

Article

ANTIOXIDANT PROPERTIES OF LYOPHILIZED ROSEMARY AND SAGE EXTRACTS AND ITS EFFECT TO PREVENT LIPID OXIDATION IN POULTRY PÂTÉ

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Abstract: This study aimed to evaluate the antioxidant activities (AA) of lyophilized rosemary extract and lyophilized sage extract and their effects on the oxidative stability of poultry pâté. For this purpose, four poultry pâté formulations with rosemary, sage, sodium erythorbate, and a control (without antioxidants) were produced. The rosemary and sage were characterized according to total phenolic compounds (TPC), and AA by several methods. The poultry pâtés stored at 4°C were evaluated by the lipid oxidation. High concentrations of TPC were detected in rosemary extract and sage extract (46.48 and 41.61 mg GAE/g: Gallic acid equivalent respectively). The AA of rosemary and sage extracts by free radical-scavenging were 4745.72 and 2462.82 µmol Trolox/g, respectively. The high concentration of catechin, rutin, myricetin and p-coumaric acids in these extracts may be responsible for the strong inhibitory action against food pathogens. Besides these compounds can be responsible for the best performance in inhibiting lipid oxidation in poultry pâtés during the storage. This study suggests that rosemary and sage extracts may be used as a natural antioxidant in meat products.

Keywords: *Rosmarinus officinalis*; *Salvia officinalis*; natural antioxidant; antibacterial activity; total phenolic compounds; HPLC; TBARS.

1. Introduction

Rosemary (*Rosmarinus officinalis*) and sage (*Salvia officinalis*) are plant of the Lamiaceae family, and both are native to the Mediterranean, however grows in many parts of the world and have adapted easily in Brazil. Several researchers reported that the rosemary and sage demonstrate excellent antioxidant potential [1, 2]. The antioxidant activity of rosemary can be attributed to the presence of phenolic compounds, mainly rosmarinic acid, carnosol, rosmanol, isorosmanol, rosmadiol, and carnosic acid [3]. While rosmarinic acid and derivatives of caffeic acid are mainly responsible for the effect of the antioxidant activity of sage extracts. Rosemary and sage essential oil has been used in several types of food, such as mayonnaise, meat products, pie dough, and salad dressing as a natural antioxidant. In fact, the rosemary essential oil and lyophilized rosemary extract exhibited an excellent inhibitory effect on lipid oxidation of pork sausage with high acceptance rate [2]. In another study, Pereira et al. [1] reported that the rosemary extract had strong anti-oxidative effects in chicken burgers at 21 days of storage at refrigerated temperature. In addition, according to Estevéz et al. [4], a mix of sage and rosemary essential oils inhibited oxidative deterioration of liver pâtés to a higher extent than BHT did.

The consumption of chicken meat has increased in recent years, and there is a tendency to substitute the use of red meat for white meat, due to the low cost of chicken meat when compared to that of other animal proteins. However, chicken meat is rich in iron and have several proteins indispensable to humans. Additionally, chicken meat is also a source of energy and other nutrients such as B vitamins (niacin and riboflavin), minerals and lipids. In 2019, a total of 5.81 billion chicken heads were slaughtered in the Brazilian market. The states of the Southern Region together slaughtered 60.6% of the total national slaughter, more than double the Region's share Southeast (19.9%), Midwest (13.9%), Northeast (3.8%) and North (1.6%). The state of Paraná in 2019 led the national ranking of chicken slaughter, with +94.52 million heads slaughtered with the participation of > 32.5 % followed by Santa Catarina, and Rio Grande do Sul [5].

The pâté is defined by Brazilian legislation as a pasty product, obtained from meat and meat products and edible offal and added with food ingredients. The paste must be subjected to an appropriate thermal process and can be cooked, pasteurized or sterilized [6]. In these products, the lipid oxidation is one of the main reactions that can occur and can affect the nutritional quality of the food products. These oxidative processes in meat products are influenced by polyunsaturated fatty acids in the presence of prooxidating agents such as iron, oxygen, salt and even mechanical processes. However, its effects can be reducing or inhibited by the use of antioxidants in meat products [7]. In fact, the use of synthetic antioxidants to extend the shelf life of meat and meat products is common in the food technology. However, the synthetic antioxidants used in the meat industry, such as butylatedhydroxyanisole (BHA), butylatedhydroxytoluene (BHT), tert-butylhydroquinone (TBHQ) and propyl gallate (PG) has been restricted by many countries due to possible risks to consumer health [8]. The toxicological effects of these chemical additives is growing the interest in studies of natural substances with antioxidant activity in meat [9].

The main mechanism of action of phenolic compounds from plants is the inactivation of lipid free radicals [10]. However, reduction of the production of reactive species at oxygen (ROS) and, consequently, interrupting the propagation phase of lipid autoxidation can also occur. Thus, this work aimed to determine the antioxidant properties, total phenolic compounds of lyophilized rosemary extract and lyophilized sage extract, and the effects of their adding in poultry pâtés, to avoid the lipid oxidation during refrigerated storage at 4 °C.

2. Results and discussion

2.1. Total phenolic compounds, total flavonoids, and preliminary chromatography analysis and antioxidant activity

The quantification of total phenolics and total flavonoids brings the perspective of how promising the sample's bioactive properties are, since they are related to antioxidant activity. In fact, phenolic compounds from fruits, vegetables and medicinal herbs are presumed to be a good source of antioxidants. The total phenolic compounds and total flavonoids present in the extracts of rosemary and sage are shown in Table 1. There was a statistical difference between the extracts for total phenolic compounds and total flavonoids ($p < 0.05$). The rosemary extract have the highest content of phenolic compounds (46.48 mg EAG/ g of plant) and this result is in agreement with a previous study Bianchin et al. [2] who found 45.67 mg EAG/g for lyophilized rosemary extract that was extracted with ethanol solution in a shaker at 40°C for 60 min. However, in this study, the sage extract showed superiority in the content of flavonoids (15.03 mg QE/ g of plant) in compared at lyophilized rosemary extract (11.89 mg QE/g). Our results showed that total phenolic content of lyophilized sage extract was lower than values reported by Kivrak et al. [11], who found for total phenolic compounds 52.3 mg of pyrocatechol /g on methanolic extract of sage from Turkey. These differences between TPC and TFC amounts obtained in our study and that

found in the literature can be attributed to the different methods of extraction, solvents and temperatures employed.

Table 1: Total phenolic content, total flavonoid content and antioxidant activity of rosemary and sage extracts

Parameters	Rosemary extract	Sage extract
Total Phenolic Compound (mg GAE/g)	46.48 ± 0.08	41.61 ± 0.91
Total Flavonoid Content (mg QE/g)	11.89 ± 0.58	15.03 ± 0.44
EC ₅₀ (µg/mL)	254.72 ± 0.66	398.86 ± 0.10
AA %*	92.25± 0.46	79.81 ± 0.56
DPPH (µmol Trolox/g)	4745.72 ± 0.47	2462.82 ± 0.03
ABTS (µmol TEAC/g)	301.47 ± 0.76	182.89 ± 0.526
FRAP (µmol de Fe ²⁺ /g)	180.09 ± 0.01	133.99 ± 0.68
β-carotene/linoleic (%)**	85.67 ± 0.66	89.29 ± 0.10

QE: Quercetin equivalent; EC₅₀: Equivalent concentration required to obtain a 50% antioxidant effect; TEAC: Trolox-equivalent antioxidant capacity; *lyophilized rosemary and sage extract at 0.33 mg/mL; ** lyophilized rosemary and sage extract at 6.66 mg/mL. Values are presented as mean ± deviation (n = 3).

Despite the importance of TPC and TFC analysis and despite being widely used in plant extracts, individual phenolic compounds analysis is very important and necessary to know which compounds may be responsible for the antioxidant activity, or even which compounds may be involved in the possible synergistic action on these extracts. Thus, the individual phenolic compounds of the both extracts were determined by HPLC/DAD and are shown in Table 2.

Table 2. Content of phenolic compounds by HPLC of rosemary and sage extracts

Phenolic compounds	Rosemary extract (mg/100g)	Sage extract (mg/100g)	RT (min)	λ (nm)
Gallic acid	3.45±0.05 ^d	0.46±0.01 ^f	6.65	280
Catechin	13.21±1.05 ^b	-	10.37	280
p-Coumaric acid	1.37±0.02 ^g	30.10±0.15 ^b	13.94	320
Ferulic acid	3.21±0.01 ^e	0.35±0.03 ^g	18.57	320
Rutin	34.62±1.15 ^a	6.16±0.10 ^c	19.88	370
Myricetin	-	166.62±1.21 ^a	27.38	320
Quercetin	11.56±0.50 ^c	0.62±0.02 ^e	31.50	320
Kaempferol	2.24±0.01 ^f	4.93±0.31 ^d	34.32	370

RT: Retention time; λ: Wave length; Values mean ± standard deviation. Different letter in the same column indicate significant difference (P < 0.05) by Tukey's test.

Among seven phenolic acids and flavonoids identified in the rosemary extracts, the gallic acid was present with the largest mass fraction (3.45 mg/100g) in phenolic acids, followed by ferulic acid (3.21 mg/100g), and p-coumaric acid (1.37 mg/100g). While rutin (34.62 mg/100g) had the largest mass fraction among flavonoids, followed by catechin (13.21mg/100g), quercetin (11.56 mg/100g), and kaempferol (2.24 mg/100g) in the rosemary extract. In this study, the same phenolic acids founded in rosemary extract were found also in the sage extract. Nonetheless, the p-

coumaric acid (30.10 mg/100g) was the most abundant acid phenolic found in the sage extracts. In the sage extract, was possible to identify five flavonoids, among them the myricetin showed the most concentration (166.62 mg/100g), followed by rutin (6.16 mg/100g), kaempferol (4.93 mg/100g) and quercetin (0.62 mg/100g). Although both plants are from the Lamiaceae family and the same region of the collect, no myricetin was found in the rosemary extract, while catechin was not found in the sage extract (Table 2).

2.2. Antioxidant and antibacterial activity

The pâté is a manufactured meat product which, due to their high-fat, is predisposed to deterioration by lipid oxidation and also microbial contamination due to high water content. However, this degradation can be minimised, and the use of natural antioxidants can increase the shelf life of the meat products. The antioxidant activity of these based-plant extracts that are rich in phenolic compounds may act at different stages in the oxidation process, lowering free radicals concentration, chelating ions and leading to non-radical compounds [12]. The structure of the phenolic compound facilitates the electron donation of the hydroxyl portion to oxidizing radical species.

Thus, the antioxidant activity of rosemary extract and the sage extract was assessed by four distinct in-vitro methods; including the free radical-scavenging ability by the use of ABTS, DPPH radical, ferric reducing antioxidant power (FRAP), and oxidation of β -carotene/linoleic acid, these results are shown in Table 1. These four spectrophotometric methods are complementary and have different mechanisms of action, which can depend on the reaction of an organic radical, a cation radical, or a complex with an antioxidant molecule capable of donating a hydrogen atom [12]. Besides, the absorbance can be measured to test the amount of iron reduced and can be correlated with the amount of antioxidants in several matrices. All this to be enabled to report complete information on the antioxidant capacity of these samples. Regarding the antioxidant activity by DPPH method expressed in EC₅₀, it's important to highlight that the EC₅₀ value is inversely proportional to the antioxidant capacity of the compounds.

Given all these considerations, the rosemary and sage extract showed EC₅₀ of 254.72 and 398.86 μ g/mL, respectively (Table 1). Based in our findings, the rosemary extract showed antioxidant activities lower than reported by Bianchin et al. [2], who found 127.33 μ g/mL (EC₅₀) in extract of rosemary leaves. In addition, Hamrouni-Sellami et al. [13] found values of EC₅₀ = 23.87 μ g/mL for sage methanolic extract from Tunisia. Several studies evaluating the antioxidant activity of *Salvia* species can be found in the literature; although, each study presents a different methodology and expresses its results in many ways. Besides, many of these studies are with sage species originating from different regions where the soil and the climate interfere in the results.

As to the antioxidant activity by DPPH method expressed in Trolox, the ethanolic extract from rosemary and sage showed a 4745.72 and 2462.82 μ mol Trolox/g content, respectively. The ability of the polyphenols and other compounds present in biological cells to reduce the ferric ion to ferrous ion has been used to evaluate the antioxidant activity in food matrices [14]. The results obtained from ABTS, FRAP and β -carotene/linoleic methods for rosemary extract were 301.47 μ mol TEAC/g, 180.09 μ mol Fe²⁺/g, and 85.67 %, respectively are shown in Table 1. Except for antioxidant activity by the β -carotene/linoleic acid model system, all these values of antioxidant activity for rosemary extract were higher than those reported for sage.

The antibacterial activity of the extracts of rosemary and sage against two strains of Gram-positive and two strains of Gram-negative bacteria is shown in Table 3. Although, Gram-negative bacteria are usually more resistant to several bioactive compounds due to their hydrophilic surface of the outer membrane [15]. In this study, the rosemary extract showed strong inhibitory activity against *Staphylococcus aureus* with MIC of 0.15 mg/mL and a slightly lower

inhibition capacity against *Salmonella enteritidis* (MIC = 0.30 mg/mL). Besides, the tested *Bacillus cereus* strains seemed to be more sensitive to both extracts rosemary and sage. In fact, in higher concentrations, the rosemary extract was able to inhibit *Klebsiella pneumoniae* and *Bacillus cereus* with MIC of 0.63 and 1.25 mg/mL respectively. Nevertheless, in the tested rosemary extract concentrations, no bacteria showed bactericidal action (MBC > 5 mg/mL) (Table 3). Similarly, Abramović et al. [16] found in rosemary leaf extracts a stronger antimicrobial activity at 0.02 mg/mL for gram-positive and 1.03 mg/mL for gram-negative bacteria. The antibacterial activity of rosemary observed can be associated with its phytochemical composition as the flavonoids mainly the catechin, rutin and quercetin according to the data highlighted in HPLC analysis. These flavonoids are described as potent antibacterial agents against several types of food pathogens [16]. The rutin is described as a strong inhibitor of *Escherichia coli*, *Klebsiella* sp, and *Pseudomonas aeruginosa* [17]. Additionally, the rutin seems to have action synergistic enhanced with other flavonoids against *Bacillus cereus* and *Salmonella enteritidis*. In another study, the addition of rutin decreases the minimum inhibitory concentration value for kaempferol [18]. Additionally, the high concentration of catechin in the rosemary extract may be responsible for the strong inhibitory action against all the pathogenic bacteria tested in this study. In fact, catechin and epigallocatechin gallate from teas were able to inhibit and kill some Gram-positive and Gram-negative bacterial species [19].

Though ethanolic extract of sage did not inhibit the *Staphylococcus aureus* at the concentrations tested in this study (MIC > 5 mg/mL), it gets inhibit the bacteria *Samonella enteritidis* and *Bacillus cereus* at higher concentrations of 0.63 mg/mL and 1.25 mg/mL respectively. Nevertheless, the sage extract at a concentration of 1.25 mg/mL was able to destroy the cells of *Klebsiella pneumoniae* during 24h incubation periods, indicating the bactericidal effect of this extract. In this study, the myricetin was the most abundant flavonol in the sage extract (166.82 mg/100g) and Cetin-Karaca and Newman [20] demonstrated antibacterial effect of the myricetin, rutin, quercetin and catechin against *Escherichia coli* and *Salmonella enteritidis*. Besides the antibacterial activity, these phenolic compounds have revealed other biological activities, among them as antioxidant, antidiabetic, anticancer, immunomodulatory, cardiovascular, analgesic and antihypertensive [21].

Table 3. Antibacterial activity of rosemary and sage extracts

Bacterial	Rosemary extract		Sage extract	
	MIC (mg/mL)	MBC (mg/mL)	MIC (mg/mL)	MBC (mg/mL)
<i>Staphylococcus aureus</i>	0.15	> 5	> 5	> 5
<i>Bacillus cereus</i>	1.25	> 5	1.25	> 5
<i>Salmonella enteritidis</i>	0.30	> 5	0.63	> 5
<i>Klebsiella pneumoniae</i>	0.63	> 5	1.25	>1.25

MIC:

Minimum inhibitory concentration; MBC: Minimum bactericidal concentration

It is known that plants have enormous chemical complexity in their structure, and the diversity of compounds present in each of these plants may be related to the biological activity of these compounds, either the action isolation or synergistic. In fact, individual chemical characteristics, as the presence of the phenolic compounds in these extract can be responsible for the activities. Besides, phenolic acids can also interact synergistically with flavonoids or other compounds, increasing the antioxidant and antibacterial activities.

2.3. Effect of rosemary and sage extracts on lipid oxidation from poultry pâtés

The oxidative degradation of lipids is one of the main reactions that occur in food products and can be inhibited by the use of natural antioxidant in several kinds of food products. These changes are the main cause of small shelflife of these foods, and the oxidative changes of the meat products can be monitoring by the 2-thiobarbituric acid reactive substances test (TBARS). This test is the most common method and is generally used as an indicator of the degree of lipid oxidation in meat products. It reflects the content of malondialdehyde (MDA) formed during the oxidation of polyunsaturated fatty acids, which are secondary products of oxidation. Thus, the results obtained in the evaluation of lipid oxidation by TBARS in the four treatments are shown in Table 4.

Table 4. Average values of TBARS in poultry pâté with rosemary and sage extract during storage at 4 °C.

Treatments	TBARS (mg of MDA/Kg of chicken pâté)				
	Storage times days				
	0	7	14	21	28
T1	0.98±0.02 ^{Dd}	1.23±0.04 ^{Cc}	1.87±0.01 ^{Bb}	1.88±0.02 ^{Bc}	2.23±0.02 ^{Ac}
T2	1.18±0.10 ^{Ec}	1.71±0.04 ^{Db}	1.86 ±0.01 ^{Cb}	2.37±0.03 ^{Bb}	2.69±0.02 ^{Ab}
T3	1.58±0.04 ^{Eb}	1.73±0.05 ^{Db}	2.00 ±0.01 ^{Ca}	2.28±0.03 ^{Bb}	2.60±0.04 ^{Ab}
T4	1.66±0.03 ^{Ea}	1.85±0.02 ^{Da}	1.91±0.03 ^{Ca}	2.87±0.02 ^{Ba}	3.96±0.30 ^{Aa}
Average	1.35±0.05 ^E	1.63±0.04 ^D	1.91±0.02 ^C	2.35±0.04 ^B	2.87±0.06 ^A

Values are presented as mean ± deviation (n = 3). MDA: malondialdehyde. All measurement was carried out in triplicate.

T1: Treatment added 0.2 g/Kg of lyophilized rosemary extract; T2: Treatment added 2 g/Kg of lyophilized sage extract; T3: Treatment with sodium erythorbate (0.2 g/Kg); T4: Treatment control (no added antioxidant); Different lower-case letter in the same column indicate significant difference ($P < 0.05$) by Tukey's test. Different capital letters in the same row indicate significant difference ($P < 0.05$) by Tukey's test

During the storage period of the pâtés, the MDA values increased over time and ranged from 1.35 ± 0.05 at the beginning of the experiment at 2.87 ± 0.06 mg MDA/Kg pâté at the end of the experiment (28 days). Regarding to control treatment, the TBARS average values ranged of 1.66 at 3.96 mg MDA/Kg pâté and had significantly higher TBARS values ($p < 0.05$) than other treatments. Besides, there wasn't a significant difference in the malonaldehyde values when compared to treatments with sage extracts and with sodium erythorbate (T2, T3) in processing day. Treatment of pâtés with rosemary extract (T1) showed lower TBARS values during any day of storage than the sage extract (T2), sodium erythorbate (T3) and control (T2) treated pâtés. Bilska et al. [22] observed similar results in liver pâtés with the addition of rosemary extract.

At the end of storage time (28 days), the poultry pâtés containing rosemary extract (T1) and sage extract (T2) inhibited respectively, 43.69% and 32.07% of lipid oxidation in comparison to the control pâtés (T4). In this point, the treatment with rosemary was better than treatment with synthetic antioxidant and the pâtés group with sage extract wasn't significant difference ($p < 0.05$) with the treatment with synthetic antioxidant (T3).

These results indicate a strong anti-oxidative effect of lyophilized rosemary extract and sage extract in poultry pâtés, probably due to the gradual release of the bioactive compounds from these plants. Rutin, catechin and quercetin were present in rosemary extract in high concentrations and may be responsible for the best performance in inhibiting lipid oxidation in pâtés containing Rosemary extract when compared to pates added with the sage extract. Besides, although p-coumaric acid and myricetin are present in high concentrations in the sage extract, the absence of catechin may have a more significant influence in reducing the inhibition of lipid

oxidation in the pâtés. Nevertheless, the pâté with sage showed no statistical differences with the formulation containing synthetic antioxidant, the sodium erythorbate. A slowed down in the formation of malonaldehyde of lipid oxidation also was observed when the rosemary extract was added in other products such as Cantonese sausage [23], pork sausage [2], flaxseed oil [24] and white pan bread [25].

3. Materials and Methods

3.1. Chemicals

Sodium erythorbate (SE), potassium acetate, ethanol, ethylenediaminetetraacetic acid (EDTA), thiobarbituric acid (TBA) and chloroform were obtained from Vetec (S~ao Paulo, Brazil). Quercetin, rutin, ferulic acid, coumaric acid, pinocembrin, DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfphonic acid), TPTZ (2,4,6-Tris(2-pyridyl)-s-triazine), Folin-Ciocalteu phenol reagents, Trolox, β -carotene/linoleic acid, were obtained from Sigma-Aldrich (Sternheim, Germany).

3.2. Material and preparation of the extracts

Rosemary (*Rosmarinus officinalis*) and sage (*Salvia officinalis*) samples were purchased at a fair of farmers in Pato Branco, Paraná, Brazil. Rosemary and sage leaves were dried in an oven with forced air circulation (Nova Ética 400/D, São Paulo, Brazil) at 40 °C for 42 h and ground in an analytical mill (less than 0.5 mm).

Samples containing 10 g of sample (dry basis) were subjected to the extraction process with 100 mL of ethanol solution (800 mL/L) in a water-bath at 70 °C for 30 min at a stirring rate of 150 rpm. The extract was filtered through qualitative filter paper, and the supernatants were evaporated in a rotary evaporator (vacuum pressure of 600 mm Hg and 40 °C) until completely dry and lyophilized (Li-top L101, São Carlos, Brazil).

3.3. Preliminary chromatographic analyses of phenolic compounds

The analysis of phenolic compounds in rosemary and sage extract through high performance liquid chromatography was carried out using a Dionex Ultimate 3000 (Dionex, Idstein, Germany) system chromatograph including an column (Acclaim® 120 C18) at 40 °C with and a photodiode array detector (HPLC/PDA). The condition of mobile phases were carried out according to Pereira et al. [1] and the data analysis were processed with Chromeleon software. Extracts were filtered through a 0.22 μ m filter nylon syringe (Millipore, São Paulo, Brazil) and the injection volume was 10 μ L with a flow rate of 1.0 mL min⁻¹. The total run time was 55 min and the spectral data were collected from 280 to 370 nm. The identification was performed by comparison of retention times and absorption in ultraviolet. The quantification was performed by external standardization [26]. The following authentic standards of phenolic compounds were examined: ferulic acid, gallic acid, chlorogenic acid, caffeic acid, p-coumaric acid, trans-cinnamic acid, syringic acid, kaempferol, myricetin, rutin, and quercetin. The content of bioactive compounds in the sample was expressed as mg/g. Determination by HPLC was also performed in triplicate.

3.4. Total phenolic compounds (TPC) and Total flavonoids content (TFC)

The total phenolic content (TPC) was performed using Folin-Ciocalteu method described by Singleton et al. [27] using gallic acid as the standard. After two hours in darkness, the absorbance

of the extract was measured at 764 nm in spectrophotometer (UV-VIS Bel Photonics 2000 Piracicaba, Brazil). The results were expressed as mg GAE/g of sample (GAE: gallic acid equivalent). For the total flavonoid content (TFC) was quantified by the colorimetric method with aluminum chloride [2]. After 40 min at room temperature, the absorbance was measured at 415 nm in a spectrophotometer. A quercetin standard curve was obtained, and the results were expressed as Quercetin equivalent (mg QE/g). All the assays were carried out in triplicate.

3.5. DPPH (2,2 Diphenyl-1-picryl-hydrazyl) radical scavenging assay

DPPH (2,2-diphenyl-1-picryl-hydrazyl) radical scavenging according to the methodology described by Brand-Williams [28]. The mixture was incubated at room temperature in the dark for 45 min and the absorbance was read using a spectrophotometer (Bel Photonics 2000, Piracicaba, Brazil) at 517 nm. The result was expressed in μmol Trolox/g. Additionally, the EC₅₀ (concentration required to obtain a 50% antioxidant effect) values were calculated by means of a linear regression between the concentration in $\mu\text{g}/\text{mL}$ (axis of the abscissas) and the mean percentage of antioxidant activity (ordinal axis).

3.6. Ferric reducing antioxidant power (FRAP) assay

The FRAP was determined as described in Pulido et al. [29]. The reaction mixture was incubated for 30 min in water bath at 37°C, and the absorbance was measured at 595 nm. Aqueous solutions of ferrous sulfate were used for calibration, and the results were expressed as μmol of Fe²⁺/g.

3.7. ABTS (2,2-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid) assay

The ABTS (2,2'-Azino-bis (3-ethylbenzthiazoline-6-sulphonic acid)) method was performed as described by Re et al. [30] in the rosemary and sage extract. The stock solutions included 7.4 mM ABTS•+ and 2.6 mM potassium persulfate. The solution was diluted by mixing 1 mL ABTS•+ solution with 60 mL ethanol to an absorbance of 0.70 ± 0.02 units at 734 nm on a spectrophotometer (Femto UV 2000, Brazil). Antioxidant activity was expressed in $\mu\text{mol}/\text{g}$ of TEAC (Trolox-equivalent antioxidant capacity).

3.8. Coupled oxidation of β -carotene and linoleic acid assay

The measure of antioxidant activity was determined by the coupled oxidation of β -carotene and linoleic acid. Emulsion oxidation was spectrometrically monitored (Bel Photonics 2000, Piracicaba, Brazil) by measuring its absorbance at 470 nm, at time zero ($t = 0$) and subsequently after every 20 min, until the characteristic color of β -carotene disappeared in the control reaction ($t = 100$ min). The antioxidant activity was determined as percent inhibition relative to control sample [1].

3.9. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC)

The in vitro potential antibacterial activities of the rosemary and sage extract were qualitatively estimated based on broth micro-dilution test in 96-well sterile plates, employing four bacterial strains [31]. The *Staphylococcus aureus* ATCC 25.923 and the *Bacillus cereus* ATCC 11.778 as Gram-positive bacterial and *Salmonella enteritidis* ATCC 13.076 and *Klebsiella pneumoniae* ATCC 13.883 as Gram-negative bacterial were used for antibacterial examinations of aforementioned herbs. The strains were reactivated from stock cultures in liquid BHI medium (Brain Heart Infusion) for 24 h at 37 °C, and later, grown on BHI agar plates. A bacterial suspension with NaCl 0.89% sterile of 1-2 x 10⁸ UFC.mL-1 on the Mc Farland scale was obtained

using the absorbance of 0.135 at 660 nm. A concentration of 1-2x105 UFC.mL-1 was obtained adding 50 µL of the bacterial suspension into 50 mL of Brain Heart Infusion (BHI) broth. In the microplate, the MIC was evaluated with 190 µL of inoculated BHI and 10 µL of the each extract in the concentrations of 0.15 to 5.000 mg mL-1. The chloramphenicol 0.12% was used as positive control, the ethanol as negative control and the resazurin dye was employed to reveal the positive wells. The plates were maintained for 24 h at 37 °C. The experiment was performed three times and the results are presented in mg/mL of the extract. For MBC test, an aliquot of each positive well in MIC was inoculated into a Petry dish containing BHI agar and incubated for 24h at 37 °C. The MBC was considered the lowest concentration without visible microbial growth.

3.10. Poultry pâté elaboration and oxidative stability of pâtés

The rosemary and sage extract were applied in poultry pâté to evaluate the effect at inhibition of lipid oxidation of the product, based on the preliminary studies with chicken pâtés [7]. The pâté formulation was prepared with drumstick and leg (330 g/Kg), breast (80 g/Kg), chicken fat (246 g/Kg). The cuts of the thigh, drumstick, breast and fat were ground twice through a 5 mm plate at -2 °C before the application of the other ingredients. 70% of this portion was cooked slowly at 60 ± 3 °C, in order to soften the connective tissue. The raw and cooked pasta were mixed and then the remaining ingredients were added: ice water (274 g/Kg), salt (13 g/Kg), a mix of dehydrated garlic, onion, chives, parsley and pepper (4 g/Kg), isolated soy protein (6.0 g/Kg), cassava starch (40 g/Kg), sodium polyphosphate (5 g/Kg), and carmine (0.73 g/Kg). This basic formulation was divided into treatments. T1: was added 2 g/Kg of lyophilized rosemary extract; T2: was added 2 g/Kg of lyophilized sage extract; T3: was added sodium erythorbate (SE) (0.2 g/kg), and the T4: no additional ingredients were included. Separately, the pâté lots were stored in sterile glasses, autoclaved and submitted to a baking process in water bath at 80°C for 30 min. After baking, the pâtés were cooled with ice and stored at 4 °C in a refrigerator during 28 days to evaluate the oxidative stability of the pâtés. The oxidative stability of poultry pâtés was estimated by using 2-thiobarbituric acid reactive substances (TBARS) according to Carpes et al. (2020). Tetramethoxypropane (TMP) was used as standard reference and substances reacting with thiobarbituric acid were measured spectrophotometrically at 532 nm at times 0, 7, 14, 21, and 28 days of the storage. The results were expressed as mg of MDA/kg of sample (MDA: malondialdehyde). The lipid oxidation was assessed in triplicate.

3.11. Statistical Analysis

Analysis of variance (ANOVA) was performed to analyze the data, and the means were compared by Tukey's test for TBARS values, using the Statistica 8.0 software (StatSoft, USA). The results were considered statistically significant when $p < 0.05$. All tests were performed in triplicate.

4. Conclusion

The present study represent a relevant contribution to the bioactivity knowledge of the rosemary and sage grown in Brazil, which are important sources of phenolic compounds with antioxidant activity. Therefore, these results suggested that these plants could be of great industrial importance and can support the development of natural additive with potential for application in the food technology. Besides, considering the interest in finding for natural antioxidants, it is possible to suggest that lyophilized rosemary extract and lyophilized sage

extract have biological activity, mainly because of the presence of reducing compounds, free radical scavengers and hydrogen donors in the plant material. In fact, the rosemary and sage extract were more effective in the lipid oxidation inhibition in poultry pâtés than synthetic antioxidant, and these pâtés with rosemary and sage can be an alternative for consumer demand for healthy foods. The antioxidant and antimicrobial activities, and mainly the inhibition of lipid oxidation in foods rich in fats, maybe are some attributes expected in the search for a natural and safe food additive.

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