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REVIEW ARTICLE OPEN ACCESS

IMPORTANCE OF NATIVE CERRADO FRUITS FOR FERMENTED ACETIC PRODUCTION: A REVIEW

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ABSTRACT

The Cerrado biome has different fruit species with great potential for agri-food use. Several studies advance in this raw material to produce alternative products with longer shelf life and added value. Vinegar is a product of commercial interest and a rational way to take advantage of native fruits. Therefore, the fruits of the Cerrado, due to its constitution, with functional properties favorable to health, can facilitate its use by the food industry to obtain new products, such as apathetic fermentation. Fruit vinegar has superior sensory and nutritional quality than other vinegar obtained from other sources, with their flavor and aroma. This review's objective was to present the importance of the existing fruits of the CerradoGoiano for possible use to produce fermented acetic. The potential fruits addressed in this review were: Araticunzeiro (Annona crassiflora), Butiazeiro (Butia purpurascens Glassman), Buritizeiro (Mauritia flexuosa), Baruzeiro (Dipteryxalata Vog.), Gabirobeira (Pub Campomanesia). Cagaiteira (Eugenia dysenterica DC), Pequi (Caryocar brasiliense Camb.), Cerrado -caju (Anacardiumothonianum Rizz.), Muricizeiro (Byrsonimacrassifolia (L.) Rich), Guapeva (Pouteria cf. gardneriana Radlk), Mangabeira (Hancorniaspeciosa Gomes).

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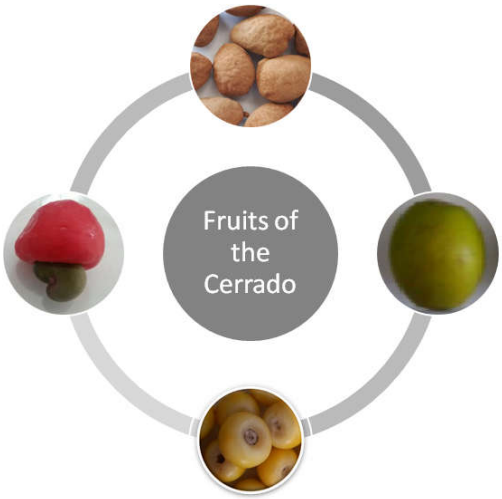
INTRODUCTION

Brazil is a significant world producer of fruits, presenting high waste levels, especially during the marketing process, since these are highly perishable products (Tessaro *et al*., 2010). Among the wealthiest savannas globally, the Cerrado biome constitutes an immeasurable heritage of renewable natural resources, emphasizing native fruit species possessing peculiar sensory characteristics. These credit to the fruits a potential for national and international exploitation, arousing interest by consumers and expressing attractiveness to the agro-industry sector for innovations that provide competitive development (Morzelle *et al*., 2015). These plants are known as a source of compounds of high biotechnological interest, which have application in both the medical and food industries (Caramori *et al*., 2004). However, although many of these species are known and used at the regional or national level, they are devalued by the industry as no industrial processes optimized for their transformation into value-added products are established. Among the various plantspecies in the Cerrado, the fruits of guapeveira, muricizeiro, caju-do-cerrado, mangabeira, cagaiteira are the most sought after. Several techniques have been used to increase these fruits' postharvest life and the full use and transformation into *final gourmet products* that meet the consumer market. Among these techniques, fermentation stands out as a viable alternative for fruits' benefit for elaborating new products. Fermentation is an efficient and low-cost technology, representing a promising alternative for industrial fruit growing (Silva *et al*., 2007; Asquieri *et al.,* 2008; Fagundes *et al.,* 2015). Regarding the nutritional aspect, organic acids, vitamins, phenolic compounds, proteins, and minerals from the fruit and alcoholic fermentation (Aquarone e*tal.,*2001; Marques*et al.,*2010; Fontan *et al.,* 2011). The product's final composition depends on raw material and the technology used in the processing. Vinegar from fruits native to the cerrado must have volatile acidity of 4 to 7.9%, acetic acid, and full ethyl alcohol content of 1% to 20ºC (BRASIL, 1999). Both acidity and pH values directly influence the sensory characteristics of this product. In vinegar with an acidity of about 5%, pH intervals from 2.46 to 3.18 are expected (White, 1971). This review aimed to present information on the importance of existing cerrado fruits for possible use for fermented acetic production since vinegar is widely used for seasonings in general and as a vehicle to improve nutritional characteristics.

Development

Fruits of the Cerradogoiano: These fruits, Figure 1, constitute a source of compounds with functional properties beneficial to health, which can stimulate their application by the pharmaceutical and food industry for the development of new products to promote the sustainable development of regions with the characteristics of the Cerrado (Siqueira *et al*., 2013). Regular fruit consumption has become a solid ally for healthy eating due to its nutritional value because it is a fiber, vitamins, minerals, and antioxidants. Some studies show that there are populations that have as habit the regular consumption of fruits and other foods rich in antioxidant compounds and that have a low incidence of degenerative diseases caused by compounds from oxidative stress (Joshipura *et al*., 2009; Soerjomataram *et al*., 2010; Roesler*et al*., 2007; Morais *et al*., 2017).



Source: Author himself

Figure 1. Fruits of the Cerradogoiano

Araticunzeiro (Annona crassiflora)

The araticunzeiro (Annona crassiflora), also known as marolo or pine forest, is a typical Brazilian Cerrado tree belonging to the family Annonaceae, highly appreciated by the local population. The fruit, Figure 2, is sincarpic (Almeida *et al*., 1998) and, under natural conditions, fruiting occurs between February and March (Silva *et al*., 1997). The ripe fruits present characteristic smell, the approximate mass of 1.0 kg, a large number of seeds, on average, with a density of 1.09 $g.cm^{-3}$, besides being non-uniform, with significant variations in mass, shape, and volume (Naves *et al*., 1995). The sweet pulp of characteristic flavor and intensearoma, Figure 2, can be consumed in nature or the form of sweets, jams, juices, yogurt, or ice cream (Almeida *et al*., 2008).

Source: Author himself

Figure 2. Araticunzeiro (Annona crassiflora)

Butiazeiro (*Butiapurpurascens* Glassman): The genus Butiá has six Brazilian species, four of which occur in the Brazilian Central Plateau (Lorenzi *et al*., 2004). Other authors state that the butiá is endemic to Minas Gerais's triangle and southwest of Goiás, especially the municipality of Jataí, also known as vassoura coconut tree (Guilherme & Oliveira, 2011; Da Silva *et al*., 2015). The fruits are ovoid, Figure 3 usually purplish, aromatic, 2.5 cm to 3 cm in length and 1.5 cm to 2.0 cm in diameter, with carnosum and sweet mesocarp (Bozza, 2009; Lorenzi, 2004; Magellan *et al*., 2013). They can be consumed mainly fresh or processed in pulp, juices, alcoholic beverages, jams, and ice cream (Schwartz *et al*., 2010; Sganzerla, 2010; Hoffmann *et al*., 2014).

Source: Author himself

Figure 3. Buritizeiro *(Mauritia flexuosa)*

Buritizeiro *(Mauritia flexuosa):* Buriti (Mauritia flexuosa) is considered the most abundant palm tree and is naturally present in the Brazilian biome. However, it is a seasonal fruit, where its fruiting on a larger scale occurs in December to June in most regions (Leo, 2005). It plays an essential role in conserving fauna since its fruits, Figure 4, serve as a food source for many species of birds and mammals. Besides, it is used to produce beverages and food in a homemade way (Vieira*et al*., 2010; Garcia *et al*., 2017).

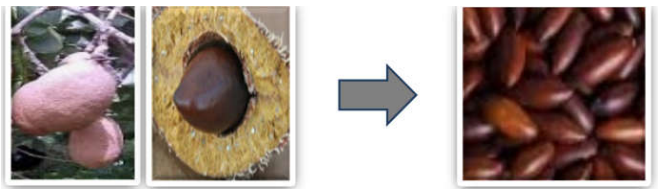
Source: Author himself

Figure 4. Buritizeiro *(Mauritia flexuosa)*

Baruzeiro (*Dipteryxalata*Vog.)

The baruzeiro is a species of the Fabaceae family, occurring infertile soils of the cerrado. Tall tree, reaching more than 15 meters high, with upright stem and smooth branches. The Baru tree blooms from late October to mid-December. The ripening of the fruitoccurs from August to October (Filgueiras, Silva, 1975). The fruit, Figure 5, is an elliptical drupaceous pod; the seed is large, ellipsoid, smooth, with white hilum. Seed color varies from dark brown to greenish-brown or yellow (Macedo, 1992). Baru seeds, according to tradition, are consumed raw or toasted. However, *in nature, consumption is not* recommended due to antinutritional factors, restring, and protein absorption (Kalume *et al*., 1995). The seed of the baru is exceptionally rich inphosphorus, manganese, andcalcium and is rich in oil and minerals. The oil extracted from the seed is of good quality, the lipid content presented in the literature is 38.2% (Takemoto *et al*.,

2001) and 33.3%, as well as 75.6% of unsaturated fatty acids (Zuchi *et al*., 2016), being used as flavoring and anti-rheumatic in folk medicine, having good pharmacological potential. In addition, fruit pulp can feed animals such as pigs and cattle (Ribeiro *et al*., 1992, Carvalho *et al*., 2008).



Source: Author himself

Figure 5. Baruzeiro (*Dipteryxalata* Vog.)

Gabirobeira

The gabirobeira (Campomanesia sp.) is a plant of wide distribution in the Cerrado and can be found in several Brazilian states, with a higher concentration in Goiás. Flowering occurs from August to November, and fruiting may extend until February from September to December. Like other species belonging to the family Myrtaceae, it presents fruits of sweet taste, and the pulp can be consumed in nature or the form of juices or jellies. The gabirobeira is a shrub that can reach 60-80 cm in height and usually thickets. Its fruiting occurs from September to Octo Like other species belonging to the family Myrtaceae, and it presents fruits of sweet taste. The pulp can be consumed in nature or in the form of juices or jellies. The gabirobeira (Campomanesia sp.) is a plant of wide distribution in the Cerrado and can be found in several Brazilian states, with a higher concentration in Goiás. Flowering occurs from August to November, and fruiting may extend until February from September to December. The gabirobeira is a shrub that can reach 60-80 cm in height and usually occurs in thickets, and its fruiting occurs from September to October. The fruit of gabirobeira, gabiroba, Figure 6 also known as guabiroba, guabiroba-do-campo, and guavira, is characterized by being round, yellow-green in color, consisting of a thin peel and a whitish pulp, involving several seeds (Vallilo *et al*., 2006; Alves *et al*., 2013). Regarding nutritional composition, gabiroba presents high moisture and dietary fiber contents, resulting in low energy density (about 50 kcal.100g$^{-1)}$, in addition to high concentrations of potassium, phosphorus, magnesium, and iron (Silva*et al*., 2008; Vallilo *et al*., 2006). It also contains appreciable amounts of bioactive compounds, such as ascorbic acid and phenolic compounds, suggesting good antioxidant activity (Pereira*et al*., 2012; Rocha *et al*., 2011).

Source: Author himself

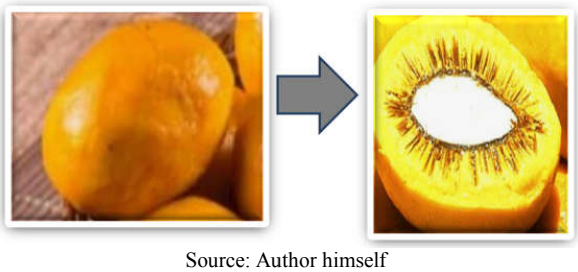
Figure 6. Gabirobeira *(Campomanesiapubescens* Berg)

Cagaiteira (*Eugenia dysenterica DC*): Cagaitais a species adapted to relatively poor soils, and its distribution in the cerrado is quite comprehensive, occurring in the states of Bahia, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Piauí, São Paulo, Tocantins, and the Federal District (Silva, 1999). The fruits, Figure 7, have a globose shape of 3 to 4 cm in diameter, light yellow color, slightly acidic, membranous epicarp, yellow pulp, meaty, edible, and, generally, with 1 to 4 seeds. The seeds are about 1 to 1.5 cm long, cream coloring, and ovals (Almeida, 1998). They are rich in vitamin C and have great regional acceptance. Therefore, they can be consumed*in nature,* and the pulp is used to manufacture sweets, jams, ice cream, and juices (Almeida; Silva; Ribeiro, 1987).

Source: Author himself

Figure 7. Cagaita (*Eugenia dysenterica DC*)

Pequizeiro (*Caryocarbrasiliense* Camb.): The pequizeiro is a native fruit tree, its fruits are many used by the regional population (Vera *et al*., 2007) and have been studied with a view to the selection of origins and progenies with better development in cultivation conditions (Moura *et al*., 2013). The species C. brasiliense occurs in the Cerrado domain of Central Brazil, in cerradão phytophysiognomies, cerrado restricted direction, cerrado ralo, and the cerrado rupestre (Ribeiro; Walter, 2008). A tree can reach 8 m in height or have a small size due to low soil fertility or genetic factors. It has a thick stem, thick and angled branches, with loss of leaves in the dry season, intensifying in June or July, coinciding with the emission of new leaves and floral buds (Santana; Ships, 2003; Vilela *et al*., 2008, Ferreira *et al*., 2015). The fruits take, Figure 8, from the flowers' opening, three to four months to reach maturation (Gribel, 1986), and this usually occurs from December to February (Almeida *et al*., 1998). Pequi pulp has a health-friendly fatty acid profile, consisting of 60% unsaturated fatty acids, predominating oleic acid (Barra *et al*., 2013). It is also noteworthy that pulp can be considered a potential source of natural antioxidants (Morais*et al*., 2013). Regarding the mineral profile, pequi pulp has many magnesium, zinc, and phosphorus (Oliveira *et al*., 2010; Ramos e Souza, 2011, Alves *et al*., 2014).



Source: Author himself

Figure 8. Pequizeiro (*Caryocarbrasiliense* Camb.)

Anacardium othonianum Rizz: Anacardium othonianum Rizzini, known as cajú-tree, is a nativespecies of the Brazilian Cerrado biome, which has recently attracted research interest principally due to its antifungal and cytotoxic growth properties, i.e., it is an essential tree for both food and medicinal purposes (Bessa *et al*., 2013; Faria *et al*., 2021; Silva *et al*., 2017). Its fruits, pseudo-fruits, barks, leaves, and flowers, popularly known as cashew and cashew, are distinguished from the other species of Brazil's Central region by the tree size and height, and diameter of the canopy (3 to 4 meters).When ripe varies from yellow to red, the coloration of the pseudofruit, and the yellowish-white pulp, being consumed in fresh or juices, liquors,

sweets, and infusions of alcohol (Correa*et al*., 2008; Bessa *et al*., 2013). The chestnut, natural fruit, is an aquenum whose stalk develops in pseudofruit, pear-shaped, and the color can vary from yellow to red. Pseudofruits, in number, between 200 and 600 per plant, are harvested between September and October. The fruit and pseudofruit, Figure 9, are rich in carbohydrates, lipids, proteins, minerals, and vitamins (Silva *et al*., 2008; Dornelles *et al*., 2014).

Source: Author himself

Figure 9. Cerrado tree cashew (Anacardium*othonianum* Rizz.)

Muricizeiro (*Byrsonimacrassifolia* (L.) Rico): The muricizeiro is a fruit tree of the Cerrado, its fruits mature between December and March, in the mountainous regions of the Southeast, in the cerrado of Mato Grosso and Goiás, and the coast of the North and Northeast of Brazil. When ripe, they have the peel and juicy pulp, sweet taste, and characteristic smell. It is yellowish, with a diameter of 1.5 to 2 cm. The pulp is fleshy and soft, and can be *consumed in natura* or in the form of juices, jams, ice cream and liqueurs (Rezende; Fraga, 2003; Alves, Alves, Franco, 2003; Guimarães *et al*., 2008; Carvalho and Nascimento, 2016). It represents a good source of energy, lipids, dietary fibers, calcium (Silva *et al*., 2008), and vitamin C (84 mg/100 g) (Vieira *et al*., 2010). Muricifruit, Figure 10, is rich in calcium and phosphorus, has high antioxidant activity levels, and plays an essential role in disease prevention (Silva &Tassara, 2001, Almeida *et al*., 2011 apud Sales, & Waughon, 2012).

Source: Author himself

Figure 10. Muricizeiro (*Byrsonimacrassifolia* (L.) Rich)

Guapeva (*Pouteria cf. Gardneriana* Radlk): Guapeva *(Pouteria cf. gardneriana* Radlk) is a tree species of the family. Sapotaceae reaches 20-30 m in height and 60-100 cm in diameter. Each tree produces between 1,000 and 3,000 fruits, measuring 4 to 5 cm in length (Cabral*et al*., 2013). The guapeva, Figure 11, presents fruits of yellowish peel color when ripe, and the pulp can be consumed in *nature or*be used in fruit salads and juices. It gives antioxidant, anti-inflammatory, antibacterial, and antifungal activities, but its real potential as a new food product source is unknown (Costa *et al*., 2014).

Source: Author himself

Figure 11. Guapeva (Pouteria*cf. gardneriana* Radlk)

Mangabeira (*Hancorniaspeciosa* Gomes*):* The mangabeira (*Hancornia speciose*) is afruit plant. Itis found in several regions of the country, from the coastal and coastal lowlands of the Northeast (Venturini Filho, 2010, Nascimento *et al*., 2014). It also grows in the Midwest Cerrados and the North and Southeast regions (Vieira Neto, 2001), its fruiting occurs between October and December. The mangabeira produces berry types, usually ellipsoidal or rounded, yellowish or greenish, Figura12, with red pigmentation or without pigmentation, sweetened yellow pulp, rich in vitamins, iron, and phosphorus, calcium, and proteins (Ganga *et al*., 2009). In the Cerrado region, mangabeira blooms from July to September, and the fruits ripen between September and December (ISA, 2009). The pulp of white, soft, fibrous, bittersweet, and aromatic color is highly appreciated in the new form, besides serving in the manufacture of beverages such as soft drinks, wine and vinegar, ice cream, jams, and dried sweets, or consumed in natura (Mattietto *et al*., 2003).

Source: Author himself

Figure 12. Mangabeira (*Hancorniaspeciosa* Gomes*)*

Production of acetic fermented: Fruit vinegar is considered superior in sensory and nutritional qualities to other vinegar types, presenting characteristics such as their flavor and aroma (Lu *et al*., 1999). The production of vinegar occurs by two distinct biochemical processes resulting from the action of microorganisms, through alcoholic fermentation, by the action of yeasts, usually,*species of Saccharomyces,*on sugary and amyloceic raw materials, followed by apathetic fermentation, by the action of aerobic bacteria of the genus *Acetobacter* (Bortolini; Sant'anna; Torres, 2001; Granada *et al.*, 2000; Tesfaye *et al*., 2002). Acetic fermentation is the product obtained from alcoholic fermented fruit must, cereals or other vegetables, honey, or vegetable mixture, or hydroalcoholic variety. It shall have a volatile acidity of at least 4 g.100 mL^{-1}, expressed as acetic acid. It may be added to vegetables, parts of vegetables or aromatic plant extracts or juices, natural flavorings, or condiments. Brazilian legislation defines that vinegar or wine vinegar is the product obtained from the acetic fermentation of wine and must have a volatile acidity of at least 40 g per liter, expressed as acetic acid (4%).

Furthermore, the alcoholic graduation must not exceed 1°GL and must be pasteurized. A vinegar with more than 80 g per liter of volatile acidity is the vinegar concentrate used exclusively for dilution. It also establishes a minimum value of 7 g. L^{-1} of dry extract for red and pink wine vinegar and 6 g.L^{-1} for white wine vinegar; for the ash content, it recommends a minimum value of 1 g.L^{-1} (Costa *et al*., 2006). The Food and Agriculture Organization (FAO) recommends vinegar production from local agricultural sources to promote local human resources and raw materials (da Rocha Neves *et al.,* 2020).

Final considerations

The fruits of the Cerrado, due to their constitution, have a potential for fermented acid production. Therefore, the Cerrado has a vast richness since its fruits because they are a source of compounds with functional properties favorable to health, facilitating its use by the food industry to obtain new products, promoting the sustainable development of cerrado regions.

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Copyright contributions: ARM defined the structure of the paper and the writing of the article. PD contributed to the writing of the article. MIRM provided extensive feedback. All authors reviewed and approved the submitted paper.

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