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Evaluation of the Antioxidant Potential of Mesquite Grains Flour in Hamburger Meat Product

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective is to approach the use of the flour of the mesquite grains in restructured hamburger meat product formulations.
Introduction: The mesquite seed is a by product of great nutritional value and little use in large scale for food purposes, being considered, also, discarding raw material in the processing of the mesquite pod. The seeds represent an agroindustrial byproduct with broad technological and

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nutritional potential, with some applications already tested and widespread in the food and environmental sector. The high sugar content associated with the high levels of nitrogen in the mesquite tree pods favours the biochemical processes and enables the production technology of alcohol, spirits, liquor, wine, honey, enzymes, acids, gums, vinegar, sugars and even a substitute drink for coffee. In some Andean countries, other beverages such as lodge, chicha, etole and algarobina (a type of stomach and aphrodisiac fortifier), flour, biscuit and cookies are made. The physicochemical characteristics of the hamburger should contain a maximum fat content of 23.0%, a minimum of 15% protein, 3% total carbohydrates and calcium content (maximum dry basis) 0,1% in raw hamburger and 0.45% cooked hamburger.

Conclusion: The use of resources to reduce the disadvantages related to the addition of fibre in meat products should be studied in order to obtain the benefits of this addition without compromising the acceptability and quality of the final product, besides allowing a greater addition of mesquite seed in order to achieve the requirements for a functional product.

Keywords: Fibre; fat; mesquite flour; restructured meat.

1. INTRODUCTION

With the dissemination of information, the consumer has increasingly demanded products that are practical, hygienically correct and with nutritional quality, promoting an increase in competitiveness among the industries, which leads to the increasing demand in the process of choosing the products. Due to the demand for low-fat products, the food industry and research institutes are intensifying the development of new formulations or modifications of traditional products to create alternatives to reduce fat content [1].

Among the many options available, red meat stands out as one of the main sources of proteins of high biological value, B vitamins and minerals such as iron and zinc. However, it is associated with a negative health image due to its high saturated fat content, is related to coronary diseases and cancer. The resolution 408 of 2008, of the Ministry of Health, was created to support and stimulate the promotion of healthy eating with impact on the reversal of the obesity epidemic and prevention of chronic non-communicable diseases, with a review of the patterns of identity and food quality, aiming to reduce the amounts of sugar, sodium, saturated fats and elimination of trans fats, making them compatible with a healthy standard of living [2].

The development of functional meat products, from the addition of dietary fibres, preserving the sensorial characteristics like colour and texture, can be a stimulus to the introduction of healthy foods in the diet of the consumers. Rapidly prepared foods of great popular variety, such as restructured meat products, have become objects of study in this area [3]. Various types of vegetable fibres have been individually evaluated or combined with other ingredients in reduced fat meat product formulations, such as restructured and emulsified products. This alternative could indirectly promote greater consumption of fibre by consumers, who even knowing the benefits of this nutrient have not yet incorporated it into their eating habits.

Due to the high antioxidant and protein activity in its composition, the mesquite seed presents a difference when compared to other seeds of commercial use. Its use in the form of flour is a viable alternative for the integral use of the pod of the mesquite, since obtaining it requires technological processes accessible to the small producer, in addition to the possibility of a larger consumption when compared to consumption only in nature. The production of a product of greater value-added from the seed of the mesquite can contribute to the generation of income of the producing region, improving the quality of life of the population. The objective is to address the use of mesquite seed meal in hamburger-type restructured meat product formulations.

2. MESQUITE (*Prosopis juliflora* Sw. DC)

The evolutionary development of the mesquite species of the genus Prosopis originated in the African continent (Tropical Africa), where *Prosopis africana* persists. Their migration to the American continent occurred when these continents were linked, involving different species adapted to the dispersion at a short distance, but of effective endozoic diffusion, through birds and mammals [4].

The genus *Prosopis* is a vegetable belonging to the subfamily Mimosoideae, native to North and South America, where most of the 44 known species of the genus *Prosopisé* are found. These species are capable of surviving and producing in soil areas of low humidity, high temperature, high evapotranspiration and high precipitation, they present great resistance to salinity, having a high capacity to fix nitrogen [5].

The mesquite tree (*Prosopis juliflora* Sw. DC) is a xerophilous whose tortuous stem measures about 6 to 8 meters in height, being able to reach up to 18 meters, the stem has a thick, slender, reddish-brown, sinuous and twisted bark. The crown may reach 6 to 20 meters in height and 0,45 to 1,00 meters in diameter, with a brown colour, armed with axillary spines, solitary or twin, rarely unaltered, housed on both sides of the nodes and branches [4].

It is an exotic species and resistant to the conditions of climatic severity, manifested in arid and semi-arid areas. It was introduced in the Brazillian Northeast through public policies that aimed to meet the needs of the rural man concerning the food supply of his herd, notably cattle and goat farming and also as alternative reforestation in areas deforested by the caatinga. It was well adapted to the climate of the Northeast region of Brazil as it developed in regions with rainfall between 150 mm and 1200 mm per year [6].

The tree of the genus Prosopis is used in the Northeastern semiarid region in three ways: in the exploitation of wood for the production of cuttings and posts and for energetic purposes, in the form of firewood and charcoal; in the feeding of sheep, goats, cattle, horses and mules by means of their fruits; and for shading, usually in the vicinity of farmhouses, parallel to fences and on property roads [7].

This plant produces a large number of pods with excellent palatability and good digestibility, presenting in its chemical composition 25-28% of glucose, 11-17% of starch, 7-11% of proteins, 14-20% of organic acids, pectins and other substances. Thus, the mesquite contains about 43% of sugars and starch, constituting an excellent fattening food, besides being relatively rich in proteins. It has an ash content of approximately 3.75% and a moisture content ranging from 16-20% wet basis [8]. The pod of the mesquite is classified as a vegetable, independent, in the form of a drupaceous lomento, linear or curved, presenting the exocarp striate, carnivorous mesocarp of yellow colour, divided into leathery segments that have one seed each, with an average of 20 seeds per fruit; measuring 10 to 40 cm in length, 15 to 20 mm in width and 4 to 5 mm in thickness [9].

The mesquite pods are flattened, more or less curved, measuring on average 20 centimetres in length and between 1 and 2 cm in width, with depressions between the seeds; are composed of light-coloured coryza epicarp; sucrose-rich mesocarp (more than 30%) and about 15% crude protein [10]. It is divided into three parts: pulp, seed and endocarp, grow in small stalks forming clusters, contains a sweet flesh and yellow colour.

2.1 Mesquite Seeds

The seeds are dark brown, oval, having an average of 6 mm in length and 4 mm in width. They consist of 3 parts: bark (15%), endosperm (35%) and germ (50%) [11]. They represent about 30% of the total weight of the fruit, varying according to the species and location of development of the pod. The seeds of *P. juliflora* have a water barrier composed by the palisade layer of seed coat and galactomannan in the endosperm [12].

Because it belongs to the family *Fabaceae*, the mesquite seed has the endosperm rich in galactomannan (polysaccharide known worldwide and widely used as a stabilizing and emulsifying agent in the food, cosmetic, textile, pharmaceutical and biomedical industries), serving as a water reservoir and source of energy to the embryo, avoiding its death by desiccation and having potential of application in films and edible coatings [13]. Galactomannans are mainly found in the endosperm of vegetable seeds as components of cell wall storage and energy reserves. During germination, these polysaccharides are discriminated and used as a reserve for the development of seedlings [12].

Polymers of this type, LBG and Guar gums, are widely used in the formulation of ice creams, pasty cheeses, salad dressings, yoghurts etc. In Brazil, the first large study on the composition and properties of pods, including the description and the elucidation of the polysaccharide structure of the seed was performed by Figueiredo [14]. It is a water-soluble polysaccharide; a galactomannan with an average molecular weight of about 250,000, found in the seed whose solutions have high viscosity and "n" applications in the food industry.

These gums are essential in food processing because of their ability to improve water retention, reduce moisture loss by evaporation, alter freezing parameters and formation of water crystals, and especially to increase and optimize viscosity food and other products [14]. Rincón et al. [13] state that *P. juliflora* gum can be used as a natural thickener and stabilizer because of the zero shear viscosity and the non-Newtonian flow behaviour of its aqueous dispersions, as well as the fact that they exhibit properties viscoelastic.

Access to products made from wheat flour substitutes that have nutritional value and pleasant sensory characteristics are difficulties encountered by celiac and the food industry. Biscuits are among the most consumed by society in general, which is justified by the ease of consumption and the affordable cost. Despite the significant production of biscuits in Brazil, the supply of this gluten-free product is very limited [15].

Freitas et al. [16] studied the elaboration of flour with pumpkin seeds and bauru to make biscuits and concluded that the addition of two flours, partially replacing the sweet sprinkles, improves the nutritional value of celiac biscuits as they increase the dietary fibre content, proteins, minerals and lipids. However, sensorially, the biscuit B containing pumpkin seed flour presented better results, showing that this flour can partially replace traditional flours in formulations of biscuits for celiac, both domestically and industrially.

2.2 Technological Characteristics of the Mesquite

The mesquite is part of the foods used by man since prehistory, in regions where the plant is native. They are palatable and aromatic (reminding vanilla) [10], it has high levels of proteins with reasonable digestibility, being equal to those of barley and corn, varying in size, colour and chemical characteristics, according to the characteristics of the species. This makes its cultivation recommended for many purposes: phytochemistry [6], allelopathy [17], antioxidant [18], food [13,19], biopesticide [20]; bioethanol [21] and use in medicine [22].

Ruto et al. [23] concluded that the methanolic extract of *P. juliflora* presented several degrees of inhibition against the microorganisms (*S. aureus, B. subitilis, C. albicans, P.aeurginosa and E. coli*). The antibacterial efficacy of the P. juliflora extract can be attributed to the presence of phenolic compounds; flavonoids and flavonoids; tannins and terpenoids. Plants can synthesize aromatic substances, most of which are phenols or their oxygen derivatives that serve as a defence mechanism against microorganisms, insects and herbivores. Flavonoids are phenolic compounds hydroxylated substance known to be synthesized by plants in response to microbial infection [24].

The high sugar content associated with the high nitrogen levels of the mesquite tree pods favours the biochemical processes and enables the technology of alcohol production [25]. spirits, liqueur, wine, honey [26], enzymes, acids, gums [13], vinegar, sugars and even drink that replaces coffee [27]. In some Andean countries other beverages such as lodge, chicha, etole and algarobina (a type of stomach and aphrodisiac fortifier), flour [28] and cookies [29].

In a study developed by Silva [30], which improved the process of obtaining a mesquite spirit, the physicochemical characterization of mesquite pods obtained in the state of Paraíba was obtained (Table 1).

Silva [31] elaborated an integral flour of mesquite for use in bakery products using the unit drying operations (45°C for 18 hours), fragmentation and sieving of the pods with the physicochemical composition described in Table 2.

Gusmão [32] prepared a meal of the mesquite pod obtained by convective drying at 60°C for the use of biscuit formulation together with the wheat flour. The characterization data of this flour are described in Table 3.

It is observed that the in natura pod has an average of 9.7% of protein, 1.9 lipids, and 15.7 of crude fibre, excellent quantitative to justify its processing in meaty derivatives. In this context, it is necessary to potentialize the use of the fruits of the mesquite tree crop in the semi-arid regions of Northeast Brazil, where malnutrition is a direct consequence of the lack of potentially nutritious and easy-to-acquire foods rich in nutrients, but wasted due to lack of information, mainly by the rural population. Choge et al. [33] show the composition of the whole pod meal of P. juliflora, confirming the product with a high protein and sugar content (Table 4).

Table 1. Physical-chemical composition (Mean ± standard deviation) of in natura mesquite pods harvested in the cities of Patos e Sousa, Sertão Paraibano

Analysis	Cities	
	Patos (%)	**Sousa (%)**
Moisture	10.30 ± 0.40	13.17 ± 0.12
Proteins	10.26 ± 1.98	9.28 ± 0.14
Lipids	2.94 ± 0.44	1.00 ± 0.17
Total acidity	2.17 ± 0.32	2.37 ± 0.12
Mineral	3.16 ± 0.08	2.50 ± 0.00
Crude Fiber	15.08 ± 0.50	15.27 ± 0.39
Reducing sugars	2.99 ± 0.19	2.44 ± 0.25
Non-reducing sugars	38.78 ± 2.23	36.48 ± 0.31
Total sugars	40.62 ± 1.30	38.92 ± 0.55
Carbohydrates	73.34 ± 1.93	74.05 ± 0.43
Energetic value (Kcal $100g^{-1}$)	360.88 ± 4.00	342.32 ± 0.38

Source: Silva [30]

3. KINETICS OF DRYING OF AGROINDUSTRIAL PRODUCTS

Drying is a traditional process in food preservation, responsible for reducing the availability of water to deterioration reactions, increasing food stability and reducing the volume and mass of the product [34]. The advantages of using this process are several, among which: ease in the preservation of food products, stability of the aromatic components at room temperature for long periods of time, protection against enzymatic and oxidative degradation, the reduction of product weight, energy savings due to the lack of refrigeration and the availability of the product at any time of the year [35].

Table 2. Physical-chemical composition of the whole mesquite flour

Analysis (g 100 g^{-1})	Mean ± standard deviation
Water content	6.8 ± 0.9
Total sugars	56.5 ± 0.4
Reducing sugars	4.6 ± 0.3
Total food fibre	7.2 ± 0.5
Proteins	9.0 ± 1.5
Ashes	3.6 ± 0.1
Ethereal extract	2.1 ± 1.3
Tannins	0.3 ± 0.0

Source: Silva [31]

The kinetic drying studies have aroused the interest of several researchers for the most different products, crambe seeds [36], seeds of mesquite [28], guandu, [37] and melon seeds [8]. According to Shanthilal & Anandharamakrishnan [38], mathematical modelling based on empirical resolutions is considered an important instrument for immersion processes, since it allows understanding food behaviour, predicting results and assists in the kinetic quality of the process in a simple way.

Table 3. Physical-chemical composition of the mesquite pod meal

Analysis	Mean ± standard deviation
(g 100 g^{-1})	
Water content	7.17 ± 0.01
Ashes	2.50 ± 0.05
Proteins	9.12 ± 0.10
Lipids	1.28 ± 0.15
Carbohydrates	74.50 ± 0.01
Fibres	15.10 ± 0.20
Ashes	3.6 ± 0.1
Total Sugars	60.50 ± 0.08
(mg 100g-1)	
Calcium	650.75 ± 1.17
Phosphor	879.12 ± 2.42
Iron	10.20 ± 1.87

Source: Gusmão [32]

Due to the importance of the mesquite seed, more research needs to be done to find out about the potentiality of the same. It is necessary to create cryopreservation protocols and one of these protocols is the drying of the seeds. In the literature, several mathematical models have been used to describe the kinetics of thin-film drying for agricultural products. Three types of thin-layer drying models are used to describe the drying kinetics of thin films, being: the theoretical model, which considers only the internal resistance to the transfer of heat and water between the product and the hot air and the empirical models, which consider only external resistance to temperature and relative humidity of the drying air [39].

Table 4. Composition of whole pod flour from *P. juliflora*

Analysis	100 g matéria seca $^{-1}$
Protein (g)	16.2
Total sugar (g)	13.0
Fructose(g)	3.2
Glucose (g)	0.8
Galactose (g)	0.8
Sucrose (g)	7.5
Maltose (g)	<0.4
Lactose (g)	0.7
Carbohydrates (g)	69.2
Energy value (KJ)	1530
Diet Fiber (g)	47.8
Fat (g)	2.12
Monosaturated fatty acids (g)	0.4
Polyunsaturated fatty acids (g)	1.06
Saturated fatty acids (g)	0.56
Sodium (mg)	20.0
Ashes (g)	6.0
Total solids (g)	93.5

Source: Choge et al. [33]

The conservative method can be described by mathematical models that make it possible to obtain estimates of the time required to reduce the water content of the product under different drying conditions so that they become useful tools for decision making and contribute to the improvement of process efficiency [40]. According to Kaleta et al. [41], some mathematical models are widely used in the drying processes, they are Henderson & Pabis, Lewis and Page (1949). In this study, it will be used in addition to the models cited by Kaleta et al. [41] the models of Fick, Cavalcanti Mata, Exponential of two terms and Midilli, to compare and analyze the different curves and drying obtained in the different models.

Vilela and Arthur [42] state that the information contained in the drying curves is of fundamental importance for the development of processes and the sizing of equipment. With them, it is possible to estimate the drying time of a certain quantity of products and, with the time necessary for the production, it is estimated the energy expenditure that will reflect in the cost of processing and, in turn, will influence in the final price of the product, in the sizing of equipment can determine the operating conditions for drying and, with this, the selection of heat exchangers, fans and others.

In spite of the great diversity of research involving grains and seeds, no studies are available in the literature that addresses the effect of temperature on the drying kinetics of processed mesquite grains for direct and indirect consumption, which makes the present study important. Considering the importance of reducing food waste and the use of mesquite seeds, it is necessary to study methods of preserving them through drying. In this way, we can study the way to use the mesquite seed meal in the development of meat restructured types.

4. RESTRUCTURED HAMBURGER MEAT PRODUCT

In the early 1970s, the term restructured meat began to be used in the inclusion of a series of products made from lean and fat meats, cut into pieces of varying size, crushed and reduced to the mass, marketed as raw products, frozen or chilled, or as precooked and cooked [43]. In the same decade, this definition covered a large number of meat products. Recently, this term is used for meat products that try to imitate the aspect of the integral meat.

Restructured products are those that undergo a process of partial or total mechanical subdivision for comminution and subsequent reconstitution of the meat. The main restructured meat products are hamburgers, meatballs, steaks and chicken nuggets [44]. Sousa et al. [45] restructured the hamburger using watermelon peel and concluded that the final product presented high fibre content and low humidity, making a product with nutritional value and capable of having a longer shelf life, besides having a high protein content and a low content of lipids.

Restructured products semi-ready for consumption are presented as an alternative to the market, meeting the demand for ease in preparation and good acceptance. For consumers, these products are an option given the growing need to minimize the time of food preparation, especially for the population of large urban centres [46]. The scientific and industrial community of the meat sector has been investing in the development of new products that meet the demand for products that are easy to prepare and healthy [47]. Restructured meat products represent a category with great potential for application of functional ingredients with appeals for health [3]. For small producers, the restructured represent a viable alternative from production and cost, because besides being a product that has good acceptance, it needs low investment for its elaboration. Also, it has the characteristic of allowing the insertion of ingredients in its formulation, which is the case of flours and fibres, aiming to add value to the product from a nutritional point of view and contributing benefits from the technological point of view.

Some products have been used as a substitute for animal fat in meat products by starch or gum mixtures [48], by vegetable oils [49] and by different dietary fibres [50,51]. These products are well accepted by the population because they are practical and convenient. In this regard, there is much relevance in studies of the technological, sensorial and functional effect of ingredients used in restructured products [44]. With the increasing increase in the diversity of this type of product, which do not require much time for its preparation, hamburgers, sausages, empanadas, salami, mortadellas and sausages are available in the market [52].

Following Brazilian Law [53], the hamburger is an industrialized meat product obtained from the ground beef of animals, added or not of adipose tissue and ingredients, moulded and subjected to suitable technological process. These meat products are easy to prepare and consumed by all popular classes [52]. Frozen crusts or frozen stews may be marketed; however, in the supermarket shelves, it is observed that the raw and frozen hamburger is the main choice of Brazilian consumers [3].

During the manufacture of meat derivatives, various ingredients may be added, among them soy textured protein and (soluble and insoluble) fibres. Food fibres are widely studied because of their benefits, including reduction of blood cholesterol, improvements in the function of the large intestine, and reduction of postprandial glycemia (thus contributing to the prevention or reduction of intestinal diseases), decreased the risk of coronary heart disease, and type 2 diabetes [54]. Also, the fibres collaborate for the rheological properties of products through characteristics such as solubility, viscosity, gel formation, water retention capacity and volume increase through the association between molecules [55]. Among the properties, the solubility of the fibres is relevant, mainly, to define the technological and physiological effects. When the functional properties of fibres are evaluated, the soluble fraction shows a greater capacity to provide viscosity, to form gels and to act as an emulsifier, without altering the texture and taste of the food, being easier to be incorporated into processed foods and beverages [56].

The incorporation of dietary fibre of vegetable origin may be of great importance for the Brazilian population since nutritional recommendations suggest the consumption of 25 to 38 g of fibre per day for young and adults. Due to its functional and technological properties, have been used as a fat substitute in various meat products [51] to adopt integrated strategies that manage the production of accessible products, and at the same time healthy formulations, with beneficial properties to the health of the consumer. Also, the addition of dietary fibre helps to modify the general technological and sensory characteristics of a meat system, such as water retention capacity, fat retention capacity and texture profile [57].

According to Oliveira et al. [52], several studies have demonstrated the possibility of substitution and addition of ingredients in the formulation of hamburgers, to incorporate substances with functional properties and reduce the high-fat content of the product; contributing to the health and well-being of consumers. The reduction of sodium and fat can bring about changes in the technological properties, as in the texture profile and presence of exudate liquid, as well as changes in sensorial properties [58].

The addition of fibre in hamburgers [59], at 2% levels, can be performed without negative impact on sensorial quality. Other studies indicate that the addition of more than 10% of dietary fibre does not have a significant impact on the sensory analysis of hamburgers [60]. It should be noted that for Brazilian legislation, in accordance with Portaria 27 [53] a fiber-rich product is defined as the minimum fiber content of 6 g per 100 g of solid product (3 g / 100 ml for liquid products), while the fibre source product must have a minimum content of 3 g / 100 g (1 g /, 5 g / 100 ml for liquids). It is valid to score the average consumption recommendation of 21-38 g / day of dietary fibre. Dietary and dietary experts suggest that 20-30% of daily fibre intake should be composed of soluble fibre [56].

According to the Technical Regulation of Hamburger Identity and Quality [53] in the burger should contain a maximum fat content of 23%, a minimum of 15% protein, 3% total carbohydrates and calcium content (maximum dry basis) 0.1% in raw hamburger and 0.45% in cooked hamburger. Note the high-fat content that this food can contain, highlighting the importance of techniques to reduce this component, so that the final product is healthier.

Trevisan et al. [3] observed that the use of oat fibre was considered effective to improve physicochemical properties in cooked burgers, such as yield, weight loss during microwave heating and colour stability during freezing storage. There were no changes in the texture, indicating that oat fibre presents a promising ingredient to aid formulations of meat products with reduced fat and salt content.

4.1 Chemical Changes: Oxidation Reactions in Meat Products

The process of oxidation is the transfer of electrons from one molecule that oxidizes to another that is reduced. During the oxidation, the oxidizing agent can abstract an electron in the form of hydrogen atoms of a molecule susceptible through the formation of free radicals by the action of reactive substances of oxygen or nitrogen [61]. Oxidative transformations have been associated with deleterious effects on the quality of foodstuffs. Food technologists consider oxidation as one of the main problems related to the deterioration of the quality of meat and meat products during storage [62].

The susceptibility to oxidation is due to the high concentrations of unsaturated lipids, heme pigments, catalysts and several different types of oxidative agents present in muscle tissue. Oxidative deterioration in meat manifests as a change in colour, taste, formation of toxic compounds, shorter shelf life, loss of nutrients and water [62]. The release of iron from myoglobin, haemoglobin, and ferritin also occurs after the steps of processing (salting, grinding, etc.), storage and cooking of meat and meat products, which promotes intense changes in colour, aroma and taste, perceptible by the consumer.

Products formed after lipid oxidation have been characterized as toxic and associated with the development of deteriorating processes of human health. Peroxides and cholesterol oxides may be involved in the development of tumours and arteriosclerosis, while malonaldehyde has been characterized as a mutagenic agent and related to the formation of nitrosamines [63]. During storage, factors such as heat, moisture, oxygen, presence of light, metals, enzymes and pigments can promote oxidation of lipids, generating compounds harmful to human health, such as malonaldehydes and cholesterol oxides, which have carcinogenic activity [64].

The technological strategies for the control of lipid and protein oxidation in meat and meat products are based on the insertion of substances with antioxidant activity in the formulation of products and / or reduction of meat exposure to molecular oxygen through the use of modified atmosphere packaging [65]. The addition of phenolic compounds from vegetable extracts has been extensively used in the control of lipid oxidation in meat products [66]. Inhibition of lipid oxidation prevents oxidative degradation of proteins by minimizing the formation of secondary compounds of lipid oxidation and, consequently, their interaction with proteins to form carbonyl compounds.

Ultimately, food quality is defined in terms of consumer acceptability: taste, aroma and appearance characteristics. The growing demand for convenient foods has led to rapid growth in the category of consumer-ready products. Many of the food ingredients contain unsaturated fatty acids that are quite susceptible to deterioration of quality, especially under oxidative stress. For this reason, efforts to reduce oxidation have increased. Most of the time, the best strategy is to add antioxidants [67].

In recent years, there has been an increase in the search for alternatives to synthetic antioxidants, due to their carcinogenic potential. Thus, there is a need to look for suitable alternatives from natural sources, such as plant-derived antioxidants, to combat oxidative instability of lipids and proteins in meat [68]. Several strategies have been adopted by the food industry, among which the reduction and/or exclusion of preservatives and artificial colors, the reduction of sodium concentration, the replacement of ingredients whose high intake may be associated with the onset of pathologies and the incorporation of bioactive compounds capable of promoting physiological health benefits for the consumer. This last strategy, in particular, has presented a high growth, is that the foods that contain the so-called bioactive compounds are called functional foods [69].

Recently, special attention has been given to several medicinal plants that can be used as a potential source of antioxidants. In this sense, several scientific studies are being carried out to find natural additives with a broad spectrum of antioxidant activity, to increase the quality and shelf life of meat products [23,70]. The efficacy of the different natural antioxidants has been reported in the reduction of lipid and protein oxidation, colour change and microbial growth in meat products [71].

Most natural antioxidants are obtained through herbs, spices, vegetables, fruits and seeds, where phenolic compounds are the main substances responsible for their antioxidant activity. Plant extracts that present phenolic compounds are considered effective sources of antioxidants since they have a high activity of hydrogen donation or have a high capacity to absorb free radicals. The antioxidant activity of these compounds depends on their structural skeleton and the pattern of their functional groups [67] Ruto et al. [23] observed that the oxidizing activity between the methanolic extracts was high for *P. juliflora*, there was a greater inhibition activity in the β-carotene assay. In the absence of an antioxidant, β-carotene undergoes rapid discolouration, but the presence of phenolic compounds inhibits the extent of β-carotene destruction by neutralizing the free radical linoleate formed in the system [72,73]. The results of this study indicate that P. juliflora extract efficiently inhibits the oxidation of linoleic acid, thus inhibiting the bleaching of β-carotene. According to Sirmah et al. [74], *P juliflora* extracts may be of valuable interest as a source of natural antioxidants for applications in the food, cosmetic or pharmaceutical industries.

Chia seeds have beneficial effects on health and high levels of protein, antioxidants and dietary fibre [75]. Due to its nutritional importance, it has been used in several products, such as baby foods, cereal bars, roasts, yoghurt, sauce, among others [76]. Fernandez-Ginés et al. [77] and Viuda-Martos et al. [78] observed that the addition of 0.5% to 2% of orange fibres produced an antioxidant effect on mortadella meat product, proving the antioxidant properties of the bioactive compounds (polyphenols, carotenes) of the citrus fibres. Vegetable oils, particularly grains, show marked resistance to rancid plants. Some grains, if not damaged or pressed, can be stored for years, thanks to the presence of natural antioxidants [79].

5. CONCLUSION

The study concluded that the mesquite seed is a promising fibre to be used in hamburger-type meat products. We can also observe that there are only a few studies regarding the mesquite seed, needing to diversify those to better understand how we can better aggregate the seed in other products.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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