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Literature review on *Prosopis africana* and the use of essential oils as preservatives

GANGBE Modesty, KPATINVOH Brice*, ATTREVY Brice, ALLAGBE Aymard et DEGNON René.

Laboratory of Study and Research in Applied Chemistry, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, 01 PO Box: 2009 Cotonou, Benin.

Abstract:
The present study aims to review the status of Prosopis africana, the fermentation of its seeds and the use of plant extracts (essential oils) as a preservative for foodstuffs. This study reveals that the main uses of Prosopis africana are human food, fodder, wood as a source of energy, production of handicrafts and furniture and traditional pharmacopoeia. It also shows that the seeds are fermented to produce food condiment (Okpeye) which is a rich food and promotes the development of certain microorganisms. In order to maintain the quality of foodstuffs, industrialists use chemical agents to preserve their food products causing huge health problems. Some recent studies show that the use of essential oils can be an alternative to preserve the quality of foodstuffs. This review of the literature therefore focuses on Prosopis africana and the use of essential oils as a preservative for foodstuffs.

Key words : *Prosopis africana, fermentation, essential oils, seeds.*

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I. Introduction

Benin is one of the countries of West Africa that has an enormous forest resource. Among these resources, we note the woody species that play a great role in the life of the rural population. Many authors have affirmed their importance on the socio-economic and cultural level as well as the products and services they offer to the populations (Mathias *et al*., 2000; Yamego *et al*., 2013 and Abdou LAOULI *et al*., 2014). In addition, these woody species constitute a very important contribution to human and animal nutrition (Moussa *et al*., 2015). Because of global warming and the abusive felling of these woody species nowadays, many species have disappeared and others are threatened with extinction. *Prosopis africana is one* of these species, no part of which escapes domestic use (Arbonnier, 2000). The general objective of this work is to review the status of *Prosopis africana*, the fermentation of its seeds and the use of plant extracts (essential oils) as a preservative for foodstuffs.

1. General information on Prosopis

The genus Prosopis belongs to the legume family (Fabaceae). There are 44 known species, three of them native to Asia, one to Africa, and the rest are native to the Americas (Sciammaro *et al.* , 2016). Different species are encountered around the world with names that vary from locality to locality. . In India, *Prosopis cineraria* is called "Khejri" or "Kalpavriksha" (Kumar *et al.* , 2019), "Jand" in Pakistan, and "Ghaf" in Arabic (Malik *et al*., 2013). The African species, *Prosopis africana*, located primarily in Nigeria, is known as "Kiriya" or "Okpehe" (Zubair *et al*., 2018), and in Kenya, *Prosopis juliflora* is known as "Mathege"(Khobondo, Kingori, and Manhique, 2019). In northern Argentina, *Prosopis ruscifolia* is named "Vinal" (Bernardi, Sánchez, Freyre, and Osella, 2010). In general, in South America, *the Prosopis tree* is called "Algarrobo" (Pérez *et al*., 2014) and in North America it is known as "Mesquite" (GallegosInfante *et al*., 2013). This plant has an essential place in the history of early settlers. Since ancient times, people from the United States, Mexico, Peru, Bolivia, Chile, Paraguay, and Argentina have taken advantage of this tree for their survival (Capparelli and Prates, 2015). In addition, the tree has significant economic value as a source of fuel and fodder (Anand *et al*., 2017), in charcoal production, and as a building material (Bekele *et al.* , 2018). *Prosopis* bark, flowers, leaves and pods are used in traditional medicine (Garg and Mittal, 2013). In the case of pods, beyond their sedative and anti-inflammatory properties, they have been a source of food for humans and animals (Pérez *et al*., 2014).

For the environment, *the Prosopis tree* has several advantages. It can grow in arid and semiarid regions (where other crops barely thrive), it does not require annual plantings and can accompany other crop species (in India is planted near the millet crop), and it tolerates extreme temperatures (Anand *et al*., 2017; Rodriguez *et al.*,

2019) as well as alkalinity and salinity. It improves and stabilizes the soil as it promotes nitrogen fixation (Cardozo *et al.*, 2010),and is fast growing and drought resistant (Estévez *et al.* , 2014). However, this legume is an orphan crop class, as it belongs to the group of minor crops of regional importance that have been neglected by researchers and industry due to its limited economic importance in the global market (Díaz-Batalla *et al.*, 2018a,b; Mamone *et al.*, 2019). Practically, industrial use of *Prosopis* is non-existent.

1.1. Description of *Prosopis africana*

P. africana is the only one of the many species in the Prosopis family that is native to Africa (Nwokocha *et al.,* 2021). *Prosopis africana* is a tree that can grow up to 12-20m tall, with a straight, cylindrical bole up to 1.10m in diameter, a spreading crown and light green drooping foliage. Its bark is cracked, rough, gray to blackish, with thin irregular scales that reveal light brown spots when detached. The edge of this tree is hard and reddish with a thick bistre and chocolate rhytidome. The branch is brown and more or less pubescent. The leaves are alternate, bipinnate, hairless, 7-15cm long, with 2-4 pairs of opposite pinnae and have 6-12 pairs of leaflets per pinnule. The leaflets are oblong or linear lanceolate 1.5 - 2 x 0.5 - 0.8 cm, with an apiculate apex, with a rounded base. The petiole is pubescent, often bearing a gland at the base of each pair of pinnules. The dense solitary spike located at the base of the leaves, with a peduncle 4-6cm long, about 1.5cm in diameter. The fruit is hard and thick, more or less cylindrical and shiny, dark chocolate to blackish, indehiscent, containing about 10 seeds, persisting for a long time on the tree. In Benin there are fruits with 18 to 20 seeds. The wood is yellow to light brown with a dark brown heart, very hard and resistant to termites (Arbonnier, 2002). Photos 1, 2, 3 and 4 show the stem, tree, seeds and fruits or pods of *P. africana* respectively.

Photo 1 : Stem of Prosopis africana

Photo 2 : Tree of Prosopis africana

Photo 3 : Seeds of *Prosopis africana*

Photo 4 : Fruits of *Prosopis africana*

1.2. Geographical distribution, ecology and phenology

The distribution area of the species extends from Senegal to Cameroon to Sudan, quite common and scattered. It is found in the Guinean and Sudanese savannahs especially on sandy-clay soils. It generally flowers at the first rains shortly after the foliage (Arbonnier, 2002).

1.3. Different uses of *Prosopis african*

1.3.1. Uses of *Prosopis africana* in the pharmacopoeia

P. africana is used in traditional pharmacopoeia. Organs such as leaves, barks and roots are used for the treatment of ailments. The most common ailments treated are stomach ache, diarrhea and hemorrhoid crisis. The method of preparation involves decoction of organs, grinding of leaves, bark and root into powder (Nwokocha *et al.,* 2021). In addition other diseases such as malaria, epilepsy, dermatitis, anemia, fragility of babies, body irritations, coughs and stomach and throat aches are also treated by *Prosopis africana* (Kolawolé F. M. ALI *et al*., 2016).

1.3.2. Use of the wood *Prosopis africana*

The wood of *P. africana* is used as a source of energy, furniture making, statuette (Kolawolé *et al*., 2016); due to its strength and hardness, it is mainly used as a support for granaries and sheds, the fence of houses. *P. africana* wood is also used in the manufacture of household utensils and tools such as mortars, pestles, handles of farming tools and to make charcoal, the quality of which is highly valued by blacksmiths.

2. General information on the seed of *Prosopis africana*

The seeds of *Prosopis africana* are ovoid, of brownish to blackish color, with hard and smooth tegument. On average, there are a dozen seeds per pod. (Arbonnier, 2002). The seeds are 8-10 mm long and 4-9 mm in diameter. They are shiny, dark brown and ellipsoidal (Vautier *et al.* , 2007). The defatted seeds of *Prosopis africana* contribute 53.6% by weight of a water-soluble polysaccharide. The Prosopis seed polysaccharide is a galactomannan and has an M/G ratio of 1.4-1.9 (Okpara *et al.*, 2017).

2.1. Use of *Prosopis africana* seed

Prosopis africana seeds are used in animal feed as fodder and in human food as food condiment case of *Okpeye* in Nigeria. (Okpara *et al.*, 2017).

3. General information on seed fermentation

Fermented foods are an integral and important part of the diet of many people in Nigeria. Plant sources, especially seed legumes, are fermented and used as traditional condiments (Odunfa, 1985a). The most popular include African locust bean *(Parkia filicoidea) dawadawa* (Antai and Ibrahim, 1986; Ikenebomeh *et al*., 1986; Odunfa, 1981a), castor bean *(Ricinus communis)* (Odunfa, 1985b) and melon *(Citrullus vulgaris)* seed (Odunfa, 1981b). *Prosopis africana* is one of the lesser known legume seed crops used as a food condiment in Nigeria. Fermented mesquite is popular in parts of Nsukka and Idah where it is locally called *Okpeye*. It adds variety and pleasure to the otherwise monotonous traditional diet. It serves not only as a seasoning but as a low cost meat substitute for traditional poor families. Fermentation of cereal and mesquite seeds is said to result in an increase in nutritional value and safety compared to the raw material (Van Veen and Steinkraus, 1970). Fermentation also contributes to the masking of undesirable odors and flavors while imparting desirable flavor to the finished product (Beauchat, 1976). Most importantly, fermentation is provided to improve the digestibility of raw materials by breaking down complex protein structures into peptides and free amino acids (Hesseltine and Wang, 1979).

3.1. *Okpeye* and its production

Okpeye is an oilseed-based seasoning somewhat like *dawadawa* (fermented soybean), but made from the fermentation of the cotyledons of the African mesquite (*Prosopis africana*). Like *dawadawa*, *Okpeye is* primarily used by people in the southeast and central belts of Nigeria to flavor soups and other varieties of traditional dishes. The details of the traditional process may also vary by culture. According to the work of Ugwuanyi (2016), the most popular process practiced in some parts of southeastern Nigeria involves first boiling the *P. africana* seeds for periods ranging from less than 6 h to more than 12 h or until they are tender and the cotyledon is swollen. This is followed by dehulling (manually) by pressing the seeds between thumb and forefinger to extract the cotyledons. The extracted cotyledons are washed several times, drained completely and heated dry (apparently to inactivate non-spore forming microbial contaminants) in a pot lined (bottom side up) with a few layers of *Alchonea cordifolia* leaves (commonly referred to by the local community as 'akwukwo okpeye' or 'abara ugba' to emphasize its role in okpeye and associated 'ugba' fermentations). Depending on the processor, other leaves may be used. The same leaves are used to line shallow local raffia or other woven baskets, also upside down, and the cotyledons are transferred to the basket at a depth of 1 or 2 cm, covered to prevent drying out with more leaves, this time upside down, and then weighted down with pebbles. Fermentation takes place under the sun for a period of 4 days. At the end of this stage of the process, the cotyledons that have turned a dark brown with a strong pungent ammonia smell are ground to a fine paste on a stone or mortar and molded into different shapes and sizes. At this stage the seasoning is ready to use, but usually and preferably the balls are then dried slowly in the sun for several days depending on the intensity of the sun (season) until they become hard and black. The drying period is a second and longer stage of fermentation and maturation (drying). At the end of this stage, the product becomes more aromatic and less pungent and generally more aesthetically acceptable. The sensitive or precarious stage corresponds to the first 4 days of fermentation. Secondary fermentation or ripening is quite unique in that it is essentially self-protected and safe from microbial spoilage, as the pH is too high for spoilage organisms. In its dried or mature form, *okpeye* can remain for several months with only occasional re-drying in the sun or fire.

3.2. *Okpeye* technology diagram

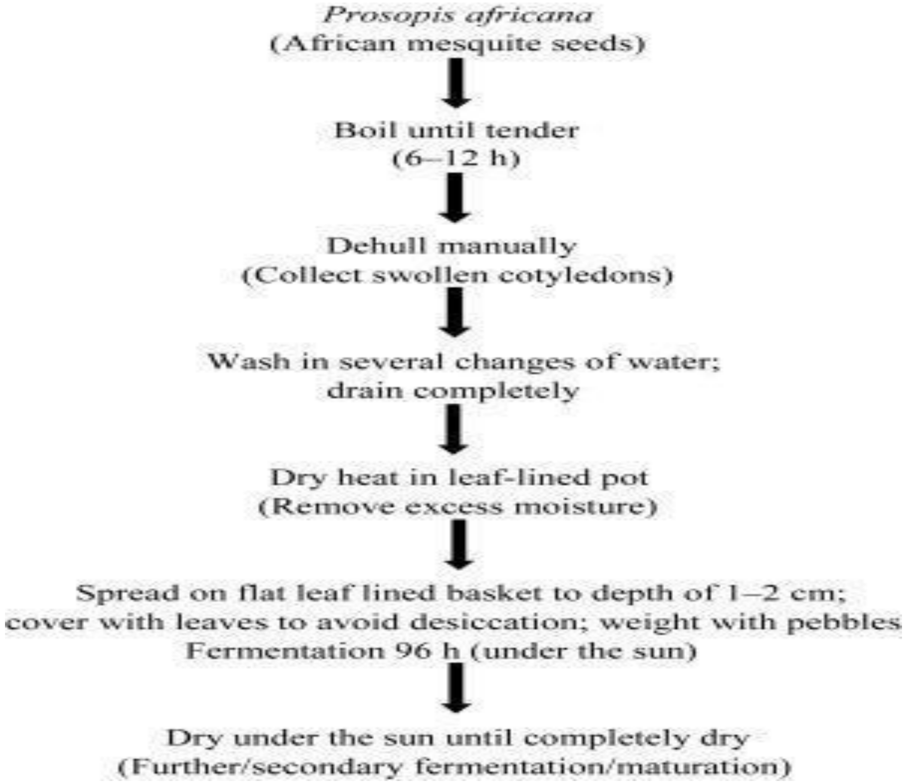

Figure 1 : Okpeye production technology diagram

Source: Okpara *et al.* 2017

4. Essential oils

4.1. Definition

Duval (2012) pointed out that there are several definitions of essential oil. Indeed, according to the Direction Générale de la Concurrence, de la Consommation et de la Répression des Fraudes (DGCCRF) reported by Duval (2012), essential oil is a volatile odorous substance produced by certain plants and can be extracted in the form of a liquid obtained by steam distillation of aromatic plants (leaves, flowers, barks, seeds, stems, etc.) which is the most commonly used extraction method. The Association Française de Normalisation (AFNOR) reported by Monvoisin (2017) defines an essential oil as a product obtained from a natural raw material of plant origin, after separation of the aqueous phase by physical processes; either by steam entrainment, or by mechanical processes from the epicarp of Citrus fruits, or by dry distillation (Standard ISO 9235: 2013). An essential oil is rarely extracted from the whole plant. Only one organ (or two) provides the desired essence. For example, cinnamon essential oil can come from the bark or the leaf, each of which then has its own properties. (Festy, 2014).

4.2. Use of essential oils:

Essential oils have many biological activities. In phytotherapy, they are used for their antiseptic properties against infectious diseases of bacterial and fungal origin. They are broad spectrum antimicrobial agents (Turbide, 2003). In the field of agri-food, essential oils are incorporated into food to reduce the microbial load and ensure preservation over a long period. In the health field, essential oils are widely used for their antiseptic, anti-infectious, anti-inflammatory, immunological, histaminic, analgesic, anxiolytic, sedative, antispasmodic, antihypertensive, vasopressor and antipyretic effects (Turbide, 2003). Essential oils act as well on Gram positive bacteria as on Gram negative bacteria. However, Gram-positive bacteria seem less sensitive to their action and this is directly related to the structure of their cell wall (Burt, 2004). Essential oils have a very broad spectrum of action since they inhibit the growth of bacteria as well as molds and yeasts. Their antimicrobial activity is mainly a function of their chemical composition, and in particular the nature of their major volatile compounds. They act by preventing the multiplication of bacteria, their sporulation and the synthesis of their toxins. For yeasts, they act on biomass and pseudomycelium production while they inhibit spore germination, mycelium elongation, sporulation and toxin production in molds (Adjou et al., 2012). The growth of bacteria, resistant and multi-resistant to antibiotics, can be inhibited by certain essential oils. Citrus, lavender, mint, juniper, tea tree, thyme, and eucalyptus essential oils have been shown to be particularly effective against methicillin-resistant staphylococcus aureus (Kalemba and Kunicka, 2003). The perfume, aroma and cosmetic industries are also among the main users of essential oils. They are indeed the basic products used to add odors, because of their high volatility and the fact that they do not leave a greasy trace. Essential oils are widely used to perfume cosmetic products: soaps, shampoos, shower gels, cosmetic and/or moisturizing creams, and others. The sector of the household products (detergents and detergents for example) consumes a lot of essential oils to mask the odors, often not very pleasant, of pure products. The use of essential oils in food flavorings is growing (Adjou et al., 2012).

4.3. Mechanism of action of essential oils:

The mechanisms of antimicrobial action of plant extracts have been widely reported by several scientific works. Indeed, essential oils kill the fungal cell by binding mainly to ergosterol, the main sterol present in the fungal cell membrane. This binding destroys the osmotic integrity of the membrane, and this is followed by an intracellular leakage of potassium, magnesium, sugars and metabolites, and finally cell death. The lipid characteristics of essential oils act by the same mechanism. It has been suggested that oxidative damage due to essential oils may also contribute to their antifungal activity against Candida (Ultee *et al.*,2002). Given the large number of different chemical compound groups present in essential oils, it is very likely that their antibacterial activity is not attributable to one specific mechanism but has multiple targets in the cell. An important characteristic of essential oils and their components is their hydrophobicity, which allows them to partition into the lipids of the bacterial cell membrane and mitochondria, disrupting the structures and making them more permeable. Leakage of ions and other cellular contents can then occur (Ultee *et al.*,2002). Figure 1 shows the locations in the bacterial cell that are considered sites of action for essential oil components. The main effects are: cell wall degradation, cytoplasmic membrane damage, membrane protein damage, leakage of cell contents, cytoplasmic coagulation, and depletion of the proton motive force (Ultee *et al.*,2002 and Burt, 2004).

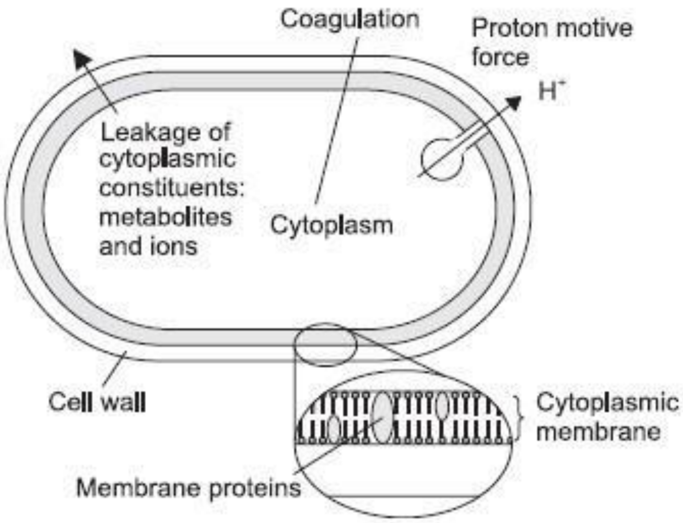

Figure 2 : Locations in the bacterial cell considered as sites of action for essential oil components (Burt, S. 2004). In addition, the use of volatile plant extracts to improve food quality has been proposed by several studies (Table 1).

Table 1 : Some uses of essential oils in food.

Categories	Food products	Plant extract/Constituents	Applied concentrations	Targeted microbial flora	Reference
	Minced mutton	Essential oil *of S. aromaticum*	0,5-1%	*Listeria monocytogenes*	Vrinda Menon and Garg, 2001
	Roast Beef	Eugenol	0,1 ml spread on the surface of 25g of product	*Listeria monocytogenes*	Hao et *al*, 1998
	Fillet of beef	Essential oil of *Origanum vulgare*	0.8% v/w	*Listeria monocytogenes and total flora*	Tsigarida et al., 2000
Meat					
	Pate	Essential oil of *Mentha piperita*	0.5 - 2.0% v/w	*Listeria monocytogenes; S.*	Tassou et al, 1995

				enteridis	
Shrimp	Cooked shrimp	Essential oil of *Thymus vulgaris*	0,75 – 1,5%	*Pseudomonas putida*	Ouattara et al., 2001
	Red *grouper* fillet, cut into cubes	Carvacrol, citral, geraniol	0.5 - 3.0% v/w	*Salmonella typhimurium*	Kim et *al.* 1995
Fish	Smoked Horse Mackerel	Essential oil *of Ocimum gratissimum*	0,25 ml/70g	*Total flora*	Dègnon et *al*., 2013
	Mozzarella (Fermented milk)	Essential oil *of S. aromaticum*	0,5 – 1% 0,005 – 0,5%	*Listeria monocytogenes*	Vrinda-Menon and Garg, 2001
	Yogurt	Essential oil *of S. aromaticum*		*Streptococcus thermophilus*	Mendoza-Yepes et *al*, 1997
Dairy products	Yogurt	Essential oil of *Mentha piperita*	0.5 - 2.0% v/w	*S. enteritidis*	Tassou et al, 1995
Plant products	Lettuce leaf	Essential oil of *Thymus vulgaris*	0.1 - 10 m/L in rinsing water	*E. coli O157:H7*	Singh et *al*. 2002
	Tomato	Essential oil *of Ocimum gratissimum*	1600ppm	*Total flora*	Houinsou et *al*. 2012.

4.4. Legislation

A number of molecules that make up essential oils have been registered by the European Commission for use as flavourings in foodstuffs. The registered flavors are considered to pose no health risk to the consumer and include, among others, carvacrol, carvone, cinnamaldehyde, citral, *p-cymene*, eugenol, limonene, menthol and thymol (Burt, 2004). Estragole and methyl eugenol were removed from the list in 2001 due to their side effects (European Commission, 2002).

The United States, through the *United States Food and Drug Administration* (USFDA) has classified these substances as Generally Recognized as Safe Food Additives (GRAS) (Burt, 2004). However, Estragole, expressly prohibited as a flavoring in the European Union, is allowed on the USFDA list (Burt, 2004).

New flavourings can only be registered after toxicological and metabolic studies according to the Regulatory Commission (EC) No. 622 (2002), which could involve a considerable financial effort. If these molecules are added to food for purposes other than flavoring, they can be considered as new food additives. Thus, obtaining approval as a safe food additive would involve extensive metabolic and toxicological studies, which may be cost prohibitive. Therefore, it would be more attractive, especially for developing countries, to use a spice or essential oil as a food ingredient than to use molecules that will require prior approval (Smid and Gorris, 1999).

II. Conclusion

In order to characterize the seeds of *Prosopis africana* and to valorize them as a food coproduct, many of alternatives have been mentioned in the literature. In our review we have highlighted the *Prosopis africana* tree, fermented *Prosopis africana* seeds such as the case of *Okpeye* which is a condiment made from *Prosopis africana* seeds and consumed in Nigeria and the use of plant extracts in food preservation. Few studies have been conducted on the preservation and processing of *Prosopis africana* into other food products (e.g. broths). The use of plant extracts such as *Occimum gratissimum* and *Syzygium aromaticum* have been suggested in this study for the preservation of food products from *Prosopis africana*.

References

[1]. Matthias M, Henri T, Félix H. 2000. Multipurpose timber in tropical farming systems: a case study from Côte d'Ivoire. Schweiz. Z. Forstwes, 151(10): 355-364.
[2]. Yameogo G, Yelemou B, Boussim IJ, Traore D. 2013. Management of the agroforestry park in the Vipalogo terroir (Burkina Faso): contribution of woody plants to the satisfaction of the population's needs. Int. J. Biol. Chem. Sci. 7(3): 1087-1105.
[3]. Abdou LAOUALI , I. DAN GUIMBO , M. LARWANOU , M. M. INOUSSA, A.MAHAMANE. 2016. Use of Prosopis africana (G. et Perr.) Taub in the south of Aguié department in Niger: the different forms and their importance. Int. J. Biol. Chem. Sci. 8(3): 1065-1074.
[4]. M. Moussa , L. Mahamane, M. Saadou. 2015. Characterization of woody stands of Faidherbia albida (Del) A. Chev. and Prosopis africana (Guill., Perrot et Rich.) Taub. parks in south-central Niger. Journal of Applied Biosciences 94:8890 – 8906.
[5]. ARBONNIER Michel, 2002, Arbres, arbustes et lianes des zones sèches d'Afrique de l'ouest. Paris, CIRDAD, MNHN, 2nd edition, 573p.
[6]. Sciammaro, L. P., Ribotta, D. P., & Puppo, M. C. (2016). Traditional Food Products from Prosopis sp. Flour. In K. Kristbergsson & J. Oliveira (Eds.), Traditional Foods (first, pp. 209-215). Springer.
[7]. Kumar, M., Govindasamy, J., & Nyola, N. K. (2019). In-vitro and in-vivo AntiHyperglycemic Potential of Prosopis cineraria Pods Extract and Fractions. Journal of Biologically Active Products from Nature, 9(2), 135-140.
[8]. Malik, S., Mann, S., Gupta, D., & Gupta, R. K. (2013). Nutraceutical Properties of Prosopis cineraria (L.) Druce Pods: A Component of "Panchkuta." Journal of Pharmacognosy and Phytochemistry, 2(2), 66-73.
[9]. Zubair, M. F., Atolani, O., Ibrahim, S. O., Oguntoye, O. S., Oyegoke, R. A., & Olatunji, G. A. (2018). Fatty acids Composition, Antimicrobial Potential and Cosmeceutical Utilization of Prosopis africana Seed Oil. Journal of the Mexican Chemical Society, 62(3), 39-50.
[10]. Khobondo, J. O., Kingori, A. M., & Manhique, A. (2019). Effect of incorporation of ground Prosopis juliflora pods in layer diet on weight gain, egg production, and natural antibody titer in KALRO genetically improved indigenous chicken. Tropical Animal

Health and Production.
[11]. Bernardi, C., Sánchez, H., Freyre, M., & Osella, C. (2010). Gluten-free bread formulated with Prosopis ruscifolia (vinal) seed and corn flours. International Journal of Food Sciences and Nutrition, 61(3), 245-255.
[12]. Pérez, María J., Zampini, I. C., Alberto, M. R., & Isla, M. I. (2018). Prosopis nigra Mesocarp Fine Flour, A Source of Phytochemicals with Potential Effect on Enzymes Linked to Metabolic Syndrome, Oxidative Stress, and Inflammatory Process. Journal of Food Science, 00(00).
[13]. Gallegos-Infante, J. A., Rocha-Guzman, N. E., Gonzalez-Laredo, R. F., & GarciaCasas, M. A. (2013).Thermal processing effect on the antioxidant capacity of pinole from mesquite pods (Prosopis laevigata). CYTA - Journal of Food, 11(2), 162-170.
[14]. Capparelli, A., & Prates, L. (2015). Explotación De Frutos De Algarrobo (Prosopis spp.) Por Grupos Cazadores Recolectores Del Noreste De Patagonia. Chungará (Arica), 47(4), 549-563.
[15]. Anand, S. S., Thakur, S., Gargi, M., Choudhary, S., & Bhardwaj, P. (2017). Development and characterization of genomic microsatellite markers in Prosopis cineraria. Current Plant Biology,9-10, 37-42.
[16]. Bekele, K., Haji, J., Legesse, B., & Scha, U. (2018). Economic impacts of Prosopis spp. invasions on dryland ecosystem services in Ethiopia and Kenya: Evidence from choice experimental data. Journal of Arid Environments, 158(December 2017), 9-18.
[17]. Garg, A., & Mittal, S. K. (2013). Review on Prosopis cineraria: A potential herb of Thar desert. Drug Invention Today, 5(1), 60-65.
[18]. Rodriguez, I. F., Pérez, M. J., Cattaneo, F., Zampini, I. C., Cuello, A. S., Mercado, M.I., Isla, M. I. (2019). Morphological, histological, chemical and functional characterization of Prosopis alba flours of different particle sizes. Food Chemistry, 274(March 2018), 583-591.
[19]. Cardozo, M. L., Ordoñez, R. M., Zampini, I. C., Cuello, A. S., Dibenedetto, G., & Isla, M. I. (2010). Evaluation of antioxidant capacity, genotoxicity and polyphenol content of non conventional foods: Prosopis flour. Food Research International, 43(5), 1505-1510.
[20]. Estévez, A. M., Figuerola, F., Bernuy, E., & Sáenz, C. (2014). Dietary fiber concentrate from Chilean algarrobo (Prosopis chilensis (Mol.) Stuntz) pods: Purification and characterization. Food Science and Technology International, 20(8), 629-635.
[21]. Díaz-Batalla, L., Hernández-Uribe, J. P., Román-Gutiérrez, A. D., Cariño-Cortés, R., Castro-Rosas, J., Téllez-Jurado, A., & Gómez-Aldapa, C. A. (2018). Chemical and nutritional characterization of raw and thermal-treated flours of mesquite (Prosopis laevigata) pods and their residual brans. CYTA - Journal of Food, 16(1), 444-451.
[22]. Mamone, G., Sciammaro, L., De Caro, S., Di Stasio, L., Siano, F., Picariello, G., & Puppo, M. C. (2019). Comparative analysis of protein composition and digestibility of Ceratonia siliqua L. and Prosopis spp. seed germ flour. Food Research International, 120 (December 2018), 188-195.
[23]. Rachad Kolawolé F. M. ALI.(2016). Uses of *prosopis africana* (guill. Et perr.) Taub leguminosae-mimosoideae in the commune of za-kpota in benin. Journal of geography of the Leïdi laboratory ,14 (June 2016), 0851 - 2515.
[24]. LMNwokocha. 2021. Woodhead Publishing Series in Food Science, Technology and Nutrition: Handbook of Hydrocolloids.Elsevier , pp 273-293
[25]. Vautier, H., Sacande, M., & Schmidt, L. (Ed.) (2007). Prosopis africana (Guill. & Perr.) Taub. Seed Leaflet, (132).
[26]. Augustina N. Okpara, Jerry Obeta Ugwuanyi. 2017. Evolving Status of African Food Seasoning Agents Produced by Fermentation. Soft Chemistry and Food Fermentation: a Handbook of Food Bioengineering, pp 465-505.
[27]. Odunfa, S.A., 1981a. Microorganisms associated with fermentation of African locust bean (Parkia filicoidea) during iru preparation. J. Plant Foods, 3: 245-250.
[28]. Odunfa, S.A., 1981b. Microbiology and amino acid composition of ogiri, a fermented melon (Citrullus vulgaris Schrad) product. Qualitae Plantarum. Plant Foods for Human Nutr, 32: 11-18.
[29]. Odunfa SA (1985a) African Fermented Foods. In: Wood BJB (ed) Microbiology of Fermented Foods. Applied Science Publishers, London, pp. 155-191.
[30]. Odunfa SA (1985b) Microbiological and toxicological aspects of fermentation of castor oil seeds for ogiri production. J Food Sci 50:1758.
[31]. Antai SP, Ibrahim MH (1986) Microorganisms associated with African locust bean (Parkia filicoidea Welw) fermentation for dawadawa production. J Appl Bacteriol 61:145-148.
[32]. Ikenebomeh MJ, Kok R, Ingram JM (1986) Processing and Fermentation of the African locust bean (Parkiafilicoidea Welw) to produce dawadawa. J Sc Food Agric 37:273-282
[33]. Van Veen AG, Steinkraus KH (1970) Nutritional value and wholesomeness of fermented foods. J Agri Food Chem 18:576-578
[34]. Beuchat LR (1976) Fungal fermentation of peanut press cake. Econ Bot 30:227 234.
[35]. Hesseltine CW, Wang HL (1979) Fermented foods. Chem Ind (London) 12:393-399.
[36]. Ugwuanyi, 2016. Microbial technology and food security: microorganisms put safe food on our tables. 106th Inaugural Lecture of the University of Nigeria. pp. 1.
[37]. Duval L., (2012). Essential oils in the pharmacy, p5.
[38]. Monvoisin J., (2017). Aromatherapy in clinical studies: What is the evidence for the effectiveness of aromatherapy? University of Lille 2. Master II thesis.
[39]. AFNOR, (1996). Recueil des normes françaises. 6th edition. Paris, 510 pages.Festy, 2014/
[40]. Turbide M., (2003). Essential oils to fight infections" Aromatherapy.2(6):11-16.
[41]. Burt S., (2004). Essential oils: their antibacterial properties and potential applications in foods a review. International Journal of Food Microbiol. 94: 223253.
[42]. Adjou E.S., Kouton S., Dahouenon-Ahoussi E., Sohounhloue D. C.K. & Soumanou M. M., (2012). Antifungal activity of *Ocimum canum* Essential oil against Toxinogenic Fungi isolated from Peanut Seeds in postharvest in Benin, *International Reserch Journal of Biological Science*, 1(7): 20-26.
[43]. Kalemba D., Kunicka A., (2003). Antibacterial and antifungal properties of essential oils. Curr. Med. Chem, 10: 813-8.
[44]. Ultee, A., Bennik, M. H. J., & Moezelaar, R. J. A. E. M. (2002). The phenolic hydroxyl group of carvacrol is essential for action against the food-borne pathogen Bacillus cereus. Appl. Environ. Microbiol, 68(4), 1561-1568.
[45]. Hao YY, Brackett RE, Doyle MP, (1998). Efficacy of plant extracts in inhibiting aeromonas Hydrophila and Listeria monocytogenes in refrigerated, cooked poultry Food microbiology15(4), 367-378.
[46]. Tsigarida E. Skandamis P. Nychas G-J.E., (2000). Behaviour of Listeria monocytogenes and autochthonous flora on meat stored under aerobic, vacuum and modified atmosphere packaging conditions with or without the presence of oregano essential oil at 5°C.Journal of applied microbiology 89(6), 901-909.
[47]. Ouattara B., Sabato S.F., Lacroix M., (2001). Combined effect of antimicrobial coating and gamma irradiation on shelf life extension of pre-cooked shrimp (*Penaeus spp*.). *International Journal of Food Microbiology*, 68: 1-9.

[48]. Kim J.M., Marshall M.R., Cornell J.A., Preston J.F., Wei C.I., (1995). Antibacterial activity of carvacrol, citral, and geraniol against *Salmonella typhimurium* on culture medium and on fish cubes. *Journal of Food Science*, 60(6): 1364-1374.

[49]. Degnon R. G., Agossou V., Adjou E. S., Dahouenon-Ahoussi E., Soumanou M. M. and Sohounhloue D. C. K. (2013). Evaluation of the microbiological quality of horse mackerel (Trachurus trachurus) during the traditional smoking process. Journal of Applied Biosciences, 67, pp.5210-5218.

[50]. Vrinda Menon K. and Garg S. R., (2001). Inhibitory effect of clove oil on Listeria monocytogenes in meat and cheese. Food Microbiol. 18: pp. 647-650.

[51]. Mendoza-Yepes, M.J., Sanchez-Hidalgo, L.E., Maertens, G., Marin-Iniesta, F., (1997). Inhibition of Listeria monocytogenes and other bacteria by a plant essential oil (DMC) in Spanish soft cheese. Journal of Food Safety 17:47-55.

[52]. Singh L., (2002). Overview of pigeonpea improvement research: objectives, achievements and looking ahead in the African context. In: Laxman S, Silim SN, Ariyanayagam RP, Reddy MV (eds). *Proceedings of the first East and southern Africa regional legumes (Pigeonpea) workshop. 25-27 June 1990, Nairobi, Kenya.* pp. 5-6.

[53]. Houinsou Rose de Lima, Yehouenou Boniface, Sessou Philippe, Noudogbessi Jean Pierre, Alitonou Guy Alain, Toukourou Fatiou, Sohounhloue Dominique (2012). Chemical composition and Antimicrobial activities of *Cinnamomum zeylanicum* Blume dry Leaves essential oil against Food-borne Pathogens and Adulterated Microorganisms. *International Research Journal of Biological Sciences* : Vol. 1(6), 1825, p4.

[54]. Smid E.J., Gorris L.G.M., (1999). Natural antimicrobials for food preservation. In: Rahman, M.S. (Ed.), Handbook of Food Preservation. Marcel Dekker, New York, 285308.

KPATINVOH Brice, et. al. "Literature review on Prosopis africana and the use of essential oils as preservatives." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 15(10), (2021): pp 27-34.