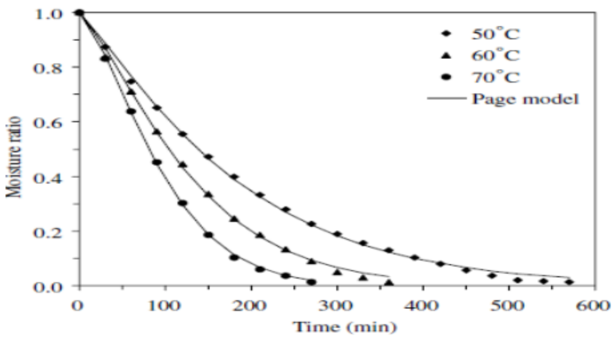


Fig. 2: Kinetics of Drying of Green Beans (Doymaz, 2005).

A decrease in relative humidity leads to a reduction in drying time and an acceleration of the drying process as we can see in Fig. 3.

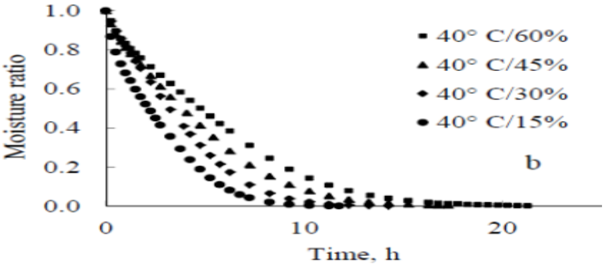


Fig. 3: Influence oOf Drying Humidity (Doymaz, 2005).

The air speed has a positive effect on the drying kinetics, especially at the start of the operation. The authors' results can be classified into three groups according to their description of the influence of air speed on drying kinetics:

- The first group indicates that the influence of air speed on the drying kinetics is very weak, represented by Fig. 4.

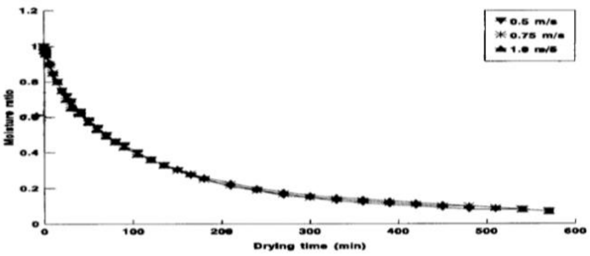


Fig. 4: Influence of Air Speed on the Drying Speed of Garlic (Madamba and Al., 1996).

- Fig. 5 is the illustration of the results of the second group which notes that the air speed influences the drying speed: when the speed is increased, the drying time is reduced and the drying speed is increased.

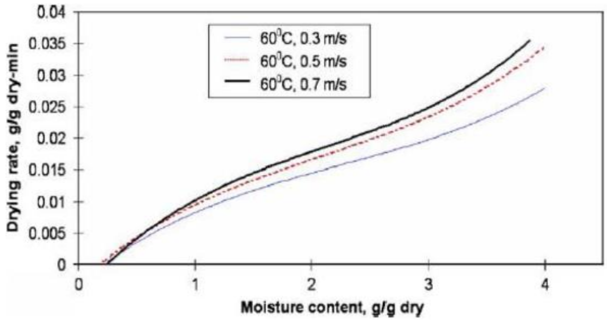


Fig. 5: Banana Drying Speed as A Function of Water Content (Karim and Al., 2005).

- The third group also notes that air speed influences drying speed. However, the air speed reaches a limit value (depending on the product to be dried) beyond which there is no longer any influence on the drying time. Fig. 6 is an illustration of their observation.

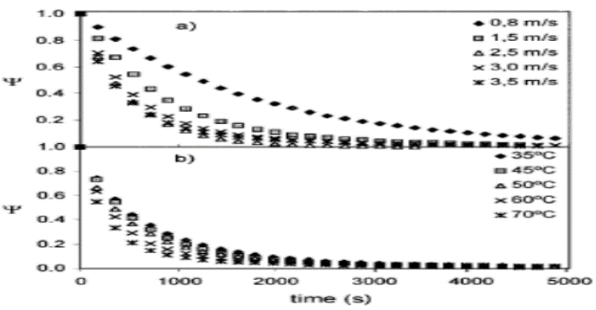


Fig. 6: Effect of Air Speed on the Kinetics of Broccoli Drying (Mulet and Al., 1999).

3. Smoking and drying processes and equipment

3.1. General smoking process

Before smoking a product, a certain number of preliminary operations are necessary. As a rule, a distinction is made between gutting, washing and salting (brining and dry salting). The smoked product processing process takes place in three main stages: preparation of the carcasses, treatment and the actual smoking.

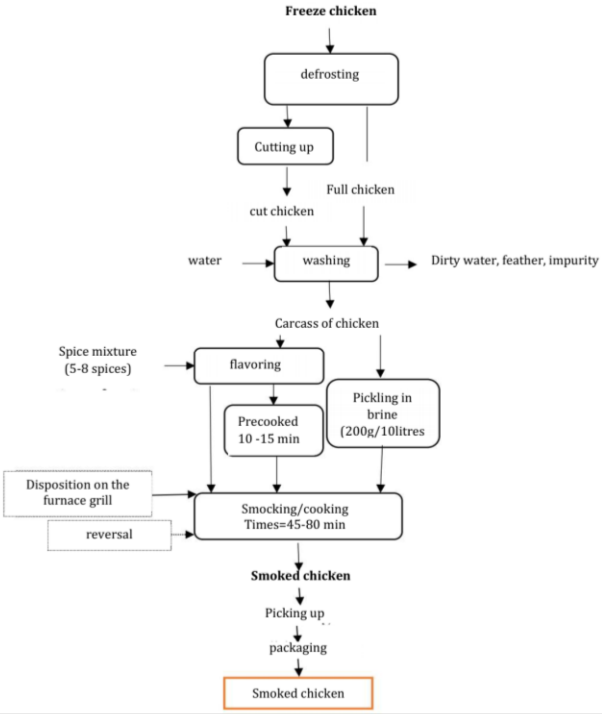


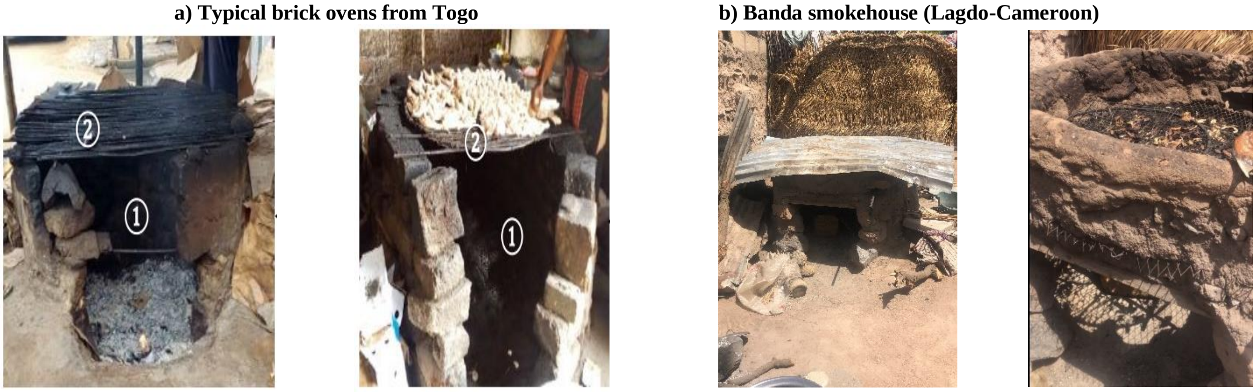
Fig. 7: Technological Diagram of Traditional Smoked Chicken Production (Akakpo and Al., 2020).

3.2. Some smokehouses and dryers

3.2.1. Brick type ovens

The brick chicken smoking device (Togo) is no different from the traditional smokehouse used for smoking fish in our country Cameroon which is commonly called Banda in the locality of Lagdo-Cameroon. Fig. 8 (a) is the illustration of the brick device for smoking chicken from Togo that Akakpo (2020) offers us and Fig. 8 (b) is that of the Banda smokehouse.

a) Typical brick ovens from Togo **b) Banda smokehouse (Lagdo-Cameroon)**



①: Combustion chamber **②: Metal grids supporting smoking chickens**

Fig. 8: Typical Brick Ovens.

3.2.2. Smokehouses made from oil barrels

Another model of smokehouse is obtained by stacking several barrels of oil on top of each other. The edges should match well. A wet bag is placed over the edge of the top barrel. This system allows better use of smoke. The order of the barrels, or the meat in the barrels, should be changed regularly because the lower barrel should not receive more heat and smoke than the others (see Fig. 9). The disadvantage of this smoking method is that the temperature is difficult to control and the finished product is not smoked evenly. Smokehouses are sensitive to rain and wind. The advantage of these smokehouses is that construction costs are low.

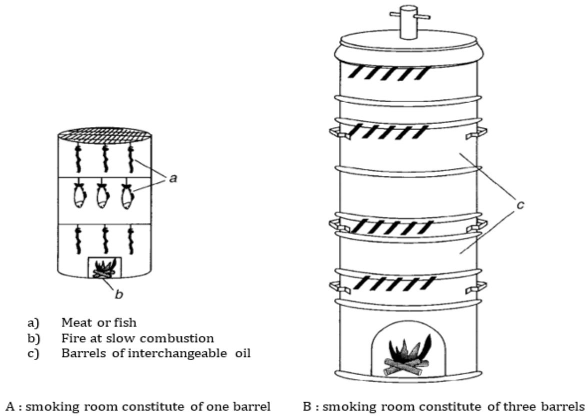


Fig. 9: Smokehouses Made from Oil Barrels (Brigitte and Al., 2005).

3.2.3. Chorkor smokehouse

These types of smokehouses, as shown in Fig. 10, are generally composed of a rectangular hearth on which are stacked a few shallow trays made of metal mesh held by wooden frames. The product is placed on the trays and wood is burned in the hearth. The oven should be low to allow several trays to be easily stacked, but there should be a distance of at least 50 cm between the flames and the lower tray. It is therefore necessary to dig a hearth 10 to 20 cm deep at each supply opening. During construction, care must be taken to ensure that the wooden frames can rest on the center line of the oven walls. The upper plate may be covered with a sheet of plywood or corrugated iron. By swapping the trays when smoking, products are smoked more evenly.

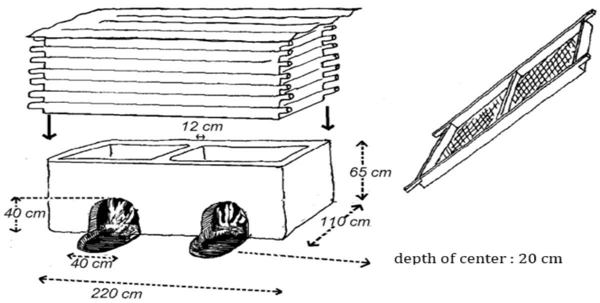


Fig. 10: Chorkor Smokehouse (Brigitte and Al., 2005).

3.2.4. FTT-Thiaroye smokehouse

The FTT-Thiaroye (FAO-Thiaroye processing technique) ensures that the processing operations of smoking and drying Thiaroye fish meet food safety requirements and can also be carried out independently of weather conditions. Not only does the FFT-Thiaroye allow the marketing of better quality products, but also leads to a reduction in the use of charcoal, an easier use of agricultural by-products and an increase in the work of women fishing operators. It includes a charcoal stove, a grease plate, a smoke generator, and an air simmer. FTT-Thiaroye is a technique born from collaborative efforts between FAO and the CNFTPA training institute in Senegal. It is a system built on the achievements of existing improved oven models which are already widely adopted in Africa, such as the Chorkor, the Banda and the Altona. Fig. 11 is one of the photos captured by FAO. These ovens become FTT from the moment a few specific components are added. These are the stove, the grease collection plate, the indirect smoke generator system, and the air distributor.

Fig.11: FTT-Thiaroye Smokehouse (FAO, 2014).

3.2.5. Electric smokers

Electric smokers, as their name suggests, draw their energy from electricity. In fact, the temperature inside the device is easily controlled thanks to its thermostat. The templates allow you to plan a very precise smoking time. This type of smoker is often composed of a chamber, a ventilation valve, grills for placing the products, a heating resistor, a supply tube for placing the briquettes, a burner briquette receiving briquette and a digital or manual control panel for easy use. Other models, working in relatively the same way, can also be used with wood as a smoke generator. However, in this case, it is often necessary to manually add the chips throughout the smoking process, control the smoke inside the chamber as well as the smoking temperature. Electric smokers are particularly effective for hot smoking, but can also be used for cold smoking. They are very self-contained, easy to clean, robust (especially in the case of the best smokers), allow impeccable internal temperature control and often have different smoking parameters built in and easy to select thanks to the digital controls. Fig. 12 is the illustration of this type of smoker which we took from Thomas' blog (Bradleysmoker.com) published in 2022.

Fig. 12: Electric smoker (Source: Bradleysmoker.com).

It is in this category of smokers that we find intelligent smoker dryers. Let us recall here that a system is intelligent if it can learn (elaborate a knowledge system and be able to integrate new knowledge), if it can reason, deduce, anticipate (from the knowledge system and data from the experience to be able to produce new knowledge), if he can have a history, have a conscience and if he can have feelings. Artificial Intelligence concerns the design of an artificial being (machine) capable of possessing or exhibiting the capabilities and characteristics specific to a human brain. Available in the Politec team catalog, Fig. 13, Fig. 14 and Fig. 15 are illustrations of smart smokers and dryers.

- Holdomat ovens

This oven has an interior and exterior construction in 18/9 stainless steel with a highly insulated oven and double-walled door. It has tactile keys and precise temperature display. It allows precise control of humidity and temperature to +/- 1°C. Static heat is also precisely controlled by a platinum probe. The temperature setting range is 20° to 120°C. it allows intelligent dehumidification for an optimal room temperature. Its side handles are retractable and very practical for transport.

Fig. 13: Four Holdomat (Source: Politec-France.Com).

- Smoki smokers

These smokers are designed for regular use and consistent smoking quality. These all stainless steel and insulated smokehouses allow cold or hot smoking depending on the version chosen. The features are as follows:

- Cold or hot smoking depending on version
- Smoked foods on rack or hanging
- Smoke intensity easily adjustable by valve
- Very large smoking capacity
- Rigid stainless steel construction with 70 mm double insulated wall
- Door with waterproof closing system
- Equipped with an automatic smoke generator

Fig. 14: Smoki Smokehouse (Source: Politec-France.Com).

- ST Series Dryers

ST series dryers have approximately 150 hours of uninterrupted drying possible. They have 2 individually adjustable temperature zones. The drying temperature is adjustable to the nearest degree. They have approximately 4 self-contained fans and 10 fan speeds. They can be used to dry fruits, vegetables, spices, meats, fish, etc. They are simple to use, easy to clean and maintenance-free. The construction is made of double-walled stainless steel. Full height horizontal ventilation, significant air flow. Easy adjustment for temperature and drying time. The thermostat is digitally controlled and the temperature varies from 30 to 70°C.

Fig. 15: ST Smoking Room (Source: Politec-France.Com).

3.2.6. Some inventions around smoking and drying

In this section, we present some limitations of smoking and drying oven invention patents.

- Individual portable smoker

Invented by Henri Giles Rouquairol on October 30, 1987 under number: 2597722 published by the National Institute of Industrial Property in Paris. The major limitation of this invention is that the parts in contact with the grid's present burns. The device diagram is shown in Fig. 16.

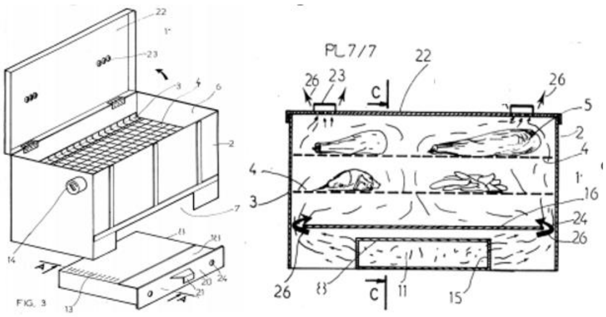


Fig. 16: Individual Portable Smoker.

- Method and device for salting-drying and cold smoking of meat food products

Fig. 17 is the diagram of Camille Knockaert 's invention published by the European Patent Office in 1995 under the number: EP 0587515A1. The limits of this invention are based on the fact that the salting device is separated from the smoking device. As well as the smoking method which is electrostatic which uses a large amount of energy.

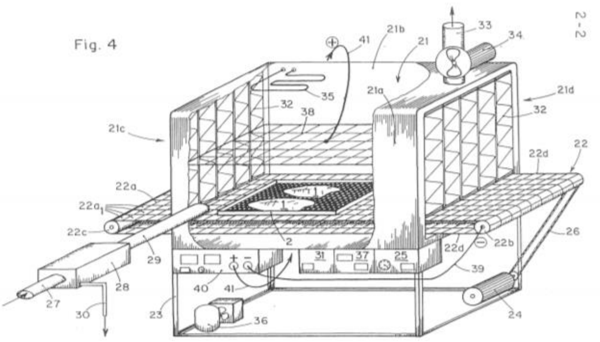


Fig. 17: Device For Salting-Drying and Cold Smoking Meat Food Products.

- Dehydrator and smoker for food products

Invented by Kenne Takala Brice June 2, 2022 under Number 20365, published by African Intellectual Property Organization. Fig. 18 is the diagram of this invention. The limits are as follows: loss of time (cleaning, salting, pre-drying in the sun); manual combustion system (you will have to relight the coal fire if it goes out) and the system not connected.

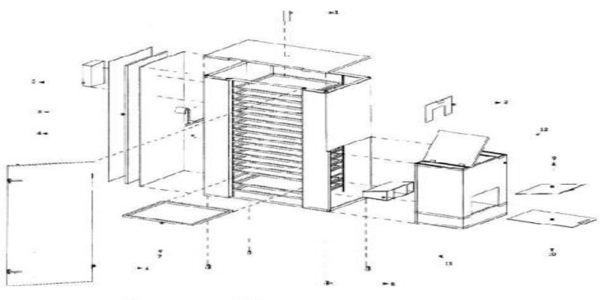


Fig. 18: Multifunction Dehydrator and Smoker for Food Products.

3.2.7. Price of some smokers and dryers

Prices for smokers and dryers vary depending on the city and country. We present in Table 3 the average prices of some smokehouses and dryers in Africa.

Table 3: Prices of Smokers and Dryers (Nadine, 2004)

Types of Smokehouses	Features	Price
Passive solar tunnel dryer (developed by CEAS)	20 kg of fresh produce	145,000 FCFA
The Coquille dryer (developed by GERES)	20Kg of fresh produce	2200 to 3000 FCFA / m² of racks.
The shell dryer improved by forced convection (developed by EIER, Burkina Faso)	20Kg of fresh produce	1200,000 FCFA
The Geho3 dryer: developed by the University of Hohenheim	150 kg of fresh produce	1400,000 FCFA
Forced convection solar dryer with diesel backup (CEAS)	6 kg of fresh product	400,000 FCFA
Banda (open)		30000 FCFA
Closed band		35000 FCFA
Chorkor (made of cement brick blocks)		200000 FCFA
Chorkor (clay)		130000 FCFA

3.3. Some scientific work on the design, construction and studies of a smoke dryer

Yves in 2005 proposed the “Humid Air” program which calculates all the characteristic quantities of humid air, namely: T, Tr, HR, Pv, and ρ whatever the case. The program provides better precision of the results compared to a reading on the diagram and also makes it possible to take into account the atmospheric pressure of the location considered which can be significantly different from 760 mmHg. The major disadvantage is that the humid air diagram remains very useful for visualizing the different air transformations.

Thierry worked on the development of a user-oriented design method: Case of tropical agri-food equipment in 2009. He proposed:

- The DCF (Functional Understanding Diagram) which allows a better understanding of the traditional process and user expectations.
- The COSU Method (User Scenario Oriented Design) which allows the involvement of the user's knowledge in the use of the product)

The limitation is that Functional Analysis does not allow the designer, even if he is a specialist in the agri-food industry, to have a complete understanding of the operations traditionally carried out by women and especially of their expectations.

Edoun, working on the development of a tool to help design small-scale drying processes in humid tropical areas in 2010, proposed the MASADryP tool “Matrice of Select an Adapted Drying Principle” which makes it possible to guide and broaden the field of research into drying principles and processes when designing a dryer. The limitation is that it applies to drying plants.

Randrianaivo in 2014 produced a smokehouse dryer and a solar dryer adapted to different regions for the smoking and drying of agri-food products in 2014 which takes into account a wide range of plant and animal products whose shelf life is greater than 1 year. The equipment allows smoking and drying even during bad weather. The limits that we have retained are as follows: No grease collector and drops of water; the turning of the product is done manually, there is a lack of information on the evolution of the transformation process, there is a loss of time (cleaning, salting, pre-drying in the sun) and non-uniformity of colour of the finished products.

Ahmat in 2015, to create a solar dryer adapted to the context of tropical countries, and which takes into account the needs of users in terms of quality of the dried product, cost and size. There is a considerable reduction (70 to 90%) of the microorganisms present in the meat. The equipment has the same limits as the equipment produced by Randrianaivo in 2014 and to these we add the fact that the use is conditioned by the climate.

Fabrice, created a biomass dryer-smoker by convection and heat recycling whose temperature is regulated and the distribution of smoke is uniform in 2020. The limits are that the system is not connected and the turning of the product is manual.

The study (Numerical study of smoke distribution in an industrial smoking chamber) carried out by IFREMER in 2002 made it possible to identify the defects of the treatment: heterogeneity and exceeding standards (too high surface speed). Also, the physical model (Euler system for air, Use of a passive scalar, Use of a passive scalar with deposition, Euler-Euler model, etc.); the Turbulence Model (Models based on viscosity, Reynolds tension model, etc.). And geometric models using the software (CFX from Ansys) of the smoke were proposed. The limits identified around this study are: the regularity of the treatment is difficult to achieve and the transformations are only conceivable in the dynamic smoking process.

According to the experiences of Boughali in 2008, to properly control a drying operation you must be able to control the three fundamental parameters: temperature, humidity and speed of the drying air. And it is also noted that the temperature factor is the most influential factor on the drying kinetics, however the effect of humidity and speed is less. The major limitation is that there has been no study of the influence of product suspension mode.

Akakpo in 2020, Diagnosed the smoking practices of chicken meat (Gallus Gallus) in the city of Lomé in Togo. And it emerges from the study that: the storage time is at least 20 hours for traditional smoking, the smoking temperature is between 45 and 80°C, the essential difference is seen in the treatments applied to the chicken before smoking and the fuels used. The limits listed are: there was no microbiological and vitamin analysis of the finished product as well as no study of the mass of the product before and after smoking.

4. Legal laws on meat products

Several laws on the consumption and marketing of meat products have been passed both internationally and for each country. In this section, we present some international laws as well as the laws of Cameroon on the consumption and marketing of meat products.

4.1. Meat quality

Saying that meat is “quality” can mean everything and its opposite depending on the frame of reference in which we place ourselves. Indeed, there are many definitions of quality, but the most common is the following: "Quality is the set of characteristics which differentiate the individual units of a product and which are important in determining the degree of acceptability of the product. this unit by the user" (Groom, 1990).

For the meat industry, meat quality is a term used to describe the overall characteristics of meat, including its physical, chemical, morphological, biochemical, microbial, sensory, technological, hygienic, nutritional and culinary properties (Ingr, 1989).

4.2. International laws

Regarding international laws on the consumption and production of meat products, we can list among others:

- Regulation (EU) No. 1169/2011 of the European Parliament and of the Council of 25 October 2011 on consumer information on foodstuffs, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council and repealing the Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Directives 2002/67 /EC and 2008/5/EC and Commission Regulation (EC) No 608/2004.
- Commission Regulation (EC) No. 2073/2005 of 15 November 2005 concerning microbiological criteria applicable to foodstuffs.
- Regulation (EC) No. 853/2004 of the European Parliament and of the Council of 29 April 2004 establishing the specific hygiene rules applicable to foodstuffs of animal origin.

4.3. Laws in Cameroon

Until now the government authorizes the consumption of all non-toxic meat, that is to say any meat that does not present:

- A bad taste and unpleasant odor (sour, rotten, musty, etc.);
- A change in color and a smell of rot;
- Swelling of the bags with the production of gas (CO and H2S) by bacteria present on packaged meats.
- Below we list some standards voted by the Cameroonian government according to the ANOR Cameroonian standards catalog published in April 2015;
- The standard (NC 183, 2014): Recommended international code of practice for hygiene for fresh meat;
- The standard (NC 184, 2014): Recommended international code of practice for hygiene for processed meat and poultry products;
- The standard (NC 307, 2014): Code of Hygienic Practice for Meat;
- The standard (NC 383, 2014): Guide to the microbiological quality of spices and condiment herbs used in processed meat and poultry products;
- The standard (NC 323, 2014): Code of practice for the reduction of contamination of foods by polycyclic aromatic hydrocarbons (PAHs) from smoking and direct drying processes;
- The standard (NC 533, 2014): Standard for smoked fish, smoke-flavoured fish and dried smoked fish.

5. The difficulties encountered by the actors and their needs

We present here some difficulties that we perceived at Yanick (6 years of experience in breeding and selling chicken in Dang-Ngaoundéré-Cameroon), who smokes chickens at the request of customers, and Christine (27 years of experience in smoking and selling fish in Lagdo-Garoua-Cameroon), who smoke fish for sale in the locality of Lagdo and Garoua; and sometimes smoking chickens on demand. These include, among other things:

- Loss of time (cleaning, pre-drying in the sun on average 1h30 minutes):
- Failure to master the processes and stopping the operation through trial and error/experience
- Distress (back pain, cough and smoke in the eyes after each operation);
- Product dry from the outside and moist from the inside; breakable often caused by failure to control smoke and temperature;
- Manual combustion system (you will have to relight the coal fire if it goes out);
- Risk of microbial contamination of the finished product because they are exposed to the open air and the particles of ash and dust which are deposited on them without forgetting the fuels, they use for the production of smoke are not clean;
- Non-uniformity of the colour of the finished product;
- Low smoke production and excessive consumption of fuels (coals, pieces of wood and sometimes they use old cardboard, sawdust and wood chips). They simply suffocate them to increase smoke production;
- Manual combustion system (you will have to relight the coal fire if it goes out).

a) Cleaning and pre-drying

b) Smoking/turning

Fig. 19: Smoking Chicken.

a) Pre-drying before smothering **b) Choking** **c) Smoking/turning**

Fig. 20: Smoking Fish.

The needs expressed by the stakeholders in terms of equipment characteristics are:

- Speed (at least 1 hour per cycle);
- The capacity of the products to be transformed must be up to 500 or even 2000 products per hour;
- The finished product must be tender and not too dry;
- The equipment must be very economical in terms of fuel and energy consumption;
- And the price/quality ratio must be affordable.

6. Conclusion

Having reached the end of our work, it should be remembered that we have taken stock of the conservation processes and equipment using smoking and drying methods for meat products. In doing so, we first, in this document, reviewed the scientific laws, the technical states, the commercial review, the patent review as well as the legal laws. We then presented the difficulties and needs expressed by the actors. From this study, it emerges that the needs of stakeholders must be taken into consideration during the design and construction phase. It is noted that, until now, equipment for smoking and drying meat products, and its process making it possible to guarantee food safety, user safety, retaining all nutrients, ergonomic, using fewer resources, fast, adaptable to any type and size of smoking products remains to be explored.

Acknowledgement

This work was supported by the Institut de la Francophonie pour le developpement durable (IFDD/Canada)/Projet de Deploiement des Technologies et Innovations Environnementales (PDTIE) funded by the Organisation International de la Francophonie (OIF), the Organisation of African, Caribbean and Pacific States and the European (EU) (FED/220421-370). I would like to offer our deep appreciation to PEPITA-UN for their constant support, important advice, and encouragement. I want to thank my Scientifics parains Pr-Hdr Ndjiya Ngasop, Pr Njintang Nicolas, Dr Boussaibo André and Dr Tchami Hilaire for their contribution. I say thank also to my father M Guidzavai Balagued, to my friends and research colleagues for theirs sustains, as well as for their insightful comments, lively debates, and helpful criticism. Their varied viewpoints substantially improved this work.

References

[1] African Intellectual Property Organization., Patent invention booklet No. 16441, 2013.
[2] African Intellectual Property Organization., Patent invention No. 20365, 2022.
[3] Ahmat T., Contribution to solar drying of meat products: Modeling and creation of a dryer suitable for tropical countries, 2015.
[4] Ahmat T., Waste A., Bruneau D., Solar drying of beef: experimental characterization of the product, modeling and implementation of a solar dryer adapted to tropical countries, 2013.
[5] Akakpo A., Edikou S., Diantom A., Osseyi E., Diagnosis of smoking practices for chicken meat (Gallus Gallus) in the city of Lome in Togo, 2020.
[6] Ango S., Bruneau D., Mbega D., Aregba W., New concept of drying and artisanal smoking of foods: application in the artisanal fishing environment in Gabon, 2013.
[7] Anne K., Fish processing techniques on the African Atlantic coast: the development of salting, drying and smoking for local use, 1998.
[8] Benabdelmoumene D., Nutritional and organoleptic qualities of local poultry meats and eggs. Influence of sex and genotypes, 2016.
[9] Benyamina H., Evaluation of the nutritional and organoleptic quality of white meats: case of Turkey and Chicken, 2017.
[10] Boulemtafes A., Semmar D., Design and Construction of an Indirect Solar Dryer, 1999.
[11] Brigitte M., Brigiet B., Corlien H., The conservation of fish and meat, 2005.
[12] Catherine B., Drying of food products, 2013.
[13] Dib A., Transformation of muscle into meat, 2021.
[14] Edoun M., Development of a tool to help design small-scale drying processes in humid tropical areas, 2010.
[15] European Patent Office., European Patent Book No. EP1985 183 B1, 2009.
[16] European Patent Office., European Patent Document No. 0587515A1, 1993.
[17] European Patent Office., European Patent Specification No. EP1619964B1, 2003.
[18] European Patent Office., European Patent Specification No. EP1994829B1, 2009.
[19] European Patent Office., European Patent Specification No. EP3500113B1, 2020.
[20] Fabrice T., Temperature regulation in a biomass dryer-smoker by convection and heat recycling: application to fish Tilapia niloticus, 2020.
[21] FAO., Traditional conservation/preservation techniques for livestock products, 2014.
[22] François D., Formulation and dehydration of poultry meat by immersion. Study of matter transfers at atmospheric pressure and under vacuum, 2012.
[23] Gret., Drying food products. Techniques, processes, equipment, 1995.
[24] Haliomer Aquatic Products Technical Center., Fish smoking, 2010.
[25] Hamdani A., Ouchen Z., Contribution to the study of the physicochemical and microbiological quality of meat products, 2018.
[26] Henry A., Cirad-sar., Valorization of fishery products at OUVEA, 1996.
[27] Iaka K., Fish smoking and smoking ovens, 2001.
[28] Khalid T., Agadir I., Salting-Drying-Smoking, 2016.

[29] Knockaert C., Electrostatic smoking: Application to seafood, 1995.
[30] Lessire M., Quality of poultry meat: the role of dietary fat, 1995.
[31] Listrat A., Lebret B., Louveau I., Astruc T., Bonnet M., Lefaucheur L., Bugeon J., How the structure and composition of the muscle determine the quality of meat or flesh, 2015. https://doi.org/10.1155/2016/3182746.
[32] Ludovic C., Acquisition of the organoleptic qualities of beef: adaptation to consumer demand, 2008.
[33] Marne A., Design of a rotating cylinder dryer for granulated cereal-based products (application to "arraw"), 2003.
[34] Ministry of Livestock, Fisheries and Animal Industries of Cameroon., Official health control of poultry meat (Procedures Manual), 2015.
[35] Ministry of Livestock, Fisheries and Animal Industries of Cameroon., Strategy document for the livestock, fisheries and animal industries sub-sector, 2011.
[36] Nadine B., Sheet on the different types of natural and forced convection solar dryers, 2004.
[37] Nadine B., Sheet on shellfish and geho dryers, 2004.
[38] National Institute of Industrial Property Courbevoie -France., Patent of Invention Book No. 3118854, 2022.
[39] National Institute of Industrial Property Paris-France., Patent of Invention Book No. 2597722, 1987.
[40] Ndiaye O., Sodoke K., Diei-Ouadi Y., The FAO-Thiaroye transformation technique (FTT-Thiaroye), 2014.
[41] OECD/FAO., OECD-FAO Agricultural Outlook 2020-2029, 2020.
[42] OECD/FAO., OECD-FAO Agricultural Outlook 2021-2030, 2021.
[43] Pascale M., Encyclopedia: Question on… Production, consumption and trade of poultry meat, in the world, 2021.
[44] Rabih R., Study of post-mortem biochemical changes in poultry muscle contribution to the determinism of the amplitude of the reduction in pH, 2005.
[45] Randrianaivo R., Creation of a smokehouse dryer and a solar dryer adapted to different regions for smoking and drying agri-food products, 2014.
[46] Rekibi A., Bernou B., Factors influencing broiler meat quality: Literature review, 2020.
[47] Rivier M., Kebe F., Goli T., Fish smoking in West Africa for local and export markets, 2009.
[48] Romain A., Fish processing and conservation in Ivory Coast, 1997.
[49] Rose E., Contribution to the study of the quality of grasscutter meat (thryonomys swinderianus, temminck, 1827): characterization of the chemical composition and color of the muscles of the pelvic limb, 2009.
[50] Salifou C., Boko K., Attakpa Y., Agossa R., Ogbankotan I., Farougou S., Mensah G A., Salifou S., Evaluation of the bacteriological quality of fresh meat from cattle slaughtered at the Cotonou slaughterhouses Porto-Novo during the distribution chain, 2013.
[51] Suisse N., Viande information, 2011.
[52] Tchamye T., Tool to help design dryers for tropical agricultural products, 2011.
[53] The National School of Technical Engineers for the Agricultural and Food Industries., Numerical study of the distribution of smoke in an industrial smoking enclosure, 2002.
[54] Tossa C., Study and design of a fish smokehouse, 2015.
[55] United Nations Economic Commission for Europe., UNECE standard for chicken meat carcasses and parts, 2007.
[56] Unknown., Poly_Meat (6pages).
[57] World Intellectual Property Organization International Bureau., Patent invention booklet, N°WO 2020/207868 Al, 2020.