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REVIEW ARTICLE

Status of research results in chemistry of biologically active substances in Benin

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Abstract

Research on biologically active chemicals extracted from medicinal plants and essential oils from aromatic plants in the West African subregion is booming. Recognition of the clinical, pharmaceutical and economic value of herbal medicines continues to grow despite the growth of the pharmaceutical industry and the continued development of new, more effective synthetic and biological medical products. On the other hand, despite the improvement in food preservation technics, food preservatives nature remains one of the most important issues for public health. Indeed, several synthetic preservatives have been banned in some countries because of their long-term adverse toxicological effects. The current trend of consumers to seek for a more natural diet has prompted the research, development and application of new natural products with antimicrobial and antioxidant activities in order to use them as alternatives to synthetic preservatives. This review aims to do an inventory of the results of research in chemistry of biologically active substances in Benin.

Keywords: Biologically active substances; food preservation; human and veterinary; pharmacopoeias; plant extracts; public health

Introduction

Medicinal plants are a valuable heritage for humanity, and especially for the majority of poor communities in developing countries who rely on their primary health care and their subsistence [1]. The last twenty years have been seeing an increasing interest in both developed and developing countries for medicinal products [2]. Africa has a significant diversity of medicinal plants. Indeed, on the 300,000 species of species found on the planet more than 200,000 species are found in tropical countries in Africa and have medicinal properties [3]. In Benin, about 3,000 species invented in ecosystems [4], 172 are consumed by local populations such as food plants [5] and 814 as medicinal plants. In fact, the use of traditional medicine is widespread and has a significant health and economic significance in the country [6]. Chemistry and biology play a central role in the study and valorization of these natural resources. Chemistry, as a discipline of experimental sciences by its structural character, federator and integrator, allows extracting, characterizing and providing health-related substances. Biological applications are, however, essential for a good recovery of these resources. In Benin, several studies focused on the valorization of medicinal plants. These studies were based on ethnobotanical and ethnopharmacological surveys, determining the chemical composition of the volatile and non-volatile extracts of the various plant organs as well as the evaluation of their biological activities such as anti-inflammatory, antibiotics, antimicrobial, anticancer activities and their use as natural food conservatives [7 - 10]. Generally, each plant material studied has been collected and identified with the help of botanists and registered under a number at the National Herbier of the University of Abomey-Calavi. This review aims to identify biologically active chemicals research results in Benin. It first deals with the biological properties of

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plants used in human, veterinary pharmacopoeia and their use in the fight against post-harvest deprecators, and in the second time potential food applications of these plant species.

Biological Properties of Plants Used in Pharmacopoeia Human, Veterinary and Pest Control in Post-Harvest in Benin

Use of plants in human pharmacopoeia

In Benin, the most frequent diseases or diseases that cause most morbidity problems, temporary stopping work and mortality are many (malaria, diarrhea, broncho-pulmonary affections, infected traumatic wounds, malnutrition, cardiovascular disease, diabetes and cancers ...). To deal with these problems, medicinal plants are required. Thus *Hyptis suaveolens* are mentioned among the plants used for treating malaria while *Eucalyptus citriodora* is sought to solve the problems of cardiovascular disease, diabetics, obesity and cough etc. Other parts, extracts from *Ceiba pentandra* and *Bridellia ferruginea* are required to treat diarrhea. Other studies [11 - 12] have taken into account the evaluation of the antimicrobial properties of *Lippia rugosa* essential oils and aqueous and ethanolic extracts of *Sebastiana chamaelea*, a plant used by traditional healers in south-central Niger to treat malaria and to relieve dental flare-ups in infants, against reference bacterial strains *Escherichia coli* ATCC 25922 and *Staphylococcus aureus* ATCC 25923 on the one hand and the antifungal properties of *Sebastiana chamaelea* against *Candida albicans* ATCC 10231 on the other hand. The phytochemical screening of *Sebastiana chamaelea* revealed the presence of tanins, polyphenols, flavonoids, triterpens, steroids and traces of quinonic compounds. As for the antibacterial activity of the *Lippia* essential oils, concentrations ranged from 0.44 to 0.88μL / mL for the two infected bacteria. In addition, the ethanolic extract of *Chamaelea Sebastiana* has been more active on the studied strains than the aqueous extract which has shown very low antimicrobial activity. *E. coli* and *C. albicans* strains showed low-moderate sensitivity with ethanolic extract (9.3 $\pm$ 1.5 mm and 11.33 $\pm$ 0.55 mm respectively). *S. aureus*, on the other hand, showed a very significant sensibility (14 $\pm$ 1.7 mm inhibition diameter) with ethanolic extract with a Minimal Inhibitory Concentration (MIC) of 3.12 mg.mL^{-1} and a Minimum Bactericidal Concentration (MBC) of 12.50 mg.mL^{-1}. It should be noted that extracts from *Hemizygia bracteosa* were also mentioned among the plants used to combat diabetes in Benin [13].

Use of plants in veterinary pharmacopoeia

The use of plants in the treatment of pathologies is a common practice among pastoralists in Benin. In 2016, a study identified the formulations used by farmers to treat foot-and-mouth disease. The survey was conducted by 370 breeders in diverse departments in Benin, between July and December 2015 and revealed to treat foot-and-mouth disease, almost all the surveyed breeders associate herbal formulas with veterinary care. A total of 32 types of formulas using 32 plant species have been summarized among breeders. *Vitellaria paradoxa* is the most quoted plant species in 3 types of formulas. Plant species such as *Citrus limon* L., *Gossypium arboreum* L., *Pterocarpus erinaceus*, *Sorghum bicolor* L., *Acacia nilotica* L., *Lannea acida*, *Khaya senegalensis*, A*gelanthus dodoneifolius* were involved in two formulations. The shrubs were involved in 14 formalations and the maceration was the most used method with 27%, followed by the powder (24%) [14].

Another study identified veterinary formulations and selected the most credible before assessing the vulnerability of the plants involved. Most represented families in cash were: leguminosae (34%) and combretaceae (11%). In total 86 recipes were reported to treat 31 pathologies with the most commonly used Pest (19%). Formulations frequencies and quotes allowed to select those that are more credible. The stalks of rod were more cited (61%). Eight (08) methods of preparation were indicated with decoction (49%) as the most frequent. Thirty and one (31) species have been found vulnerable [15].

Another study has listed a range of medicinal plants commonly used to treat animal parasitic pathologies. For this purpose, an ethno-botanical survey was conducted with 787 breeders and agro-farmers of the eight agro-ecological zones of Benin. In total, five (5) medicinal plants (*Azadirachta indica*, *Cajanus cajan* , *Citus quadrangularis*, *Nicotiana tabacum* and *Vernonia amygdalina*) are used to treat coccidiose against two (2) plants (*Bombax costatum* and *Afsana prosopis*) for piroplasmose and 12 (12) plants, including *A. polyacantha*, *C. sieberiana*, *C. febrifuga* , *D. microcarpum*, *P. kotschyi*, *Z. mays* for trypanosomiasis. In addition, eighteen (18) plants, including *A. digitata*, *A. senegalensis*, *A. leiocarpa*, *Bambusa vulgaris*, *F. exasperata* were invented to treat ectoparasitoses against seventeen (17) plants including *A. flagellaris*, *C. papaya*, *E. guineensis*, *M. charantia*, *Senna alata* for forty and two (42) plants including A. digitata, A. sativum, *Anacardium occidentale*, *A. leiocarpa*, *B. ferruginea*, *C. papaya*, *C. ambrosioids*, *K. senegalensis* on, *M. inermis* and *N. canensis* to treat helminthiases. The most used organs were sheets and shells. The majority of remedies were prepared as decoration [16].

Finally, extracts from species such as *Ximenia americana*, *Khaya senegalensis* and *Daniellia oliveri* are used to treat gastrointestinal diseases of animals. The African Porcine Pest is treated by the root of *Cochlospermum planchoni* while salmonellose is treated with *Cissus quadrangularis*. Extracts from *Pseudocedrala kotschyi* and *Khaya senegalensis* were used in the traditional medicine of trypanosomiasis in livestock breeding animals [17].

Plant species used in the fight against pests in food post harvest

Benin's problems by producers during the post-harvest phase of agricultural products have long been negligible with those related to production. Meanwhile, post-harvest losses are becoming increasingly growing, since traditional technology storage and processing technologies are generally inaccurate with risks of infestation of stored products [18]. Chemical control has always been the main measure to reduce the impact of contamination after harvesting. However, applying to high doses of these synthetic chemicals in a diet storage control perspective increases the risk of presence of toxic residues in these products.

The use of plants in crop conservation has been practiced even before the appearance of synthetic insecticides. Plants were used against pests for their repulsive, contact or fumigating effects. Active molecules can vary from one family to another, within the same family and sensitivity can differ for one given insect from one stage to another. According to the studies reported by the authors [19], *Tephrosia vogelii* Hook f. has a repulsive and toxic action on *C. maculatus*, whereas *Blumea aurita* (L.) DC, which has no toxicity, has a strong repellent power over the same deprecator. In addition, *Dracaena arborea* harvested in the Mono department in Benin is repulsive while the same species collected in the Borgou department is not effective.

Other researchers have taken a look at the chemical composition and biological properties of *Cymbopogon citratus* (DC.) Stapf (Poaceae), *Cymbopogon schoenanthus* (L.) Spreng. (Poaceae), *Cymbopogon giganteus* Chiov. (Poaceae), and *Eucalyptus citriodora* Hook. (*Myrtaceae*) in the fight against the depressor *Tribolium castaneum* [20] and *Callosobruchus maculatus* [19].

In the same perspective, other authors [21 - 23] assessed the toxicity of essential oils of *Dennettia tripetala*, *Uvariodendron angustifolium*, *Premna angolensis*, *Premna quadrifolia*, *Polyalthia longifolia* and *Clausena anisata* against *Sitotroga cerealella*, a rice depaire. The chemical analysis by GC and GC / MS of these extracts showed that the *D. tripetala* essential oil was mainly composed of 2-Phenylnitroethane (52.6%), linalol (26.8%) and methyl eughenol (5.6%); that of *U. angustifolium* was dominated by geranial (44.9%), neral (32.1%) and geraniol (2.0%). The essential oil of *P. angolensis* contained 29 compounds representing 96.1% of oil against 42 compounds corresponding to 91% for the essential oil of *P. quadrifolia*. The majority compounds of these two oils (*P. angolensis* and *P. quadrifolia*) were β-caryophyllene (13.1%), (E) -β-caryophyllene (13.5%), octen-3-ol (3.2% -28%), phytol (3.7% - 4.9%), β-elemene (1.4% -21%), globulol (11.2%), germacrene-D (8.9%), α-humulin (2.9% -6.4%), α-pinene (5%), sabinene (3.7%), δ-cadinene (0 , 4% -3.3%) and linalool (3.3%). As for the essential oils of *Polyalthia longifolia* and *Clausena anisata*, the majority compounds were β-Caryophyllene (24.5%), Allo-Aromadendrene (13.5%), α-Zingiberene (9.4%), α-Humulene (8.5%) and α-Selinene (2, 6%) for *Polyalthia longifolia* oil and chavicol methyl oil (69.9%) for *Clausena anisata*. Oral toxicity assessment against *S. cerealella* at the laboratory by fumigation method in a glass jar closed at 29 ± 2 ° C and natural photoperiod with relative humidity of $70 \pm 10\%$ showed that these extracts have an insecticide and repulsive activity on the alucite. In addition, the toxicity of essential oils was also illustrated by the significant inhibition of insect emergence compared to the control groups without affecting the germination of treated rice grains.

These results suggest that studied volatile extracts can be used as a substitute for synthetic chemicals in paddy rice protection against *Sitotroga cerealella* and the reduction of food poisoning due to the use mainly of synthetic chemicals. Table 1 provides a summary of the chemical composition and the biological activity of a few species of plants.

Potential Food Applications of Vegetal Extraits in Conservation and Preservation of Public Sante

Antimicrobial properties are due to the essential oil fraction and secondary metabolites contained in the plants. The current trend of consumers to seek safe food and without food additives has led to a renewed interest in the Beninese scientists for these substances. In fact, for decades, studies have been conducted on the development of new applications and the exploitation of natural properties of plant extracts in the food sector.

Several extracts of plants have shown, in the laboratory, proven antimicrobial activity. But before they adoption as a food conservation agent, experimental results should be checked in the selected food. In general, the experimental results obtained in the model medium are confirmed on foods, but with slightly higher oils concentrations. Thus, the authors reported the efficacy of plant extracts for tomato [46], milk [47], milk waragashi cheese [48], peanut [49], fish [50], tchakpalo (local beer) [10], mango purse [51] and cowpea [52 - 53] conservation.

Table 1: Chemical and biological profiles of some plant species studied in Benin

Name of the plant / Family	Used parts	Identified chemical compounds	Sensitive microorganisms	MCB ou MIC (mgxmL-1)	Other activities detected	References
*X. Americana (*Olacaceae)	Trunk bark	phenolics, alkaloids sterols and terpenes	*Escherichia coli*	50[1]	antiradical	[24]
*K.senegalensis P. kotschyi (*Meliaceae)	Trunk bark	phenolics, alkaloids, sterols and terpenes	*Staphylococcus aureus* Escherichia coli, *Salmonella typhi* et *Klebsiella pneumoniae*	0,78-6,25[1]	antiradical	[25]
*C. quadrangularis (*Vitaceae)	Leafed stem	phenolics alkaloids, sterols and terpenes	*Salmonella typhi*	0,78[1]		[8]
D. oliveri (Fabaceae)	Trunk bark	catechol	*Escherichia coli*	0,78[1]	antiradical	[26]
C. planchoni (*Cochlospermaceae)*	Root bark	flavonoids, alkaloids	*Staphylococcus aureus, Escherichia coli , Salmonella typhi et de Klebsiella pneumoniae ,*	6,25-100[1]	antiradical, insecticide	[27] [28]
Eucalyptus citriodora (Myrtaceae)	leaf	Isopulégol, citronellal et citronellol	*Staphylococcus aureus, Escherichia coli, Candida albicans*	0,63 à 1,25[1]	antiradical	[29]
S.longepedunculata Polygalaceae)	Root bark	salicylate méthyle	*Escherichia coli, Candida albicans*	0,4-12,79	antiradical	[7]
*D. africanum (*Apiaceae)		Methylstyrene, Menthatriene, Limonene	*Staphylococcus aureus, Escherichia coli, Candida albicans*	0,53-8,43		[30]
C. odorata (Asteraceae)	leaf	Germacrène, pregeijerène, geijerène,pinene	*Staphylococcus aureus, Escherichia coli*	1,28-5,11		[31]
C. Rubens Asteraceae)	leaf	Myrcene, limonène, thujene	*Staphylococcus aureus Escherichia coli, Candida albicans,*	1,08-4,38		[32]
H. suaveolens (lamiaceae)	Aerial part	phenolics , tannins,	*Plasmodium falciparum*		antiradical, antiplasmodial	[9]
S. caudatum (Poaceae)	stem	phenolics, tannins,				[33]
O. canum (Lamiaceae)	leaf	Terpinène ; linalol, terpinèn-4-ol, caryophyllène			Fungicide antimicrobial	[34]

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Table 1 continued

Name of the plant / Family	Used parts	Identified chemical compounds	Sensitive microorganisms	MCB ou MIC (mgxmL-1)	Other activities detected	References
P. senegalensis (polygonaceae)	leaf	phenolics, alkaloids	*Staphylococcus aureus, Candida albicans,*	5-20	antiradical	[35]
P. butyracea (clusiaceae)	bark	Caryophyllène, humulène				[36]
C. giganteus (Poaceae)	leaf	cis-p-mentha-1(7), 8-dien-2-ol, transp-mentha-2,8-dien-1-ol limonène	*Escherichia coli, Staphylococcus aureus*	0,32-064	insecticide	[37]
C. schoenanttus (Poaceae)	leaf	piperitone, 2-carene	*Escherichia coli, staphylococcus aureus*	0,63	antiradical	[37]
*C.ambrosioides (*Chenopodioideae)	leaf	terpinen, ascaridole, p-cymene , isoascaridole	*Escherichia coli, staphylococcus aureus*	1,56-6,69		[37]
P. racemosa (Myrtaceae)	leaf	eugenol, myrcene, chavicol, limonene, 1,8-cineole	*Escherichia coli, staphylococcus aureus Salmonella typhi, Candida albicans*	0,24-2, 24		[37]
C. zeylanicum (*Lauraceae)*	leaf	cinnamaldehyde , cinnamyl acetate, cinnamyl benzoate;	*Escherichia coli, staphylococcus aureus, Candida albicans*	0,2-1,6		[38]
S. aethiopicus (Zingiberaceae)	leaf					[39]
A. difformis (Araceae)	racine	ethyl acetate, Toluene, décadiyne, cymene, caryophyllene			antiradical	[40]
P. biglobosa (Mimosaceae)	leaf	ethyl acetate,			antiradical	[40]
P. longifolia (*Annonaceae*	leaf	ethyl acetate,			antiradical	[40]
N. laevis (*Bignoniaceae)*	leaf	flavonoids, coumarins, tannins	*Salmonella typhi, Klebsiella pneumoniae, Escherichia coli*	0,32-1,25	antiradical	[41]
P. Santalinoides (*Fabaceae)*	leaf	flavonoids, tannins	*Salmonella typhi, Klebsiella pneumoniae, Escherichia coli*	0,32-1,25	antiradical	[41]

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Table 1 continued

Name of the plant / Family	Used parts	Identified chemical compounds	Sensitive microorganisms	MCB ou MIC (mgxmL-1)	Other activities detected	References
Eucalyptus tereticornis (Myrtaceae)	leaf	cymene, Crypton			insecticide	[42]
Cochlospermum tinctorium (Bixaceae)	leaf	cyclododecanone,			insecticide	[42]
Citrus sinensis (Rutacea)	leaf	sabinene, carene, Limonene,	*Salmonella typhi, Klebsiella pneumoniae, Escherichia coli*		antibactérienne	[43]
Melaleuca leucadendron	leaf	Terpineol, cineole, cymene, pinene, nerolidol, ledol			insecticide	[23]
Aframomum sceptrum (Zingiberaceae)	leaf	Pinene,Sabinene, myrcène, phellandrène, linalool, borneol, terpineol, myrtenyl acetate, elemene, caryophyllene, humulene, germacrene				[22]
Bridellia ferruginea (Euphorbiaceae)	Bark of stem	flavonoids, tannins, alkaloids,			antiradical	[44]
Ceiba pentandra (Bombacaceae)	root	flavonoids			antiradical	[44]
Dennettia tripetala	leaf	Phenylnitroethane, linalol, méthyleugénol			insecticides	[22]
Uvariodendron angustifolium	leaf	Géranial, le néral et le géraniol			insecticides	[22]
Pimenta racemosa (Myrtaceae)	leaf	Mycenes, chavicol, eugénol				[45]
Hemizygia bracteosa (Lamiaceae)	leaf	Known chemical profile				[13]

[1]=calculated value for MICs; - Not determined

Thus, plant extracts, especially the essential oils extracted from acclimated aromatic plants in Benin, were first addressed from their chemical composition as well as their antibacterial and antifugal power against many pathogens and alteration strains of foods. In this context, the chemical composition and biological properties of essential oils extracted from the fresh leaves of *Lippia rugosa* A. Chev [11], *Cymbopogon citratus* [54 - 55] and *Ocimum scissimum* [47] have been investigated for their use in the conservation of food products. The results of these studies have shown that the essential oils extracted from *Lippia Rugosa* A. Chev, *Cymbopogon citratus* and *Ocimum gratissimum* collected in Benin, have interesting antimicrobial properties, offering new perspectives in the fight against microorganisms which contaminate foodstuffs. Better still, the essential oil extracted from the fresh leaves of *O. gratissimum* has properties of bio-conservation of the tomato, food of great importance for the Beninese population. The antiaflatoxinogenic power of these extracts was also invested in the protection of cereals and peanuts, in large post-harvesting systems against mold contamination and the production of mycotoxins[56 - 58]. The results show the antiaflatoxinogenic power of essential oils extracted from fresh leaves of *Lantana Camara*, *Congzoidate Ageratum*, *Ocimum Scissimum* and *Ocimum Canum* harvested in Benin against toxinogenic peanut millet.

In the same order, other investigations focused on the preservation of highly perishable food products such as fish products. Indeed, in Benin, fishing has a relatively significant place in the national socio-economic balance because it contributes approximately 3% to the Brut Interior Product (GDP). However, fish conservation is difficult because of the lack of appropriate adequate conservation and climatic and environmental conditions that contribute to its rapid degradation. To limit these losses, fumes are one of the conservation methods of the fish. However, despite the many efforts made for its conservation, smoked fish remains still very perishable due to increased microbial proliferation. In this context, the chemical composition of the essential oil of *Syzygium aromaticum* acclimated in Benin and its antimicrobial properties against smoke-free ingredients, especially those of the trailer (*Trachurus trachurus*) were invested on the one hand [59]. On the other hand, the comparative efficiency of essential oils for high antibacterial activity, extracted from aromatic plants, including *Ocimum gratissimum*, *Pimenta racemosa*, *Cymbopogon citratus* and *Mentha Piperita* was studied for their use as natural conservatives of very much perishable like fried fish [59], cheese [60] and fresh cow milk [48]. These plants have the advantage of being already part of the Benenese culinary traditions.

Still with a view to valorizing agro-resources and taking into account endogenous knowledge, the plant species *Hemizygia bracteosa* (Benth) has been the subject of deep investigations. Indeed, in rural areas people use every day, local drinks from traditional production processes during festive celebrations. However, the technologies used as well as the production conditions still do not guarantee enough the health and organoleptic quality of these beverages. Thus, a diagnostic study has led to the status of endogenous knowledge of local beverages, as well as the use of plant extracts in the improvement their hygienic and organoleptic quality [10]. Similarly, the botanical species *Hemizygia bracteosa* (Benth), widely used in ethnomedicine in Benin, was studied for its biological properties in improving the sanitary and organoleptic quality of traditional *tchapalo* beer [61]. However, toxicity tests on the Wistar Albinic rat showed a toxicity at a dose of 3g / Kg of body weight on the liver [13].

These results provide new perspectives in the preservation of highly perishable foodstuffs in Benin and also illustrate the importance of using natural extracts of plants as an alternative in replacing commonly used synthetic chemicals.

Lastly, the biological properties of plant species *Spondias Mombin* L. and *Vitellaria paradoxa* Gaertn F. were also evaluated for use as a source of molecules to galactogenic properties [62]. They provide new perspectives in solving one of the many problems related to infant feeding.

However, there are some limits to the use of essential oils as food conservation agents, notably the flavoring power of some of them. However, dearomatization techniques exist and are more and more effective. Better, undesirable organoleptic effects may be limited by carefully selecting the essential oil according to the type of food concerned, but it is important to note that, in most cases, the oils concentrations used are so low, they do not alter the organoleptic qualities of food [63].

Table 2 shows effective thresholds (Minimum Inhibitor Concentration) of some essential oils for pathogens and an overview of studies showing antimicrobial activity of plant species in foods.

Conclusion and Perspectives

This work has made the inventory of research results in chemistry of biologically active substances in Benin. It appears that medicinal plants are a valuable heritage for Benin and still remain a significant source of medical care. Specific wealth and diversity of uses demonstrate the level of knowledge of medicinal plants and the dependence of the local population for primary health care. The research strives to identify the active ingredients in the perspective of developing improved traditional medicine. On the other hand, many natural properties of plant extracts make very promising conservation agents for the food

Table 2 Plant species, chemical compositions and potentialapplication in agri-food of some plant species

Plant species	Chemical compositions (%)	Sensitive isolated strains (from foodstuffs)	Concentration of extracts tested (µL.mL^{-1})	Probable Uses	References
Cymbopogon citratus	Myrcene (*10,4),* Neral (*33),* Geraniol (*6,6),* Geraniale (*41,3),*	*Saccharomyces cerevisiae, Aspergillus niger, Fusarium oxysporum, Penicillium camembertii*	500-2500	*Conservation of traditional *tchakpalo* beer * Preservation of the peuhl cheese *waragashi* * Preservation of cow's milk	[48][55-56]
Ocimum gratissimum	γ-terpinene (20,0), thymol (26,9), p-cymene (17,6), α-thujene (8,2).	*Aspergillus candidus* *Penicillium camemberti* *E. coli* *S. aureus* *Fusarium oxysporum* *Fusarium graminearum* *Fusarium poae* *Aspergillus niger*	5-1600	* Preservation of tomato * Preservation of smoked fish	[47] [60]
Pimenta racemosa		*Aspergillus candidus* *Penicillium camemberti*	5-10	Smoked fish	[60] [53]
Hemizygia bracteosa	(E)-b-Farnesene (67), trans-Nerolidol (6,2), b-Elemène (7.4)	*Penicillium citrinum*, *Aspergillus oryzae*, *Penicillium italicum*, *Penicillium citrinum*,	0.5-1.5	Conservation of traditional *tchakpalo* beer	[62] [64]
Mentha spicata	carvone (66.57), limonène (16.33) and 1.8-cineole (7.22)	*Aspergillus flavus, Aspergillus parasiticus* *Penicillium digitatum*	100-300*	Conservation of traditional beer *tchakpalo*	[65]
Mentha piperita	1,8-Cineole (*6,5), Menthone(7,4),* Menthol (*46,7),* neo-menthol (*8,28),* menthyl acetate (*6,7),*	*Aspergillus parasiticus, A. versicolor and Mucor spp*	0.50-2.5	Conservation of mango puree	[51]
Tectona grandis	Gallic tannins, catechic tannins, flavonoids, anthocyanins,	-	-	Food packaging (corn dough)	[66]

industry. Each plant extract has a variable biological activity depending on the microorganisms tested.

The use of extracts proves to be a relevant choice in the face of a specific risk of contamination or the need to reduce or replace synthetic chemical preservatives. In addition, their use in very small amounts could be envisaged due to their high efficacy. Their combined use with other conservation methods will definitely make the most important natural antimicrobial agents in the coming years to improve food life. Other properties of extracts, including antiparasitic, insecticide, antimicrobial and antiviral drugs are currently being studied to meet medical requirements, biological farming (developing biopesticides, producing animal supplements.).

In the medium and long term, this work could be an answer to the problem of antibiotics and their resistance, and to have a human and animal health application.

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