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Chemical composition and biological activities of the species capsicum frutescens l. (*chili pepper*) – A literature review

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ABSTRACT
Peppers are known to have compounds that are responsible for some of their characteristics. One can find, for example, natural antioxidants, phenolic compounds, capsaicinoids, caretonoids, among other chemical components. Some of these compounds allow peppers to carry out important biological activities, so that some species of these fruits can be used for medicinal purposes. In this sense, the peppers that most stand out are those of the genus Capsicum, which have universal use and are widely produced and commercialized, this genus has about 30 species, among which is Capsicum frutescens (chili pepper), which is a of domesticated species. Thus, in view of its importance from a medicinal point of view, this work presents a literature review, gathering information on the chemical composition of chili pepper, pointing out several compounds, among which capsaicin, dihydrocapsaicin, phenolic compounds, acids fatty acids and vitamin C. The biological activities reported for the species are also highlighted, such as antioxidant, antimicrobial, analgesic and anti-inflammatory, among others. Thus, it was verified the great potential of this pepper in the realization of beneficial effects to health and the importance of carrying out more studies regarding the attributes of this fruit.

Keywords: Chemical composition, biological activities, capsicum frutescens, chili pepper.

1 INTRODUCTION

The name pepper comes from the Latin *pigmentum* "coloring matter" and that is currently understood as "aromatic spice" (BONTEMPO, 2007). It is one of the most used condiments around the world, second only to table salt, because its spicy taste attracts the attention of millions of people from different cultures, even if its consumption generates a burning sensation in the mouth and throat (MASSABNI, 2010).

Peppers have great importance for cooking, medicine and the world economy. Long before the 5th century BC, peppers were already used in the preparation of food and also in the treatment of different diseases. There are records of its use in ancient medicine of different peoples, such as the Tibetans, Indians, Chinese, Mesopotamians, Persians and Arabs (BONTEMPO, 2007). From the sixteenth century its cultivation extended throughout the world, being produced on a large scale over the years. In 2010, for example, there was the cultivation of approximately 3.8 million hectares with peppers and peppers, producing a total of 30.6 million tons worldwide. In this sense, the peppers that stand out the most are those of the genus *Capsicum*, which have universal use and are widely produced and marketed (REIFSCHNEIDER *et al.*, 2015).

The peppers of the genus *Capsicum* (from the Greek Kapso, which has the meaning of chopping or burning) have their origin in the American continent, however, through the exploitation carried out by the Europeans, these plants were transported to Europe, Africa and Asia, thus gaining space in the world cuisine. In this genus there are about 30 species, among which only *Capsicum annuum*, C. baccatum, *C. chinense*, C. pubescens and *C. frutescens* are domesticated, presenting peppers such as tabasco, biquinho, dedo-de-moça and chilli (ALENCAR, 2017).

The chillies – belonging to the species C. frutescens – are found mainly in the northern region of Brazil, but also appear in the Southeast, Northeast and Midwest. They have the following characteristics: the plant is shrubby (reaching two meters in height) and its fruits have very thin walls, when immature they are green and when ripe they become red, usually small (they can measure from 1 cm to 3 cm long by 0.4 cm to 0.5 cm wide), elongated, erect and very spicy (CARVALHO *et al.*, 2006). In addition, it is one of the groups of peppers most used in Brazilian cuisine and folk medicine (BONTEMPO, 2007).

Thus, in view of its importance from the medicinal point of view, the objective of this work is to gather information on the chemical composition and biological activities reported for the species *Capsicum frutescens L.* (chili pepper).

2 OBJECTIVE

- To review the literature on the chemical composition and biological activities of the species *Capsicum frutescens L.* (chili pepper).

2.1 SPECIFIC OBJECTIVES

- Identify the main chemical constituents present in chili pepper, through a comprehensive literature review;
- To investigate the biological activities associated with this species, highlighting properties such as antioxidants, antimicrobials, anti-inflammatory and others, as well as discussing the possible mechanisms of action involved in these activities.

3 METHODOLOGIES

The methodology used in this work was the bibliographic review, a method that aims to use materials already elaborated, such as books, theses and scientific articles, to carry out an exploratory and systematic research on a certain theme or issue, allowing a broader understanding of a problem treated (GIL, 2002).

The following research problem was used to direct the study: What is the chemical composition of the species *Capsicum frutescens L.* (chili pepper) and what biological activities are described in the literature for the species?

To answer this question, information collection was carried out entirely digitally, in scientific articles, theses and dissertations, mostly published from 2010 onwards, searched in the Google scholar database, using the following keywords: Chemical Composition, Biological Activities, *Capsicum frutescens* and chili pepper.

We selected texts that dealt directly with the theme under research and also those that dealt indirectly, that is, that although they were dealing with another theme, at some point presented data about chili pepper that were relevant to the formulation of the work.

After gathering the sources, a systematic analysis of the texts was carried out so that it was possible to extract only the knowledge related to the chemical composition and biological activities of the species *C. frutescens*. Thus, a synthesis of the ideas of each author was performed, which were presented in a descriptive manner in this research.

4 LITERATURE REVIEW

The following topics will be aimed at the literature review on the following central themes of this work: chemical composition and biological activities of chili pepper (*Capsicum frutescens*). The first topic will be intended for the presentation of this fruit, the topic referring to the chemical composition will gather information about the substances that can be found in this pepper, while the topic on biological activities will bring data on the ability of chilli to perform actions such as: antioxidants, antimicrobial, analgesic, anti-inflammatory, among others. Therefore, this last topic will be divided into four subtopics.

4.1 CHILI PEPPER (*CAPSICUM FRUTESCENS*)

Chili – a traditionally Brazilian pepper – is widely known and consumed throughout the Brazilian territory. It can be called chilli or maleguetão, when its fruits are very small or very large respectively, when compared to the traditional chili pepper. However, regardless of size, all chillies have the same coloration and are equally spicy (LANA *et al.*, 2021).

Figure 1: Malagueta Pepper

Source: Lana et al., 2021.

Lana *et al.* (2021) explain that the fruits of the chilli can be consumed green or ripe, however, usually the ripe ones have a higher degree of spicy. The authors also report that this pepper can be consumed fresh or in the form of a preserve, which can be produced using cachaça, vinegar or oil. In addition, it is a great ingredient to give sting to mixed pepper sauces.

Chili pepper is mainly used in canning whole fruits and it is important to note that the market for these sauces and preserves is growing, both for large industries and for home industries (LOPES *et al.*, 2007).

Lopes *et al.* (2007) mention that spicy peppers, as is the case of chili peppers, can also be dehydrated and marketed, in flakes with the seeds and powder, this type of processing allows the organoleptic characteristics and energy values to be conserved. They also indicate that, due to their composition and their benefits, they can be used in different ways, as is the case of their use in the pharmaceutical and cosmetic industries.

4.2 CHEMICAL COMPOSITION OF CHILI PEPPER

Peppers are known to possess compounds that are responsible for some of their characteristics. One can find, for example, natural antioxidants such as vitamin C and phenolic compounds. In addition, capsaicinoids, caretonoids, ascorbic acid, vitamin A and tocopherols are also found that are among the main chemical components present in peppers (PINTO *et al.*, 2013).

These and other compounds can be divided into two groups. One of them, responsible for characteristics such as flavor, aroma and color, in which are found capsaicinoids, carotenoids, polyphenols and volatile components such as pyrazines and organic acids. The other group is in charge of the components responsible for the nutritional characteristics, such as carbohydrates, lipids, proteins, vitamins, fibers and minerals. In addition, the concentrations of all these components may vary according to the species, degree of maturation and the different conditions involved in cultivation (PINTO *et al.*, 2013).

In the research of Nascimento (2012), regarding the chemical composition of chili pepper, using High Performance Liquid Chromatography (HPLC) of the ethanolic extract of *Capsicum frutescens*, the presence of capsaicinoids Capsaicin (**1**),[1] dihydrocapsaicin (**2**) and the flavonoid chrysoeriol (**3**, 3'-methoxy-luteolin). These substances were quantified and their concentrations were respectively, 9.2 mg/g, 4.0 mg/g and 2.1 mg/g.

In the study conducted by Zampieri (2022), for identification and quantification of the chemical constituents of the resinous oils of the species C. frutescens, C. chinense, C. baccatum var. pendulum and C. *annuum*, higher levels of capsaicin were found in the species *C. frutescens (284.7404b ± 1.0938 μg. g-1), and* C. baccatum var. pendulum (419.7945a ± 0.4057 $^{\mu g.\ g\text{-}1}$).

Zampieri (2022) reports that knowledge of capsaicin content is important for plant breeding processes, done through targeted crossbreeding. In addition, this information is also taken into account so that the peppers meet the different profiles of consumers.

Rodrigues *et al.* (2021) described the use of the miniaturized sample preparation method of the QuEChERS method (μ-QUECHERS) and analysis by ultra high-performance liquid chromatography coupled to sequential mass spectrometry (UHPLC-MS/MS), for determination of phenolic compounds in varieties of peppers (*Capsicum* SPP.). In relation to chili pepper, the following phenolic compounds were identified: 4-Hydroxybenzoic acid (4, 226d±**4 μg kg^{-1}), Vanillic acid (**5, $^{1330ef\pm89}$ μg kg^{-1}), p-Coumaric acid (6**, 706a±7 μg kg^{-1}), Ferulic acid (7**, 4711b±33 μg $^{kg\text{-}1}$), Sinapic acid (**8**, $^{300b\pm20}$ μg **kg^{-1}**), Naringenin (**9**, 13458a±126 μg kg^{-1}), Luteolin $^{(10,\ 46\pm3\ \mu g\ kg\text{-}1)\ and\ Quercetin\ (}$11**, 320a±12 μg** kg^{-1}). Moreover, it was found that among the peppers studied, chilli (*C. frutescens*) is among those that presented higher concentrations for the compounds that were found in all the species studied (4-Hydroxybenzoic, p-Cumaric, Ferulic, Vanillic and Naringenin acids).

Rodrigues *et al.* (2021) also inform that the non-identification of some compounds, which may be present in these peppers, such as gallic, caffeic and chlorogenic acids, apigenin, Kaempferol and myricetin, also not detected in chilli, may be a result of limitations of the method. However, they explain that μ-QUECHERS is a technique that shows promise for this type of analysis, as well as considerably reducing the amount of sample, reagents and solvents.

[1] The bold numbers ranging from **1** to **39** are being used to relate the compounds to their respective figures, found at the end of this text.

Simões (2014), in his dissertation on extraction and characterization of oleoresin – obtained from chili peppers (C. frutescens*) and dedo-de-moça* (C. baccatum var.pendulum*), by solid-liquid extraction, associated with ultrasound* – detected the presence of seven types of fatty acid methyl esters in chilli, linoleic (12), oleic **(13**), linolenic (14), myristic **(15), palmitic** (16), stearic (**17**) and arachidic (18**), with concentrations that vary according to the solvent used for oleoresin extraction, as can be seen in table 1.**

Table 1: Percentage of fatty acids present in the oleoresin extract of Malagueta pepper (C. frutescens).

Fatty acids	Ethanol (%)	Acetone (%)	Hexane (%)
Myristic	1,994	1,806	2,950
Palmitic	19,728	21,744	31,808
Stearic	4,299	4,316	6,813
Araquídico	0,779	0,817	1,295
Oleic	30,674	25,542	17,663
Linoleic	36,348	42,505	35,291
Linolenic	6,178	3,270	4,180

Source: Adapted from Simões (2014)

As can be seen, linoleic acid was the lipid component present in larger amounts. It is a polyunsaturated fatty acid, which needs to be present in the diet, as it is the main representative of the omega 6 group. This substance acts in the reduction of cardiovascular damage, total cholesterol and blood LDL (SIMÕES, 2014).

In addition, using High Performance Liquid Chromatography, Simões (2014) identifies capsaicin in the oleoresin of *C. frutescens* and a compound analogous to this substance, probably dihydrocapsaicin, the second capsaicinoid in higher concentrations in *Capsicum peppers*. The concentrations (mg·mL-1) also varied according to the solvent used, as can be seen in table 2.

Table 2: Concentrations of capsaicin ($mg{\cdot}mL^{-1}$) and the analogous compound ($mg{\cdot}mL^{-1}$) in chilli pepper oleoresin with different extracting solvents.

Fatty acids	Ethanol	Acetone	Hexane
Capsaicin	1410,019 ±112,627	1636,930 ±111,212	995,294 ±104,541
Analogous Compound	95,361 ± 4,885	105,976 ± 2,766	75,535 ± 2,498

Source: Adapted from Simões (2014)
Note: Results expressed as mean ± standard deviation (n=3).

In the research of Borges *et al.* (2015), in which the morphoagronomic and physicochemical characterization of six accessions of peppers widely consumed and marketed in the state of Roraima (among them *C. frutenscens*) was carried out, the following fatty acids were found in chili pepper through gas chromatography: myristic acid, pentadecylic acid (**19**), palmitic acid, palmitoleic acid (**20**), stearic acid, oleic acid, linoleic acid, (alpha)-linolenic acid, arachidic acid and behenic acid (**21**).

With regard to health benefits, oleic acid stands out which according to Azevedo (2012) acts in the reduction of cholesterol linked to low-density lipoproteins (LDL) and linolenic acid – belonging to omega-3 fatty acids – which according to Cortes *et al.* (2013) can be used as a positive strategy to help in the treatment of symptoms of anxiety, depression and chronic pain. Also noteworthy is the linoleic acid that has already had its benefits explained previously.

Silva (2017) reported the fatty acid composition determined by Gas Chromatography using indirect transesterification and the nutritional composition of chili pepper (C. *frutescens*), chili pepper (C. *chinense*) and lady's finger pepper (*C. baccatum*).

Thus, in *C. frutescens*, the following fatty acids were identified in % mass: myristic (1%), palmitic acid (20%), stearic acid (4%), arachidic acid (2%), behenic acid (1%), lignoceric acid **(22.1%), palmitoleic acid (3%), oleic acid (5%), vaccenic acid (**23.1%), linoleic acid (54%) and (α-)**linolenic acid (**7%).

It is observed the predominance of linoleic acid in chilli, which even presents a higher percentage of this acid in relation to the other species studied.

The following were also found *in C. frutescens* (expressed in g/100 g of pepper): moisture (73.07 ± 0.66), proteins (1.73 ± 0.06), ashes (10.17 ± 0.07), lipids (0.83 ± 0.04) and carbohydrates (9.96 ± 0.05).

Among the peppers analyzed, it was precisely the chilli that presented the highest levels of these substances, with the exception of moisture only (SILVA, 2017).

However, Golcz *et al.* (2012, *apud* SILVA, 2017) reported that these values may vary depending on some factors such as: time of fruit harvest, soil, sunlight intensity, amount of water, among others.

Silva (2017) also performed the analysis of capsaicinoids in extracts of chili peppers, lady's finger and chili pepper, using the spectroscopic techniques Infrared (IR) and Nuclear Magnetic Resonance of hydrogen (NMR $^{1H). It was observed that among them,}$ *C. frutescens* is the one with the highest capsaicin content.

It is worth mentioning that, when well-managed, capsaicin can do a lot of good to its consumers, offering benefits such as: weight control due to its good thermogenic action and antioxidant action (MAURER, 2021).

In studies on chili pepper (*C. frutescens*) and its components, Valim (2019) performed the extraction of capsaicinoids using the solvent methanol, with the aid of an ultrasonic vat. The compounds were identified by Gas Chromatography coupled to the Mass Spectrometer (GC-MS). The results obtained indicated the presence of three intense peaks that were identified as capsaicin, dihydrocapsaicin and nonivamide.

However, after purification and isolation of these capsaicinoids through chromatographic techniques, the techniques of Nuclear Magnetic Resonance of Hydrogen (1H NMR) and carbon (13C NMR) were used to characterize and confirm the structures of these compounds, confirming the presence of capsaicin and dihydrocapsaicin, however, the characterization of the other capsaicinoid through 1H NMR did not coincide with the nonivamide and the elucidation of its structure was not possible due to the lack of signals in its 13C NMR spectrum, thus being an unknown capsaicinoid (VALIM, 2019).

Valim (2019) also explains that capsaicin and dihydrocapsaicin are considered predominant among capsaicinoids, corresponding to 90% of these chemical components present in pepper, in addition, it makes clear that the lack of NMR signals of 13C for the unknown capsaicinoid may have happened due to the low solubility of this compound in the solvent used and the small amount of mass used.

Maurer (2021), in his work on peppers of the genus *capsicum,* presents the nutritional composition of chilli, showing that this pepper contains: Protein, Lipids, Carbohydrates, Fiber, Sodium, Magnesium, Phosphorus, Potassium, Calcium, Iron and Vitamin C (**24**).

These nutrients are important when applied in a balanced and adequate diet, as they bring several benefits to the vital functions of the human body, such as: energy availability and biological balance to maintain quality of life (SANTOS, 2018 *apud* MAURER, 2021).

Pinto *et al.* (2013) report that several varieties of peppers produced in Brazilian territory have high nutritional value and low-calorie content. To illustrate this, the authors present a table with the nutritional composition and other characteristics of different peppers. The data presented for Malagueta can be seen in table 3.

Table 3: Nutritional composition and other characteristics of Malagueta pepper.

Composition	Chili pepper
Protein (g/100g)	4,5
Lipids (g/100g)	5,9
Carbohydrates (g/100g)	8,5
Ash (g/100g)	1,7
Dietary fiber (g/100g)	15,9
Humidity (g/100g)	63,5
Caloric value (Kcal)	105,2
Sodium	45,7
Magnesium	65,2
Phosphorus	108,3
Potassium	638,3
Calcium	59,9
Manganese	0,4
Iron	6,8
Copper	0,4
Zinc	0,9
Vitamin C (mg/100g)	Nd
Poignancy (SHU)	164.000
Total acidity (v/w)	4,0
Soluble solids (° Brix)	10,0

Source: Adapted from Lutz and Freitas (2008, apud PINTO et al., 2013)
Legend: nd – not determined; SHU – Scoville Units.

It is worth mentioning that the pungency of peppers is linked to the presence of capsaicin. Thus, capsaicin concentration (and consequently pungency) is expressed by a sensory scale called Scoville Heat Units (SHU), where values range from zero for milder peppers to 1 million SHU for the spicier varieties (PINTO *et al., 2013). As can be seen through table 3, the Malagueta pepper presents 164,000 SHU, being considered a very spicy variety.*

The presence of these substances and characteristics in chili pepper is very important because, as Pinto *et al*. report. (2013), they confer properties that make this pepper a functional food.

Vitamin C, for example, attributes to this fruit antioxidant properties, which provide defense against substances that can cause cancer and slow down the aging process (COSTA *et al.*, 2009 *apud* PINTO *et al.*, 2013).

When performing the metabolomic analysis of peppers *(Capsicum* spp.), with the objective of knowing the total of compounds present in these fruits, Aranha (2016) performed the characterization of the metabolic profile of an access of pepper of the species *C. frutescens* (chili pepper) through Gas Chromatography and Mass Spectrometry, presenting the total content of different classes of metabolites found: amino acids (mean: 4.1 $mg.g^{-1}$ dry mass), sugars (average: 64.2 mg.g-1), organic acids (average: 10.8 mg.g-1), hydrocarbons (average: 0.9 mg.g-1), esters (mean: 2.6 $mg.g^{-1)}$ and capsaicinoids (mean: 54.4 $mg.g^{-1).}$

It is worth mentioning that chili pepper presented norvaline (**25**) as the predominant amino acid (content of 1.14 mg. g^{-1}), fructose (26) was the sugar in greater quantity (content of 27.8 mg. g-1), on average 44% of the total sugars of this species), the organic acid in greater abundance was succinic or butanedioic acid

(**27**, content of 8.3 mg. g^{-1}, equivalent to 77% of the total organic acids for this species). With regard to capsaicinoids, capsaicin was predominant, representing on average 59% of the total of these compounds in this pepper (ARANHA, 2016).

In addition, according to Aranha (2016) the presence of other substances was also observed, even if in smaller quantities, such as: the amino acids alanine (**28**), valine (**29**), tyrosine (30), glutamine **(31), phenylalanine** (32), threonine **(33), lysine** (34), cysteine (**35**), glycine (**36), aspartic acid (37**) and glutamic acid (**38**); sucrose sugar (**39**); the capsaicinoid dihydrocapsaicin; among others.

Valverde (2011) presents in his work a physicochemical characterization of chili pepper (*C. frutescens*) in natura *(in the natural state) and processed in pickle (conservation in brine or vinegar solution), in the phase of physiological maturation fully developed (mature), performing in the midst of it analyzes the identification and quantification of the chemical components and nutrients of this vegetable.*

Thus, Valverde (2011) found the presence of moisture, lipids, proteins and ashes in this pepper, however, in different contents when in *natura* and when processed in canned, as can be seen in table 4.

Table 4: Chemical composition of chilli pepper (C. frutescens) in natura and processed into pickled.

Components	Malagueta pepper in natura	Pickled processed chilli pepper
Humidity (%)	29.4 ± 0.100	15.3 ± 0.200
Lipids (%)	0.63 ± 0.022	0.62 ± 0.091
Proteins (%)	4.8 ± 0.100	4.76 ± 0.288
Ash (%)	0.039 ± 0.029	0.043 ± 0.004

Source: Valverde (2011)
Note: Values expressed as mean ± standard deviation.

Through the analysis of table 4 it is possible to perceive that the value for moisture in the processed pepper (15.3%) is lower than that of the in natura pepper *(29.4%), which can be explained by the loss of water to the brine solution, the lipid and protein contents did not present differences between the two samples and the values for ashes were 0.039*% (in natura) and 0.043% (processed) (VALVERDE, 2011).

In addition to these components, Valverde (2011) also identifies and quantifies vitamin C (ascorbic acid) in fresh and canned chili peppers, presenting values that can be seen in table 5.

Table 5: Vitamin C content of chilli pepper (C. frutescens) in natura and processed in canned form.

Samples	Vitamin C (mg/100 sample)
Chili pepper in Natura	121.5 ± 0.300
Pickled processed chilli pepper	14.5 ± 0.300

Source: Valverde (2011)
Note: Values expressed as mean ± standard deviation.

It can be noted that the levels of ascorbic acid for the in natura and processed samples are very different, with the processed chili pepper presenting a loss of 88.06% of vitamin C in relation to the chili pepper in natura (VALVERDE, 2011).

This may have occurred due to processing, because according to Correia *et al.* (2008), this procedure can generate significant changes in the qualitative and quantitative composition of these nutrients, since vitamins are very sensitive compounds.

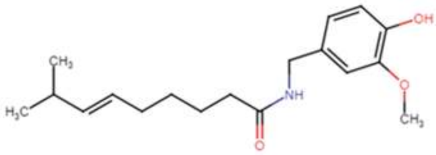
Given these results, Valverde (2011) concluded that chili pepper (*C. frutescens*) after processing has a considerable loss in its nutritional quality.

Lemos *et al.* (2022) perform the characterization of chili pepper in *fresh* and lyophilized form (submitted to drying process), confirming the presence of components already identified in previous studies: proteins, lipids, moisture, ashes, carbohydrates, phosphorus, potassium, calcium, magnesium, sodium, iron, zinc, copper, manganese, phenolic compounds, and vitamin C. In addition, sulfur, boron and carotenoids were also found.

In natura *and lyophilized chilli* have different contents for these components, with lyophilized ones exhibiting the highest amounts in most cases, however, the two states have a good nutritional composition, with the presence of macro and microminerals in the amounts necessary for food, which already indicates the importance of consuming chili pepper.

In addition, these two states are also rich in bioactive compounds responsible for biological activities, such as the antioxidant potential they present (LEMOS *et al.*, 2022).

Figure 2: Structures of compounds 1 – 4



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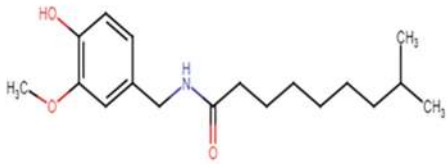

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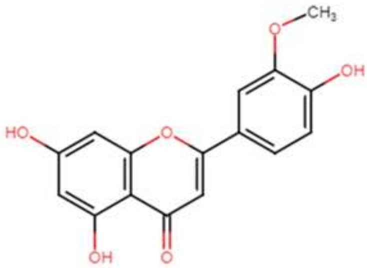

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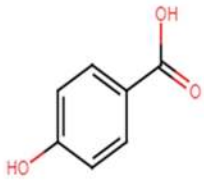

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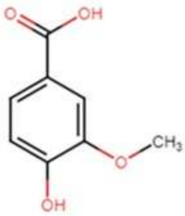
Figure 3: Structures of compounds 5 – 8



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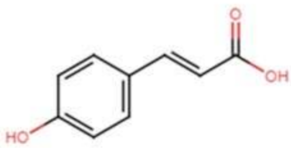

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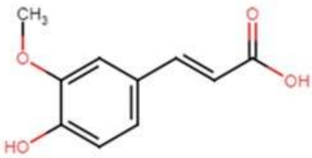

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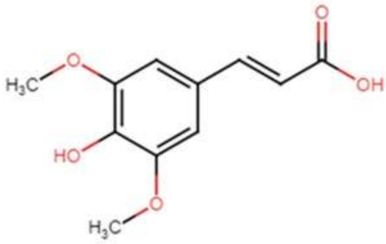

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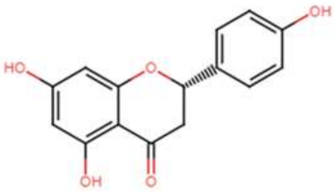
Figure 4: Structures of compounds 9 – 12



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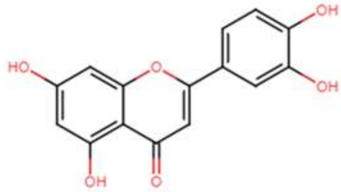

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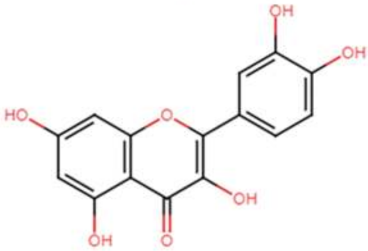

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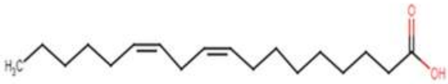

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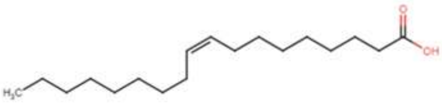
Figure 5: Structures of compounds 13 – 16



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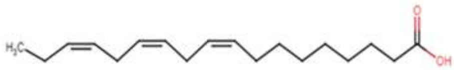

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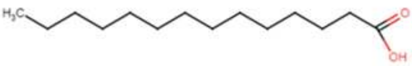

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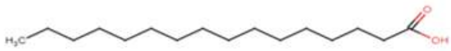

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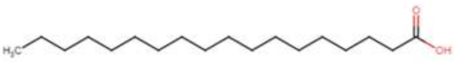
Figure 6: Structures of compounds 17 – 20



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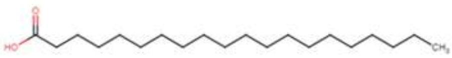

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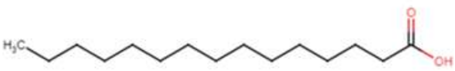

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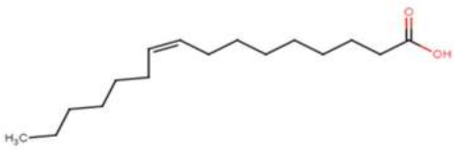

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Figure 7: Structures of compounds 21 – 24

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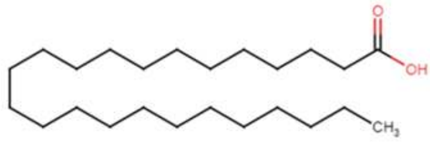

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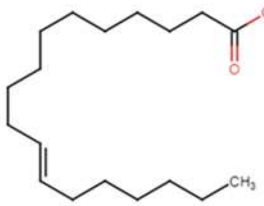

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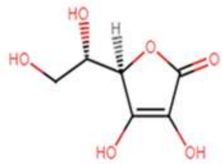

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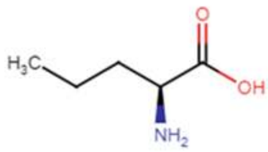
Figure 8: Structures of compounds 25 – 28



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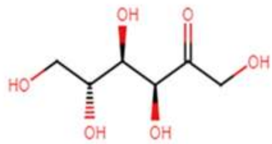

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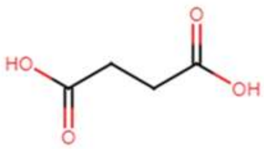

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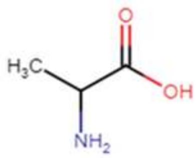

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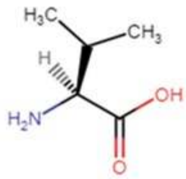
Figure 9: Structures of compounds 29 – 32



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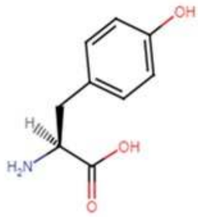

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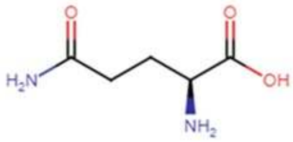

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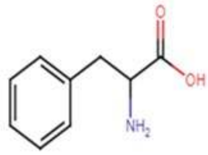

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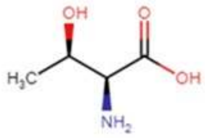
Figure 10: Structures of compounds 33 – 36



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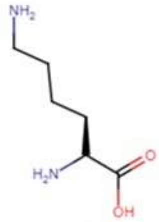

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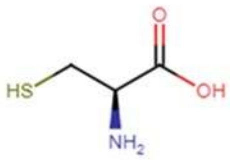

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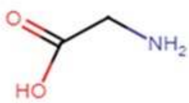

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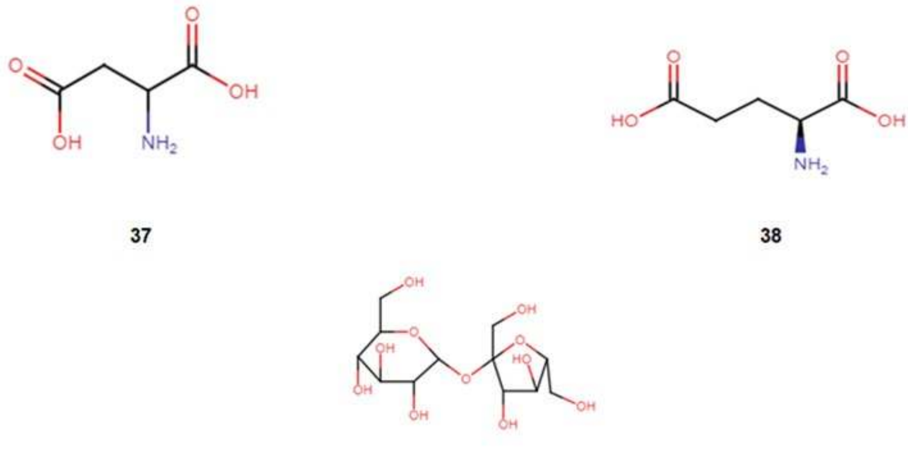
Figure 11: Structures of compounds 37 – 39



4.3 BIOLOGICAL ACTIVITIES

The peppers of the genus *Capsicum* have been studied by several researchers around the world and some of these studies indicate that these peppers have substances that give them different biological effects, such as antioxidant properties, anti-inflammatory, chemopreventive effects in the treatment of nerve fiber disorders, among others (ALPIOVEZZA *et al.*, 2015).

It was possible to notice this in the research on the chemical composition of Malagueta pepper, belonging to this genus, which shows the diversity of substances that it has, and some of them, such as capsaicin and vitamin C, are responsible for conferring some of these activities.

Thus, in the following topics will be presented syntheses of some studies about the biological actions exerted by Malagueta pepper (*C. frutescens*).

4.3.1 Antioxidant Activity

Free radicals in living organisms can generate oxidative stress, causing health problems such as damage to genetic material and consequently contributing to the appearance of problems such as: liver diseases, degenerative neurological diseases and the spread of cancer (DAIRAM *et al.,* 2008; MANJUNATHA and SRINIVASAN, 2006 *apud* ORTOLAN *et al.,* 2019).

Thus, natural antioxidants act in the reduction or inhibition of this oxidation process (PANYA *et al.*, 2015; ROJAS and BUITRAGO, 2019 *apud* ORTOLAN *et al.*, 2019).

Ortolan *et al.* (2019) evaluated the antioxidant capacity of oleoresins rich in phenolic compounds of the peppers C. *chinense* and *C. frutescens*, in addition to the crude extract of the species *Tripodanthus acutifolius*, using the Oxygen Radical Absorbance Capacity (ORAC) method that evaluated the ability of these vegetables to perform the deactivation of free radicals (peroxyl radicals) induced by 2,2'-azobis-(2-methylpropaneamidin) (AAPH).

Through this method, they were able to confirm and quantify the antioxidant capacity of chili pepper and other plant species analyzed, presenting the following results, expressed in trolox micromolar (standard solution used) equivalent per gram of oleoresin: 603.746 µmol TE/g sample (C. *frutescens*), 5277.764 µmol TE/g sample (*T. acutifolius*) and 550.210 µmol TE/g sample (*C. chinense*).

In addition, the researchers also concluded that there is a direct relationship between the presence of phenolic compounds and antioxidant activity.

In the β-carotene/Linoleic Acid System technique, antioxidants are used to slow the absorbance drop of β-carotene and thus protect lipid substrates from oxidation (SOKMEN *et al.*, 2004).

The DPPH technique consists of the reduction of the DPPH• radical (2,2-diphenyl-1-pyricylhydrazyl), which receives an electron or a hydrogen radical, changing its coloration, becoming stable and with the disappearance of the absorption that can be evaluated by the decrease of the absorbance (ROGINSKY; LISSI, 2005).

Using these two methods, Costa *et al.* (2010) were also able to evaluate the antioxidant activity of the crude extract and the hexane, chloroform and ethyl acetate fractions of chili pepper, confirming its good performance in performing this biological action

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4.3.2 Antimicrobial Activity

Natural antimicrobials can be of animal, plant and microbial origin. These biological agents have the ability to inhibit the growth of microorganisms, such as: bacteria, fungi and viruses (FOOD INGREDIENTS BRASIL, 2010).

In their research on antimicrobial activity of different types of peppers of the genus *Capsicum*, Lucas *et al.* (2015) analyzed the effectiveness of the alcoholic extracts of the peppers Dedo-de-Moça *(C. baccatum var.pendulum*), Malagueta *(C. frutescens*), Arriba Saia *(C. chinense), Pimenta de Cheiro* (C. chinense), Pimenta de Bode *(C. chinense), Pimenta Biquinho* (C. chinense), Pimenta Fidalga *(C. chinense) and Cumari do Pará (*C. chinense) being used as natural antimicrobial agents against the bacterium *Staphylococcus aureus*, a microbe isolated from the hands of food handlers.

Using the method of cylinders in plates, with cylinders of 6 mm in diameter in Petri dishes containing Mueller Hinton culture medium and inoculum agar, with the presence of *S. aureus* already developed, tests were carried out with two types of extracts for each pepper, and in one there was volatilization of 96% alcohol under heating (more concentrated) and in the other the volatilization took place at room temperature (less concentrated) (LUCAS *et al.*, 2015).

With these tests, Lucas *et al.* (2015) confirmed the antimicrobial capacity of Malagueta pepper against *S. aureus* (higher activity among the peppers studied), and in the more concentrated extract this activity was more effective, because capsaicinoids (mainly capsaicin) were also more concentrated, presenting greater toxicity to the bacteria and consequently greater inhibition. In addition, the authors found that the antimicrobial activity is related to the content of capsaicinoids, the pungency of the peppers and the treatment given to the extracts.

Barbosa *et al.* (2012) in addition to analyzing the antimicrobial property of C. *frutescens* pepper extract against the bacterium *S. aureus*, they also analyzed against the bacteria *Salmonella typhimurium* and *Escherichia coli*. In vitro antagonism tests were performed by the Agar Diffusion method, thus confirming the inhibition performed by the extract against these three microorganisms and consequently realizing that there are inhibitory substances in these fruits, verifying the antimicrobial activity of chili pepper.

4.3.3 Analgesic and Anti-inflammatory Activity

A large part of the world population suffers from some type of pain, a problem that ends up reducing the quality of life of these people (DE SOUSA, 2011). Thus, contemporary science has recognized the importance of natural products and their metabolites in the control of these pains, currently using medicines that have these products as a primary source, including medicinal plants (PETROVSKA, 2012).

Rheumatoid Arthritis is a disease that generates, in many of its carriers, including medicated patients, a significant degree of pain and limitation in hand movements, which has caused an increase in the search for alternative and complementary treatments (ALVES, 2016).

Thus, Alves (2016) evaluated the effectiveness of topical application of *C. frutescens* in relieving pain and improving the function of the hand of a patient with rheumatoid arthritis, analyzing whether this pepper has analgesic and anti-inflammatory effect.

For this, the study was carried out with four patients with this disease and who presented the characteristic pains of this condition, they were submitted to the topical application of chili pepper in the form of ointment (the oleoresin of Capsicum incorporated in semisolid petroleum jelly) and the following methods and instruments were used to make comparisons between before and after application: Visual Analogue Scale (VAS) and Algometer (equipment developed to measure tolerated strength, considering hand grip and thumb resistance) to verify pain intensity, Dynamometer to assess handgrip strength and the Health Assessment Questionnaire (HAQ) to analyze functional repercussion.

With all this, Alves (2016) demonstrated that there was a reduction in the symptoms of Rheumatoid Arthritis (such as pain) during application of *C. frutescens ointment* and that, in addition, when suspending this application, a slight increase in these symptoms was noted, but still with final values lower than those seen before treatment.

With the use of the ointment, an improvement in tolerance to hand compression pressure was observed in all patients, an increase in hand strength exerted by the patient himself (with the exception of one of the patients) and an improvement in functional capacity (performing basic activities of daily living) for most of the participants.

It is also clear in the work of Alves (2016) that these benefits generated by chili pepper were attributed to capsaicin, a chemical compound present in it.

4.3.4 Other Biological Activities

Capsaicin is an active compound found in great abundance in chili pepper and it has several benefits, such as: Treatment of inflammation, rheumatoid arthritis and vasomotor rhinitis (ZHENG *et al.*, 2017).

Studies indicate that capsaicin plays anticoagulant activity as it acts in lowering blood pressure, lowering cholesterol and preventing the formation of blood clots that can end up causing heart attack, stroke and thrombosis.

These researches also prove that this compound can be used in the treatment of colds, fevers, relieve skin itching and calm the pain caused by herpes, in addition to being used in sports medicine for the treatment of injuries, twists and neuralgias (MASSABNI, 2010).

Some studies also report that there are interesting perspectives in the use of capsaicin for the treatment of osteoarthritis and psoriasis.

They also indicate that the consumption of pepper in food helps in digestion and burning calories faster, accelerating the metabolism (MASSABNI, 2010).

The study conducted by the compounding pharmacy, Botica Magistral (2013), reports that daily doses of capsaicin can be used to help in the process of weight loss, because this bioactive compound increases energy consumption at rest, inhibits the desire to eat and extends the satiety time, helping to decrease waist circumference and body mass index.

Thus, combining the consumption of capsaicin with healthy habits can be a great ally in the fight against obesity, thanks to its thermogenic activity and effect on satiety (BOTICA MAGISTRAL, 2013).

Massabni (2010) explains that capsaicin is not destroyed and does not lose its original properties when the pepper is fried or preserved in oil for a long time and also warns that despite the benefits one should not exaggerate the consumption of pepper, because the excess can also generate problems such as, for example, the appearance of stomach ulcers, but it makes it clear that the amount that can generate these negative effects varies according to the individual.

Finally, one can also mention the vasorelaxing and antidiabetic properties played by chili pepper (SRICHAROEN *et al*., 2017; MACHADO *et al*., 2021).

5 FINAL CONSIDERATIONS

Finally, one can also mention the vasorelaxing and antidiabetic properties played by chili pepper (SRICHAROEN *et al*., 2017; MACHADO *et al*., 2021).

At the end of this bibliographic review, we can conclude that chili pepper, a well-known pepper consumed throughout Brazil, is a fruit of great importance, not only for cooking and for economic movement – as it is used in most cases – but also for traditional medicine. Through several studies, it was possible to better understand the chemical composition of this spice and its biological activities, which contribute to its wide use.

Capsicum frutescens is known for its intensity and pungency (164,000 SHU), which are linked to the presence of capsaicin, a chemical compound responsible for the sensation of heat and burning. In addition to this substance, other compounds have been identified, such as fatty acid methyl esters, phenolic compounds, vitamin C, amino acids, sugars, macro and microminerals, among others. Substances that contribute to the nutritional properties and biological activities of chilli.

With regard to these activities, the studies used for research have shown that chili pepper can be used to perform antioxidant, antimicrobial, analgesic and anti-inflammatory, vasorelaxing, antidiabetic, anticoagulant, thermogenic actions, among others. Properties that make chili a functional fruit, offering additional health benefits and can be used in the prevention and treatment of different diseases.

In this way, this pepper has the ability to act in the fight against pathologies such as: cancer, rheumatoid arthritis, infarction, stroke, thrombosis, colds, fevers, obesity and more. However, it is important to note that excessive consumption of this fruit can also cause problems, so it should be consumed in moderation.

Finally, it is notable that chili pepper presents a promising potential as a source of bioactive compounds with relevant biological activities. Its moderate and regular consumption can contribute to a healthy diet and to the prevention of diseases.

Thus, it is demonstrated the importance of conducting more studies on the attributes of this fruit, to better understand its effects, help establish appropriate recommendations for its medicinal use and 36 thus can be increasingly used in the realization of benefits to human health.

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