Functional and nutritional properties of chilli sauce

Propriedades funcionais e nutricionais do molho de pimenta

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ABSTRACT
Pepper is a functional food due to is capsaicin or piperine, minerals, vitamins, phenolic acids and flavonoids. Peppers are classified according to their characteristics, such as stinging, color, size and flavor. The consumption of peppers is related pungency sensation and to the benefits to human health, as they are a source of vitamins and have nutritional and antioxidant properties that can have a significant impact on diseases. Pepper crops present problems, as pests and irrigation, which are frequently reported. The objective of this work was to report the panorama of the chili pepper sauce production process, finding regarding beneficial on properties of pepper and discuss its several forms of sold, pepper cultivation and beneficial effects and disadvantage of pepper consume.

Keywords: pepper, irrigation, *Capsicum frutescens*, beneficial effects.

RESUMO
A pimenta é um alimento funcional devido à sua capsaicina ou piperina, minerais, vitaminas, ácidos fenólicos e flavonóides. Os pimentões são classificados de acordo com suas características, como ardência, cor, tamanho e sabor. O consumo de pimentas está relacionado à sensação de pungência e aos benefícios à saúde humana, pois são fonte de vitaminas e possuem propriedades nutricionais e antioxidantes que podem ter impacto significativo em doenças. As culturas de pimenta apresentam problemas, como pragas e irrigação, que são frequentemente relatados. O objetivo deste trabalho foi relatar o panorama do processo de produção do molho de pimenta, constatando as propriedades benéficas da pimenta e discutir suas diversas formas de comercialização, cultivo da pimenta e efeitos benéficos e desvantagens do consumo da pimenta.

Palavras-chave: pimenta, irrigação, *Capsicum frutescens*, efeitos benéficos.

1 INTRODUCTION

The pepper, *pigmentum*, a vegetable crop, is a functional food due to its capsaicin or piperine compounds, minerals, vitamins, phenolic acids and flavonoids (Kim *et al*. 2019; Xu *et al*. 2021). In all over the world, the pepper is marketed and consumed mainly it is sensory attributes such as color and spicy taste (Mi *et al*. 2020).

It has been reported that peppers are sold in processed and nature form, as coloring, sauces, additives and condiments, such as pepper paste, paprika, fermented pepper products and *Doubanjiang* (Santos *et al.*, 2020; Ye *et al*. 2022). The diversity of application highlights the economic importance of pepper for the local, national and international agribusiness and market (Xu *et al*. 2021).

Peppers are economically important in the world. In 2019 the production of pepper (Piper spp.) in Brazil was 109 thousand tons and the world production 1.1 million tons (FAO 2021). It is estimated that the pepper agribusiness mobilizes around R$80 million from processing to commercialization (Guerra *et al*. 2021). According to FAO data (FAO

2021), from 2009 to 2019 pepper (piper spp.) production in Brazil increased by 67% and world production by 63%, these increases are attributed to population growth and the search for healthier foods and nutritious.

2 CHILLI PEPPER SAUCE PRODUCTION

Sauce represents an alternative of commercial interest, requires the proper combination of conditions that contribute to increasing the shelf life of the pepper (Pereira *et al*. 2016; Baenas *et al*. 2018).

The quality of the sauce is related to the selection of pepper that depends of the type, color, productivity in relation to the region sold and on the degree of pungency desired.

A traditional chilli pepper sauce is produced with the pepper, water, salt and spices. To obtain a different flavor to the sauce, sugar, garlic, tomato and spices are used (Pereira *et al*. 2016). Techniques such as fermentation are also used in some chilli pepper sauce (Farias *et al*. 2020). Table 1 shows compositions of sauce pepper.

Table 1. Composition of several chilli pepper sauce.

Compound	This work[a]	Lee et al. (2012)[b]	Dubinina et al. (2018)[b]	Cárdenas-Castro et al. (2019)[c]
Chilli pepper (%)	50.8	11.0	80	5
Tomato (%)	-	29.2	-	85
Onion (%)	-	18.2	-	4
Water (%)	34	-	-	-
Sugar (%)	-	11.5	0.5	-
Vinegar (%)	13.5	10.9	-	-
Salt (%)	1.7	5.46	1.5	2.0
Garlic leaves (%)	-	-	5	1.0
Dill	-	-	5	-
Celery leaves	-	-	5	-
Chitosan	-	-	0.5	-
Others	-	herbs, plum extract, and oligosaccharide	parsley leaves	"salsa roja"-red sauce, spices

Note: a = *Capsicum frutescens*, b = *Capsicum annuum* L., c = Mexican sauce

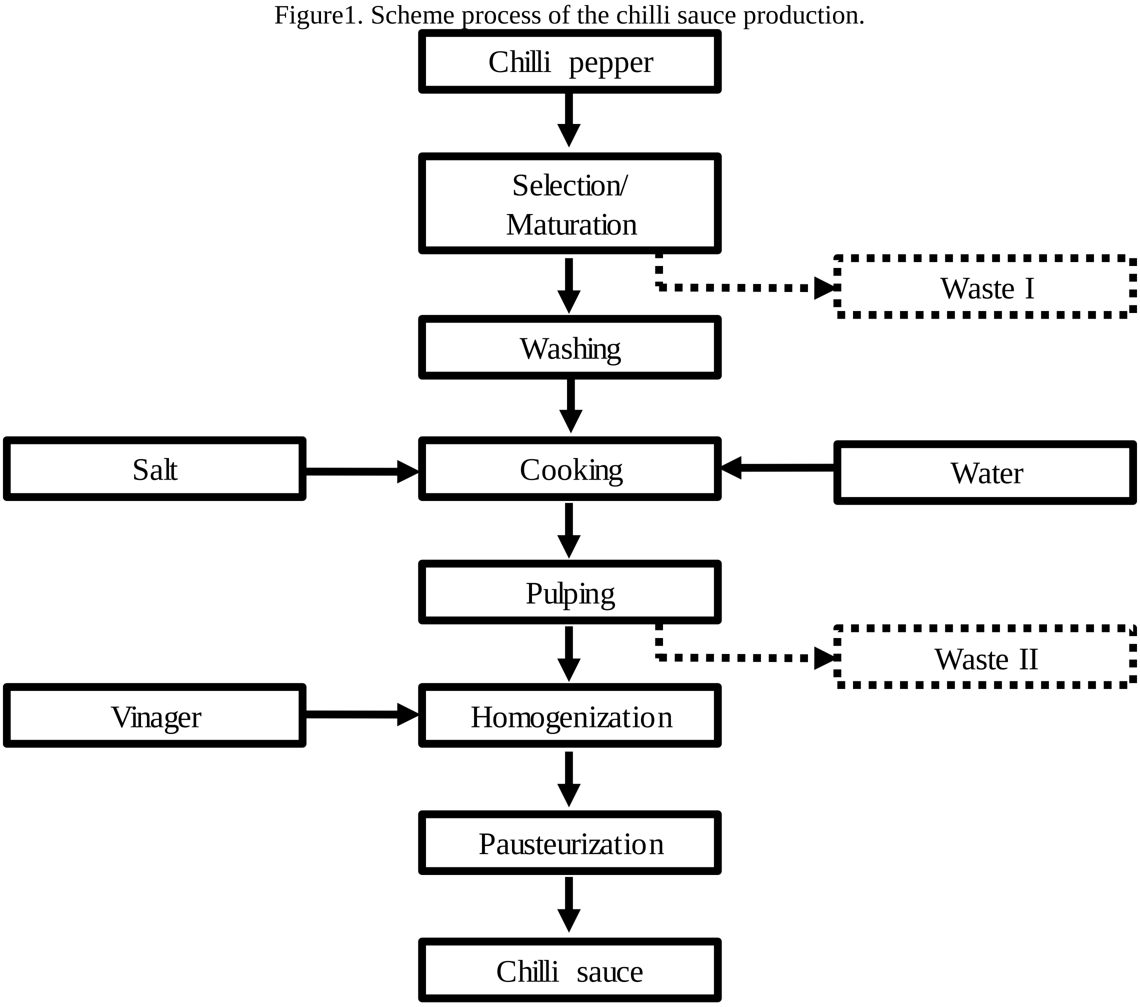
For each manufactured batch, parameters are inspected, such as flavor, aroma, color, pH, °Brix, salt content and microbiological analysis, are standards with variable tolerances, which depend on the desired product and must be established by the manufacturer. Lee *et al*. (2012) produced a hot sauce with Korean chilli peppers (*Capsicum annuum* L.) whit salt 5.46%, total acidity 6.04%, pH 3.32 and °brix 58.50. Some physicochemical attributes and their acceptable values in standardizing the quality characteristics of spices, seasonings and sauces are not established in regulations (Farias *et al*. 2020).

The production of pepper sauce can take place almost entirely in an automated way, requiring manual labor to move raw materials and control equipment. The sauce must be prepared with fresh peppers and in good condition, without insect marks and not too ripe, so as not to compromise the final flavor and appearance.

Chilli pepper harvesting takes place four months after planting. After harvesting, the fruits must be stored in a clean, cool and ventilated place until of the processing.

The production of pepper sauce follows the stages of reception, storage, selection, maturation, removal of undesired materials, cleaning, cooking, pulping, mixing, homogenization, pasteurization and storage, according the scheme steps shown in Figure 1 (Uzel 2018; Farias *et al*. 2020).

Figure1. Scheme process of the chilli sauce production.



The mature peppers are use into the process and the unripe are sent to the maturation step. When stored below 7.5 ºC with relative humidity greater than 95%, peppers have a shelf life of three to five weeks (Mani-López *et al*. 2016). While to Rehman *et al*. (2021), below of storage temperature (<10 ºC) the sweet pepper fruits suffer a chilling injury.

The waste I from the selection step, are the branches, other dirt and rotten fruits - mainly damaged by Botrytis, Alternaria and soft rot bacteria, the mechanical damage is very common in pepper fruits, which favors rot (Mani-López *et al*. 2016).

Only peppers of high quality go to the washing process, that can be is performed by sprinkling. The first wash is carried out with a sanitizing solution and the second wash, is carried with water to remove the remaining the sanitizing solution (Mani-López *et al*. 2016).

After washing, in the cooking stage, the peppers are heated and mixed with water and salt for 30 min at 100 ºC to avoid excessive softening. Cooking is an important step in the process, as non-enzymatic browning reactions occur during this step, dissolving the ingredients and, in addition, time and temperature have a great influence on the flavor of the sauce, the greater the time and temperature of cooking, the greater the volatilization and degradation of the compounds that impart aroma and flavor to the product.

Waste II from the pulping step, are seeds and peels (Farias *et al*. 2020). In the industrial processing of peppers between 5 and 30% of the fruit, such as peel, stalk, seed and pulp, are not processed, generating wastes (Baenas *et al*. 2018). However, these are as sources of nutrients and secondary metabolites for application in industry, benefit producers due to reduced waste and increased income generation for the sector (Viacava *et al*. 2013).

The pulping step gives a better final appearance to the sauce, in addition to preventing decanting and facilitating homogenization. The pulp goes to the mixing stage, where the mixture of pepper pulp with vinegar is carried with low agitation to obtain a uniform mixture. Vinegar guarantees the homogenization of the sauce (Rengsutthi and Charoenrein 2011) and corrects the pH, which must be less than 4.5, contributing to microbiological safety, in addition to giving the sauce an acidic taste.

In the homogenization the reduction of pepper particles and fibers occurs through. From this stage, a sauce pepper with a stable and permanent suspension is obtained, preventing the constituents from separating. The sauce acquires adequate fluidity and viscosity.

The product must contain a label on which the mandatory information required by the local regulatory agency is provided, such as the manufacturer's name and address, batch number, date of manufacture and expiration date and basic information about the product, such as the type of pepper used.

3 PEPPER CULTIVATION

One of the problems reported in pepper crops is the need for water for irrigation. For this, some authors recommend the use of gray water. Gray water, defined as wastewater produced from bathtubs, showers, washbasins, washing machines and kitchen sinks, excluding any input from toilets (Shaikh and Ahammed 2020). Disha *et al*. (2020) reported that their results showed a clear positive impact of treated gray water irrigation on the growth of *Capsicum frutescens* compared to untreated gray water irrigation. However more studies are needed for this application.

Another agricultural practice that reduces the need for irrigation water is the use of mulch that helps to conserve soil moisture. The combined effects of irrigation and rice straw mulch on the growth and production of two pepper varieties, *Capsicum frutescens L*. and *Capsicum chinense* were evaluated and the results showed that they improved vegetative growth, shortened the number of days to flowering and fruiting, and improved yield and water use efficiency compared to other treatment combinations (Adekaldu *et al*. 2021).

Pepper crops present other problems, such as pests, which are frequently reported. An important pest affecting pepper crops is *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), an aphid that is among the main species of arthropod-pests that can attack pepper crops (Carmo *et al*. 2021). The use of insecticides is the main method of controlling this aphid.

Pepper is susceptible to anthracnose, a disease of high economic importance. The cultivation of peppers is preferably carried out in periods when the climate is hot, rainy and windy, which favors the occurrence of diseases such as anthracnose, caused by the worldwide pathogen, *Colletotrichum scovillei* (Diao *et al*. 2017; Gao *et al*. 2021). In Brazil, *Colletotrichum gloeosporioides*, *Colletotrichum acutatum* and *Colletotrichum coccodes* have been identified as causing anthracnose in nightshade vegetables, the first two being the most important pathogens of Capsicum (Pedroso *et al*. 2011).

The *Colletotrichum*, causal agent of anthracnose produces dispersed conidia that spread water droplets on the fungus acervulas and undergo various spores transport stages in secondary droplets until the conidia are deposited at new sites of infection (Pedroso *et al*. 2020; Gao *et al*. 2021). In China, the development of the chilli pepper industry has been limited due to the presence of anthracnose, as the management of anthracnose of chilli pepper depends on expensive fungicide sprays (Gao *et al*. 2021).

Anthracnose infection begins with the appearance of small circular lesions that expand rapidly throughout the fruit (Gomes and Souza 2013). This anthracnose is an important Capsicum disease that affects unripe or ripe fruits in the field or in the post-harvest stage, it spreads rapidly and makes crop management difficult, which can reduce pepper production by 40% to 50% (Diao *et al*. 2017; Pedroso *et al*. 2020; Gao *et al*. 2021). With the reduction in production, there can be a great economic impact on these crops that are even more harmed in environments of high relative humidity and frequent rains, such as summer crops in Brazil, so in individual fields losses can reach 100% (Pedroso *et al*. 2020). The main method of controlling anthracnose in pepper is the application of fungicides such as benomyl, thiophanate-methyl, azoxystrobin, prochloraz, chlorothalonil and mancozeb (Harp *et al*. 2014).

Despite causing problems, the application of fungicides in pepper crops in order to obtain higher yields is frequent (Gao *et al*. 2021). The accumulation of pesticide residues in the environment, resistance to pesticides and reduced economic benefits are some problems associated with the use of pesticides, which are not fully efficient and which during the fruiting phase are applied more than 10 times (Pedroso *et al*. 2020; Gao *et al*. 2021). Pedroso *et al*. (2020) highlight that chemical products cannot be used by organic farmers and their use is increasingly examined even among conventional farmers.

Due to this reported scenario, alternative control measures to pesticides have been investigated and reported in the literature. Intercropping with relatively tall plants to provide a physical barrier and shade to protect pepper crops is an alternative option. Gao *et al*. (2021) evaluated the performance of black pepper intercropped with corn in different intercropping proportions on anthracnose disease and yield and reported that compared to monoculture intercropping significantly reduced the incidence of anthracnose and delayed disease onset. The intercropping system provided an increase in the efficiency of land use, reduced the incidence of anthracnose by interfering with the dispersion of spores, reducing the incidence of scalding and altering the microclimate.

Pedroso *et al*. (2020) in order to control anthracnose in pepper crops, studied the planting time, organic soil mulch, fungicide and moderate nitrogen fertilization. The authors reported that the choice of planting time is the most decisive factor for the management of anthracnose in peppers and that the use of fungicide, although a less decisive factor, is still important, followed by the choice of substrate for ground cover and fertilization with nitrogen.

The effects of natural products were evaluated in the control of anthracnose caused by *Colletotrichum gloeosporioides* in pepper fruits (*Capsicum baccatum L.*) at postharvest, at different dosages and application times (Gomes and Souza 2013). The authors report that among the ten treatments evaluated, the biopirol® and acadian® inducers provided greater reduction in the pathogenicity of the causal agent, in addition, in the other treatments they observed a delay in the size of the lesions.

Increasing productivity and reducing losses during and after pepper cultivation is necessary to strengthen the economy and diversification of this sector. Alternative and environmentally friendly pest control methods are evaluated to ensure the sustainable development of the pepper industry.

4 BENEFICIAL AND CONTRAINDICATIONS EFFECTS OF PEPPER CONSUME AND THEIR CHEMICAL COMPOUNDS

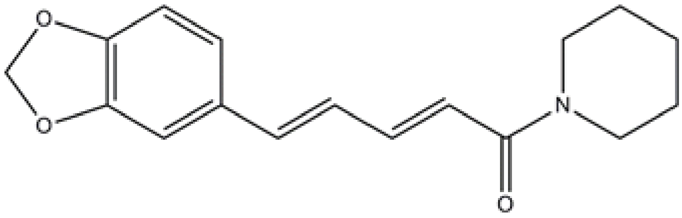
4.1 BENEFICIAL OF PEPPER CONSUME

Peppers are classified according to their characteristics, such as stinging, color, size and flavor. Pungency is the main characteristic of peppers and depends on the concentration of capsaicinoids, which are substances that do not have an odor and taste and cause a pungent sensation. The pungency level is measured by the Scoville scale (Scoville 1912). As for the flavor, peppers have non-spicy varieties, the so-called sweet peppers, such as paprika, and spicy varieties, such as cayenne and chilli pepper.

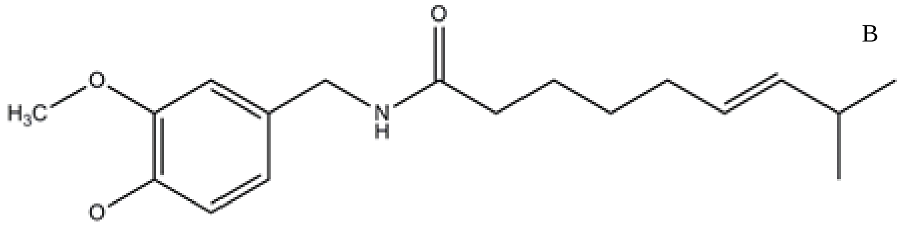
In addition to the characteristic pungent sensation, the high consumption of peppers is related to the benefits to human health, as they are a source of vitamins and have antioxidant properties that can have a significant impact on diseases (Pereira *et al*. 2016). Maruta and He (2020) report in their study that natural substances such as Sichuan pepper can be used to combat the coronavirus by inhibiting the PAK1 kinase (RAC/CDC42-activated kinase 1).

There are two genera of peppers best known and sold worldwide, Piper and Capsicum, which contain piperine and capsaicin (Figure 2), respectively, which have anti-inflammatory and antioxidant effects (Reis *et al*. 2015; Martinez *et al*. 2021).

Figure 2. Chemical structure of (A) piperine and (B) capsaicin.



A



B

Of the peppers of the Piper genus, the best known is black pepper (*Piper nigrum*). From this genus, from the long pepper (*Piper hispidinervum*), an essential oil rich in safrole is extracted (Riva *et al*. 2011; Andrés *et al*. 2017).

The active component of peppers of the Capsicum genus, capsaicin, has application in medicine, preventing bleeding, wound healing, increasing physical resistance and has disinfectant properties (Sricharoen *et al*. 2017; Silva *et al*. 2020). Due to its rich composition in phytochemicals - phenolic compounds, carotenoids, flavonoids), capsaicin acts by stimulating the immune system, which favors the body's defense against pathogens (Sricharoen *et al*. 2017; Silva *et al*. 2020). In Brazil, the most common ones of the Capsicum genus are chilli pepper (*Capsicum frutescens*), chilli pepper (*Capsicum bacccatum* var. Pendulum) and murupi pepper (*Capsicum chinense*) (Favos *et al*. 2017).

Table 2 presents nutritional data for fresh and processed peppers. The chilli pepper has in its composition water, carbohydrates, proteins, lipids, zinc, calcium, copper, iron, phosphorus, magnesium, manganese, potassium, sodium, fiber and also vitamins A, B, B2, B5, C and E (Sricharoen *et al*. 2017; Baenas *et al*. 2018).

Table 2. Composition of fresh and processed peppers, macronutrients in g 100^{-1} g sample and micronutrients in mg 100^{-1} g sample from literature.

Parameters	Chilli pepper	Chilli pepper (*Capsicum frutescens*)	Chilli pepper (*Capsicum frutescens*) processed canned	Sweet pepper
Moisture	88.3	29.4	15.3	-
Protein	1.9	4.8	4.76	-
Fat	0.3	0.63	0.62	-
Carbohydrate	6.4	-	-	-
Fiber raw	2.4	-	-	-
Ash	0.7	0.039	0.043	-
Ca	25	-	-	7-18*
P	25	-	-	26-46*
Fe	1.4	-	-	0.3-1.2*
Na	-	-	-	4-7*
K	-	-	-	211-340*
Vitamine B1	0.08	-	-	-
Vitamine B2	0.11	-	-	-
Niacin	2.2	-	-	0.9*
Vitamine C	19.0	121.5*	14.5*	127-300*
References	Salaue (2019)	Rebouças et al. (2013)	Rebouças et al. (2013)	Baenas et al. (2018)

* mg 100 g^{-1} sample.

The chilli pepper fruits belong to the Solanacea family of the Capsicum genus *(Capsicum frutescens*), when ripe they are red and small, between 1.5 and 3 cm in length and 0.4 to 0.5 cm in width (Pereira *et al*. 2016). The chilli pepper is commercially important due to its red color and flavor from capsaicin. It is consumed fresh, in powder and in the form of preserves and sauce, its application in the food industry is a very profitable activity. The production of pepper is growing due to its high consumption, which is related to healthy eating. Rebouças *et al*. (2013) report that after processing canned chilli peppers, there may be losses in its nutritional quality.

4.2 CONTRAINDICATIONS OF PEPPER CONSUME

When capsaicin, present in peppers, is consumed in high levels of continuously form or excessive doses, can appear effects as uncomfortable gastrointestinal symptoms as eartburn, diarrhea, pain and severe abdominal pain (Koprdova *et al*. 2020; Xiang *et al*. 2022).

According to Gupta (2008), the consumption of chili pepper can increase symptoms of pathologies like acute anal fissure.

Chilli pepper is commonly associated with ulcers. However, according to research of Satyanarayana (2006), is the most common ulcers in Chinese section of the population in Singapore than among the Malaysians and Indians that consuming more chillis in their diets. The author shown capsaicin has been found to inhibit the growth of Helicobacter pylori and the release of gastrin and stimulates that of somatostatin, the physiological inhibitor of acid secretion.

5 CONCLUSION

The pepper is most consumed in the form of sauce than fresh. Pepper sauce is a product used in several recipes and is often homemade, has high nutritional value and its consumption is allied to a healthy lifestyle, in addition, its characteristic flavor adds a spicier flavor to dishes. In addition to the nutritional factors that draw attention in cooking, the composition of pepper is of interest in pharmaceutical industries, and its use is also being investigated in cosmetics and in the treatment of diseases. The main form of current consumption of peppers is in the form of a condiment, whose alternative has great marketing potential. Relevant aspects of pepper sauce quality should be considered in the process, such as pepper appearance, degree of pungency, productivity, conservation method, appearance, flavor and aroma of the sauce, pH, °Brix and final packaging. Sauce quality and their flavor depending on the pepper and elaboration methods.

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HIGHLIGHTS

1) Pepper is an important vegetable crop, consumed mainly it is sensory attributes such as color and spicy taste.

2) The presence of capsaicin or piperine compounds became the pepper a functional food.

3) Pepper is a source for healthier foods and nutritious due to its, minerals, vitamins, phenolic acids and flavonoids.

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