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APPLICABILITY OF YERBA-MATE (*Ilex paraguariensis*) IN DIFFERENT FOODS

Aplicabilidade de extratos de erva-mate (Ilex paraguariensis) em diferentes alimentos

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Abstract: Yerba-mate is a plant from the south of South America that has in its constitution substances with several biological properties such as stimulant, antioxidant and anti-inflammatory. These properties are due to bioactive compounds (methylxanthines, saponins, and phenolic compounds). Recent studies have increased the development of research on yerba-mate both in the food and pharmaceutical industries. Research has been conducted on adding yerba-mate to common foods in order to make them functional. The objective of this work was to perform a literature review on the works developed using yerba mate or yerba mate extracts in the formulation of different types of foods, demonstrating the technological potentialities of this plant. Works between the years 2003 and 2021 were selected, totaling 38 kinds of research and one patent. It was possible to divide the work into three distinct categories: "development of new products", "application in foods as an antioxidant agent" with antioxidant action as a natural preservative in meat and cheese products, and "incorporation of compounds in polymeric matrixes". The foods developed were jam, bread, beverages such as beer, chocolate, cake, cereal bars, yogurt, gelatin, biodegradable films, and extracts incorporated into starches. The result shows that the area of development of products based on yerba-mate is promising, however, there is still a need for research on acceptability by consumers so that these products reach the supermarket shelves.

Keywords: *Ilex paraguariensis. Functional food. Antioxidant activity. New product development.*

Resumo: *A erva-mate é uma planta característica do sul da América do Sul que possui em sua constituição substâncias com diversas propriedades biológicas, como estimulantes, antioxidantes e anti-inflamatórios. Essas propriedades são devidas aos compostos bioativos (metilxantinas, saponinas e compostos fenólicos). Recentes descobertas têm propiciado o desenvolvimento de pesquisas em diversas áreas do conhecimento, como farmacêutica e alimentícia. Pesquisas têm sido desenvolvidas com adição de erva-mate em alimentos comuns buscando torná-los funcionais. O objetivo deste trabalho foi realizar uma revisão de literatura sobre os trabalhos desenvolvidos utilizando erva-mate ou extratos de erva-mate na formulação de diferentes tipos de alimentos, demonstrando as potencialidades tecnológicas desta planta. Foram selecionados trabalhos entre os anos 2003 e 2021, totalizando 38 estudos e uma patente. Foi possível dividir os trabalhos em três categorias distintas: "desenvolvimento de novos produtos", "aplicação em alimentos como agente antioxidante" e "incorporação dos compostos em matrizes poliméricas". A aplicação como agente antioxidante se deu em alimentos ricos em lipídeos, como queijos e carnes. Dentre os alimentos desenvolvidos estão geleias, bebidas, chocolate, bolo, pães, barra de cereal, iogurte, gelatina, filmes biodegradáveis e incorporados de extratos em amidos. O resultado demonstrou que a área de desenvolvimento de produtos com erva-mate é promissora. No entanto, ainda há necessidade de pesquisas sobre sua aceitabilidade pelos consumidores, a fim de que estes produtos cheguem às gôndolas dos supermercados.*

Palavras-chave: *Ilex paraguariensis. Alimento funcional. Atividade antioxidante. Desenvolvimento de novos produtos.*

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1 INTRODUCTION

Yerba-mate (*Ilex paraguariensis* A. St. Hil.) has known to be rich in bioactive compounds[1]. The leaves have polyphenols (phenolic acids and flavonoids), alkaloids (methylxanthines – caffeine, theobromine, theophylline), and terpenes (carotenoids and saponins)[2-5].

The extraction path can affect the quality and stability of these compounds, like time and temperature[6]. Temperature is an extremely important factor because phenolic compounds are sensitive to high temperatures[7]. The solid-liquid extraction using hot water is used to prepare a typical drink from southern region of South America called *chimarrão*[8]. Yerba-mate products found in supermarkets are variations of mate tea, *chimarrão* and *tererê*[9,10]. It is estimated that 30% of the South American population consumes at least one liter/day of some mate herb product[11,12].

Interest in studying *Ilex* grew after 1980. In the last five years, almost 400 scientific papers were produced about yerba-mate with more than 200 citations in 2018 (Figure 1)[13].

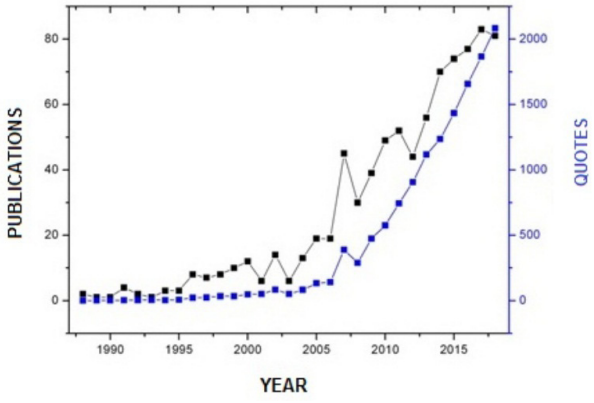

Figure 1. Annual publications and citations report[13]

The properties of yerba-mate are used by folk medicine to treat diseases such as arthritis, headaches, fatigue, hemorrhoids, hypertension, obesity, constipation, liver and stomach problems, fluid retention, and rheumatism[12-14]. *In vitro* studies demonstrated the action of yerba-mate extract on liver tumor cells, justifying its popular use as a hepatoprotectant[15, 16].

The use of yerba-mate extracts in the development of new products with technological potential has been highlighted[17], both in the food and pharmaceutical industries. Research developed over the years has sought to turn common foods into functional foods by adding yerba-mate extracts[18-24]. Studies have shown that the inclusion of yerba-mate in the diet improves the immune system, reduces oxidative stress, improves cholesterol and triglycerides[25-27].

Considering the increase in research on yerba-mate, the content of bioactive compounds, as well as its use in the human body, this study aimed to make a literature review of the works carried out using yerba-mate in the formulation of different foods. Thus, this work intends to demonstrate the technological contributions of yerba-mate in food production as well as its contribution as a functional food.

The literature review was carried out between the months of August 2019 to July 2020 and basically sought published and/or patented works in the last two decades, and should deal with food for human consumption. National and international scientific journals were consulted, searched in online databases, such as WEB of science, CAPES site, Scielo, ScienceDirect, and Google Scholar. Thesis and dissertation were not included in this work. The main terms searched were *Ilex paraguariensis*, yerba-mate, development of new products, and bioactive compounds in plant extracts.

2 YERBA-MATE EXTRACT: BIOATIVE COMPOUNDS

Among all the compounds that can be found in yerba mate, the most prominent are those that have biological activity as polyphenols, methylxanthines and saponins[2-5].

According to Jacques *et al.*, the concentration of compounds in fresh leaves varies depending on several factors such as light intensity, soil, and genetic factors[28]. Isolabella et al.[29] reported that the processing of yerba-mate leaves considerably changes the amount of some compounds such as methylxanthines (caffeine and theobromine), and flavonoids (rutin). In 62,5 g of dry yerba-mate leaves, there is approximately 3767-4085 mg of polyphenols, 303-962 mg of methylxanthines, and 50-146 mg of saponins[1].

Compounds found, mainly in yerba-mate leaves, phenolics stand out for their variety and quantity[8]. Phenolic compounds, also known as polyphenols, are responsible for the bitterness, astringency, color, flavor and smell, and oxidative stability in food[30,31]. The most well-known property of these compounds is their antioxidant activity (phenolic acids and flavonoids), however recent research indicates that they may have anti-inflammatory responses[32,33], regulate energy metabolism, and still have activity in the health of the intestine[34]. The phenolics present in yerba-mate are flavonoids (rutin, quercitin, and kaempferol) and caffeic acid derivatives[35-37].

The methylxanthines in yerba-mate are caffeine, theophylline, and theobromine, and their action on the human body is diverse, such as stimulating the central nervous system, cardiac and respiratory systems, relaxing the smooth muscles, and even analgesic. Methylxanthines as well as phenolic compounds are responsible for the antioxidant capacity of yerba-mate extracts[38,39]. Caffeine is a psychoactive drug widely used in the world, and to have a significant effect it is necessary to ingest about 60 mg. A 150 ml volume of mate tea has between 70 and 90 mg of caffeine[40].

Regarding saponins, few studies have evaluated the total amount of this compound in the leaves of yerba-mate, as well as the amount that is ingested. Saponins also have anti-inflammatory and hypocholesterolemic properties[11,41].

The aqueous extracts of yerba-mate have bioactive compounds with biological activities beneficial to health, acting on cholesterol levels, lipid and glycemic controls (reducing body fat in humans), antioxidant activities (restoring the body's redox balance), in insulin release, as a cardioprotective and as a stimulant on the central nervous system[42-44].

A recent study[45] presents results of the absorption and metabolism of the phenolic compounds of yerba-mate in humans. The study shows that the permanence of these bioactive compounds in the body is prolonged due to the time of metabolism of these molecules by the microbiota.

The bioactive compounds from yerba-mate can be decomposed when reacting with atmospheric oxygen. Avoiding this problem, it is necessary to apply technologies that maintain the extract quality, such as enzymatic inactivation[46].

One of the ways to insert these bioactive compounds in the diet, besides traditional consumption like *chimarrão* or tea, is through the addition of yerba-mate (*in natura* or extract)[‡] in the formulation of new food products.

[‡] *In natura*: leaves dry or processing residue (leaves, powder); extract: aqueous extract obtained by solid-liquid extraction (water and leaves).

3 NEW FOOD PRODUCTS WITH YERBA-MATE EXTRACT

Hot and cold infusions are the main presentations of yerba mate consumption (*chimarrão*, *tererê* or tea). Anothers uses of the yerba mate in food are leaves extracts (drinks), essential oil, caffeine, theobromine, saponins and flavonoids extracts (dyes, food preservative)[9]. However, through a literature review are found work beyond these applications and are listed in Table 1. Jellies, bread, various beverages such as beer, white chocolate, cake, cereal bars, yogurt, gelatin and biodegradable films can be produced by adding yerba mate and can be used as a natural preservative with antioxidant action in meat products[18-24, 48-78]. Nevertheless, there are many examples of the yerba mate use in food formulation, including wheat flour and yerba mate can be mixed together to make a commercial product (FARIMATE)[47]. This product:

> comprises wheat flour enriched with yerba-mate, without side effects, with efficiency equal to or greater than that of offered by certain medications, with the addition of other health benefits related to the consumption of yerba-mate periodically and in proportions appropriate to the absorption of its nutrients.

Both the product and its manufacturing process are already patented (Patent application number BR 10 2013 011160 0 A2, filing date: 06/05/2013, publication date: 12/23/2014, Inventors: Filipo Tomás Sangalli and Helio José Sangalli, Attorney's name: Leão Intellectual Property)[47].

Observing these results, it can be seen that the production of works with the incorporation of yerba extracts in food is growing, with an average of 2,2 works/year. This research was restricted to a category of works (food technology), however there are many types of research with yerba-mate in the health area and works with determination of phytochemical components.

The evaluated works were divided into three groups:

a) antioxidant action of extracts in products with lipids (13 works);

b) development of new products (18 works);

c) incorporation of extracts in flours/starches (7 works and one patent).

Table 1 – List of works published between 2003 and 2019

	1st group: Antioxidant action of extracts in products with lipids
01	Biological activity and quantification of bioactive compounds in yerba-mate extract and its application in fish hamburger[18]
02	Control of lipid oxidation in jerked beef through the replacement of sodium nitrite by natural extracts of yerba-mate and propolis as antioxidant agent[48]
03	Enhancement in the oxidative stability of green peas by *Ilex paraguariensis* addition in a blanching process before their refrigerated and frozen storage[49]
04	Influence of the addition of natural antioxidant from yerba-mate leaves (*Ilex paraguariensis A. St. Hil*) on the chemical, microbiological and sensory characteristics of different formulations of *prato* cheese[50]
05	Mate extract on lipid and color changes of *dourado* (*Salminus maxillosus*) fillets during frozen storage[51]

06	Influence of antioxidant potential of mate leaves extract (*Ilex paraguariensis* A. St. Hil.) in cooked, stored, and heated thighs chicken[52]
07	Oxidative stability of fermented Italian-type sausages using yerba-mate leaves (*Ilex paraguariensis* A. St. Hil.) extract as natural antioxidant[53]
08	Natural Antioxidant from yerba-mate (*Ilex paraguariensis* A. St. Hil.) prevents Hamburger Peroxidation[54]
09	Yerba-mate (*Ilex paraguariensis*) as a dietary additive for broilers: performance and oxidative stability of meat[55]
10	Sensory evaluation of precooked chicken meat with yerba-mate (*Ilex paraguariensis*) added as antioxidant[56]
11	Yerba-mate (*Ilex paraguariensis*) as a source of water-extractable antioxidant for use in chicken meat[57]
12	Effect of yerba-mate (*Ilex paraguariensis* A. St. Hil.) addition on the functional and technological characteristics of fresh cheese[58]
13	Antioxidant effect of *Ilex paraguariensis* and condiments on lipid oxidation of *Oreochromis niloticus* steak[59]
	2nd group: Development of new products
14	Development of white chocolate with yerba-mate extract[19]
15	Breads enriched with bioactive compounds from yerba-mate (*Ilex paraguariensis*)[60]
16	Yerba-mate (*Ilex paraguariensis* A. St. Hil.) as a partial substitute for bitterness in handmade brewing[61]
17	Association of powder residue from the yerba-mate industry with wheat flour[20]
18	Chemical Characterization of Candy Made of yerba-mate (*Ilex paraguariensis* A. St Hil.) Residue[21]
19	Bread with yerba-mate aqueous extract (*Ilex paraguariensis A. St. Hil.*)[62]
20	Cake with the addition of yerba-mate[63]
21	Evaluation of phenolic compounds and antioxidant capacity of ingredients for the production of yerba-mate (*Ilex paraguariensis* A. St. Hil.) jams with ginger (*Zingiber officinale*)[64]
22	Carrier systems for yerba-mate extract (*Ilex paraguariensis*) to enrich instant soups. Release mechanisms under different pH conditions[65]
23	Effect of yerba-mate on the sensory and physicochemical characteristics of cereal bars[66]
24	Development of an Innovative Nutraceutical Fermented Beverage from yerba-mate (*Ilex paraguariensis* A. St. Hil.) Extract[67]
25	Microbiological analysis and challenge test in an energy drink based on extracts of yerba-mate (*Ilex paraguariensis* A. St. Hil.)[68]
26	Sensory analysis of cereal bars formulated with regional ingredients at the state corn fair – FEMI[69]
27	Development of functional yerba-mate jelly[70]
28	Formulation of light yogurt using extract of mate tea (*Ilex paraguariensis* A. St. Hil.) and probiotic addition[71]
29	Gasified drink of green yerba-mate[72]
30	Potency edulcorant, sweetness equivalency, and acceptance of different sweeteners in drink prepared with grass infusion of *mate* when served hot[73]
31	Fatty acid and volatile compounds from salami manufactured with yerba-mate (*Ilex paraguariensis*) extract and pork back fat and meat from pigs fed on diets with partial replacement of maize with rice bran[74]
	3rd group: Incorporation of extracts in flours/starches
32	Incorporation of polyphenols from yerba-mate in the corn starch[22]
33	Incorporation of freeze concentrated extract of yerba-mate in corn starch[23]
34	Corn starch systems as carriers for yerba-mate (*Ilex paraguariensis*) antioxidants: effect of mineral addition[24]
35	Corn starch incorporated with freeze-concentrated *Ilex paraguariensis* extracts: a potential nutraceutical product[75]
36	Biofilms based on cassava starch-containing extract of yerba-mate as antioxidant and plasticizer[76]
37	Development and evaluation of the effectiveness of biodegradable films of cassava starch with nano cellulose as reinforcement and yerba-mate extract as an additive antioxidant[77]
38	Sustainable use of *Ilex paraguariensis* waste in improving biodegradable corn starch films' mechanical, thermal and bioactive properties[78]

In the first group, the products used ranged from meat, cheese, chocolate, and green peas. The second group refers to the development of new products, with emphasis on yerba-mate drinks (soluble powder, beer), followed by other products such as yogurt, gelatin, jam, cereal bar, soup, cake, bread. The third group includes biodegradable films for food and the enrichment of flours and starches with bioactive compounds from yerba-mate extracts.

Some products were formulated only with the *in natura* or extract of yerba-mate, others with combinations between extracts of *Ilex paraguariensis* A. St. Hil. with others plants/substances (*Zea mays*[22-24], *Zingiber officinale*[66], propolis[48]) intensifying the intended action on the final product (antioxidant).

Antioxidant potential was evident in studies such as the development of cassava biofilms in which palm oil was stored for 40 days in an accelerated oxidation condition. It was verified by the peroxide index that the product did not oxidize at the same speed as the control sample, indicating that the biofilm was losing polyphenols, which were reacting[77].

In studies with *prato* cheese, yerba-mate compounds also guaranteed lower levels of lipid and protein oxidation compared to the control, however, after 45 days of storage it presented a bitter aftertaste[50]. Fish fillets evaluated, after submersion in yerba-mate extract, stored for 12 months at 7 ºC, also showed few changes, due to the antioxidant action of the compounds[51]. Fish burgers added with yerba-mate extract showed a preservative action due to the presence of quantified phenolics[18].

Zanchett et al.[19] added yerba-mate in white chocolate, and the results showed that the product was well accepted and the yerba-mate extract gave white chocolate compounds with antioxidant action. In Coró et al.[48] the lipid oxidation in the jerked beef meat product was evaluated using extract of wild herb and propolis. The result showed a decrease in oxidation of up to 2,5 times when compared with the control. Thus, yerba-mate is a natural antioxidant alternative for the meat industry in place of healing salts.

Another proposal is the incorporation of aqueous extracts of yerba-mate in starch. This product is widely used in several areas (pharmacological and nutritional), making it a functional product by enriching it with bioactive compounds[22-24,75].

The yerba-mate extract was also well evaluated in the development of handmade beer, whose function was to replace the bitterness hops, responsible for the polyphenols transferred to the final product[61,79].

In addition to the extract produced from the leaves of yerba-mate, 03 works were found that used residue from the industrialization of yerba-mate. Vieira et al., supplemented candies with the powdered residue, significantly increasing the number of polyphenols and minerals in the final product and were sensorially accepted and approved[21]. Christiano and Thys[20] added the powdered yerba-mate powder to domestic wheat flour, through the preparation of pre-mixes with substitution between 0 to 20% of the flour, and the final product presents great potential in the production of products that use wheat flour. The third product was mate-based flour (powdered residue), which is currently marketed under the name FARIMATE and is patented[47].

The results of the studies showed that the yerba mate addition is promising for the new products development with differentiated nutritional and/or functional qualities. Sensory analysis also showed that products with good acceptance by consumers can be obtained. It appears that there are several options for product development so that the population can have access to quality food when added with yerba-mate, rich in bioactive compounds.

4 CONCLUSIONS

The literature review showed that the amount of research developed with yerba-mate has increased, indicating its technological potential in food. The works developed with yerba-mate, have brought advances to the knowledge of the uses of this plant. The result of this research shows that the area of development of new products based on yerba-mate is promising, it is noticed that there are many new products development. However, there is a need for research regarding the acceptability of the product by consumers so that these products can reach supermarket shelves.

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