Article

Bioactives of lemongrass used in the industry

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Abstract

In the research, an analysis on the importance of the biological activity of lemongrass (*Cymbopogon citratus*), its benefits and application in the food and non-food industry was carried out. The objective was to identify, analyze, organize and compare information on the bioactive components of the plant species in the industry. The method used is exploratory with a documentary approach of secondary order, since a thorough search of bibliographic information of documents obtained in scientific bases that support the work was carried out. Twenty-four bioactive components and 33 constituents of essential oils were determined, in relation to the use in the industry two applications were determined: in the food area, it is used in beverages (energizing, hydrating, functional) and as a food additive (antioxidants, preservatives and flavorings) and in the non-food area in the agricultural field (insecticides, fungicide and herbicide), in the cosmetics area (perfumery, deodorants and shampoos) and in the pharmacological area (antibacterial and antifungal). It was determined that the biological components of lemongrass have been used in the food and non-food industry, elements such as myrcene, citronella, citronellol and geraniol are used because they enhance the aroma and prevent fungal and bacterial infections, citral is the element that provides functionality to foods and prevents toxicity.

Keywords: agricultural, chemical composition, cosmetics, food additive, pharmaceutics.

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Introduction

The Food and Agriculture Organization of the United Nations (FAO), the Pan American Health Organization (PAHO) and the World Health Organization (WHO), as international organizations, mention the importance of functional foods, because they contain nutritional characteristics, which help reduce the risk of the presence of diseases, therefore they have physiologically active components of plant origin that have pharmacological, therapeutic, antibacterial effects that favor the health, physical capacity and mental state of the person (Asgary *et al*., 2018).

Currently, political and social changes related to clear changes in the conduct and behavior of people. Eating habits have even been changed, leaving aside the traditional diet, rich in cereals and legumes, to adopt a new culture such as fast food, with high energy value, but deficient in some essential nutrients (Ramírez *et al*., 2003). For this reason, society seeks a healthy diet, in this way, science develops products fortified with some bioactive component or ingredient that provide properties to the body (Britez and Romero, 2019).

The aspects of diet related to health must be linked to cultural and religious factors and historical development, which can help us clarify important data. The origin of the word 'diaita' is Greek and was used by the Greeks, especially by Pythagoras and the pupils of its school in Crotone. The 'Diaita Kala Physin' is the right ordering of the regime of life, it is what regulates the microcosm of man with the macrocosm of the universe! by regulating the body, it purifies it, the 'diaita' of Pythagoras becomes, with Hippocrates, in the fifth century BC, a part of the medical technique that helps maintain balance in health and improve in disease.

In more current times, for Spanish naturopathic doctors, this diet means regulating our regime of life according to human nature, for the Hippocratic doctor, the diet includes lifestyle habits: food, exercise, rest, hydrotherapy and balneotherapy, professional activity, relationships and social norms (Lain 1986).

Functional foods arise with the advancement in knowledge about the functioning of the metabolic, biochemical and genomic processes that determine organisms. The term is dynamic because it depends on changes in concepts and theories about cellular activities, which are currently under intense and rapid advance, which is why the trend of consumption of functional foods in the twenty-first century has been increasing globally (Enríquez *et al*., 2022). The International Lile Science Institute (ILSI) certifies that a food is functional if it can be satisfactorily demonstrated that it has a beneficial effect on one or more specific functions.

For this reason, the idea was developed in Japan during the 80s as a necessity to reduce the high cost of health insurance (Chasquibol *et al*., 2003). (Hurtado and Zamora, 2015) argue that functional foods are intended to strengthen, improve and stabilize metabolic activity, the action of a functional food on an organism occurs holistically, that is, functional foods contain a set of active components that influence a series of cellular processes and the result can be described at different

scales of complexity, such as cellular, that of tissues and organs or the whole organism, this holistic approach has also been useful for understanding the influence of the exposome on other types of superorganisms.

In response to the great interest in health and food, functional foods were born in Japan in 1984, which were developed specifically to improve health and reduce the risk of contracting diseases. This is due to the concern of the Japanese health authorities, to preserve a better quality of life for its increasingly long-lived population. Functional foods in that country and in the whole world continue with enormous growth, a value of approximately 175 000 million D was estimated for 2012, being 25% higher than the levels of 2007. The legislation does not say what a functional food is.

Therefore, regulation is through legislation on labeling, through the declarations that a food can carry in its commercialization (Arai, 2000). Living beings that use oxygen for energy generation release free radicals, so there must be defense mechanisms against these chemical species and thus ensure life. The formation of free radicals by natural processes leads to the oxidation of biomolecules, leading to various diseases. Photosynthetic organisms such as plants are exposed to very oxidative environments, so they have a very effective antioxidant system. The present paper aims to identify the bioactive components of the lemongrass used in industry.

Materials and methods

The research carried out was specifically a bibliographic review and for the development the methodology used was (Salsa), acronym for Search, Appraisal, Synthesis, Analysis, modified by Gunnarsdottir *et al*. (2020). The traditional Salsa method for systematic reviews involves four steps, which are: search, appraisal, synthesis and analysis; however, Gunnarsdottir *et al*. (2020) added an additional step known as the snowball technique, as seen in (Figures 1 and 2).

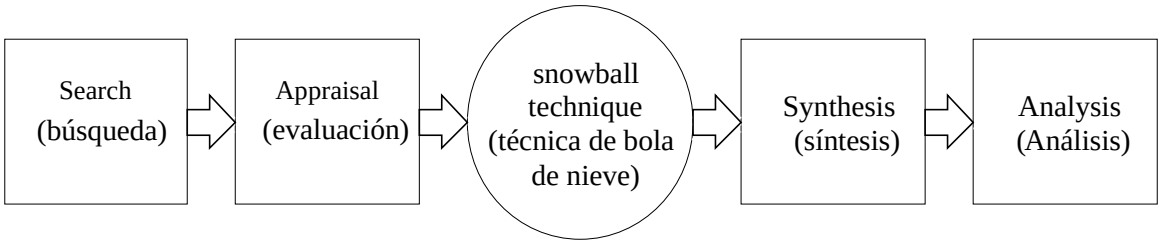

Figure 1. General diagram of the Salsa method modified by Gunnarsdottir *et al*. (2020).

The SALSA method consists of a comprehensive search process and critical review that allows documents to be prepared using the best available information while minimizing the potential for bias (Luengo *et al*., 2016; Gunnarsdottir *et al*., 2020). The modified SALSA method used to carry out this research is described below; it can also be visualized in a schematized way in (Figure 2).

The first step of the SALSA method consisted of searching for relevant information on bioactives of lemongrass, in undergraduate and postgraduate theses, scientific papers and books found in search engines and databases such as google academic, web of Science, Science Direct, Scopus, Pubmed, Scielo.

The second step allows for further evaluation of whether the results meet the criteria of inclusion (quantitative and qualitative studies, full access to bioactive information) and exclusion. This point allowed the evaluation and classification of the literature used, in addition, it served as a basis for continuing with step three.

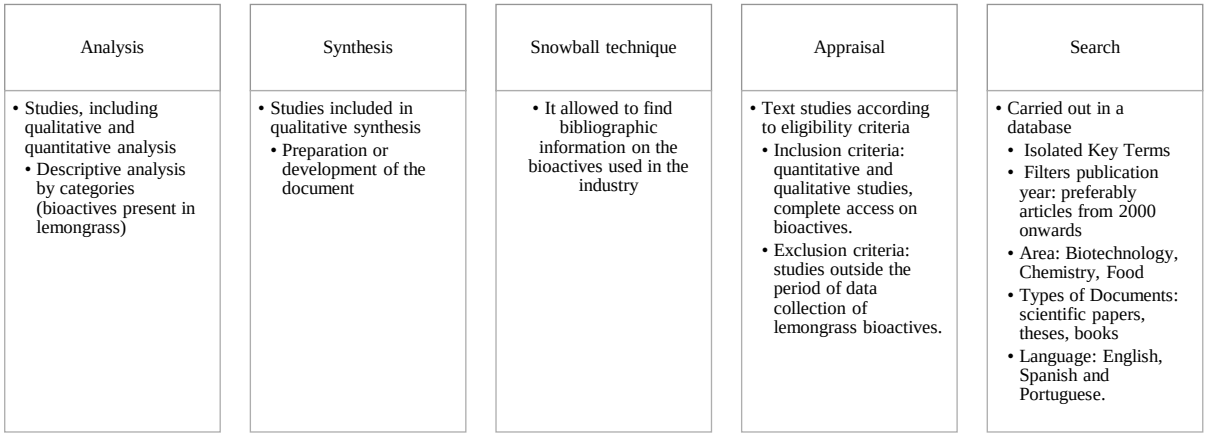

Figure 2. Diagram of the salsa method.

The third step, the snowball technique consists of the use of references and citations of papers to identify more relevant literature, that is, the review literatures found through the initial search served as the basis for the snowball in order to find 15 additional bibliographic studies. The fourth consisted of the synthesis or preparation of the document based on the relevant information of the literature selected under criteria mentioned above. For this, the publications identified and evaluated in the previous stages were read carefully in order to relate the relevant information in the written document.

Finally, the synthesized information was analyzed so that it meets the objective of the research. For this, unit operations, processes and raw materials involved in obtaining protein isolates from legumes were analyzed for the development of the results and discussion of the present work.

Results and discussion

Chemical composition of lemongrass

Essential oils are secondary metabolic produced by plants, they are composed of a complex mixture of terpenoids, mainly, monoterpenes (C10), sesquiterpenes (C15), and a variety of aromatic phenols, oxides, ethers, alcohols, esters, aldehydes and ketones that determine the characteristic aroma and smell of the plant, the biologically active component of the plant species is citral, which is a mixture of two monoterpene, stereoisomeric aldehydes that come from geraniol and neral, with their respective components, as detailed in Table 1.

Table 1. Bioactive components of *Cymbopogon citratus.*

Phytonutrients	Mineral content	Vitamins
Flavonoids	Sodium	Vitamin A
Alkaloids	Potassium	Vitamin C
Vitamins	Calcium	Vitamin E
Tannins	Iron	Folate
Phenols	Phosphorus	Thiamine
Saponins	Selenium	Niacin
Essential oils	Zinc	Pyridoxine
Steroids	Magnesium	Riboflavin
	Essential oil constituents	
Citral	α-Terpineol	β-Myrcene
Borneol	β-O-Cimene	Allo-o-cimene
α-pinene oxide	Myrcenol	t-Muurolol
Linalool	1-Octyn-3-ol	Trans-chrysanthemum
Citronellal	Neral	3-Undencyne
Nerol	trans-(-)-Carveol	Geraniol
Geraniol	Nerol	Citronellol
Methyl-n-nonylketone	Dextro-carvonene	Geranic acid
α-Bergamotene	Isolongifolene	Muurolene
α-Farnesene	α-Elemol	α-Gurjunene
Viridiflorol	Humulene	α-Selinene

(Ekpenyong *et al*., 2014; Ayay and Infante, 2019).

Applications in industry

In recent decades, the prevalence of several diseases such as obesity and diabetes has increased, causing high morbidity and premature mortality and considerably increasing health costs. Consequently, researchers have focused their studies on alternative treatments to prevent these diseases and improve human health. In this sense, it has been stated that botanical sources provide beneficial properties related to several physiological disorders.

For these reasons, in recent years, researchers have focused on the challenge of extracting bioactive compounds from plants to increase the nutritional value of food products. Aćimović *et al*. (2020) considers that *C. citratus* is of great interest in the industry for its composition and generates an average dose between 1 to 5 ml L^{-1} depending on the process.

Reina and Fernández (2022) mention that lemongrass oil is used in the food and non-food industry for its bioactive components that contribute to the improvement and conservation of products. In the food industry, *C. citratus* industrially serves as an additive, flavoring, preservative in beverages and foods (Oladeji *et al*., 2019). As detailed in Table 2.

Table 2. Applications of lemongrass extract in the food industry.

Application	Type	Benefit	Reference
Beverages	Energizing	Due to its citral content, it provides nutritional values, and they have the ability to contain antioxidant agents, which represents health benefits.	(Silva, 2016)
	Hydrating	They have a pleasant aroma and flavor for their constituents citral, limonene and terpene, which are responsible for recovering the energy lost by physical activities.	(Fernández *et al*., 2020) (Carranza *et al*., 2020)
	Functional	Due to its phenolic content (flavonoids), it prevents the generation of free radicals.	(Ramos, 2016)
Food additives	Preservative	Lemongrass extract is an oily, volatile liquid whose main constituent is citral, which is responsible for antioxidant and fungitoxic activity	(Martínez *et al*., 2018) (Majewska *et al*., 2019)
	Flavouring	The components citral and limonene are used in dressings, vinegars, and in confectionery, they serve to give better flavor and aroma to the final product.	(Silva *et al*., 2016) (Criollo, 2019)

Silva (2016) states that, containing citral, energy drinks provide health benefits and Ramírez *et al*. (2021) affirm that they are non-alcoholic because they are composed of plant extracts that include vitamins, minerals, etc. While they mention that, having natural flavoring, hydrating drinks have the purpose of replenishing the energy and electrolytes lost by the human body during physical activity. Salazar (2006) argues that consumption is due to its pleasant taste, guaranteeing proper hydration.

Cucaita (2017) adds that, having bioactive components, the functional drinks of *Cymbopogon citratus* reduce the risk of diseases and Carranza *et al*. (2020) express that it contributes to nutritional well-being due to its high consumption index. The use of *Cymbopogon citratus* in the preparation of drinks is of great interest as it has functional properties that benefit the mental or bodily health of people.

On the other hand, Enríquez *et al*. (2018), in their study of lemongrass in a functional drink with orange, determine that the antioxidant activity found depends on the concentration, in the inhibition of degradation of 2-deoxyribose up to 59% (4 000 ~g ml^{-1}), likewise, it inhibited the radical ABTSo + up to 53.1% (1 000 ~g ml^{-1}) and the radical DPPHo up to 53% (1 000 ~g ml^{-1}). It also showed a positive correlation of 0.93, with 2 - Dx; 0.96 with the cation ABTSo+ and 0.99 with the radical DPPHo, with the content of total polyphenols (1.01 ~g AGE g^{-1} sample) showing positive affinity.

Non-food industry

In this industry it was possible to identify the use of myrcene, citronellol, geraniol and neral, applied in the agricultural and cosmetic areas, as detailed in (Table 3).

Table 3. Applications in the non-food industry.

Applications	Type	Benefits	References
Agricultural	Insecticide	Lemongrass extract repels insects such as mosquitoes, aphids, so it contains citral and also myrcene, citronellol and geraniol.	(Narayan and Maheshwar, 2017)
	Fungicide	The high fungicidal power is due to the citral component, which inhibits germination and mycelial development of the fungus.	(Rodríguez *et al*., 2018)
	Herbicide	It is used for weed control for its main compound citral.	(Garcia, 2013)
Cosmetics	Perfumery	The main elements geraniol and neral are responsible for enhancing the aroma, which, being a natural component, does not damage the skin and its fragrance is more durable.	(Durán *et al*., 2021) (Narayan and Maheshwar, 2017)
	Deodorant	α-citral and myrcene have antibacterial and cleaning properties that help fight unpleasant body odor and prevent fungal and bacterial infections.	(Narayan and Maheshwar, 2017)
	Shampoo	Citral, myrcene, geraniol have repellent effects on lice, it is also used to reduce dandruff through its antimicrobial and anti-inflammatory properties.	(Narayan and Maheshwar, 2017)

Kaur (2021) indicates that lemongrass oil, having active components, has the ability to repel insects that are present in the environment. On the other hand, Moreta (2018) suggests that being a natural product, it helps stimulate the metabolic processes of crops to strengthen them and protect them from microorganisms. Likewise, Rodríguez *et al*. (2018) argue that, in their study conducted on the antifungal activity of *C. citratus*, the main component is the (citral), which has the characteristic of inhibiting the growth of molds and fungi.

In addition, Vargas (2013) considers that, being an organic input, it contributes to the defense functions of plants, influencing as a toner to counteract adverse conditions. Montero *et al*. (2017) underline that herbicides provide weed control in the field because they destroy the cell membrane and cause the desiccation of invasive plants.

Durán *et al*. (2021) emphasize that, in the preparation of perfumes, the active ingredients enhance their aroma. Even Kim *et al*. (2022) establishes that, in deodorants, having antioxidants, they eliminate body odor and have the protective capacity on the skin. Similarly, Khan (2020) defines in his study on lemongrass shampoo that it has effects on the presence of dandruff on the scalp. The use of *C. citratus* in the non-food area has non-toxic effects due to the natural active components that it has and generates an environmentally friendly impact.

Pharmaceutical industry

The components identified are myrcene, neral, citral, geraniol, citronellol and linalool, which are applied in aqueous form, playing a key role in health care systems worldwide, as detailed in (Table 4).

Table 4. Pharmacological activities.

Pharmacological activity	Bioactive component	Reference
Antibacterial activity	They are attributed to three specific compounds: α-citral, myrcene and β-citral, which individually act on gram-negative and gram-positive bacteria.	(Ekpenyong *et al*., 2015)
	Because of its components myrcene, neral, citronellol and geraniol, they are useful in skin conditions, such as acne, because they help inhibit dermatophyte strains.	(Morillo and Ibarra, 2018)
Antifungal activity	They can be attributed to the presence of several constituents, such as citral, ÿ-myrcene, linalool and geraniol because it causes the death of the fungus.	(Boukhatem *et al*., 2014)
Antioxidant activity	They report methanol, aqueous ethanol, flavonoids, they are free radical scavengers, are responsible for the antioxidant activity, it has effect on cardiovascular diseases.	(Cetina, 2018)

Also, Ekpenyong *et al*. (2015) evaluated the antifungal activity, obtaining as a result the destruction of phytopathogens present in the environment. In addition, Enríquez (2021), in his study of the Guaviduca, describes that flavonoids contain antioxidant properties that contribute to the reduction of diseases. González *et al*. (2008) indicate in their study that *Cymbopogon citratus* is applied in the pharmaceutical industry to make medicines and cleaning products, demonstrating its effectiveness against diseases, fungi and bacteria.

According to Chambal (2015), lemongrass essential oil has an inhibitory capacity against strains of *Candida albicans*, which suggests the potential value of this element for this skin treatment. In addition, Auccapiña *et al*. (2017) conducted studies on ointments and creams containing this element, having an efficacy in its use, considering the susceptibility of *Candida* spp. to antifungals. Angos and Duque (2013) state that the extract of the plant species on *Staphylococcus aureus* ATCC 25923 has a MIC (Minimum Inhibitory Concentration) of 0.3 mg ml^{-1} and a CMB (cosmic microwave background) of 1.25 mg ml^{-1}, while MIC and CMB on *S. epidermidis* ATCC1228 have a similar value of 0.63 mg ml^{-1}, demonstrating the antibacterial power. Enríquez *et al*. (2018), in their study on Garlic Vine, indicate that the antioxidant activity of a plant species is the expression of the different phenolic elements that are being used to neutralize reactive oxygen species.

Conclusions

Forty-nine scientific papers obtained from Springer, Scielo, Google Scholar, Researchgate, Pubmed, Scpus, Rdalyc were analyzed, of which 70% indicate the biological power and use of the lemongrass extract. Twenty-four bioactive components and 33 total constituents of the essential oil were determined, in relation to the use in the industry, 2 applications were determined in the food (beverages, food additive) and non-food industry (agricultural, cosmetic, pharmacological).

After the literature review, the significant antibacterial, antifungal effect on Gram (+) and Gram (-) strains is identified, having a promising source of antimicrobial chemical compounds that were used in industry. *Cymbopogon citratus*, for its biological components, has been used in industry in recent years, in the non-food field, myrcene, citronella, citronellol and geraniol are the most used elements and are responsible for enhancing the aroma and preventing fungal and bacterial infections.

In the food area, the citral bioactive is used as a functional element that allows lowering production costs and avoiding toxicity. The use of lemongrass extract plays an important role in the industry locally and worldwide for its biological components that replace, preserve and improve the final products offered in the food and non-food market.

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