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Essential oils, an alternative to synthetic food additives and thermal treatments

Bouabida Khayreddine

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Contents

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Acronyms

AAPCP, association of American pesticide control officials; CFIA, Canadian agency for safety and food inspection; EASA, European food safety agency; AFC (Panel), scientific panel on food additives, flavorings, contact processing aids and materials with food (the panel); AFNORL, French association for standardization; MA, authorization market; ANSES, national agency for the safety of food, environment and work; ODIHR, federal association of business and industry for medicines, health foods, dietary supplements and body care; CAP, poison control center; THIS, European commission; IARC, international agency for research on cancer; COP 21, climate change conference; SCF, scientific committee on food; ECOCERT, private enterprise control and certification; EPA, environmental protection agency; FAO, food and agriculture organization; INSEE, the national institute of statistics and economic studies; ISO, international organization for standardization; JECFA, food additives joint committee of experts; NF, French standard; WHO, world health organization; EU, European union

Abstract

This report aims to explore the repercussion of the framed use of Essential Oils. These substances represent a real potential for the food industry in order to substitute for the synthetic compounds and processes that have damaging effects on health and the environment. The first part of this study highlights their main characteristics and generalities. The second part is oriented to the optimization and development of the exploitation of EO in food products. The third and final part summarizes the results of the survey submitted to the public and involving the context of alimentary EO. The conclusion, very encouraging, exposes the positive outlook regarding their use and considers a promising future for EO.

Keywords: essential oils, food-processing industry, additives, active compounds, pathogenic flora, toxicity

Abbreviations: LC50, median lethal concentration; CT, chemotype; ADI, acceptable daily intake; LD50, median lethal dose; DSE, no dose effect; DTM, toxic dose low; E, additive approved by the European union; IDF, detector flame ionization; G6PD, glucose 6-phosphate dehydrogenase; GC-MS, gas chromatography coupled to mass spectrometry; HE, essential oil; PM, picometers

Introduction

From time immemorial, the vegetable kingdom has offered man essential resources for his food. Plants, flowers and other petrol trees produce essential oils (HE) to protect against insects and diseases and to remove unwanted substances from their metabolism. These volatile and odorous substances, extracted by steaming or by expression, were already known and used by the Greeks and the Egyptians. Today, after the economic boom that France experienced since the 1960s, we observe that essential oils are increasingly used in various industries and particularly in the food industry.[1]

After the cosmetics and perfumery industries, after the pharmaceuticals industry, the agri-food industry becomes the third largest consumer of essential oils, with a global demand estimated at 18.4 billion US dollars in 2012, while it was only US $ 8.3 billion in 2004.[2] It first uses HE to flavor and color foods. Possessing different chemical composition profiles, they are also used as natural food preservatives. Several studies have been conducted on their different biological activities, such as antioxidant and antimicrobial activities.[3] These have proved to be a very promising way to overcome the risks of alterations caused either by microorganisms or by the oxidation of lipids. Nevertheless, the agri-food industry remains hesitant for large-scale application of these substances. Also, the use of synthetic additives remains predominant compared to the use of HE. It turns out that this difference calls into question their credibility.

Before using them on a large scale, the industry wants answers to the following questions: “Are essential oils substances that are safe for the health of consumers? Are they financially profitable products? Are ETs substances without limits and without technical barriers, and if not, are there viable development paths and technologies? Is the consumer prepared to buy food products containing HE? Are HEs a credible alternative, a solution for the future or just a high-tech gadget? “

Essential oils arouse a lot of interest and excite the curiosity of professionals and scientists. Many questions arise regarding their use techniques as additives or as combinations to thermal processes. This has led professionals to take advantage of these substances, provided that they also develop incorporation technologies into food products and create innovative solutions to overcome their weak points. However, these natural substances, generally presented as “safe” in food use, concentrate active compounds of plants that could sometimes be toxic or cause adverse effects on human health. Between the notions of “natural substances beneficial to health” and “natural toxic substances”, the consumer gets lost and seems to need more information about them. The industrialists realized that their only technological development was no longer sufficient. Informing and reassuring the consumer is an essential key to the successful use of EO.

It is in this context that this study is articulated, whose main objectives are to discover the expectations of consumers and their perception of HE. We aim to shed more light and answer a number of questions concerning the impact of essential oils on health. On the possibility, also, of “adopting” them as a credible alternative for an application in the food field as a conservative and aromatic natural agent, reliable and safe, with a significant interest for both the consumer and the industrialist.

Chapter I

Presentation of Essential Oils

It seems to us necessary, from the beginning of this study, to define more precisely what are the essential oils, where they come from, how they are extracted and their different uses.

Definitions and characteristics

Essential oils are widely used in the plant kingdom; some families are very rich, especially:

a) Labises: mints, cuttings, rosemary, sage, lavender.

b) Rutaceae: citrus fruits, citrus fruit, bergamot.

c) Myrtaceae: eucalyptus, guava, myrtle, clove.

There are various definitions of essential oils, but the most accurate is probably that proposed by the AFNOR (French Association of Normalization) and the FAO (Food and Agriculture Organization). The standard AFNOR NF T 75-006 defines the essential oil as being “a product obtained from a vegetable raw material, either by steam distillation or by hydro-distillation. The essential oil is separated from the aqueous phase by physical methods.[4]

The FAO gives a definition almost similar to that of the AFNOR that “essential oils are volatile and aromatic substances, extracted from many plants, most often by steam or expression training and are used mainly in pharmacy, perfumery and in the food industries.[5]

Essential oils are not present in all plants: among the 800,000 listed plant species, only 10% are able to synthesize a species and are then called “aromatic”. HEs are only composed of volatile aromatic molecules because of very low molecular weight. They are very flammable and very fragrant. Their nature is hydrophobic: totally soluble in alcohol and oils (vegetable or mineral) but not in water. Although called “oils”, these substances contain no fat and, unlike a vegetable oil, a drop of HE deposited on a paper will evaporate without a trace.

Since its 9th edition, the pharmacopoeia uses only the term “essential oil” to designate them, also called in the common language “natural essence” or “aromatic extract of plants”. The term “oil” refers to the viscous and hydrophobic nature of these substances, and the term “essential” is understood to be the main characteristic of the plant.

Used parts of the plant

Essential oils can be stored in all plant organs: flowers (oregano), leaves (lemongrass, eucalyptus), bark (cinnamon), wood (rosewood, sandalwood), roots (vetiver), rhizomes (acore), fruits (badiane) or seeds (carvi). They can be present both in different organs, the composition may vary from one organ to another (eg fruit and lemon blossom) (Annex 1).[6] The essential oil content of plants is low to very low: to obtain one liter of essential oil, it is necessary, for example, 10 kg of cloves, 4 to 10 tonnes of rose petals, 150 kg of wild flowers. lavender or 10 ares of cultivated area of hemp. The difference in yield depending on the plant will influence the price of the oil.[7]

Annex 1 List (not exhaustive) of essential oils, their Latin name, the portion used, their origin and their mode of extraction

Oil essential	Latin name	Part used	Origin	Extraction mode
Garlic	Allium sativum lily	Crushed garlic	la France	Steam distillation or hydrodiffusion PE
Dill	Anethum graveolens	Seeds	India	Hydrodistillation PE
Angelic	Angelica archangelica	Roots	France, Belgium	Hydrodistillation PE
Anise	Pimpinella anisum	Ripe fruit and dried	la France	Hydrodistillation PE
Armoise	Artemisia vulgaris	Flowering plant	Morocco	Hydrodistillation **PE**
Newt	Lavandula latifolia	Flowering tops	Spain	Hydrodistillation PE
Basil	Ocimum Basilicum	Flowering tops	Egypt	Hydrodistillation PE
Bay St Thomas	Pirenta racemosa	Leaves	Porto Rico	Hydrodistillation PE
Bergamot	Citrus Bergamia	Bark Fruit pericarp	Calabria, Sicily	Expression of Zest PE
Bigarade	Citrus aurantium, variety Amara	Bark Fruit pericarp	Italy	Expression of Zest PE
Birch	Betula alba	Birch tar	Finland	Hydrodistillation PE
Cajeput	Melaleuca leucadendrom	Leaves and stems	Florida	Hydrodistillation PE
Calamus	Acorus calamus	Rhizomes	Ceylon	Hydrodistillation PE
Cinnamon	Cinnamomum zeylanicum	Barks	Guatemala	Hydrodistillation PE
Cardamone	Elettaria Carda MOMUM	Seeds	Russia	Hydrodistillation PE
Carrot	Daucus Carotta	Seeds	Netherlands	Hydrodistillation PE
Caraway	caraway Carum	Seeds	France	Hydrodistillation PE
Cedarwood	Cedrus Atlantica	Wood	Morocco	Hydrodistillation PE

Chamomile	Anthemis nobilis	Flowers	France (Maine & Loire)	hydrodiffusion PE
Roman	Apium graveolens	Seeds	France	Hydrodistillation PE
Celery	Citrus limonum	Fruit pericarp	Italy	Expression of Zest PE
Lemon	Cymbopogon winterianus	Plant	China	Hydrodistillation PE
Lemon Ciste	Cistus labdaniférus	Leaves and flowering Tops	France	Hydrodistillation PE
Coriander	Coriandrum Sativum	Seeds	Russia Poland	Steam distillation or Hydrodiffusion PE
Cubebe	Piper Cubeba	Fruit	Malaysia	Hydrodistillation PE
Cumin	Cuminum CYMI num	Seeds	Egypt	Hydrodistillation PE
Cypress	Cupressus sempervirens	branches and dried leaves	France (Drôme)	Hydrodistillation PE
Tarragon	Artemisia Dracunculus	Flowering plant	South of France, Italy	Hydrodistillation PE or PE hydrodiffusion
Eucalyptus	eucalyptus globulus	Leaves	Spain	Hydrodistillation PE
Fennel	Foeniculum vulgare	Seeds	Provence	Hydrodistillation PE
Galbanum	Ferula Galbaniglua	Rubber	Iran	Exudation + alcoholic wash PE
Geranium	Pelargonium Graveoolens	Plant	Egypt	Hydrodistillation PE
Juniper	Juniperus communis	Berries	France, Yugoslavia	Hydrodiffusion PE
Ginger	Zingiber officinalis	Rhizomes	China	Hydrodistillation PE
Girofle Nails	Eugenia Caryophillata	Dried buttons	Madagascar la	Steam distillation or Hydrodiffusion PE
Hyssop	Hyssopus officinalis	Flowering plant	France	Hydrodistillation PE
Lavender	Lavandula officinalis	Flowering tops	France (Drôme)	Hydrodistillation **PE**
Laurel	Laurus nobilis	Leaves	France	Hydrodistillation PE
Lemongrass	Cymbon citratus	Leaves	India	Hydrodistillation PE
Lovage	Levisticum officinalis	Root	France	Hydrodistillation PE
Mandarin	Citrus reticulata	Bark Fruit	Italy	Hydrodistillation expression Zest PE
Marjoram	Thymus Masticina	Flowering stems	Spain	Hydrodistillation PE
Scentless	Matricaria chamomilla	Somrnités flowers and stems	Hungary	Hydrodistillation PE
Melisse	Melissa officinalis	leaves	France (southern)	Hydrodistillation PE
Mint	Piperata mint	Flowering plant	La France,	Hydrodistillation PE
Myrtle	Gommiphora Myrrha	Rubber	Saudi	Exudation + alcoholic washing PE
Myrrh	Myrtus Gommunis	Flowers and leaves	France	Hydrodistillation PE
Neroli	Citrus aurantium	Leaves	Tunisia	Steam distillation PE
Niaouli	Melaleuca viridiflora	Flowers	Australia	Hydrodistillation steam PE
Nutmeg	Miristica officina2is	Fruit	Indonesia	Distillation Hydrodistillation PE
Onion	Allium Cepa	Bulbs	Florida	Expression of Zest PE
Sweet Orange	Citrus aurantium, Variety dulcis	Bark fruit	Spain	hydrodistillation steam PE
Oregano	Thymus capitatus	Flowering Plant	France	distillation hydrodistillation PE
Parsley	Petroselinum sativum	Seeds Leaves	France	Steam distillation PE
Small Grain, Bigarade	Citrus aurantium	Flowering Plant	France (Southern)	Hydrodistillation steam PE
Pine	Pinus sylvestris	Seeds Leaves and stems Pine Needle	Russia	distillation hydrodistillation PE
Pepper	Piper nigrum	Ripe fruit dried and ground	India	Hydrodistillation PE
Rosemary	Rosmarinus officinalis	Stems and	France	Hydrodistillation PE

Sandalwood	Santalum album	Leaves Wood	India	Hydrodistillation PE
Savory	Satureia Hortensis	flowering plant	la France	Hydrodistillation PE
Sassafras	Sassafras albidum	Wood	USA	Hydrodistillation PE
Sage	Salvia officinalis	Flowering stems	Alps H -Provence	Hydrodistillation PE
Clary Sage	Salvia sclarea	Flowering stems	la France	Hydrodistillation PE
Terebenthine	Pinus palustris	Leaves	la France	Hydrodistillation PE
Cedar	Thuja occcidentalis	Leaves	Canada	Hydrodistillation PE
Thyme	thymus Vulgaris	Flowering plant	la France	Hydrodistillation PE
Verbena	Lippia citriodora	Flowering plant	la France	Hydrodistillation PE
Vetyver	Vetiveria zizanoides	Roots	Madagascar	Hydrodistillation PE
Wintergreen	Gaultheria procumbens	Leaves	USA	Hydrodistillation PE
Ylang Ylang	Cananga odorata	Flowers	Madagascar	Hydrodistillation PE

Principles of manufacture and extraction processes

There are several manufacturing principles that depend on the plant used. The two most common processes are distillation and expression.[8]

Distillation with water vapor

Steam distillation is the most common process because it is suitable for most plants. It is also called "extraction by hydro-distillation": the plants are deposited on a grid through which circulates steam. This brings with it the scented molecules released by the plants. The resulting solution circulates in a coil where it condenses while cooling. The essential oil has a density less than 1, lighter than water, so it remains on the surface. We thus obtain two immiscible phases which are the consequence of the hydrophobicity of the HE, which can be separated by decantation: the essential oils and the aromatic waters (or hydrolates) are charged with the water-soluble parts of the distilled essences (ex: water orange blossom, rose water, lavender water). The distillation is slow, under low temperature and low pressure with non-calcareous spring water (Figure 1).

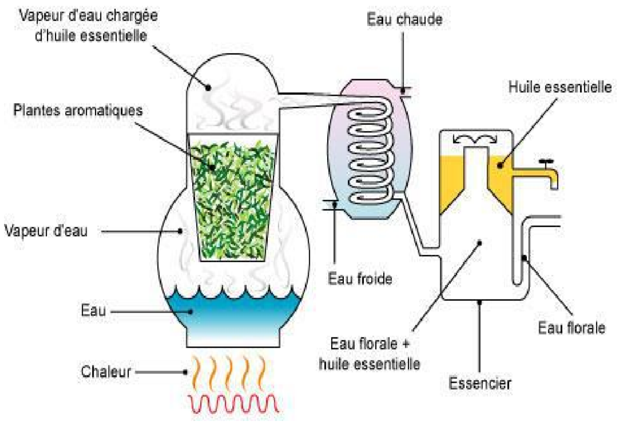


Figure 1 Extraction Process HE by steam distillation.

Expression (or cold pressure)

The citrus essential oil is found in the zests (outer part of the pericarp). To extract it, is used the technique of expression: fruits (bergamot, orange, lemon) are cold pressed. The HE is then separated from the juice by centrifugation. The product obtained is generally called "gasoline".

Other principles

When the essential oil cannot be extracted by these methods, we use:

i. **Enfleurage (or maceration)**: an ancient method used only for fragile flowers (eg jasmine, rose). The perfumes are extracted by contact with a fat which is then washed with pure alcohol. After evaporation of the alcohol, we obtain an absolute.

ii. **Solvent extraction:** a technique used to extract certain compounds contained in plants that are not driveable by water vapor. By using solvents, we obtain more complete extracts (volatile substances, triglycerides, waxes). These solvents are then removed to preserve the most volatile substances: either concrete (fresh vegetable substances) or retinoids (dry vegetable substances). The organic solvents used must be free of toxicity and easily removable: the most used are hexane, ethyl alcohol, ethyl acetate or certain chlorinated solvents. Note that benzene, widely used in the past, is now prohibited carcinogen certain (category 1) by IARC since 1987 (and category A by the US EPA since 1998).[8]

iii. **Supercritical CO_2 extraction:** Is a relatively new method that has the advantage of not using a solvent.[9]

Biochemical composition

Essential oils are complex mixtures, containing many chemical species (identifiable by chromatography). They represent the most heterogeneous group that exists, with various compounds representing a good number of organic functions (hydrocarbons, alcohols, ketones, aldehydes, esters and acids).

These major compounds belong to a class of natural products called terpenes or terpenoids. Terpenes are hydrocarbons resulting from the combination of several units of isoprene (C_5H_8), and have the basic formula of multiples thereof, i.e. (C_5H_8) -n. Terpenoids can be considered terpenes modified with added or removed methyl groups, or added oxygen atoms. The term "terpene" is used more broadly, including terpenoids. Like terpenes, terpenoids can be classified according to their number (n) of isoprene units.[1]

In addition to the majority compounds (usually 2 to 6), we find minority compounds and a number of constituents, in the form of traces. The structure of the essential oil compounds consists of a hydrocarbon backbone, constituting a more or less long chain. On this basic skeleton is often present one or more similar or different functional sites: terpenes (eg limonene, camphor), alcohols (eg linalool, geraniol), ketones (eg thujone, carvone), phenols (eg thymol, carvacrol), aldehydes (eg cinnamic aldehyde), ethers (eg eucalyptol).[10] (Tables 1–3).

Table 1 Chemical composition of the essential oil of thyme (%)[11]

Molecules	A laboratory origin 1	A laboratory origin 2	Original B laboratory 1	Origin laboratory B 2
Thymol	16.6	44.7	0.24	48.9
Camphor	3	0	38.54	0.2
Borneol	28.4	0.5	4.92	1.7
p-cymene	2.4	18.6	1.19	19
Camphene	6.9	0.3	17.19	0.8
γ- terpinene	1.7	16.5	0.55	4.1
Carvacrol Ether Methyl	9.6	0	0	1.7
α-pinene	4.2	0.8	9.35	1.2
α -humulène	6.4	0	0	0.3
1,8-cineole	0.1	0	5.45	0.7
Carvacrol	5	2.4	0	3.5

Table 2 Chemical composition of the essential oil of oregano (%)[12]

Molecules	Oregano		
	A Origin	Origin B	Origin C
Carvacrol	18.47	1.23	0.14
Linalool	0.58	28.18	3.92
Thymol	21.65	10.88	0.72
γ -terpinène	18.2	4.85	1.82
Linalyl acetate	0	0	0
Caryophyllene oxide	0.6	3.56	15.82
γ -terpinéol	0.12	0.88	2.71
E-caryophyllene	6.02	13.24	6.68
Germacrene-d-4-ol	0.33	1.49	10.69
γ - muurolène	3.99	10.48	8.72
ρ -cymène	9.37	2.18	2.67
Bourbonène β-	0.15	0.46	8.81

These paintings present us with a remarkable characteristic of essential oils. Indeed, the variability of their content of active ingredients is what characterizes their qualitative and quantitative compositions. Agronomic conditions such as the nature of the soil, geographical origin, climate, altitude. strongly influence the composition of the HE of a plant. The compositions also vary according to the physiological state of the plant, such as its age and maturity (stage and period of harvest), as well as the organ of the plant (leaf, flower, root) used to extract the HE which sometimes explains the difference in results between laboratories. The latter, in the tables above, did not use the same organ of the plant or the same age. And plant harvesting conditions play a role in the content, that is, they impact the quantitative composition of HE in active substances, even if the plants have the same origin.[1]

To this variability, inherent to the plant, is added that related to its treatment after its harvest (drying, extraction method). The nature of the solvents and the extraction conditions (extraction solvent concentration and composition, contact time, temperature, etc.) select variable compounds and can lead to products with different activity levels and properties. The composition of the HE can then vary with conservation conditions due to the relative volatility of some components whose concentrations may decrease over time. During the manufacture of food, interactions can occur, with constituents of premixes or food, or with the application of technological processes (such as heating for example), which can lead to the reduction or even the total disappearance of certain components or their structural modification.[11–13]

We will return to another chapter on this question of the influence of the variability of the composition and the content of substance of the HE as well as on the problems caused by this characteristic.

Table 3 Chemical composition of the essential oil of rosemary (%)[13]

Molecules	Rosemary			
	Origin A laboratory 1	Origin A laboratory 2	Original B lab 1	Original B laboratory 2
α-pinene	8.11	7.07	13.44	8.28
Camphor	18.64	17.88	21.88	24.57
1,8-cineole	18,03	21.28	21.98	19,07
Verbénone	13.63	11.98	14.31	16
Camphene	2.24	2.88	0	0
Terpinène	4.84	7.83	0.49	0
Borneol	6.18	5.66	6.79	7.7
Trans Caryophyllene	6.03	4.9	5.3	6.24
Bicycloheptane	0	0	0	0
Abietatriène	0.36	0.3	0.21	0.37
γ -terpinéol	4.5	3.72	4.38	4.91

Chemotype concept

A chemotype (CT), or chemical race, designates a distinct chemical entity within the same species. Depending on the biotope (sunshine, climate, soil composition, altitude), the same plant can secrete biochemically very different species.[14]

It is these variations in the biochemical composition of essential oils that give rise to the notion of "chemotype". Two CTs of the same essential oil will present not only different activities but also highly variable toxicities. This is also the sensitive and incompressible point of essential oils explaining the complexity of the hazard characterization and thus leading to the notion of evaluation of the health risks associated with their consumption and use.[1]

Control and analysis

Different methods have been used to control and analyze the essential oils currently. However, the identification of the components of essential oils is generally carried out using the technique of gas chromatography coupled to mass spectrometry (GC-MS) equipped with a flame ionization detector (FID) and a MS detector.[15]

Chromatography and spectrometry

The double analysis by gas chromatography and by mass spectrometry makes it possible to know the qualitative and quantitative biochemical composition of an essential oil. Gas chromatography is carried out by means of a sophisticated apparatus which makes it possible to identify the aromatic molecules present in an essential oil (up to 450 aromatic molecules). The graph provided by the chromatograph includes a series of peaks; each peak represents a very specific aromatic molecule that is identified by software.[1]

Mass spectrometry

The mass spectrometer determines the relative proportion of each of the aromatic molecules of an essential oil (quantitative composition).[1]

Aromatogramme

The aromatogram is a method of in vitro measurement of the antibacterial power of essential oils. The technique is identical to that used to measure the bactericidal activity of antibiotics.[1]

Biological activity

The biological activity of an essential oil is related to its chemical composition, the functional groups of the major compounds (alcohols, phenols, terpene compounds and ketones) and their synergistic effects.[1] Several works have highlighted the different biological activities of aromatic and medicinal plants, and in particular their antifungal, antibacterial, antioxidant and insecticidal powers. It should be noted that the first demonstration of the action of essential oils against bacteria and fungi was carried out in 1881 by Delacroix. Since then, many oils have been defined as antibacterial and antifungal. The most recent study is the one that appeared in the review "Processalimentaire" of May 11, 2015. In this review we discover that a team of American researchers from the Wayne State University in Detroit, has highlighted the antimicrobial effect of a nano-emulsion of oregano oil on fresh salads like lettuce. In the same context, another study conducted in 2013 by the CFIA (Canadian Food Safety and Inspection Agency) highlighted the antibacterial activity of thyme essential oils against E. coli O157H7.

The spectrum of action of HE is very wide, acting against a wide range of bacteria, including those that develop resistance to antibiotics. This activity is also variable from one essential oil to another and from one bacterial strain to another. They can be bactericidal or bacteriostatic. Their antimicrobial activity is mainly a function of their chemical composition and in particular of the nature of their major volatile compounds. The compounds with the greatest antibacterial efficacy and the broadest spectrum of action are phenols: thymol, carvacrol and eugenol. Carvacrol is the most active of all. Recognized for being nontoxic, thymol is also an active ingredient.[1]

These three compounds act on both Gram-positive and Gram-negative bacteria. We can therefore state that they have an antimicrobial effect against a broad spectrum of bacteria and in particular: Escherichia coli, Bacillus cereus, *Listeria monocytogenes*, *Salmonella enterica*, *Clostridium jejuni*, *Lactobacillus sake*, *Staphylococcus aureus* and *Helicobacter pylori*. Many researchers around the world are studying their potential as a conservation agent. Most of the above compounds are also very good antifungal agents. A large number of volatile compounds have been tested on a wide range of fungi, including Candida (*C.albicans*), *Aspergillus* (*A.niger*, *A.flavus*, *A.fumigatus*) and *Penicillium chrysogenum*.[16]

Uses of essential oils

Their use is extremely diversified depending on the source, the quality, the extraction method, etc. Essential oils have proved their interest in the industrial application for the manufacture of perfumes, cosmetics, shampoos, soaps, gels and even cleaning products. One of the non-negligible aspects of these oils is their potential as a therapeutic agent or else in aromatherapy as an active drug ingredient. Another of their important applications is found in the agri-food industry; both in the production of beverage flavors and in that of a number of foods.

Cosmetic

Some essential oils rich in cosmetic properties can enter the preparation of several cosmetic products. The concrete chemotypes of salvia, Lavender and thyme are particularly popular for obtaining new prestige perfumes. For this purpose, the production technology and the adequate selection of source raw materials are essential elements to improve the quality of finished products.

Essential oils used in cosmetics are used in the manufacture of many products such as creams and ointments for the care of the skin. Their virtues also help to reduce unsightly problems such as cellulite and stretch marks. They are also used in the manufacture of champoings to treat dandruff, hair brittle, dull, dry, greasy, devitalized, etc. The most privileged in the cosmetics industry are lavender, mint and lemon, used mainly for their aromatic function (perfumes, deodorants, gels and refreshing) as well as for their antimicrobial function (soaps, disinfectants, toothpastes).[17]

Therapeutic potential

Essential oils are used in pharmacy for their potential as a medicinal agent. In recent years, researchers have investigated the antioxidant properties of cinnamon, nutmeg, clove, basil, parsley, oregano and thyme. These properties are notably attributed to the presence in their composition of phenolic compounds, such as thymol and carvacrol, but also to the presence of oxygenated monoterpenes such as linalool, 1,8-cineole, geranial, neral, citronellal, isomenthone and menthone. And finally to the presence of some hydrocarbon monoterpenes such as α-terpinene, γ-terpinene and α-terpinolene.[17]

The antioxidant activity of these compounds is exploited in the prevention and fight against diseases such as Alzheimer's, arteriosclerosis and skin cancer. Essential oils are also used clinically to treat inflammatory diseases such as rheumatism, allergies or arthritis, by additional contributions in the diet of these antioxidant compounds. Indeed, these diseases occur during the imbalance between the production of free radicals and antioxidant enzymes.[18] These compounds seem to act by playing an important role in the neutralization of free radicals and in the decomposition of peroxides thanks to their oxydo-reducing properties.[17] The emergence of antibiotic-resistant pathogenic microorganisms has allowed antimicrobial essential oils to position themselves as particularly credible candidates for replacing antibiotics.[19]

Food

The use of essential oils in cooking is more anecdotal. However, we note that we have found for many years non-industrial food products containing and that more and more traditional cookbooks propose to use them, in small quantities, to raise some dishes: seasoning with the vegetable oil supplemented with essential oil (thyme, basil, rosemary, oregano), flavor of desserts (citrus, vanilla).

Essential oils are also used in a wide variety of consumer goods such as confectionery, soft drinks and distilled alcoholic beverages from the agri-food industry. In addition to their wide use as a flavoring element, they are used in food and agricultural fields for their antibacterial, antifungal, antiviral, nematicidal, insecticidal and antioxidant properties.[3]

The table presented in Appendix 2 summarizes some examples of the use of essential oils in the various sectors mentioned above. Future applications of EOs in the agri-food sector will be discussed.

Appendix 2 Examples of the variety of applications of essential oils[2]

Oil	Perfumery		Food	Medicine
	Cosmetic	Technical		
Basil	Perfume		Flavoring for sauces and condiments	Antispasmodiqu system controller
Lemongrass		Flavor for soap, disinfectant, insect repellent	Flavoring for beverages and sweets	Anti-inflammatory, antioxidant
Eucalyptus			Flavoring for beverages, sweets, ice cream	Anti-inflammatory, antioxidant
Geranium	Perfume		Flavoring for sweets, chewing gum	Antispasmodic relaxing
Lemongrass				Vasodilator sedative
Pepper mint		Flavor tooth paste	For flavor liqueurs, ice cream, chewing gum, chocolate	Analgesic anesthetic tonic, Nervous system stimulant
Green mint			Flavor to drinks, sweets, ice cream	Flavored syrups

Chapter II

Regulatory context and quality criteria

The legislative framework governing essential oils is essential to better understand their "place" and the different ways in which they are used today.

Regulatory context

Legal definition and scattered regulatory context of essential oils

Currently, there is no specific legal definition of essential oils. This deficiency therefore exposes professionals in this sector of activity daily to difficulties related to uncertainties in this area. HEs can be regulated by regulations applicable to chemicals, cosmetics, medicines and even foodstuffs, but these texts do not specifically address them.

Regulatory status of essential oils for human consumption

They are often used to flavor foods and beverages. Flavorings for use in foodstuffs are regulated by Directive 88/388 / EEC of 22 June 1988 on the approximation of the laws of the Member States relating to flavorings intended for use in foodstuffs and basic materials for their production. Essential oils are concerned by this text and because of this; their use may be limited in the manufacture of foodstuffs.[20]

Directive 88/388 / EEC: Council Directive 88/388 / EEC of 22 June 1988, as amended by Regulation 1882/2003, defines several points: The different categories of flavoring agents: natural flavoring substances, identical to natural and artificial ones, flavoring preparations, smoke flavorings and processing flavors. HEs fall into the category of flavoring preparations, The rules for the labeling of flavorings and in particular the use of the term "natural" for the classification of substances and flavoring preparations, General criteria of purity and maximum levels of heavy metals.

Regulation 2232/96 / EC: Regulation EC No 2232/96 of the European Parliament and of the Council of 28 October 1996 lays down a Community procedure in the field of flavoring substances used or intended for use in or on foodstuffs. It introduces a safeguard clause allowing a Member State to take the necessary measures when a flavoring substance is likely to present a danger to public health. Appendix 3 lists substances banned for direct use but whose presence is tolerated, with limitation in flavored foodstuffs due to the use of natural flavorings such as HE and especially the substances that are derived there from.

Appendix 3 The 26 flavoring substances in limited use and declaration mandatory

Substance	INCI name	CAS no.	Einecs
2- benzylidèneheptanal	Amyl cinnamal	122-40-7	204-541-5
Benzyl alcohol	Benzyl alcohol	100-51-6	202-859-9
Cinnamyl alcohol	Cinammyl alcohol	104-54-1	203-212-3
Citral	Citral	5392-40-5	226-394-6
Eugenol	Eugenol	97-53-0	202-589-1
7-hydroxycitronellal	Hydroxy	107-75-5	203-518-7
Isoeugenol	isoeugenol	97-54-1	202-590-7
2-pentyl-3-phenylprop-2-en-1-ol	Amylcinnamyl alcohol	101-85-9	202-982-8
Benzyl salicylate	Benzyl salicylate	118-58-1	204-262-9
Cinnamaldehyde	Cinnamal	104-55-2	203-213-9
Coumarin	Coumarin	91-64-5	202-086-7
Geraniol	geraniol	106-24-1	203-377-1
4- (4-hydroxy-4- methylpentyl) cyclohex_3-enecarbaldehyde	Hydroxyisohexyl3- cyclohexene carboxaldehyde	31906-04-4	250-863-4
4-methoxybenzyl alcohol	Anise alcohol	105-13-5	203-273-6
Benzyl cinnamate	Benzyl cinnamate	103-41-3	203-109-3
Farnesol	Farnesol	4602-84-0	225-004-1
2- (4-tert-butylbenzyl) propionaldehyde	Butylphenyl Methylpropional	80-54-6	201-289-8
linalool	linalool	78-70-6	201-134-4
Benzyl benzoate	Benzyl benzoate	120-51-4	204-402-9
Citronellol	Citronellol	106-22-9	203-375-0
α-hexylcinnamaldehyde	hexyl cinnamal	101-86-0	202-983-3
(R) -p-mentha-1,8-diene	Limonene	5989-27-5	227-813-5
methyl oct-2-ynoate	Methyl 2-octynoate	111-12-6	203-836-6
3-methyl-4- (2,6,6-trimethyl-2-cyclohexen-1-yl)-3-butene-2-one	Alpha isomethyl ionone	127-51-5	204-846-3
Evernia Prunastri, extracts	Evernia Prunastri extracts	90028-68-5	289-861-3
Treemoss, extracts	Treemoss extracts	90028-67-4	289-860-8

Directive 2002/46 / EC: Directive 2002/46 / EC of the European Parliament and of the Council of 10 June 2002 on the approximation of the laws of the Member States concerns food supplements. It considers that the evaluation of the substances is not complete and that some of them (not meeting the general criteria for the use of flavoring substances laid down in Regulation (EC) No 2232/96 (Appendix 3)) have been removed from the list. For example, the following substances considered by the Scientific Committee for Food as genotoxic: methyl eugenol and estragol (Decision 2002/113 / EC of 23 January 2002). They are therefore no longer usable as such in flavorings and their presence in food, due to the use of natural flavoring agents, is limited.

Council of Europe recommendations: The Council of Europe has issued recommendations on the use of sources of flavoring matter extracted from HE. The "Blue Book", 3rd edition, "Flavoring Substances and Flavoring Substances of Natural Origin"[21] contains the respective lists of: Active ingredients" to limit in foodstuffs, Sources of natural flavoring substances with indication of the active ingredients they contain, sources that is toxicologically unacceptable. For the 4th edition, Volume II,[22] the Committee of Experts on Natural Flavoring Matters has scheduled the examination of more than 600 sources. A first report on 101 natural sources was published in 2000. A second report on 70 sources was published in 2007, while a report on "active principles constituents of toxicological concern contained in natural sources of flavourings") in 2006.

Regulatory status of essential oils in animal feed

Since 2003, products for animal feed based on HE are regulated by Regulation (EC) No 2003 / 1831. It has imposed among other things that all additives already authorized are subject to a new deposit before 7 November 2010 to be re-evaluated by EASA (European Food Safety Agency). Thus, each HE product manufacturer is led to position it in one of the five additive categories defined in the Regulation and to file the corresponding authorization dossiers. The content of the authorization dossier and the scientific elements to be provided for each of the five categories of additives are given in Regulation (EC) No 2008/429 (European Commission 2008). The choice to position an additive in one category or another can thus significantly vary the number of studies to be provided, in particular in the "Efficiency" part, but at the same time, it makes it possible to extend the list of authorized claims. on the label. At present, the exact number of dossiers filed with EASA is not known, but it would be several hundred.[23]

The five categories of feed additives, classified according to their functions and properties in Annex 4, are simplified.

Annex 4 Article 6 of the EC Regulation 2003/1831, ranking additives for animal feed [20]

Technological additives	All substances added to feed for a technological purpose
Sensory additives	All substances which are added to animal feed improves or changes the organoleptic properties of the feed or the visual characteristics of the food derived from animals
Nutritional additives	
Zootechnical additives	All additives used to affect favorably the performance of animals in good health or the environment
Coccidiostatics & histomonostats	

Quality criteria for essential oils in food

The safety of food products containing HE is largely related to the quality of raw materials used and the formulation of the finished product. To guarantee their quality, HE must be obtained from precisely identified raw materials, controlled according to defined processes, presented with precise physicochemical characteristics and kept in a satisfactory manner. Their physical, organoleptic, chemical and chromatographic characteristics are defined in France by standards established by AFNOR.[24] These standards are established in[22] close collaboration with the producers as well as the importers and are the result of an exchange between experts. Most of them are taken over worldwide to become ISO (International Organization for Standardization) standards taking into account the information of world experts. We can cite in particular the ISO 4720 standard listing the botanical nomenclatures of the plants used as well as their main characteristics for the production of HE, with their common names, in English and in French (alphabetical index of these common names in both languages).

When using EOs by specific consumers in the form of a food supplement or by professionals and manufacturers in various food products (such as flavorings for example), it is important to ensure the quality of the EO used. . It should not be cut, stretched or mixed with other HE or synthetic molecules. The AFNOR standard (NF T75-002) defines the general rules for labeling and marking containers containing essential oils. To avoid their "falsified" use, the following information, signs of quality and traceability, must be indicated on the bottle:

i. **Botanical variety**: the same term can mean different products. The name of the botanical species must appear in French and especially in Latin on the packaging. The part of the plant from which the essential oil is extracted: some plants can produce several different essential oils according to the distilled parts Appendix 3.
ii. **Origin or place of cultivation**: plants of organic essential oils must not have been grown with fertilizers, pesticides or herbicides. The products must come either from wild harvesting from sites remote from polluted areas, or from organic crops or traditional controlled crops.

iii. **The extraction method**: it allows knowing if the essential oil was produced using solvents.

Labels and certifications

The quality of essential oils can be guaranteed by several labels (Appendix 5). There is, among other things, a French certification by ECOCERT and in Germany a charter, BIDH, which certifies since 1996 the composition of essential oils, their method of manufacture and their effectiveness regardless of the interest of their use.[25] Some laboratories have created their own "labels" to justify the quality of their HE and others integrate the criterion of BIO in their specifications.

Appendix 5 Characteristics of Standards and Quality labels˝ HE. (Not exhaustive)

Standards and labels	Characteristics
ISO	ISO 4720: 2009: botanical name of the plant, with the common names of ET in English and French.
AFNOR	National standard : French Association for Standardization
T 75A	002 Labeling: Latin name, plant part, production technology 004 name, chemotype, hybrid, geographical origin 005 Botanical Nomenclature 006Matières aromatic raw natural: Vocabulary
CTEO	"Essential Oil Chemotype" created by Dominique Baudoux for Pranarom (1991) Name, chemotype, hybrid, geographical origin, method of cultivation, botanical stage development, producing organ.
EOBBD	"Essential Oil Botanically and Biochemically Defined" created by Philippe Mailhebiau (1984) for some laboratories and brands like Phytosun'aroms, created by itself (Omega Pharma laboratories today). botanical species producing member, chemotype.
EOBBD	"Essential Oils Botanically & Biochemically Defined", Created by Philippe Mailhebiau (1998) Panacea Pharma ... Botanical specificity, the stage of development of the body and distilled the absence of pesticides.
QBI®	"Quantum-Bio-Info», Created by Daniel Pénoël for Osmobiose (1991):
HESD	"HE Scientifically Defined" created by the laboratory Eona (1991): chemotyped, 100% pure and integral, obtained by steam distillation of water in a still (except citrus zest essences obtained by cold), favors the biological origin.

Chapter III

Toxicity of essential oils

This part of the study provides a number of elements necessary to reflect on the positive and / or negative effects of essential oils on human health, effects implicitly resulting from the current market design that relates to HE.

Toxicokinetics of essential oils

The toxicokinetics of essential oils is difficult to establish. Indeed, if we can study and describe the biological and / or pharmacological effects of a pure monoterpene or sesquiterpene, it is more difficult, if not impossible, to talk about the pharmacology, pharmacokinetics or metabolism of an essential oil. that is, a mixture of one hundred compounds.[26] In addition, there are still no comprehensive and rigorous studies, such as the "toxicological part" of a Marketing Authorization (MA) dossier. Many studies have been carried out by different laboratories, with different objectives and very different experimental conditions. The diversity of sources of information, the sometimes limited accessibility of data and the varying level of complexity of studies make it difficult to carry out a systematic and exhaustive search. The action of the essential oil is assimilated to that of one (or more) of its components as well as to certain metabolites resulting from the biotransformations of these compounds.

From the information available in some theses and mainly in the pharmacy sector, we will summarize the common characteristics of the toxicokinetics of essential oils. Knowledge of biophysical mechanisms, absorption, and biochemical composition is fundamental to understanding the phenomenon of ET toxicity.

Absorption

Absorption into the body can be done by three types of pathways: oral, cutaneous and respiratory. This mechanism is possible by passive diffusion and depends on several parameters[27]:

Xenobiotics: molecular weight - hydrophilicity - lipophilicity.

Exchange surface: size - thickness - time of presence of xenobiotic on the surface.

The mechanism of passive diffusion does not require energy but the existence of a concentration gradient. The characteristics of this transport are as follows:

a) It starts from the region with the highest concentration to the one with the lowest concentration,

b) It is without energy,

c) It has no specificity,

d) It cannot be saturated by competitive inhibition phenomena.

The major constituents of essential oils are small (MW = 150 to 200), poorly soluble in water, but have many affinities with organic solvents such as ethanol. On the face of it, their low solubility might appear as an obstacle, but in fact this disadvantage can be compensated for by the nature of the exchange surface.[27]

Food poisoning caused by an essential oil corresponds to absorption by the oral route. After ingestion of HE and the transport of active substances to the gastrointestinal system, localization of their passage of the gastrointestinal barrier. The membrane of this system has a very marked lipid nature. It is composed of a biomolecular layer of lipids whose hydrophobic poles are directed towards the inside and the hydrophilic poles towards the outside. This first thickness is covered on the surface with a mono-molecular layer of proteins. Aqueous pores interrupt this membrane. These characteristics are decisive for understanding this absorption. The main condition is the hydro solubility. The essential oil can be absorbed only after dissolution in the digestive tract. For this reason, the compound must have a certain degree of solubility. Any undissolved fraction cannot cross the membrane.[27]

The only data available about the crossing mechanism is just the fact that essential oils are "well absorbed through the mucous membranes". Note that "facilitated dissemination" and "active transportation" are not mentioned. In addition to the amount of compound absorbed, it is also interesting to know the rate at which this absorption takes place. Indeed, it conditions the moment of obtaining the peak of maximum concentration.[27] A kinetic study on the absorption of menthol administered in humans provides some details.

In this study, three forms of ingested menthol were tested: A capsule containing menthol, a placebo capsule, a candy or mint tea.

We measured in blood samples (after a 48-hour fast of any menthol compound) the amount of menthol found at different times. Only menthol conjugated with glucuronic acid was detected in blood or urine and, regardless of the administration of the menthol product, the average maximum concentration of menthol glucuronide was Cmax = 16.73 +/- 5.53 micromoles / liter. The time to reach this concentration was 61 +/- 26 minutes.[27]

This study shows that menthol is relatively well absorbed and quite fast. Maximum concentrations are obtained approximately one hour after administration. Other observations, unquantified, confirm that other essential oils are also rapidly absorbed orally. Depending on the presentation, the essential oil may be more or less bioavailable. For example, in the plant, the bioavailability will be lower than a liquid presentation. The presence of surfactants (frequent formulation of potpourris) can also increase the absorption of terpenes. In general, given the relative homogeneity of the terpenes of HE, we can consider a good oral absorption.[27]

The other two absorption pathways, the "cutaneous and respiratory" are also important in the context of the toxicity of the HE. However, we chose not to go further into this subject of inhalation and skin contact so as not to deviate from the primary context of this study, which focuses mainly on the consumption of food for HE. Indeed, these two other absorption routes relate more particularly to the use of HE in pharmacy and cosmetics, areas that are not directly related to the food and nutritional context. It is for this reason that only oral absorption has been presented and detailed.

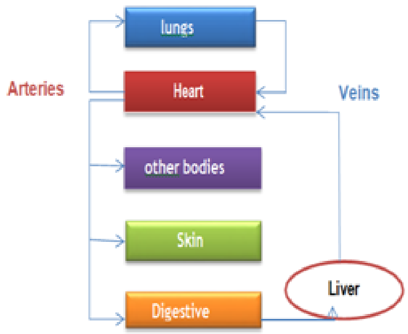
Distribution

There is little information on the distribution of HE in the body. It acts according to the molecular structures of their compounds and their physical properties.

Note that the phenomena of conjugation with other biological molecules such as albumin have not been observed. As a result, experts believe that HE molecules remain free as they circulate in the blood. We can thus extrapolate that a wide diffusion is carried out inside the cells. The compounds are soluble in organic solvents, which facilitate their passage or their accumulation in lipid-rich organs such as the central nervous system. Like thujone, which is a mono-terpene ketone found in the essential oils of wormwood, sagebrush and sage and is also found in the mouse brain during experiments described about neuro-toxicity of this terpene?

Metabolism

Once again, very little data has been collected on the phenomenon of the metabolisation of essential oils, hence the fact that we approach them in a general way. The processes of metabolization are enzymatic reactions intervening in the organs crossed. The compound is then bio transformed into metabolites. All organs contain biotransformation enzymes but the quantities vary: first the liver, which contains the greatest amount of enzymes compared to other organs, then the kidneys and lungs, then the skin, the intestinal mucosa, and finally, the other organs, such as the nervous system, the muscles, & c. Two types of biotransformations are possible: the first pass effect and the biotransformations after distribution in the organism Annex 6.[27]



Annex 6 General circulation of a compound in the body (ET concerned substances).[27]

This first-pass effect may decrease the bioavailability of xenobiotics, as shown in the diagram in Annex 6. The most important is found with oral absorption. There is no data on the first passage, intestinal. We will only talk about the first hepatic and pulmonary passage. The study of these biotransformations is interesting in the context of a chronic toxicity (progressive necrosis lesions of the liver and the lungs).[27]

The organs of metabolization or rather of biotransformation: The first pass effect consists in a loss of the initial compound by the metabolism; it is the action of the enzymes of an organ. The compound is transformed into products called metabolites. Enzymatic reactions may occur in the intestinal mucosa even before the initial compound has reached the general circulation. he can therefore there is a loss of substance at this level, but we also do not have specific data on this. The first pass effect in the intestinal mucosa is negligible. As for the liver, it is a real organ with metabolites due to the importance of the enzymes present and their intensity of action. It is the place of a first hepatic pass. Thus, biotransformations become responsible for: The transformation of xenobiotics before it reaches its target: this is the first pass. The metabolic elimination of xenobiotic essentially by the liver.

The different biotransformation reactions: There are many enzymes that catalyze biotransformation reactions.[27]

i. Phase 1 reactions: oxidation, reduction and hydrolysis.
ii. Phase 2 reactions: conjugations such as glucuroconjugation, sulfoconjugations, acylations, methylations, conjugations with glutathione.

Most oxidation is catalyzed by microsomal oxygenases. Three classes of enzymes are involved, namely monoamine oxidases, flavins monooxygenases and cytochrome.

Formation of metabolites: These reactions result in an inactive metabolite and a more active metabolite called a “reactive”. Three cases can be considered for the active metabolite:

i. Metabolite responsible for the activity as a whole,
ii. Metabolite whose activity is added to that of the parent compound,
iii. Metabolite causing adverse effects that is toxic.
iv. Metabolic reactions are therefore numerous and lead to inactive or reactive metabolites such as electrophiles.[27]

Elimination

There are two cases. The compound can be either eliminated directly by excretion functions (renal, biliary), or converted into metabolites, more water-soluble and more easily excreted. The half-life time of the essential oil compounds is a parameter that depends on its distribution and elimination characteristics (mode of administration, absorption, diffusion in organs, organ clearance).

For examples, the mean half-life times of menthol in plasma are:

a) 56 +/8 min with a menthol capsule.
b) 43 +/16 min with a candy or mint tea.

In the urine, this half-life time is: 75 + / 22 minutes with the capsules, 74 + / 15 minutes with sweets or tea.

As another example, citral (a mixture of two isomeric aldehydes) is rapidly metabolized and eliminated as carboxylic acid 2 in the urine of rabbits. In rats and guinea pigs, urinary excretion of the p-cymenemetabolite is approximately complete within 48 hours. Similarly, 75 to 95% of oral D-limonem is excreted as urinary metabolites in 2 to 3 days in different animal species as well as in humans.[28]

The elimination of these compounds is therefore rapid, without bioaccumulation, despite a high affinity for lipid-rich tissues. The removal of 90% of the compounds is done in two days. It is mainly urinary but a small part is eliminated in the feces and a last part, even weaker, by respiratory and cutaneous way.[29] Even today, scientists do not know whether patients with renal or hepatic insufficiency have a particular sensitivity to these compounds, but, in principle, we can imagine that this influences elimination.

After having reviewed all this information and results collected in scientific books and theses, we have just seen that essential oils had a rapid absorption and that they could be important; that their distribution in the organism is wide and their elimination fast; that bioaccumulation does not occur. Essential oil compounds can therefore reach their targets and cause toxic effects.

Dose-effect relationship

Context

As we have already mentioned, essential oils are sought in the food sector mainly for their aroma and preservative functions. They are therefore subject to the same regulations as food additives. All food additives, including HEs, must not only demonstrate their useful purpose, but must also meet a thorough and rigorous scientific assessment of their safety prior to approval.

Until the creation of the European Food Safety Authority (EFSA), the safety of additives was assessed by the Scientific Committee for Human Nutrition (SCF). Today, the EASA Panel on Food Additives, Flavorings, Processing Aids and Materials in Contact with Food (AFC Panel) is the body responsible for this task. At the international level, there is also the Joint Committee of Experts on Food Additives (JECFA) of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO).[30]

Threshold of dose-effect concern

The concept of threshold of toxicological concern, mentioned more than 30 years ago, is currently attracting increasing interest in toxicology and more particularly in food toxicology. It was estimated that the number of substances to which humans were thus exposed was inversely proportional to the logarithm of their concentration in food (Figure 2).

Indeed, among the very large number of substances brought by food, only a small proportion of them appears in significant quantity in the food ration. On the other hand, the substances representing a small or very small part of this ration are very numerous.[31]

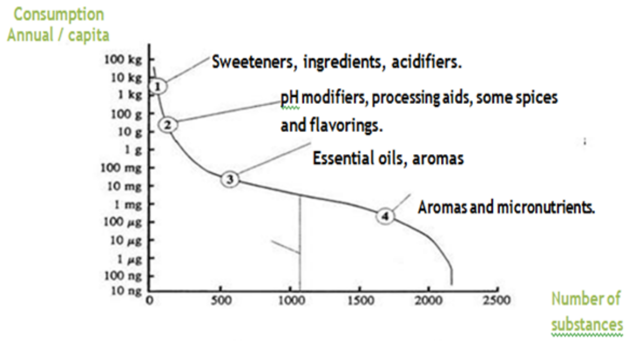


Figure 2 Classification of substances in foods based on their annual per capita consumption.[31]

Health security level

The approach differs according to the nature of the adverse effect induced by the substance. We speak of a deterministic compound when it is possible to define a threshold from which no biological effect is observed. In this case, it is possible to define a tolerable daily intake (ADI). On the other hand, for certain compounds, we consider that it is not possible, a priori, to define a no-effect dose and this is the case of essential oils. The effect is then probabilistic or stochastic, as we find it in carcinogens and genotoxic, for which the risk managers will define acceptable or tolerable risk levels.[31]

Do the essential oils incorporated in foods present health risks? Given the complexity of HE on the one hand and the concept of “toxicity” on the other hand, it is obviously impossible to formally answer this question. Nevertheless, we can draw up a table illustrating the results recorded for the toxicity of certain essential oils and compounds, presented in Table 4. We find the most common essential oils and active compounds suspected of having a toxic effect. The values illustrated in this table come from a thesis on the toxicity of HE from the National School of Veterinary Toulouse.[32] The LD 50 values shown therein were determined after ingestion.[33]

Compound / HE Route of Administration DTM LD50 ADI (Human) Oral menthol 2 mg / kg 3 180 mg / kg (rat) 0.2 mg / kg / day Oral Pregon 425 mg / kg (male) / 20 mg / kg / Oral 1,600 mg / kg (dog) EO of oral turpentine 100 mg / kg (male) / 100 mg / kg / day Oral camphor 50 mg / kg (human) / / Oral Pennyroyal HE 500 mg / kg (male) Dermal 2000 mg / kg (dog) Melaleuca oral HE 2,800 mg / kg (male) 5,000 mg / kg (rabbit) / dermal 2,500 mg / kg (rabbit) Oral thymol 0.6 mg / kg (male) 980 mg / kg (rat) / oral thujone 45 mg / kg (mouse) 45 mg / kg (mouse) / oral 3,000 mg / kg (dog) oral eucalyptus HE 1 mg / kg (male) 3 000 mg / kg (mouse) / HE of oral hyssop 1250 mg / kg (rat) / / HE of oral sage 3200 mg / kg (rat) / / D-limonemal oral 1000 mg / kg (rat) 5000 mg / kg (rat) / (/) no data available.

In September 2014, ANSES (National Agency for Food Safety, Environment and Labor) published an opinion on the creation of a new functional group of additives to decontaminate animal feed, in which the essential oils were part of these decontaminant additives studied. The assessment of health risks has therefore focused on the essential oils most commonly used in animal nutrition. In this document, ANSES concluded that, as a general rule, common HEs had low or very low oral toxicity with LD 50s greater than 5 g / kg.[32] (Table 5)

Table 4 Toxicological parameters of certain essential oils and compounds defined in animal models and humans[27]

Compound /H.E	Way	DTM	DL50 of Directors	ADI (Man)
Menthol	Oral	2 mg / kg	3180 mg / kg (rat)	0.2 mg / kg / day
Pulegone	Oral	425 mg / kg (male)	/	20 mg / kg / day
	Oral	1600 mg / kg (dogs)		
Turpentine	Oral	100 mg / kg (Male)	/	100 mg / kg / day
Camphor	Oral	50 mg / kg (Male)	/	/
Pennyroyal	Oral	500 mg / kg (male)	/	/
	Cutaneous	2000 mg / kg (dogs)		
Melaleuca	Oral	2800 mg / kg (male)	5000 mg / kg (rabbit)	/
	Cutaneous	2500 mg / kg (rabbit)		
Thymol	Oral	0.6 mg / kg (male)	980 mg / kg (rat)	/
Thujone	Oral	45 mg / kg (mice)	45 mg / kg (mice)	/
	Oral	3000 mg / kg (dogs)		
Eucalyptus	Oral	1 mg / kg (male)	3000 mg / kg (mice)	/
Hyssop	Oral	1250 mg / kg (rat)	/	/
Sage	Oral	3200 mg / kg (rat)	/	/
D-limonème	Oral	1000 mg / kg (rat)	5000 mg / kg (rat)	/

(/) No data available

Table 5 The LD 50 values of some ET and compounds[32]

Compound / HE	LD_{50}
Oregano	1400 g / kg (Oral, Rat)
D-limonene	5000 mg / kg (Oral, Rat)
Thymol	980 mg / kg (Oral, Rat)
Menthol	3180 g / kg (Oral, Rat)
HE Melaleuca	2000 mg / kg (Skin Rabbit)
Thujone	134 mg / kg (Oral, Rat)

Comparing the results of the LD 50 of the ANSES opinion with the results of the LD 50 of the thesis, we note that the values are compatible and of the same order of magnitude, whatever their sources. But these are not exactly the same values because the conditions and expertise parameters (such as the number of animals, rearing conditions, age and sex) are not identical.

The toxicity of essential oils is therefore variable. In view of the data cited above, essential oils inside plants pose little problem. In contrast, concentrated solutions of HE can be responsible for toxicity. This is the case of sage: the plant is sold over the counter and used as an herb, while its essential oil is toxic and its use regulated.[27]

The toxicodynamics of essential oils

Pathogenicity of active substances

The majority of essential oils used have an LD 50 of 2 to 5g/kg (anise, eucalyptus, clove), or more frequently greater than 5g /kg (lemon, thyme, mint). Their toxicity is observed thanks to their constituents, (rare are those whose LD_{50} is lower than 2g/kg and moreover they are not authorized in the food use). In France, the maximum ADI for food HE is set at 1 g / kg.[33] In the case of ingestion of a large amount of HE, the active substances can cause many effects and health problems, among the most observed effects and related to an oral ingestion, we can mention:

Hepatotoxicity

The constituents of essential oils are not directly hepatotoxic. It is the reactions of the previously mentioned biotransformations that are responsible for the formation of hepatotoxic metabolites. The liver, a very rich organ of biotransformation enzymes, is the most exposed organ. The most observed effect in rats is hepatic carcinoma. The compounds suspected to be at the origin of this toxicity are safrole and estragole. Risk assessment in humans is difficult because of different metabolic pathways; however, the dietary use of high EOs of these substances needs to be monitored.

Toxicity studies are therefore difficult to interpret. Indeed, the metabolisms formed by the liver are not identical in humans and animals, due to a difference in enzymatic equipment. It should also be noted that menthol-rich EOs cause liver problems in patients with liver enzymes such as G6PD "glucose 6 phosphate dehydrogenase".[27]

Neurotoxicity

HEs pass the blood-brain barrier of the nervous system. Examples of neurotoxicity are numerous and some have been known for a long time. Thujone has a well-known neurotoxic effect. This is the main terpene of the "wormwood" (wormwood) oil that goes into the composition of wormwood. Anethole (especially its synthetic form) induces chronic convulsions, psychic excitement and liver damage. Pinocamphone (terpene of the essential oil of hyssop) causes seizures and epileptic seizures. The essence of rosemary is convulsive and menthol can inhibit reflexes and even induce bulbar paralysis. It causes spasm of the glottis and its use is contraindicated in children.

The convulsive effects of many HE are attributed to the presence of the following terpenes: camphor, pinocamphone, cineole, pulegone, sabinylacetate, fenchone.[34]

The reproduction

Some essential oils are not safe during pregnancy, especially those of eucalyptus and thyme, which are thought to interfere with the development of the fetus in rats and are therefore contraindicated during pregnancy.

Others may affect the fertility of their consumers such as: Artenisia Anua called "annual sagebrush" used in aromatherapy and consumed orally. It is known among others for its harmful effect on fertility in humans. HEs rich in anethol and citral (such as Foeniculum vulgare, known as "sweet fennel", salvia sclarelea, known as "clary sage", and citrus hystrix, "lemon tree or zest of combava") were also tested in rodents. Results showing a weak but nevertheless real action, these HE remain contraindicated orally during pregnancy; an impact on the development of the fetus is always possible. They are also contraindicated in infants and children less than 7 years of age.[27] Other effects and diseases may be caused by ingestion of HE and are shown in Table 6.

Table 6 Adverse effects encountered most[33]

Effects	Molecule	Example E	Authorization to use food
Allergenic	Limonene Geraniol Eugenol Isoeugenol Ctral Citronellol	Lemon Orange Eucalyptus lemon	Yes
Disruptors Hormonal and Endocrine	Trans-anethole, Sclareol A-humulene.	Fennel Clary sage	No
Amazing	Trans-anethole-Methyl chavicol	Basil Parsley	Yes
Carcinogens	Anethol Safrole	Badiane	No
Liver and Nerve	Thymol Carvacrol Eugenol	Thyme Oregano	Yes
Convulsant	Thujone pulégone Menthone Piperitone	Eucalyptus mentholated Warbler mint Pepper mint	No
Interactions with Drugs	Eugenol Thujone	Cloves Eucalyptus	Yes

The data presented show that the effects of HE are related to the active substances that compose them. However, they remain common, which cannot be established for all HEs. It is indeed difficult to establish a constant toxicological profile (dose effect, target population). As we mentioned earlier, the geographical origin and the biotope manipulate their qualitative and quantitative composition into active substances.

It is therefore difficult to develop this type of profile just for a single species when there are more than one hundred food species with more than one hundred different geographical origins. It becomes almost impossible to know the exact toxic effects of each HE without knowledge of their precise qualitative and quantitative composition, especially as these more than one hundred plant species are spread over many geographical areas.[33]

History of poisoning in France

After the main dangers related to the use of essential oils, we will briefly present their impact on French consumers in recent years. We will then analyze the reasons that led to these cases of toxicity (Table 7).

Table 7 Evolution of poisoning by HE in France depending on the age of the last decade[33]

Age / Case Number	2000/2003	2008/2010
0-1 years	3	27
14 years old	49	109
5-9 years	1	11
10 - 15 years	0	7
15 - 19 years	1	
20-49 years	2	47
50-69 years	2	23
70 and over	1	10
Total	59	234

We note that between 2000/2003 and 2008/2010, the number of cases of intoxication has significantly increased. The distribution of cases by age group is rather well maintained concerning the peak in children aged 1 to 4 years. This phenomenon is explained by the habit they have to wear everything they find in the mouth. On the other hand, we note a higher incidence of intoxication in adults over 20 years of age. In these individuals, intoxication can be explained by product confusions (eg the HE bottle is confused with that of a culinary aroma) (Figure 3).[33]

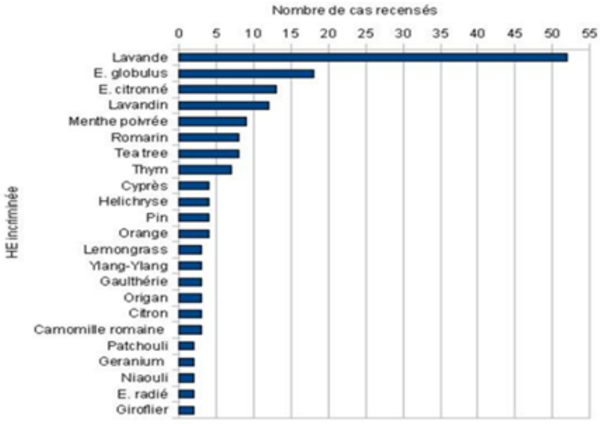


Figure 3 Number of cases of poisoning depending on the nature of HE concerned (census 2012).[33]

The first five essential oils responsible for more than 80% of poisonings recorded in France for a decade are those not used in products or for food consumption such as lavender, lemon eucalyptus or peppermint. HEs used in food products such as orange, lemon, thyme and oregano are the cause of poisoning in less than 10% of cases. In addition, the purpose of food use of these oils has never been mentioned. In general, no case following ingestion of food or nutritional HE has been recorded following consumption of dishes or products containing them.

In the United States, in 2006, the surveillance system, the AAPCP, recorded 7,377 cases of ingestion of essential oils, 74% of which mainly concerned accidental ingestions of children under 6 and only 1 2% follows normal use. [35] We can already take a number of important points for the rest of our study.

Many scientific studies show that essential oils may have some toxicity, but they appear to be toxic by ingestion only if it is made in large quantities and outside the usual framework of use, that is to say in food (flavors, preservatives, food supplements).

In the literature, no deaths have been reported following ingestion and / or consumption of HE, regardless of the objectives or circumstances of ingestion (accidental, food consumption, etc.). Nevertheless, as we have seen previously, essential oils are concentrates of active molecules derived from the plants from which they are extracted. Their precautions of use must therefore be in adequacy with their power. Too many accidents occur mainly because of the fashion phenomenon that surrounds them and the lack of advice and supervision that accompanies their sale.

Chapter IV

The essential oils market

We briefly mentioned the notion of the essential oils market. The set of different data asked and studied previously allow us to address this essential point by better understanding the issues that may arise.

Market overview

The global market for essential oils is clearly changing for twenty years. This promising market experienced in 2012 an increase of 13.2%. We are seeing a continual increase in demand, but also the appearance of different varieties of products through the effort of research on their development and quality, stress found in the producing countries. We can identify more than 3000 kinds of EO extracted from roots, bark, leaves, seeds and flowers of various plant species. Only 500 of them are marketing object. The supply and demand of essential oils are important. Despite fairly strict requirements of quality standards, market access is free. There are no barriers to entry. In this market there is genuine competition between producers on the one hand, and local producers of the same on the other countries.[36]

Worldwide production of essential oils

Approximately 150 HE are currently marketed today, up from 300 50 years ago. This may seem at odds with what has been said about the evolution of the market a little higher. It should be noted that even though tonnage production is indeed growing steadily, production in terms of number of species and varieties is shrinking. Some species are over-demanded over others because of their multi-use and because the market is changing by adapting to changing demand. The world's first tonnage of essential oil is orange EO, which is a by-product of orange juice production since it is extracted from orange peel by cold pressing. It is produced to the tune of more than 50,000 tons, mainly from Brazil and Florida, representing nearly 90% of the total volume traded. Then come mint (*Mentha arvensis*), whose production is estimated at 32,000 tons, followed by essential oils of eucalyptus (4,000 tons) and peppermint (3,300 tons).

As for the lavandin essential oil, typically produced in France, it ranks tenth among the most produced essential oils in the world (1,000 to 1,200 t). World production of essential oils has recently been estimated at more than 110,000 tons. Nevertheless, the top three most expensive EOs in the world account for nearly 90% of this total volume, with two major groups: citrus fruits and mints.[36] Table 8 - World production of the 13 most important essential oils (int) inventoried in 2013.[37]

Table 8 World production of 13 major essential oils (t) recorded in 2013[37]

Essential oils	Production (t)	Main producing countries
Orange Oil	51000	USA - Brazil - Argentina.
Japanese Mint Oil	32000	India - China - Argentina.
Lemon Oil	9200	Argentina - Italy - Spain
Eucalyptus Oil	4000	China - India - Australia - South Africa
Oil Of Peppermint	3300	India - USA - China
Clove Oil	1800	Indonesia - Madagascar
Citronella Oil	1800	China - Sri Lanka
Spearmint Oil	1800	USA - China
Cedar Wood Oil	1650	USA - China
Oil Litsea Cubeba	1200	China
Patchouli Oil	1200	Indonesia - India
Lavender Oil	1100	la France
Corymbia Citriodora Oil	1000	China - Brazil - India - Vietnam

Brazil is the world's largest producer of essential oils by volume, the second being India for its mint HE production, developed in particular north of Delhi. India has taken over the leadership of this production at the expense of China. Eucalyptus, produced mainly in China, is also one of the major products of the HE industry and is mainly used in functional perfumery and agri-food as aroma.

Growing world market

For several years, the market for HE has appeared to be constantly increasing. In 2010, a growth of the European market of about 3% per year is noted, while the major commercial flows are established mostly between the European Union, the US and Japan.[34] Looking at the European production market, we find that production no longer meets demand. Four main reasons explain this imbalance:

The craze for natural raw materials is no longer just a speech, it is a fact today.

The aromatherapy market has been developing in recent years. For example, Lavandin accounts for almost 10% of market shares according to the latest estimates.

The emergence of new applications of HE, particularly in the food industry, and especially their aromatic function (most often sought) has pushed industry to increase demand. ▪ Production can no longer meet demand on traditional production areas. Indeed, farms are already at the highest level of production and the emergence of new areas presents many difficulties, particularly in terms of investment and know-how.

Importing countries

The three main players in their import are Europe, the United States and Japan. Canada and Australia are also major consumers, but they import less. Several countries in Africa and Latin America are also used to consuming them but import very little. In Europe, the main applicants are France, the United Kingdom, Italy, Belgium, Spain, Holland and Germany.[36]

Price of essential oils

The difference in prices between different HE remains very important. If the price of an orange EO is estimated at approximately € 6 / kg, the price of a rose is currently between € 6,000 and € 7,000 / kg. Those of eucalyptus and thyme are between 700 and 1000 € / kg. The factors influencing the difference in these prices are in: the botanical species and the place of provenance, the method of extraction and the efficacy and application sought.[36]

The French market

French production

France concentrates most of the production of essential oils of lavender and lavandin which represents 60% of the European production. As this production is a highly competitive field, France faces the competitiveness of Spanish, Mediterranean and Eastern European productions (Bulgaria, Ukraine, Moldova). France also produces other essential oils from cypress, mint, clary sage, rosemary, thyme, myrtle, petit grain and juniper, all from Provence. Chamomile comes from the Loire Valley while geranium and vetiver bourbon come from the island of Reunion. Mayotte produces ylang essential oil in a market dominated by Madagascar. Since 2008, a downward trend has begun to emerge in volumes of French origin treated for export. Some crops such as orange blossom are destined to be phased out in favor of the world's largest producer, Tunisia.[38]

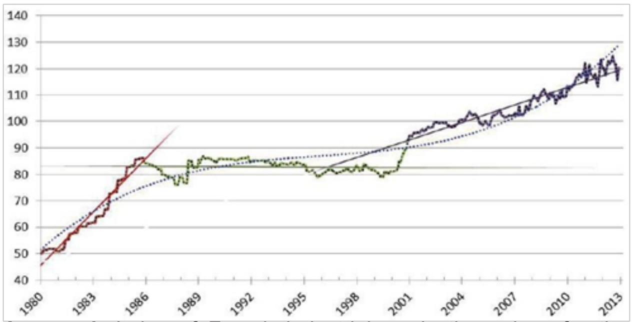
HE production in France peaked in 1999 and 2000 (Annex 7), with more than 17,000 tonnes. It then tended to decrease between 1999 and 2011. To mitigate this phenomenon, the main players in the industry expanded their customer base in 2002, beyond the traditional sectors of perfumery, cosmetics and personal hygiene, to extend to manufacturers of detergents, detergents, cleaning products, insecticides and diversifying by the production of flavors for the food industry.[38]

As part of the downward trend in production, starting in 2005, the relocation of companies is accentuated by increased competition, both in terms of crop quality and costs. There are also many very small businesses that count in 2005: more than eighty units with fewer than twenty employees. Often positioned in niches, they surf the current wave of well-being. The economic weight of these companies remains modest; however, it is equivalent to 10% of the workforce and the turnover generated by companies with twenty or more employees.

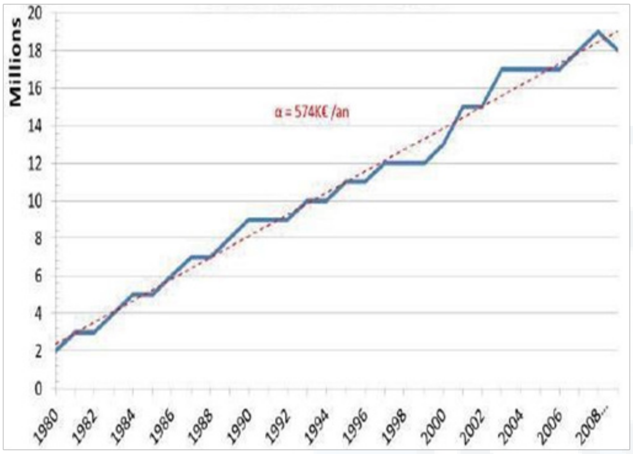
French market price and household consumption

INSEE provides two indicators that evaluate household consumption at current prices and price trends for the French market. If the average of French production decreases since 2001, we find that over the same period, producer prices would tend to increase (Annex 7). This production price inflation follows a period of stagnation of nearly fifteen years, between 1986 and 2001. The prices of essential oil production for the French market have experienced two major periods of inflation. The first proceeds the year 1986 and the second is 40% increase between 2000 and 2011. Between 2005 and 2013, inflation was 20%. For the years 2000 and 2001 alone, prices rose by 16.8%. Household consumption is growing almost linear, averaging 574 K€ / year between 1980 and 2009. The statistical series has not been updated by INSEE; the graphical representation of the trend for household consumption beyond 2008 is not currently available. The growing trend of household consumption in terms of expenditure must therefore be put in the context of rising prices of French production (Annex 7).

Annex 7a Average annual industrial production (manufacturing essential oils)[37]



Annex 7b Index of French industrial production prices for the French market of essential oils, discount CPF - 20.53 Essential Oils[37]



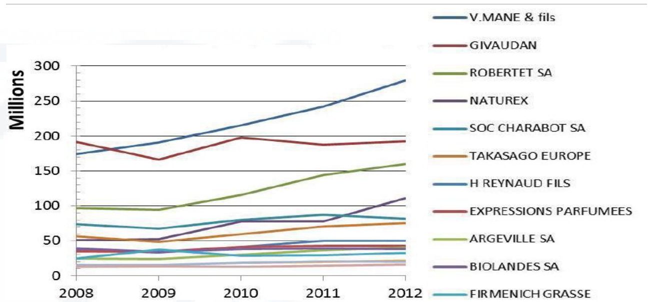
Annex 7c Effective Household consumption, euro value[37]

Turnover of French companies

The turnover of the main companies has its source in the public balance sheets of companies. In 2012, the company "V. Manne & fils" dominates the market of French companies. Since 2008, each year, 50% of the production of this company is used by the food industry and mainly the beverage industry which is now the leading French supplier of flavorings. The company "Givaudan" remains among the leading companies and ranks second in 2012. Finally, the company "Robertet" also confirms its third position by increasing its significant turnover since 2010. The turnover of main companies in the French market is also involved in international trade. The list of the main importers and exporters of essential oils for the year 2012, published in 2014 by INSEE, provides information on the main companies that operate in foreign markets. In 2012, "V.Manne & fils" followed by "Robertet" were at the top of the list of importers and exporters of essential oils. In France, in a context of delocalization, a drop in average production, as well as an increase in production prices, the main French operators have been able to maintain themselves both on the French market and on foreign markets Appendix 8.

Foreign trade of France

Historically surplus, the balance of foreign trade of France's deficit since the first reversal in 2001 and continuously since 2005. But France is historically the largest producer and consumer of essential oils that are exported around the world. The strong French consumption HE then maintains that the local average production and exports decline. The drop in exports was due to competition experienced in foreign markets and by the relocation of production. France imported in 2013 essential oils for a total value of €68 million, almost 17 000 tons. She also exported, again in 2013, for a total value of € 44 million, or nearly 6 500 tons. The trade balance of €-24 million, or 10 000 tons (Figure 4).[37]



Appendix 8 Turnover of major French companies[37]

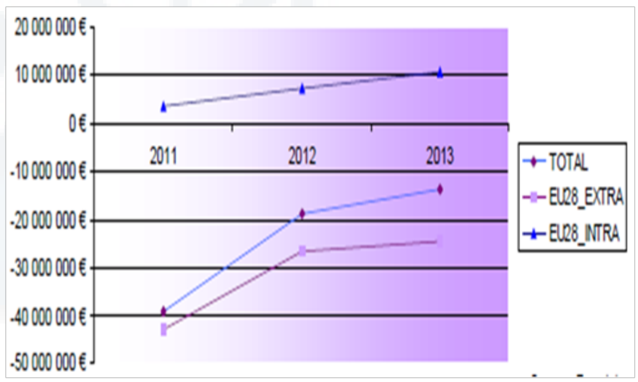


Figure 4 Foreign trade balance French essential oils.[37]

In 2013, the balance is in surplus and increase in trade in France within the EU (13.8 M €). The balance is in deficit, but growing outside the EU (€-24.5 million). The overall balance of France is €10.7 million. Countries that represent the most exchanges with France are the USA, Italy, Germany and Spain.

Chapter V

Applications, limits and perspectives

Essential oils have long been known for their culinary use and are also used to increase the shelf life of foods. As such, HE and its components are currently used as food flavorings. They are also known to possess antimicrobial activities and could therefore be used as food preservatives, all the more so because they are mostly classified as "generally recognized as healthy" as defined by GRAS (Generally Recognized). As Safe) and also approved as food additives. A large number of HEs, therefore, do not require food use authorization in both Europe and North America. However, preliminary studies are needed to better understand their antimicrobial activity.[5]

Double interest

Many people ask the question "Are essential oils additives or dietary supplements, or both?"

HEs have antioxidant and antiradical properties that improve the shelf life of the food and also interest the consumer in their nutraceutical values and health benefits. In addition, they are widely consumed as a dietary supplement, for example, to reduce fatigue, fight against memory problems, or even strengthen the humanitarian system. We can group them according to their usual interests and their current functions in the following table 9.

Table 9 Key interests of HE supply

Interest or function	Family	Example ET	Example products
Organoleptic	Aroma	Lemon, Mint	Soda, Juice, Yogurt
Organoleptic	Flavor enhancer	Cinnamon, Parsley	Dehydrated Soups, Chips
Organoleptic	Tasty	Orange, Vanilla	Salad Dressing, Cakes, Ice Cream
Sanitary	Tory	Thyme, Lemon	Prepared Meals, Sausages
Nutritional	Dietary supplement	Oregano, Eucalyptus	Capsules, Tincture

In agri-food, the use of essential oils is not limited to just one function. Indeed, technically, they can assume several, which give them many advantages over other substances such as synthetic additives for example, which are in most cases designed for a single function. This diversity of applications is also a negative point for these substances and in particular with regard to their price. Their wide use makes them very popular; strong demand that is not, unfortunately, at the same level as the offer. This contributes to the increase of their cost.

Essential oils, promising food preservatives

Food borne illness is a growing public health problem worldwide. In Europe in 2014, we estimate that thirty-one species of pathogens caused 8.4 million cases of food-borne intoxication.[37]

Effective control of food-borne pathogens requires the use of several conservation techniques in the manufacture and storage of food products. A recent consumer trend, showing a strong preference for low-salt and low-sugar products, shows the increased need for effective food preservatives but not generating other health problems such as diabetes, obesity or even cardiovascular problems. A wide range of preservatives is used to prolong the life of a product by inhibiting microbial growth.

However, a negative consumer perception of synthetic food additives has sparked interest in attempting natural alternatives to traditional solutions. Although initially added to foods to improve taste and flavor, the now proven antimicrobial activity of HE makes them attractive to replace synthetic preservatives. In the face of health crises and food-borne diseases due to conservation issues, scientists and industry professionals have decided to explore new technologies and substances that could counteract these problems without using questionable synthetic chemicals. The HE track has become a real alternative; the tests followed one another, the results were mostly confirmed conclusive. The use of HE is therefore the new solution against pathogenic flora.

Important antimicrobial properties

HEs have a very broad spectrum of action since they inhibit the growth of bacteria as well as those of molds and yeasts. Their antimicrobial activity is defined primarily by their chemical composition, and more particularly by 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 the biomass and production of the pseudo mycelium while inhibiting spore germination, elongation of the mycelium, sporulation and toxin production in molds.[5]

Targeted level of effectiveness and micro-organism

A recent study led by a Canadian team from the Research Laboratory for Applied Food Sciences (RESALA) reports on sixteen years of work on the development of the use of HE to reduce the incidence of pathogenic bacteria in food. foodstuffs. This team has researched and tested several HEs to study their kinetics of inhibition and the survival of pathogenic bacteria. Practiced on more than a hundred HE, they allowed to select about thirty, directed specifically against a wide range of pathogenic bacteria most commonly found in food (*Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus, Listeria monocytogenes*) and also spoilage bacteria (*Pseudomonas*, *Serratia liquefaciens*, *Lactobacillus curvatus*, *Lactobacillus sake*) of the 30 selected effective EOs, we can cite the four most successful ones: cinnamon, lemon, oregano and thyme.[3]

In order to then select the best that can be used as a food preservative, the researchers studied their efficiency threshold.

That is to say the lowest concentration of oil capable of inhibiting any bacterial growth, because depending on the desired effect and the targeted bacteria, the concentration will not be the same. Each microbial species reacts in a particular way to the different essential oils, and some of them have the specific inhibitory effects of a bacterium. The results obtained in this study in synthetic culture medium were confirmed in foods, but at slightly higher doses. However, the efficiency threshold of the most effective oils being very low (often less than 0.1 mg / kg of product) their addition in very small quantities does not significantly alter the organoleptic qualities of the food.[5]

Mode of action against bacteria in 3 phases

Essential oils have several modes of action on different strains of bacteria, but, in general, their action takes place in three distinct phases[5]:

a) Attack of the bacterial wall by the essential oil, causing an increase in the permeability and then the loss of the cellular constituents,

b) Acidification of the interior of the cell, blocking the production of cellular energy and the synthesis of structural components,

c) Destruction of the genetic material, leading to the death of the bacteria.

Alternative to chemical additives and heat treatments

Alternative to synthetic preservatives

Essential oils could be a credible alternative to chemical preservatives such as “E210: Benzoic Acid”, ubiquitous in sweetened beverages or “E214: P-Hydroxybenzoate ethyl”, better known as Paraben name and frequently used in cold cuts and sweets, which endanger the health of consumers especially when they are contained in highly consumed products such as sodas, fruit juices, prepared dishes, etc. After consulting some of the results of recent studies on the application of EOs as preservatives, we have noticed that nowadays they come in new forms, different from what we know, and often in the form of substances incorporated directly into foods during their manufacture. One of the most interesting applications of HE as a natural preservative is that these substances could be incorporated directly into food packaging. In order to improve the properties of food films, the addition of a low dose of these essential oils could effectively prevent the deterioration of the food and prolong its shelf life, without having to incorporate any additives in the food. This tactic is a real alternative to the strong odorous HE that is sometimes unpleasant. We were inspired by this technique to propose some solutions facing the technical limits of HE uses.

This technique consists of stabilizing the essential oils in edible polymers (biofilm, coating, capsule, emulsion) that allow their diffusion to the food throughout its storage. Another technique for adding HE in foods to keep them longer has been used in the USA and Canada since 2015: the principle is to apply them by spraying on the surface of the food (piece of meat, sausage, chicken, whole fruit and vegetables) thus helping to control the microbial flora and to preserve the food of the oxidation phenomena.

Combination with thermal treatments

Essential oils can also represent a very important financial interest for manufacturers and manufacturers. They can replace or significantly reduce the cost of heat treatments, very expensive. We know that in the economic context of the agri-food industry, energy is also a real issue. The food industry is the third most energy-intensive industrial sector after the chemical and metallurgical industries. This is related to the important energy needs of the manufacturing processes, but also to the requirements in terms of sanitary safety (sterilization, pasteurization, cold chain,) whose purpose is to ensure a safer and above all longer lasting storage. Energy therefore represents a challenge that is both economic and environmental, but also an important competitiveness issue for this sector. This is, on average, the first item of cost of production ahead of that of raw materials and labor. Beyond the high blow of the physical treatments, are added some technical problems which appear on the food products, generated by this kind of processes which can be negative. We talk about adverse effects such as, for example, the destruction of nutrients and the loss of taste qualities. A heat treatment, with its ability to destroy the microbial action has also an action on the rest of the components of the food: enzymes, proteins, vitamins, etc., which can affect its physical properties as its color, its shape, even its consistency.

Given the high cost of the impact on the environment by gas emissions, as well as the complexity of the actions of heat treatment of food, it is necessary to find another way of reducing or reducing the use of physical treatments. Optimizing the way we store food products on a large scale and with huge amounts of production without harming health or the environment has become possible and feasible today. So we can ask that essential oils are a real trail to explore and develop in the coming years to use as a substitute for physical treatments. We wish, through our reflection, to arouse the interest of the concerned industrialists to adopt a project of exploitation of the essential oils. Some readers will recognize that this is indeed feasible but HE are relatively expensive and, moreover, are not all of the same efficiency, especially in terms of destruction of germs or shelf life. Our response to this question is reflected in the presentation of a table setting out the technical characteristics of each process (Table 10).

These elements allow us to see very clearly that the conservation technique with essential oils sometimes has more advantages than the first two processes. The organoleptic and nutritional quality of a food constitutes a first criterion of purchase for the consumer. The research and testing of HE preservatives showed no impact on the organoleptic or nutritional quality of the products. The results of these tests, carried out on dozens of types of products, cold cuts, salads, fruit juices, sodas, prepared dishes, but also on dairy products such as yogurts and creams have shown that the products have now remained stable, sensory and gustative as well as nutritional. The shelf life of a food product is an important purchase criterion for consumers. Now, thanks to the HE storage technique, consumers can consume their products for several days after opening and for some of them it is no longer even necessary to keep them cool. In general, we find that the effectiveness of HE is now obvious and that this efficiency is sometimes better than pasteurization or sterilization. The second point, after the efficiency, on which readers can also ask the question, is the cost of essential oils. Some people think that "Yes, now their effectiveness is proven and confirmed, but HEs are very expensive, right? The only way to answer this question concretely is to make a comparative calculation of the cost of a thermal process and of that of the technique by using essential oils. Research and trials have shown that an average incorporation of 0.1 ml of HE per 1 kg of products is sufficient to ensure optimal preservation of several types of food products. This dose is of course, variable depending on the type of product and the species of HE. Essentially, in the majority of the cases studied, the effectiveness of the antimicrobial effect of HE usually starts from a dose of 0.5 ml. A pasteurization of 10 tons of food products consumes an average electrical energy estimated at 4666 KWH. The average price of a 1 kWh is 0.15 €.

Table 10 Characteristics of 3 processes and conservation techniques food

Processes	Pasteurization	Sterilization	HE use
Interest	Destruction of some microorganisms in a vegetative state (yeast, mold, somenon-spore forming bacteria)	Destruction of all microorganisms (including spore forming bacteria)	Destruction of several microorganisms (including spore forming bacteria)
Principle	Temperature (between 62 and 88 °C)	Temperature (between 100 and 120 °C)	Selection ET (ET have a specific efficacy) of Incorporation ET
	Time (between 2 min and 20 min depending on the type of product)	Time (15 sec 5 min depending on the type of product)	
Duration	Before opening	Before opening	Before opening
	Storage Temperature (Between 4 and 6 °C)	the fee is not required	the fee is not required
Conservation Average (Lifetime Product)	Some months (1-12 months)	Months (12 to 36 month)	Several months (12 to 36 month)
	After opening	After opening	After opening
	Some days (3-5 days)	Some days (3-5 days)	The fee is not required
	Temperature storage (Between 6 °C)	Temperature retention (Between 6 °C)	Several days
Type of Product and Packaging	Several types of products, liquid, semi-liquid, solid …	A limited number of products	
	Several types adaptable packaging (Bottles, jars, cans metallic, plastic pots)	Some types of packaging Attachments (bottles,jars, boxes)	
Potential Impact Product	Low degradation of the organoleptic and nutritional quality	A significant deterioration in the organoleptic and nutritional quality (risk denaturation)	A slight deterioration in taste quality (odor) No degradation nutritional

Before making the calculation, we decide to choose yogurt as a type of food product. Lemon essential oil is oil that has a very high efficiency and antimicrobial effect against pathogenic flora in dairy products in particular, (*Listeria monocytogenes* and *Staphylococcus aureus*). Cinnamon HE also has potent antagonistic power in dairy products. The great advantage of these two oils is that they do not destroy the bacteria that are useful and indispensable to manufacture of derivatives of dairy products, in particular lactic acid bacteria and acidification ferments. The average price of a 15ml bottle of lemon or cinnamon HE is estimated at 5 €. We now have all the data needed to make a comparative calculation (Table 11).

Although these essential oils are actually considered expensive, it turns out that ultimately, their cost of use for the control of pathogenic flora as for conservation, remains lower compared to the energy consumption of the pasteurization process for the same purpose. HEs are a real trail to explore for a future without excessive energy costs that are harmful to the environment and expensive for industry. We are aware that they will not permanently replace, overnight, heat treatment processes such as pasteurization. Nevertheless, we can already begin to introduce them gradually into our processes. Why not adopt the HE technique as a support for the physical process. In Canada, the dairy industry giant (Agropur) is one of the first manufacturers to use HE in the combination and modulation technique with mild heat treatment. It is a practice to incorporate HE in food products and apply heating at 50°C for one minute. This technique allows to reduce the energy consumption but also to keep a perfect level of nutritional value and the organoleptic aspect of the product. It also ensures a very high level of sanitary quality. In France, the most common use of essential oils remains used for organoleptic purposes, mainly for flavorings in beverages.

At the same time, the use of HE in storage remains timid, very few industrialists apply them for sanitary purposes, especially in the neutralization or control of pathogenic flora and the alteration of food.

Table 11 Calculation of the cost comparison between pasteurization and essential oils

Pasteurization	HE lemon Or cinnamon
Product: 10,000 kg of yoghurt pots	Product: 10 000 kg of yogurt pots
Energy consumption: 4666 kWh (0.4 666 kWh / kg)	Incorporation: 1000 ml to 10 000 kg of yoghurt (0.1 ml / kg)
1 kWh0.15€	15 ML5€
4666 kWh700€	1000 ml333.33€
Total cost : 700€	Total cost : 333.33€

Limits of essential oils and solutions

Technical limits

Essential oils have shown a lot of benefits and usage interests in food products. Despite this, there are some limitations on their use as a preservative in foods, including the flavor of some of them. The main technical limit is the intense aroma of essential oils. Indeed, sometimes even low concentrations can lead to negative organoleptic effects, exceeding the acceptable threshold in some products. Given this limit, different strategies can be put in place to work around this problem. The context of use of HE in packaging, which we mentioned earlier, has left us thinking of a technique of using essential oils in active packaging rather than as an ingredient in the product itself. More concretely, we aim with this technique to encapsulate essential oils in polymers, coatings or sachets edible and biodegradable that provides a slow release of active substances on the surface of the food or the free space of packaging, as per example, fruits, meat and fish. These sachets releasing volatile active substances, HE could simply be placed in a closed food packaging.

The advantage of incorporating volatile components of essential oils into edible films or coatings is that the diffusion rate of the agents away from the food product can be reduced, while maintaining the active compounds in the free space of the food product. Packaging or on the surface of foods for extended periods of time. It is important to note that in most cases, the concentrations of oils used are so low that they do not alter the taste quality of the food. Another limit and aspect to be taken into account, is to verify that the selected essential oil has no antimicrobial effect against the useful bacteria, especially against the ferments of acidification, aromatization and ripening, essential to the manufacture of dairy products. The only way to intervene that we can propose, in order to minimize these effects on beneficial germs, is to carefully select the essential oil according to the type of food. Two main HEs are now the most adaptable to this kind of food products; those of lemon and cinnamon, the most recommended for applications on this type of products.

Regulatory limits related to the assessment of toxicity

A wide range of essential oil components has been accepted by the European Commission for use as flavoring or preservatives in food products. Registered and accepted substances include, for example, linalool, thymol, eugenol, carvone, cinnamaldehyde, vanillin, carvacrol, citral and limonene, all of which are considered safe for consumer health. Despite the large number of EOs or their compounds that do not require an application for authorization for their use, regulatory limits exist for some of them. A first limitation concerns the question of the acceptable daily intake of these substances, so that before they can be used in food products, a clinical trial dossier on the ADI must be provided for obtaining authorization. The dossier must be designed on the results of toxicological studies of the oil or of the active substance concerned, a study that is sometimes very difficult to carry out because of the instability of the compounds. Therefore it is necessary to "boost" progress on the issue of toxicity and their effects on health. In the literature, there is no comprehensive evaluation of the toxicity of essential oils. Variability and instability in the quantity and quality of EOs make it difficult to assess the toxicity of all EO species of all origins.

We considered a strategy that could be a solution to this difficulty of study, due to the variability and instability of the active compounds of HE. The following table illustrates the principle of strategy that could be developed by industry to circumvent the problem of the difficulty of toxicological study of HE (Table 12).

The principle of this strategy proposal is to implement a study on all families of HE compounds that would initially allow us to establish minimal LD_{50} values only by ingestion and then allocate ADIs. Maximum with this strategy, we want the study of the effects of essential oils to be conducted on families of HE compounds and not on whole HE species. Indeed, the EOs changes composition permanently for the causes that we mentioned previously, which makes it impossible to constantly evaluate their toxicity. It is understood that this proposal remains only an "idea", likely to be developed and materialized in a future project so that this table can be completed.

Table 12 Evaluation Strategy Proposal of the toxicity of food ET by families of active compounds

Family biochemical components of ET (partial list)	Example plants	LD 50 (Minimal)	ADI (Minimal)	Health effects (diseases, target organ ...)	Population exposed
Acids	Citrus				
	Sage				
Aldehydes	Lemon				
	Cinnamon				
Ketones	Rosemary				
	Mint				
Coumarins	Celery Orange				
Esters	Vanilla				
	Eucalyptus				
Ethers	Basil Pepper				
Mono terpenes	Thyme				
	Oregano				
Monoterpenols	Eucalyptus lavender				
Phenols	Pepper				
	Thyme				
Sesquiterpenes	Nail				
	Parsley				
Sesquiterpénols	Carrot Basil				

The perspectives

Control of pathogenic flora and the deterioration of food products through a reasoned use of the potential of essential oils

The use of the potential of the HE, which can be modulated in the processes, in order to increase the lifetime of the products and to reduce the environmental impact related to their manufacture and their transport which requires a chain of cold without interruption. HEs are clearly in the perspective of applying energy-saving technology through a gentler, less expensive heat treatment that will enhance the quality and microbiological safety of foods and, consequently, contribute to reducing indirect economic costs for consumers. Operators and distributors, linked to withdrawals of poorly preserved products during their marketing. The use of essential oils therefore offers opportunities in the agri-food sector, namely, to strengthen their competitiveness in the context of developing methods and techniques for the preservation of the food product.

Healthy food with sustainable processes

Preserving food products while preserving their properties and their microbiological safety, by using a technology with reduced environmental impact, are feasible by the HE technique. This sector has been criticized at length for its harmful contribution to environmental pollution by its greenhouse gas emissions. Much of its emissions are generated by food preservation processes. After the COP 21 held in Paris in December 2015, the major global industrial groups in the sector have become very attentive to the development of new technologies and moderated processes to reconcile nutritional quality, sensory quality and food preservation. Some manufacturers have already started to introduce these substances into their factories, and these professionals have even mentioned their satisfaction with performance during the first tests of these products.

Today, we can think that, thanks to a reasoned use of essential oils, ensuring a healthy and sustainable diet through innovative food processes has become feasible. Nevertheless, these development technologies must be thoughtful, well regulated and respectful of our environment. In the case otherwise, they risk losing some of their credibility as so-called “natural” substances. One of the key points to be considered by the agri-food industry when designing these technologies is the consumer. Study the trends of consumption by the public to determine which technologies they could appreciate (or not), for which types of products would they like to see the composition mentioned (eg “substances from HE”), what kind of packaging would he be attracted to, what price would he be willing to pay, etc.?

Chapter IV

Survey, results and discussion

Consumer expectations are therefore one of the key factors in determining and choosing technologies for the development of essential oils in food products and we decided to question them on these topics.

Background and purpose

Recall that the purpose of this survey was to explore consumers' perceptions of essential oils and food products containing HE-based additives. We wanted to question them on their vision of the food consumption of these oils after having noticed that the concept had not been defined by the main interested parties. On the other hand, we also wanted to assess whether the consumption of these natural products could be of interest to consumers and to better understand the factors related to their purchase or not. This survey should therefore highlight indicators influencing the consumption or not of HE, their most consumed species, but also the degree of knowledge of the possible advantages and disadvantages of their consumption. We have proposed the following questions:

i. What are the consumers of food HE?

ii. What is the perception of consumers of this type of product?

iii. Why do consumers choose HE?

iv. Where do they buy these products?

v. What are their criteria for choosing HEs?

This questionnaire is available in its entirety in Appendix 9.

Appendix 9

Essential oils in food products, do you say?

I am a student of the Faculty of Engineering and Management of Health (ILIS, University of Lille) in Master "Nutrition and Food Sciences", and I chose the subject of essential oils for my graduation project. I would like to conduct a survey to find out to what extent it would be interesting to integrate essential oils into food products.

Thank you in advance (essential oil consumers OR NO), your answers would be a great help.

1. What age group do you belong to?
Only one answer possible.
18 39 years
40 59 years old
60 74 years
75 years and over

2. What is your gender?
Only one answer possible.
Man
Wife

3. What is your profession?
Only one answer possible.
Frame
Student
Worker
Liberal professions
Intermediate professions
No occupation
Other: ....

4. Do you know that you can use essential oils in food products?
Only one answer possible.
Yes
No

5. Do you use edible essential oils in your kitchen?
Only one answer possible.
Yes
No

6. Do you eat food products containing essential oil additives in their composition?
Only one answer possible.
Yes
No
No idea

7. If no, why the consumption of essential oils does not appeal to you?

8. What are the benefits of using essential oils in your kitchen or consuming food products containing essential oils?

9. What is the essential oil that you use or search for most often in food products?
Many possible responses.
Citrus
Basil
Eucalyptus
Mint
Oregano
Rosemary
Thyme
Sage
Other: ....

10. Where do you buy your essential oils?
Many possible responses.
On the Internet
Specialty stores of the type Franchises bio Large surfaces
pharmacies
Other: ....

11. Choose one or more quality requirements that you are looking for most in essential oils?
Many possible responses.
Place of origin (Origin)
Natural 100% (Bio)
Pure 100% (No additives)
Flavor
Color
Other: ....

12. Do you find accessible essential oils (point-of-sale prices)?
Only one answer possible.
Yes
No
I do not know the prices
I have never seen in store

13. If a product containing only additives based on essential oils (flavorings, preservatives ...) went out in supermarket / supermarket, would you be ready to buy it?
Only one answer possible.
Yes
No
Perhaps
87

14. Do you find that the consumption of essential oils is dangerous for your health?
Only one answer possible.
Yes
No
No idea

15. If yes, why?

Exploitation of the results

The survey was formulated on Google forms and thus broadcast on the internet. During the 15 days of its diffusion, we were able to obtain 103 answers via internet. However, having noticed that some age groups were not represented, a face-to-face administration of the same questionnaire as the online one was conducted.

The results presented in this thesis are based on the analysis of the responses from the sample of participants, i.e. 122 participants in total. The two age categories in question are the 60-74 age groups and the 75+ age bracket. Indeed, in August 2015, INSEE, published on its website that in France, 27% of the population aged over 60 was Internet users and only 8.4% of people born before 1936, were “unavailable “ online. The fact that they do not have or use much less internet compared to younger people, explains their absence in the responses of this survey when it is broadcast online. The collection of information concerning all the people who responded gives the following observations.

Age groups

According to the results of INSEE, the total population, by sex, age and employment status on 1 January 2016, estimates the population aged over 68 to 13 million, which represents 21% of the total of the French population whereas in our survey this age group constitutes only 12% of the participants (Figure 5).

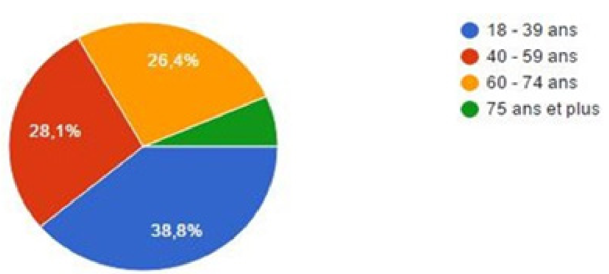


Figure 5 Percentage of age groups of participants.

The age range for which we have the highest number of responses is between 18 and 39 years old. The high availability of this category on the internet explains why it was strongly represented. We then find two age groups, namely those aged 40 to 59 and 60 to 74, respectively. Note that the response rate for these two categories is almost similar. Lastly, we reach the age group greater than 75 years.

Percentage male / female

In our survey, gender representation is more in line with INSEE surveys, which estimate that 54% of the population is female. Of all participants, this genre is represented by a value of 56% against 44% for the male gender.

Socio-professional categories

Concerning the representation of the professional situation of the participants, we can say that all the categories are represented, and, with percentages relatively close for most of them (Figure 6).

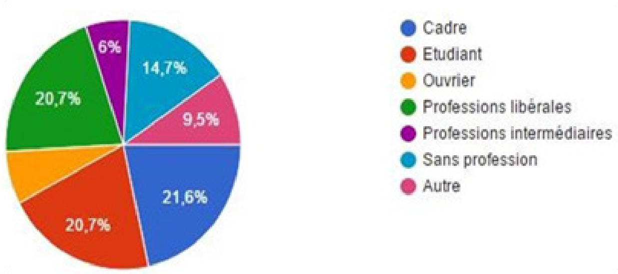


Figure 6 Socio-professional categories of participants.

We recorded participants from all socio-professional categories. The highest participation was recorded among executives at 21%, followed by students and professionals, with 20.7% for each of these categories. The category of workers is the least represented in this survey.

Answers to questions

a) **Do you know that essential oils can be used in food products?**

The objective of this question was to define the degree of knowledge of people about the use of HE. More than 20% of participants do not know that they are used for food consumption. The majority of them is young students and thinks that essential oils are used for purposes only therapeutic, care and beauty. The results of this question have been reconciled with the interactions of the age group and the socio-professional category and are presented in the following Chart 1.

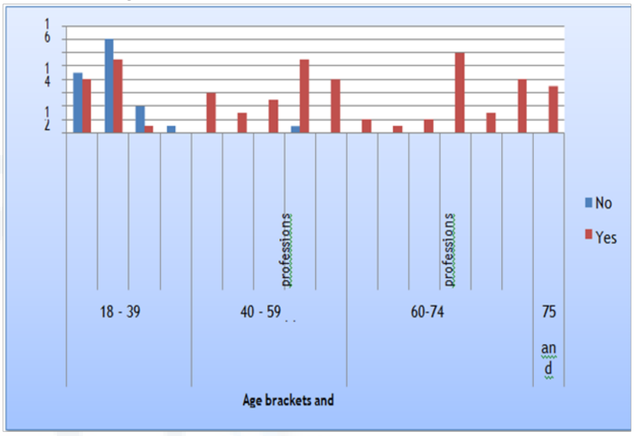


Chart 1 Knowledge of the participants on the use of HE in the field food / N = 122

b) **Do you use edible essential oils in your kitchen?**

More than 30% of participants use essential oils when cooking or consuming them indirectly when buying food products containing HE as either a main ingredient or an additive. The results of this question with the interactions emanating from the age group and socio-professional category concerned are shown in the Chart 2.

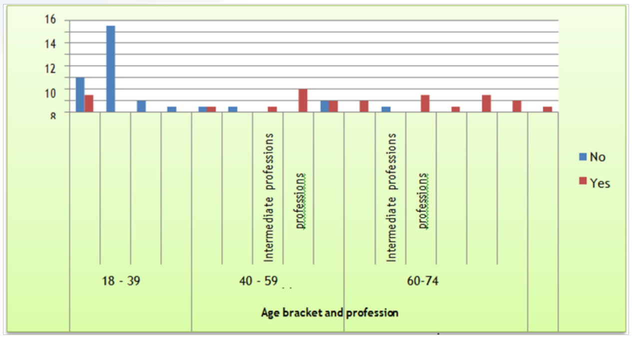


Chart 2 Use of HE depending on the age group and occupation / N = 122

These results clearly show that no young student uses essential oil in their diet and that people over 60 are the ones who consume the most. This is reflected in their eating habits. We also found that women consume HEs slightly more than men, with a percentage of 56% versus 44%. We study the motivations and the obstacles to this consumption of HE in the following part.

c) **Motivations and barriers on consumption**

40 respondents consume HE (motivations)

82 respondents do not consume HE (brakes) (Table 13)

In order to obtain credible answers on the motivations and the brakes on the consumption of HE, we left the freedom of response to the participants. During their processing, we grouped them and classified them in Table 12. The items, even with "zero answer", make it possible to evaluate if certain brakes for the non-users represent the motivations given by the users and vice versa. The goal is also to see how much the two categories are in agreement. Knowing that an HE consumer respondent may choose several motivations, so the same item for a non-consumer may express several barriers explaining "non-consumption"

Table 13 Key motivations and brakes to the consumption of ET

Motivations	Number of respondents	Brakes	Number of respondents
Taste, flavor	39	Price	78
Natural, Organic, without dangers	33	Availability	71
Beneficial health effects	30	Ignorance of products	38
Convenient	8	Taste, flavor	23
Other	8	Other	15
Price	0	Doubt quality	15
Availability	0	Convenient	0

The main motivations are the highly appreciated organoleptic aspect, the natural origin as well as the organic production method, but also the positive effects on health (some consumers expressing that the EOs improve the functioning of the organism). Among the examples of benefits given, we find: rich in antioxidants, rich in vitamins, strengthen the memory, fight against cardiovascular diseases, etc. The practical aspect has also been mentioned, as some consumers find that HE is more practical than other products such as spices for example. Some people did not mention any motivation, they say that they only eat them because they eat with their family and that other family members use HE in their kitchen and that it does not bother them to eat food cooked with.

As for the brakes, the main reason is the accessibility, the price first and then the unavailability of the products on the traditional points of sale, mainly in large and medium surfaces. A category of people who do not consume HE thinks it's dangerous for health and refers to the term "toxic" in this regard. We interpret that it raises fears concerning the toxicity of these products and that the level of current knowledge does not allow to appease them. To clarify the question of accessibility, we have asked the question to people who consume essential oils because they are best placed to answer them (unlike people who do not consume them), since they buy more or less regularly. The answers confirmed that the lack of accessibility is a real obstacle to the consumption of essential oils. Participants' views on the accessibility issue of EOs are shown in Figure 7.

A small proportion of participants believe that essential oils are available at affordable prices in stores. While more than half said "no", so finding that HE is expensive and not quite available in the market in terms of quantity and quality. Several participants said they have never seen in store which confirms that their unavailability is one of the potential brakes to their consumption.

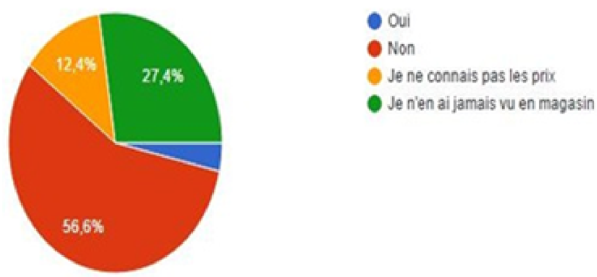


Figure 7 Notice of participants on the accessibility of ET.

d) **The most consumed essential oils.**

EOs for food consumption consists of a wide range of plant species. In order to get an idea of the most requested and consumed, we asked the question to our participants, those now users of these products, to evaluate their preferences, knowing that they had the choice to select several The most appreciated are shown in percentage below (Figure 8).

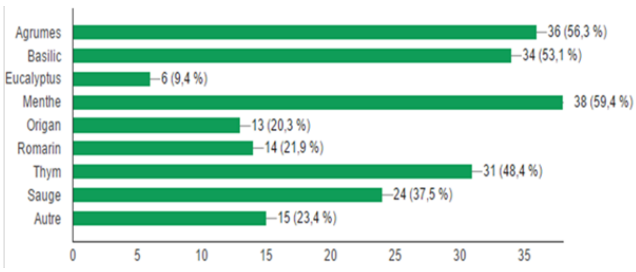


Figure 8 Species of the most consumed ET by participants.

The most consumed HEs are citrus fruits (lemon, orange) and mint. They are most frequently used, especially in desserts and pastry products. The HE of thyme, basil and sage are also consumed in the preparation of hot sauces. In the "other" category, respondents mentioned several culinary essences, such as cinnamon, caraway and ginger.

e) **Place of purchase and quality requirements.**

The issue of accessibility of EOs mentioned by the participants is relatively related to the place of purchase and the selection criteria in order to know where users are supplied and what their selection criteria are. Here again, we asked the participants.

The results concerning the place of purchase and the main criteria are represented in the two following Figure 9 & Figure 10.

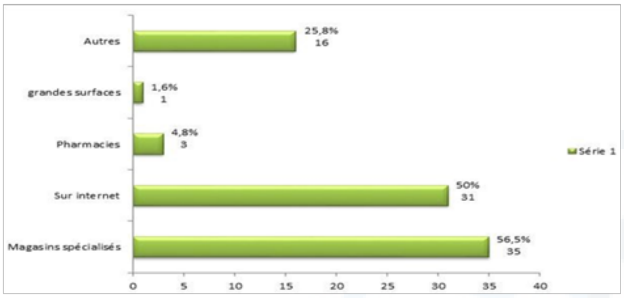


Figure 9 Shopping Places of ET.

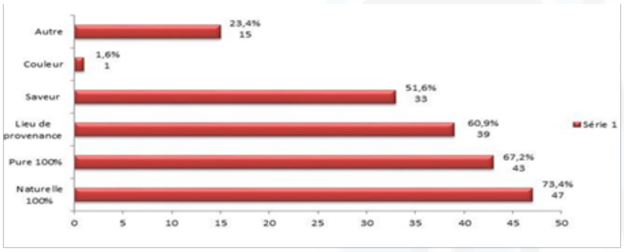


Figure 10 Main HE criteria.

The first places of sale of essential oils are specialized stores, followed by close by online sales on the internet. Supermarkets come in last place. Some people mentioned that HEs were present on large and medium-sized retailers, but at the same time expressed doubts about their as part of this large distribution. It would seem, therefore, that the consumer has a greater confidence, guaranteed quality by buying HE on the internet, or directly from producers or specialized stores. Regarding selection criteria and quality requirements, consumers require HEs to be organic, pure and have also mentioned many times the importance of the type of place of provenance.

f) **Consumers' knowledge of the possible negative effects on health.**

To assess their knowledge and the level of fear of the participants concerning the possible harmful effects caused by the consumption of oils essential, we decided to ask the following question:

"Do you find that the consumption of essential oils is dangerous for health?"

The recorded results are shown in Figure 11.

This graph shows that more than 40% of participants think that HE does not have possible negative effects on health, while more than 20% of them consider essential oils as potentially dangerous in food consumption: most of these people do not consume essential oils. Respondents who answered "yes" added that HEs were toxic to the body, while others also indicated that they were dangerous when their consumption was excessive. The 3rd category, the most important, has no idea about the dangerousness or not of essential oils, a response that we interpret as lack of knowledge about HE.

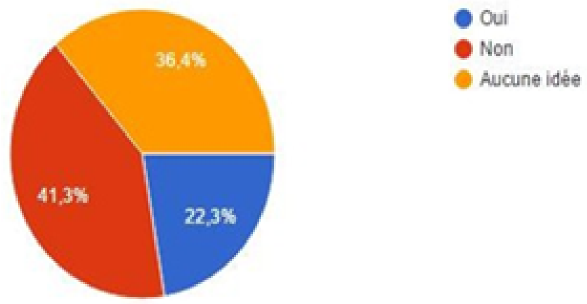


Figure 11 Review of the participants on the toxicity of ET.

At the end of the questionnaire we wanted to know if the participants were interested in purchasing products containing HE ingredients and additives Figure 12.

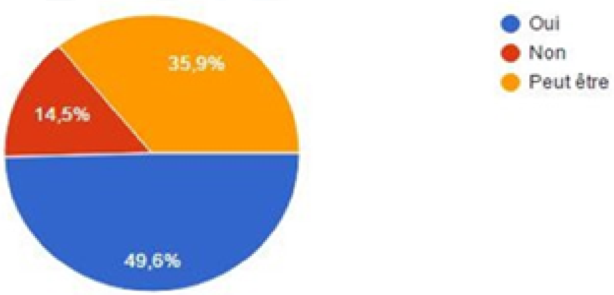


Figure 12 Percentage of participants who are ready or not to buy HE.

We find that if half of the respondents are ready to buy this type of product, 35% say they are uncertain. A small proportion said they would never buy one.

Analysis of survey results

The results of this survey made it possible to classify participants into 3 categories.

The first category consumes essential food oils in a direct manner in their dishes or indirectly by consuming products containing HE-based additives. The second category does not consume essential oils.

However, we have noticed that both categories share opinions in common; indeed; they both recognize that HE is not very accessible compared to other products, and that they have a good organoleptic function. These two categories, however, disagree about the possible effects of HE consumption.

The third and last category includes "non-interested" participants who do not have real knowledge of EOs, their functions in foods, or their effects on health. Some even mentioned that they did not know their use in cooking and thought that they were used only in pharmaceutical and cosmetic. Therefore, these participants do not share any opinions or show any disagreements about food HE with the first two categories. Nevertheless, their majority showed a certain interest for the purchase of products containing HE-based additives Figure 13.

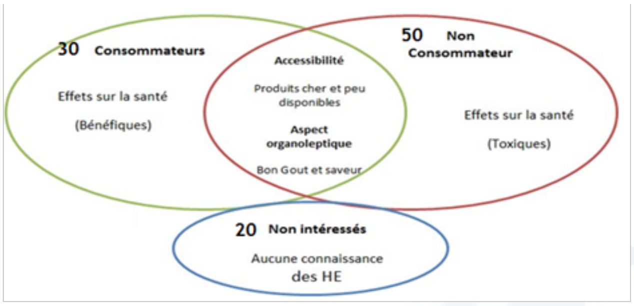


Figure 13 Categories of participants and interaction opinions.

This analysis of the survey results suggests that consumers have a vision of HE that is similar to that of the literature, that is to say rather positive, except for one category of consumers, that of the "dangerous to "health", some consumers actually consider HE as dangerous for human health. With regard to the item "motivations", the aspect of organic consumption and natural products beneficial to health seems to be predominant.

Various other motivations are cited by the participants such as taste, aroma and practicality. Besides the justification of the dangerousness of essential oils for health, the main obstacle to their consumption is accessibility, mainly with the notions of price and unavailability.

The survey also shows that participants, in general, do not have much knowledge about essential oils. Some of them, for example, mentioned beneficial and negative effects on health, which do not prove to be true in reality.

Apart from the highly sought-after organoleptic function, the other functions of HEs also remain unknown for all participants, even those who do not know their other applications or their scientifically proven interest, particularly in the functions of conservation and preservation of food products.

Conclusion

Remember that the objective of this work was to highlight the potential of essential oils and the recovery of these substances by their use in innovative food manufacturing processes. The survey allowed us, at the same time, to interpret the perception and knowledge of EO by the general public. During this study, we were able to draw some conclusions.

The many natural properties of essential oils make them both nutraceutical ingredients and preservatives very promising for the food industry. Each essential oil has a specific activity, which varies according to microorganisms and environmental conditions. Also, the generalization of their antimicrobial action is not easily conceivable for all foods.

The use of essential oils nevertheless proves to be a relevant choice in the face of a risk of specific contamination and the need to reduce or even replace chemical and synthetic preservatives. Their use in very small quantities is therefore possible because of their high efficiency, unlike some additives such as salts or whole spices. Their use, combined with other preservation processes, will certainly make it the natural antimicrobial agent in the coming years to improve the shelf life of foods. In addition, the addition of essential oils in a food could give it a nutraceutical value.

Moreover, if we can find a real weak point to essential oils, apart from the technical limits, we consider that their reputation is a real one, requiring a lot of progress to make. The vast majority of food HEs are considered safe, but this appreciation is not enough to reassure a large number of people, remaining generally very suspicious about their use. Indeed, a relatively large number of survey participants told us that "if the essential oils of aromatherapy, cosmetics and pharmaceuticals were dangerous, why would not food HEs be too, being made of the same way and by the same principle? "

We infer that an amalgam is made by the general public between the different kinds of essential oils and that the ignorance of the fact that, only their manufacturing process will determine if they become or not dangerous substances, plays into71 disfavor for possible use. There are also a multitude of other factors, such as climate, origin of HE. that govern their toxicity and these parameters are not sufficiently known to the public.

The challenge now is to reassure potential consumers, in particular by clarifying the context: conduct campaigns to raise awareness and presentation of these products to a wide audience, "go out" essential food oils of the same group as HE others and having a different interest (aromatherapy, cosmetics). In the face of the paucity of information and existing documentation, scientific communication and the technical valorization of the results of studies carried out in this field also become one of the keys to success for HEs.

In view of all the elements discussed throughout our study, we can conclude that essential oils are a real and credible alternative to synthetic additives and that their application also generates a real evolution in the ever more respectful approach of our environment, especially in terms of energy savings Appendix 9.

References

1. Fernandez Xavier, Chemat Farid. La chimie des huiles essentielles. *Tradition et innovation.* 2012. 288 p.
2. K Husnu Can Baser, Gerhard Buchbauer. *Handbook of Essential Oils*. 2nd ed, Science, Technology, and Applications, CCR Press; 2013.
3. Victor R Preedy. Essential Oils in Preservative Food, Flavor and Safety. 2015. p. 875-895.
4. AFNOR. Huiles essentielles -recueil des normes françaises. Paris; 1986.
5. The United Nations Food and Agriculture Organization. 2016.
6. Raul Leon, Hernandez Ochoa. Substitution de solvants et matières actives de synthèse par un combine « solvant/ actif » d'origine végétale. Thèse de l'Institut National Polytechnique. Toulouse, France; 2005.
7. Ministry of Economy, Finance and Industry. Parachimie in numbers. 2007. p.14-15.
8. List of solvents used during extraction. Pierre and Marie Curie University, Paris; 2016.
9. Degryse AC, Delpla I, Voinier MA. Health Environment Workshop. IGS EHESP; 2008.
10. Pibiri MC. Assainissement microbiologique de l'air et des systèmes de ventilation au moyen d'huiles essentielles. École Polytechnique Fédérale De Lausanne; 2005. p. 171.
11. Porte A, Godoy R. Chemical composition of *Thymus vulgarius* L. (thyme) essential oil from the Rio de Janeiro State (Brazil). *J Serbian Chem Soc.* 2007;73:307–310.
12. Sokovic MD,Vukojevic J, Marin PD, et al. Chemical composition of essential oils of thymus and mentha species and their antifungal activities. *Molécules*. 2009;14(1):238–249.
13. Santoyo S, Cavero S, Jaime L, et al. Chemical composition and antimicrobial activity of *Rosmarinus officinalis L.* essential oil obtained via supercritical fluid extraction. *J Food Prot*. 2005;68:790–795.
14. Adams RP. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry. 4th ed. Allured Publishing Corporation; 2007.804 p.
15. Zellner BA, Dugo P. Analysis of Essential Oils. *Hand Book of Essentiel Oils. Science, Technologies and Applications*. 2010. 151 p.
16. Dorman HJD, Deans SG. Antimicrobial agents from plants: antibacterial activity of plant volatile oil. *J Appl Microbiol*. 2000;88(2):308–316.
17. Edris AE. Pharmaceutical and therapeutic potentials of essential oils and their individual volatile constituents: A review. *Phytother Res*. 2007;21(14):308-323.
18. Braga PC, Dal Sasso M, Culici M, et al. Antioxidant potential of thymol determined by chemiluminescence inhibition in human neutrophils and cell-free systems. *Pharmacology*. 2006;76(2):61–68.
19. Maruyama N, Sekimoto N, Ishibashi H. Suppression of neutrophil accumulation in mice by cutaneous application of geranium essential oil. *J inflamm*. 2005;2(1):21–11.
20. AFSSAPS. Recommandations relatives aux critères de qualité des huiles essentielles. 2008.
21. ANSM. Recommendations on Quality Criteria for Essential Oils - Contribution for the Safety Assessment of Cosmetics Containing Essential Oils. 3rd ed. Council of Europe, Blue Book; 2008. 18 p.
22. ANSM. Substances aromatisantes et sources naturelles de matières aromatisantes. 4th ed. Council of Europe. Blue Book Paperback; 2015;2.
23. INRA. Productions Animales, Utilisation des huiles essentielles en alimentation des volailles. Performances de croissance et règlementation. 2013;26(1):3–12.
24. Essential oils. Sampling and methods of analysis-Monographs relating to essential oils. 2000;1(2).
25. Organisme français de certification. *Ecocert*. 2016.
26. Bruneton J. Pharmacognosie Phytochimie Medicinal plants. Tec & Doc, Lavoisier, Paris; 1993. 915 p.
27. Couderc Véronique Lucette. Toxicity of essential oils. Thesis. National Veterinary School, University Paul Sabatier of Toulouse; 2001. 84 p.
28. Food additives. 2016.
29. Knight MJ, Hansen SR, Buck WB. Toxicity of Melaleuca and related essential oils applied topically on dogs and cats. *Vet Hum Toxicol.*. 1994;36(2):139–142.
30. Saller R, Berger T, Reichling J, et al. Pharmaceutical and Medicinal Aspects of Australia Tea Tree Oil. *Phytomedicine*. 1993;5(6):489–495.
31. Munro IC, Shubic P, Hall R. Principles for the safety evaluation of flavouring substances. *Food and Chemical Toxicology*. 2008;36(6):529-540.
32. http://www.centres-antipoison.net/nancy/
33. Opinion of ANSES. Maisons-Alfort; 2014.
34. Wichtl M, Anton R. Therapeutic Plants. Technical and Documentation, Paris; 1999.
35. FDA. Food and Drug Administration, 2010.
36. Eurostat Regional Yearbook. 2015.
37. Moja S, Jullien F Mints. Diversity of species and chemical composition in Jardins de France. n° 630 Simple and aromatic: the well being to cultivate. 2014.
38. Source INSEE. National Institute of Statistics and Economic Studies. 2014.