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Dipteryx alata, the baru: An analysis of its potential for general use

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ABSTRACT
Dipteryx alata, popularly known as baru, is a species native to the Brazilian Cerrado. It is a species belonging to the genus Dipteryx alongside 25 other species documented for the genus. The production chain of *Dipteryx alata* begins with the extractives through the collection and processing that is carried out manually and by hand. Subsequently, the almonds are destined for cooperatives or associations, where the process of roasting, bottling, labeling and sent to trade takes place. However, it is considered a promising species for cultivation, due to its multiple use, establishment of seedlings and high germination rate. The use of baru ranges from the ecological aspect due to its shading potential in the phytophysiognomy in which it is found, through the food, cosmetic and even pharmaceutical importance.

Keywords: Cerrado, Baru, *Dipteryx*, Potential, Utilization.

1 INTRODUCTION

The Cerrado is the second largest biogeographic system in South America, occupying about 22% of the national territory. With regard to biological diversity, this biome is characterized as the richest savanna in the world. It is also one of the world's biodiversity hotspots, containing numerous endemic species. In addition, several local communities use the Cerrado as a source of income through the sale of various fruits, such as buriti (Mauritia flexuosa), mangaba (Hancornia speciosa), cagaita (Eugenia dysenterica) and baru almonds (*Dipteryx alata* Vogel.) (BRAZIL, 2019).

Dipteryx alata Vogel is a native species of the Brazilian Cerrado (COLLEVATI et al., 2010) and has been used by the regional population as a source of family income. It is considered a promising species for cultivation, due to its multiple use, establishment of seedlings and high germination rate

(SANO; BRITO; RIBEIRO, 2010). It is a food rich in energy, fiber, protein and carbohydrates, and can be consumed pure or added to other preparations such as cakes, cookies and cereal bars (FREITAS et al., 2014; LIMA et al., 2010; ROCK; SANTIAGO, 2009; VALILO; TAVARES; AUED, 1990).

This species belongs to the botanical family Fabaceae, former Leguminosae that constitutes the third largest family of angiosperms, presenting cosmopolitan distribution (JUDD et al., 2009). The species range in size from trees to vines. Most of the leaves are composed and alternate, while the flowers are hermaphroditic, zygomorphic or actinomorphic (SCHULTZ, 1990). The roots present nodules that allow the biological fixation of nitrogen, allowing the occupation of the species in tropical regions, especially in areas of poor and leached soils (SIMÕES et al., 2017; SCHULTZ, 1990).

This family comprises approximately 18,000 species, belonging to 630 genera (JUDD et al., 2009). The Fabaceae presents great economic relevance, due to its species being used in urban afforestation, human food, soil recovery and others (LEWIS et al., 2005). Among the genera related to Fabaceae, Dipteryx can be highlighted.

2 THE GENUS DIPTERYX

There is no consensus regarding the number of individuals belonging to the genus, there are indications of 25 species. In 1791, only based on the similarities of the flowers and without taking into account the diversity of the fruits, Schreber proposed the union of two genera, the Taralea and the Coumarouna, resulting in the *Dipteryx* (TORRES, 2001).

The classification of 25 species is carried out according to the Missouri Botanical Garden and the Kew Royal Botanical Garden. Sixteen are from the genus Coumarouna (*Dipteryx alata*, *Dipteryx charapilla*, *Dipteryx coreacea*, *Dipteryx ferrea*, *Dipteryx lacunifera*, *Dipteryx magnifica*, *Dipteryx mircantha*, *Dipteryx odorata*, *Dipteryx oleifera*, *Dipteryx panamensis*, *Dipteryx polyphylla*, *Dipteryx punciata*, *Dipteryx rosea*, *Dipteryx speciosa*, *Dipteryx tetraphylla* and *Dipteryx trifoliolata*), four classified simultaneously as Taralea and Coumarouna (Dipteryx crassifolia, Dipteryx nudipes, *Dipteryx oppositifolia* and *Dipteryx reticulata*), two identified directly as belonging to the genus *Dipteryx* (*Dipteryx phaeophyla* and *Dipteryx pteropus*) and one species has synonymy with the genus Pterodon (*Dipteryx emarginata*) (TORRES, 2001).

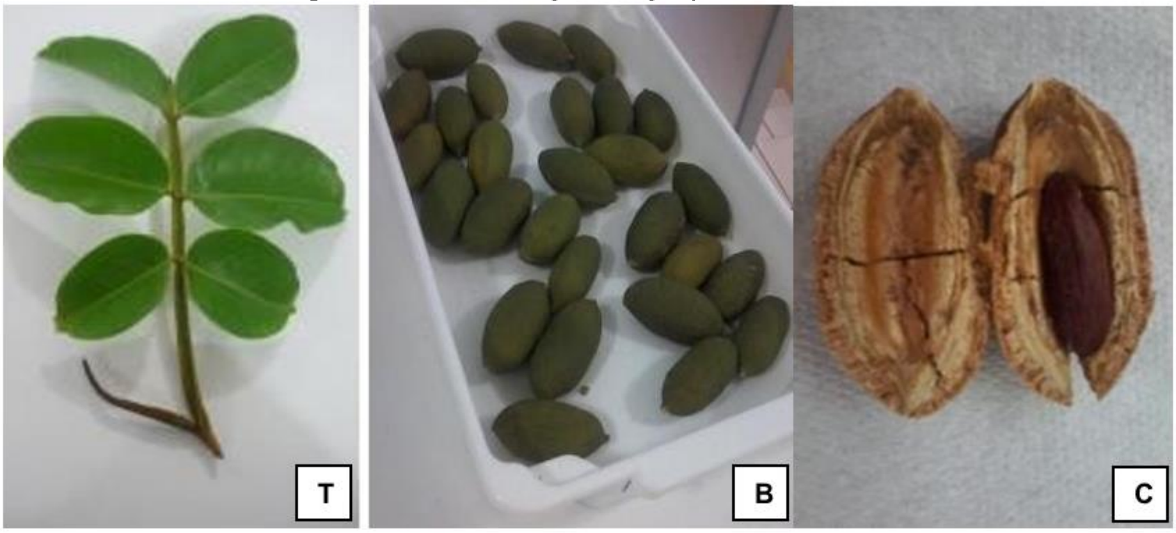
The species are found in South and Central America, mainly in the Amazon region. Of the 25 species, 15 are found in Brazilian territory, and only *Dipteryx alata* is found in the Cerrado. Its best known species are *Dipteryx alata* and *Dipteryx odorata* , often confused with the baru (LEWIS et al. 2005, TORRES, 2001).

Dipteryx odorata Aublet is popularly known as cumaru, cumaru-yellow, cumaru-de-cheiro, cumarurana, cumaruzeiro, ipê-cumaru, baru, champagne, muimapagé and umarurana. In Bolivia it is called almendro and almendrillo, in Colombia by charapilla, in Guyana by tonka bean, in French

Guiana by gaiac de cayenne, in Honduras by ebo, in Peru by charapilla murciélago, in Suriname by koemaroe and in Venezuela by sarrapia (SILVA et al., 2019; CARVALHO, 2009).

The cumaru is an arboreal species, of evergreen or evergreen behavior of leaf change. It is found in the states of Acre, Amazonas, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Pará, and Rondônia. The trees can reach 40m in height (CARVALHO, 2009), figure 1 presents the image of the leaves, green fruits and almond of *Dipteryx odorata*:

Figure 1- Details of the species *Dipteryx odorata* Aublet.



Legend: A- General aspect of the branch with leaves; B- Unripe fruits; C- Fruit with the almond.
Source: Sousa (2017).

The leaves are composed and alternate. The flowers are hermaphroditic, aromatic, small, zygomorphic, with pinkish perianth and short pedicellate. The fruit is of the drupaceous legume type, oval and woody, with a seed. In the Amazon, fruit production begins around 4 or 5 years of age. Pollination is carried out by several species of bees. In Pará, flowering occurs from August to October, in Amazonas from September to October and in Pernambuco in December. The dispersal of seeds can occur by gravity, rodents and bats (CARVALHO, 2009).

This species is used in medicine, pharmacology, perfume and cosmetics industries (SILVA et al., 2019). In folk medicine, almonds are used as diaphoretic or sweating and to them are attributed acaricidal activity. Cooked fruits and almonds are used in the treatment of respiratory, cardiac problems and in the fight against worms. The bark is indicated for the fight against coughs, flu and lung problems. Almond oil is indicated against mouth ulcer, otitis and scalp problems. It was discovered that the oil has the ability to inhibit blood clotting, with this, it can be used in the manufacture of rodenticide-type poison (CUNHA, GODOY, BRAZ FILHO, 2016; CARVALHO, 2009).

The species is also known as the "tonka bean tree", its seeds being called the "tonka bean". Studies indicate the presence of coumarins in their composition, these compounds can cause toxic effects for humans and animals (BAJER et al., 2018). Almonds are edible and are also used in the making of handicrafts in general. However, it is not recommended its use in the manufacture of handicrafts, due to the almonds present antispasmodic, diaphoretic, cardiac and emmenagogue action (CARVALHO, 2009).

Almonds have a volatile oil that is widely used in the manufacture of perfumes and cosmetics. The oil has a light yellow color, fragrant, oxidizes quickly in contact with the air and has great demand in the international market. Through the fermentation of almonds is produced a volatile oil (coumarin anhydride) that is used as a narcotic, stimulant and as a fixative in the perfume industry (CARVALHO, 2009).

Histochemical studies performed in idioblasts and in secretory cavities (epithelium and lumen) identified the presence of alkaloids and phenolic compounds in the idioblasts and absence of terpenes in the three samples tested (SILVA et al., 2019).

The resistance of *Dipteryx odorata* wood to xylophagous fungi can be justified by the action of isoflavonoids that have been identified in its composition (GARCIA et al., 2018).

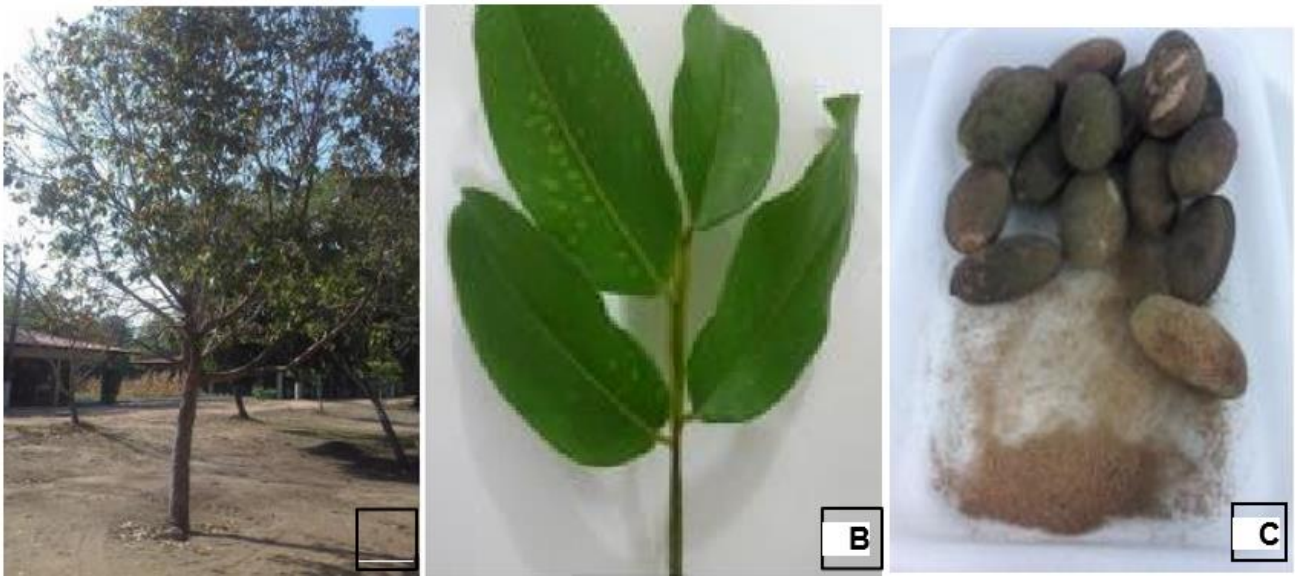
We identified 190 volatile compounds present in extracts of *Dipteryx odorata*. Among the identified compounds are alcohols, aldehydes, ketones, acids, esters, monoterpenes, monoterpenoids, sesquiterpenes, sesquiterpenoids, lactones, hydrocarbons and others, with coumarin being the majority compound, with an area of 51-85% (BAJER et al., 2018). In the flowers of *Dipteryx odorata*, 32 volatile compounds were characterized, the main ones being gerinacrene D (34.2%), bicyclogermacrene (14.3%), spathulenol (12.4%), α-cadinol (4.3%) and nonanal (2.9%). It is interesting to note that coumarin was not found in the flowers, which is the main constituent found in the almonds of *Dipteryx odorata* (ANDRADE et al., 2003).

In the endocarp of *Dipteryx odorata* were identified the flavonoids, 3',4',7- trihydroxyflavone, 3',4',7-trihydroxyflavanone, 3',4',6-trihydroxyaurone, 3',4',5,7- tetrahydroxyflavone, 2',3,4,4'-tetrahydroxychalcone and 2',4,4'-trihydroxychalcone, being the flavonoids 3',4',7-trihydroxyiflavone and 2',3,4,4'-tetrahydroxychalcone unpublished for the species (CUNHA, GODOY, BRAZ FILHO, 2016). The 3',4',7-trihydroxyflavone had been identified before, along with butin, buteine, isoliquiritigenin, luteolin, sulfuretin (CUNHA, 2003). In the methanolic extract of the wood were found four isoflavones 8-o-methylturbine, cladastrin, 7,3'- dihydroxy-8,4'dimethoxyisoflavone and the unprecedented 7,3'-dihydroxy-5,6,4'-trimethoxyisoflavone (GARCIA, 2013).

Compounds were isolated from ethyl acetate extract from *Dipteryx odorata* almonds and tested in mouse breast organ culture assay. Isoliquiritigenin showed inhibition of 76% with a concentration of 10μg/mL, 6,4′-dihydroxy-3′-methoxyaurone inhibited in 48.2% and sulfuretin was responsible for 58.2% of inhibition (JANG et al., 2003).

Dipteryx magnifica Ducke is popularly known as cumaru-rosa, it is an arboreal species that can reach an average of 6m in height. The leaves are composed and alternate, the fruits are of the drupe type and the dispersal of the seeds is carried out by bats and rodents. Figure 2 shows the image of the tree, leaves and fruits of *Dipteryx magnifica*.

Figure 2- Species *Dipteryx magnifica*.



Legend: A-Individual adult, with tree size; B- General aspect of the branch; C- Fruits
Source: Sousa (2017).

In the extract of the leaves of *Dipteryx magnifica*, taraxasterol was identified as the major compound (51.9%), it was also identified in the extract of the branches. In the extract of the peels of the fruits, spathulenol and α-cadinene were found. In the seed extract, 1,2-benzopyrone and 3,4-dihydrocoumarin (25.2%) were identified (SOUZA, 2017).

It was verified that the extracts of the leaves, branches and seeds of *Dipteryx magnifica* showed no bacteriostatic or bactericidal effect for the pathogens Burkholderia cepacia (ATCC 25416), Escherichia coli (ATCC 11775), Pseudomonas aeruginosa (ATCC 13388) and Staphylococcus aureus (ATCC 6538). However, the extracts of the bark and endocarps of *Dipteryx magnifica* showed action against Escherichia coli and the strains of Staphylococcus aureus were also sensitive to the action exerted by the extract of the peels, at the concentration of 2000 μ g.mL-1 (SOUZA, 2017).

Dipteryx lacunifera Ducke is a little known species, being popularly called by chestnut-of-gurgueia, bat bean and garampara. It has a natural occurrence in the Cerrado of Piauí, where fruits and nuts are sold in local commerce (CARVALHO, 2008; CARVALHO et al., 2008; VIEIRA JÚNIOR et al., 2007). The almond has a pleasant flavor and in the fruits was identified the presence of calcium, phosphorus, potassium, magnesium, copper, manganese, zinc and iron (RIBEIRO, SOUZA, LOPES, 2012).

In the fixed oil, 8.3% moisture, 41.9% lipids, 2.3% ashes, 13.3% proteins and 34.4% carbohydrates were identified. In the composition it was observed the presence caproic, caprylic, lauric, palmitic, margaric, stearic, arachidonic, behenic, lignoceric, oleic, linoleic, linolenic and eicosadienoic acids. The major fatty acids were oleic (65.1%) and linoleic (14.1%) (QUEIROGA NETO et al., 2009). In the fixed oil, Vieira Júnior et al. (2004) had already characterized the palmitic, linoleic, oleic, stearic and lignoceric acids. Oleic acid (75.8%) and palmitic acid (14.34%) were the major compounds.

The thermogravimetric profile (TG/DTG) of *Dipteryx lacunifera* almond oil was also traced. The oil showed thermal stability up to 224.2ºC, decomposition and carbonization occurred in a single step, with a temperature of 491.3ºC (QUEIROGA NETO et al., 2009).

In the flour manufactured with the almond of *Dipteryx lacunifera*, 41.86% of lipids, 13.28% of proteins, 34.42% of carbohydrates, 2.29% of ash and 8.25% of moisture were quantified. The amino acids valine, leucine, isoleucine, threonine, lysine, histidine, phenylalanine, tyrosine, cysteine, methionine, glycine, alanine, serine, aspartic acid, glutamic acid, arginine and proline were also identified. It was observed that the almond flour did not present hemagglutinating activity or trypsin inhibitor, with this, the flour presented potential to be used in human food (QUEIROGA NETO et al., 2009).

Studies carried out with the volatile oil extracted from the peels of the fruit *Dipteryx lacunifera* identified α-copaene, β-elemene, trans-caryophyllene, β-farnesene, germacrene-D, bicyclogermacrene, γ-cadinene, spathulenol and caryophyllene oxide. The β-farnesene was the majority compound with 27.82%. In the fixed oil, palmitic, linoleic, oleic, stearic and lignoceric acids were identified. Oleic acid was the majority compound with an area of 75.8% (VIEIRA JÚNIOR et al., 2007).

In the hexane fraction of the fixed oil of the almonds of *Dipteryx lacunifera*, capric, lauric, palmitic, stearic, arachidonic, arachidic, behenic, lignoceric, oleic, linoleic, linolenic and erucic acids were identified. The major compounds were oleic (36.1%), palmitic (20%) and linoleic (14.4%) (MENDES, SILVEIRA, 1994).

In the hexane extract of the peels of the fruit and in the oil of the almonds, the β-farnesene, spathulenol and vinhatic acid were isolated and identified, the latter compound is unprecedented in the genus *Dipteryx* (VIEIRA JÚNIOR et al., 2007). In the ethyl ether fraction of the almond, the phenolic derivatives eriodictiol, butin, luteolin, 3', 4', 7-trihydroxyflavone, butein and sulfetin were identified. In the hexane extract of the almonds, sesquiterpenes, furanocassano, diterpenes and fatty acids were found (MENDES, SILVEIRA, 1994).

Different concentrations of *Dipteryx lacunifera* bark extract (1.2 and 6mg) showed low inhibition against Staphylococcus aureus (ATCC 25923 and 29213), methicillin-resistant Staphylococcus aureus (MRSA PI-98), Staphylococcus epidermidis (MRSE H-111), Enterococcus faecalis (ATCC 29212) and Enterococcus faecalis (7426) strains. The strains of Staphylococcus epidermidis (ATCC 12228), Escherichia coli (ATCC 25922 and 35218), Klebsiella pneumoniae

(ATCC 700603), Pseudomonas aeruginosa (ATCC 27853) and Stenotrophomonas maltophilia (MS 012004) did not show significant activity (halos smaller than 9 mm) (AYRES et al. 2008).

Another species, *Dipteryx panamensis* Pittier is native to Latin America and is widely used in the manufacture of wooden floors due to its strength and durability. In addition, it has an important ecological role serving as a food source for several animals at risk of extinction (LÉON et al., 2017).

In the methanolic extract of the wood of *Dipteryx polyphylla* Huber four isoflavones were isolated and identified, 2',7-dihydroxy-4'-methoxy-isoflavan (vestitol), 2',8- dihydroxy-4',7-dimethoxyisoflavana, 3',8-dihydroxy-4',7-dimethoxy-isoflavan and 3',7- dihydroxy-4'-methoxy-isoflavana, the last two being unpublished in the literature (MELO, 2016).

The species *Dipteryx micranta* Harms is used in folk medicine in the treatment of burns. The ethanolic extract of the stem bark showed significant microbial activity against Bacillus cereus (ATCC 11778), Bacillus subtilis (ATCC 6633), Bacteroides fragilis (ATCC 25285), Enterococcus faecalis (ATCC 29212), Staphylococcus aureus (ATCC 25923), Staphylococcus epidermidis (ATCC 12228) and Streptococcus pyogenes (ATCC 19615). However, it was considered inactive against Escherichia coli (ATCC 25922), Pseudomonas aeruginosa (ATCC 27853) and the fungus Candida albicans (ATCC 10231) (KLOUCEK et al., 2007).

3 *DIPTERYX ALATA* VOGEL, BARU

Dipteryx alata Vogel, popularly known as baru, is a tree species native to Brazil, with a wide distribution in the Cerrado biome (COLLEVATI et al., 2010), being found in the Midwest, North, Northeast and Southeast of the country (LIMA, 2010). The term "baru" originates from the Tupi, mbore, which means "excites the tongue" (SILVA JÚNIOR, 2005).

In folk medicine it is known to present aphrodisiac properties being called "Viagra do Cerrado", it is also used in the treatment of spinal problems (CAMPOS FILHO, 2009).

The production chain of *Dipteryx alata* begins with the extractives through the collection and processing that is carried out manually and by hand. Subsequently, the almonds are destined for cooperatives or associations, where the process of roasting, bottling, labeling and sent to trade takes place. The extraction of *Dipteryx alata* generates income and autonomy for farmers and their families, contributing to the settlement of this population in the rural area and to the conservation of the biome (CAMPOS, 2019).

The barueiro is a tall tree, with a long trunk (LORENZI, 1992) (figure 3-a), being a hermaphrodite species and its pollination is carried out mainly by large and medium bees. *Dipteryx alata* presents a rapid growth with fruit production from the age of four and is able to improve the fertility of the land due to the formation of nodules that make available in the soil the nitrogen taken from the air (CAMPOS FILHO, 2009). Seed dispersal is performed by monkeys and bats

(COLLEVATI et al., 2010). The leaves are composed and alternate (figure 3-b), flowering occurs in the months of November to May and fruiting occurs from July to October (SANO; BRITO; RIBEIRO, 2010; ALMEIDA; SILVA; RIBEIRO, 1990).

In the dry season, *Dipteryx alata* is consumed by cattle as a complementary form of calories and the rumination process accelerates seed germination (ALMEIDA; SILVA; RIBEIRO, 1990).

The fruit has an oval shape with a brown coloration. It is composed of epicarp (thin layer), mesocarp (fibrous layer of brown color) and endocarp (harder, woody and yellowish layer) (VALILO; TAVARES, AUED, 1990), as shown in Figure 3-c.

Figure 3- *Dipteryx alata* and its morphological characteristics.

Legend: A- General aspect of the species in tree size, b- Leaves, c- Fruits, d- Almonds.
Source: Own author.

Dipteryx alata, considered a drupe, has edible pulp and almond (VERA; SOUZA, 2009). The pulp has a sweet taste (ALMEIDA; SILVA; RIBEIRO, 1990) and can be consumed in natura or added to preparations such as cakes (VALILO; AUED, 1990), bread (ROCHA; SANTIAGO, 2009), biscuits (FREITAS et al., 2014) and others. The almonds (figure 3-d) have a taste similar to that of peanuts and can be used in the preparation of paçocas, tomboy's feet and nutritious bars (LIMA et al., 2010;

ALMEIDA; SILVA; RIBEIRO, 1990). In addition, they can be used to replace nuts, such as in the preparation of pesto sauce and in the preparation of chocolates and liqueurs (SANO; BRITO; RIBEIRO, 2010).

Both pulp and almond are used as raw material for small and medium-sized food industries, contributing to the economy of the Midwest of the country (COLLEVATI et al., 2010). Figure 4 shows products manufactured with *Dipteryx alata*, such as popsicles, cakes, liqueurs, tomboy's feet and lollipops.

Figure 4- Products obtained from the use of *Dipteryx alata*.

Legend: Popsicles, cakes, liqueurs, tomboy's feet and lollipops
Source: Own author, Albertini (2019), Mother Earth (2020), Ana Maria Braga (2020), Redação paladar (2020).

It is documented in the chemical composition of *Dipteryx alata* that the peel of the fruit has the highest content of dietary fiber (24.1g/100g) and the pulp the highest concentration of carbohydrates (57g/100g). They were also quantified about 23g of sugars and 20g of fiber for each 100g of pulp, finding that these contents increased during the storage period (SANTIAGO et. al, 2018).

The following minerals were identified and quantified in the pulp composition: potassium (572mg/100g), phosphorus (82.20mg/100g), calcium (75.20mg/100g), iron (5.94mg/100g), magnesium (3.90mg/100g), manganese (3.84mg/100g), copper (3.54mg/100g), sodium (1.7mg/100g) and zinc (1.08mg/100g). Regarding the amino acids present in the pulp, valine, isoleucine, leucine, threonine, methionine, tyrosine, phenylalanine, histidine, lysine, tryptophan, aspartic acid, serine, glutamic acid, proline, glycine, alanine and arginine were identified. The pulp of the immature fruit contains high levels of tannins, which decrease with maturation (VALLILO; TAVARES; AUED, 1990).

Lima et al. (2010) produced cereal bars with 14% almond and with different proportions of pulp (0.5 and 10%) to replace oat bran. This food presented good acceptability of consumers and an increase in nutritional value and fiber and a decrease in energy value were perceived. The bars were considered important sources of energy, fiber, protein and carbohydrates. And in addition to adding nutritional value, its use contributes to the sustainability of *Dipteryx alata*.

Breads were also produced from different proportions of husk and pulp in place of wheat bran, having a good acceptance in relation to appearance, texture and flavor. In addition to the sensory aspects, the food has a low content of total fats, reduced energy value and an increase of up to 58.2% in fiber content. The researchers suggest the joint use of the peel and pulp in the preparation of whole grain breads, adding to the food a greater nutritional and sensory value (ROCHA; SANTIAGO, 2009).

Other researchers produced biscuits with the pulp of *Dipteryx alata* and obtained good acceptability from consumers, and the formulation containing 10% of the flour of the pulp was the one that presented the greatest acceptance. However, the samples with 20, 30 and 40% also obtained good acceptance results. These values indicate the potential of the pulp to improve the nutritional quality of foods and even the development of new products (FREITAS et al., 2014).

4 THE ALMONDS OF THE BARU

The extraction process of almonds begins with the selection of fruits. The breakage can be performed by cross-cutting or by mechanical pressure. The rotten almonds are used as fertilizer, the cut ones are used for the production of flours and other derivatives and the whole almonds are destined for consumption in natura or roasted (CERRATINGA, 2020). Almonds have a good durability of 12 months when stored at low temperature (BOTEZELLI; BOTEZELLI; DAVIDE; MALAVASI, 2000).

The amount of almonds obtained per kg of fruit may vary according to the region of origin. We found 960 almonds per kg for fruits from Brasilândia-MG, 719 almonds for fruits collected in Capinópolis-MG, 1,093 almonds for fruits from Curvelo-MG and 932 almonds for fruits from Jequitiá-MG (BOTEZELLI, 1998).

The fruit is one of the few species that have fleshy pulp during the dry season in the Cerrado, serving as an important food source for fauna. The planting of baru favors the recovery of environmental protection areas such as springs, river banks and streams, providing the conservation and maintenance of other species (SANO; BROOK; BRITO, 2004).

Generally, the baru is collected by rural workers who keep the species along with the pastures, the fruit is collected directly from the ground and requires, approximately, 1,000 fruits to obtain 1kg of almonds (NEPOMUCENO, 2006). *Dipteryx* has great potential to be inserted in the market as an organic and functional food, favoring the health of the consumer and the economic and social development of the Cerrado (MARTINS, 2010).

Almonds, compared to the shell and pulp, have a high energy value due to the high amount of lipids. They also have a higher content of phenolic compounds and antioxidant capacity, and raw almonds obtained even higher values than roasted almonds (SANTIAGO et al., 2018).

Lemos et al. (2012) conducted studies to identify and quantify bioactive compounds in baru almonds with and without shell and also to evaluate the effect of roasting on these compounds and antioxidant capacity. It was found that the almonds with shell presented a higher amount of phenolic compounds, and the raw ones obtained even higher values than the roasted ones, followed by the raw and roasted almonds without shell. The values for antioxidant capacity were also higher for shelled almonds. Eight phenolic compounds were also identified - gallic acid, catechins, picatekines, ferulic acid, p-coumaric acid, hydroxybenzoic, ellagic acid and caffeic acid. With the exception of gallic acid, the contents of the other seven phenolic compounds decreased considerably after roasting the shelled almonds.

It was observed that the almond in natura presented a high level of phenolic compounds, vitamin C, antioxidants, sterols, monounsaturated fatty acids and low thrombogenic and atherogenic indices. Almonds dried at 65°C for 30 min showed a decrease in the levels of caffeic acid, chlorogenic acid, anthocyanins, p-coumaric acid, ferulic acid, o-coumaric acid, quercentin and polyunsaturated fatty acids. But an increase in the levels of gallic acid, rutin, catechin, trans-cinnamic acid, vanillin, m-coumaric acid, tocopherols, monounsaturated fatty acids and antioxidant activity was also observed. In almonds heated for 30 min at a temperature of 105°C there was a reduction in the level of vitamin C and increase in the levels of flavonoids (CAMPIDELLI et al., 2020).

Bioactive properties are exacerbated by processing. According to the purpose, almonds can be subjected to different forms of drying to be consumed pure, in the form of oils or added to cereal bars, chocolates, in baking and others (CAMPIDELLI et al., 2020).

The fractions (hexane, dichloromethane, ethyl acetate and methanol) of the fruit bark of *Dipteryx alata* were verified against the damage caused to the muscle tissue and the neuromuscular blockade of the venom of the snake Bothrops jararacussu. The hexane extract was the most promising and therefore its chemical constitution was investigated. Four triterpenoids, nine isoflavonoids, one chalcone, one aurone and three phenolic compounds were identified (PUEBLA et al., 2010).

Due to the nutrients, the fruit can be used in the diet in general. However, the consumption of almond in natura is not indicated, as a result of the existence of antinutritional factors such as tannins, phytic acid and trypsin inhibitor that compromise the absorption of nutrients (SANO et al., 2014, KALUME; SHAH; MORHY, 1995, TOGASHI; SGARBIERI, 1994). A phytic acid concentration of 0.005g was identified for every 100g of raw almonds, while for roasted almonds 0.001g of phytic acid were found (TOGASHI, 1993). The values obtained for the trypsin inhibitor were even higher, in raw almonds it was quantified 38 ICU/mg, after roasting it was obtained 0.63 ICU/mg (KALUME; SHAH; Morhy, 1995).

In the almond were found about 23.02% of carbohydrates, much lower than the amount found in the pulp. It presented high levels of lipids and proteins, and can be considered a promising source of oilseed and protein (BORGES, 2013; VALLILO; TAVARES; AUED, 1990). It has a protein content (244g.kg−1) higher than that of Brazil nuts (140-160g.kg-1), pine nuts (130g.kg−1), cashew nuts (175g.kg−1), hazelnuts (145g.kg−1), pistachios (200g.kg−1) and almonds (210g.kg−1) (CRUZ et al., 2011).

Bento et al. (2004) found that the intake of *Dipteryx alata* alata almonds reduce total cholesterol and LDL (low density lipoprotrein) levels. It is important to mention that for these lipid changes a portion with 20g/day of baru almonds was ingested, a value of 2 to 5 times lower than daily portions of other oilseeds such as almonds (73g), macadamia nuts (42.5g) and pistachios (60g).

Regarding minerals, potassium, phosphorus, magnesium, calcium, manganese, iron, selenium, copper and zinc were identified (SOUSA et al., 2011). The almond has a high content of vitamin E, low amount of selenium (FERNANDES et al., 2015) and a significant amount of essential amino acids that varied according to the origin of the almond (FERNANDES et al., 2010).

The roasted almond has a higher concentration of total tocopherols compared to the almond in natura. Roasting probably generates products of the Maillard reaction, causing changes in the concentration of tocopherols. It was noticed that the content of γ-tocopherol was higher for roasted almonds, while in natura obtained higher values for β-tocopherol (BORGES, 2013).

It was identified that roasting causes an increase in the concentration of sterols, being identified and quantified the β-sitosterol, stigmasterol, campesterol, sitostanol and cholesterol (BORGES, 2013).

Studies conducted on rats indicate that the use of almond causes an improvement in the lipid profile and a protection against oxidative stress. The results suggest that the high content of monounsaturated fatty acids may be responsible for the antidyslipidemic effect and that the use of the almond of *Dipteryx alata* may have great potential in the prevention and control of dyslipidemias (FERNANDES et al., 2015).

In a recent study, 32 volatile compounds present in roasted almonds (45 min with a temperature of 150°C) were identified. The major compounds were hexanal (71.18%), 2,5-dimethyl-pyrazine (9.43%), 3-methyl-1-butanol (3.12%), methylpyrazine (2.07%), D-limomen (1.91%) and nonanal (1.46%). In the characterization of phenolic compounds, 20 compounds were identified, and in the crude extract were found 12 phenolic acids and 6 tannins, while in the hydrolyzed extract it was characterized 9 phenolic acids and 6 tannins. The study also found that baru has the potential to inhibit the proliferation of colorectal cancer cells in HT29 cells (OLIVEIRA-ALVES et al., 2020).

The consumption of *Dipteryx alata* contributes to plant biodiversity and the conservation of the Cerrado biome, in addition, it benefits the health of consumers due to its nutritional and bioactive properties (CAMPIDELLI et al., 2020).

5 THE BARU AND ITS "SACRED" OIL

Fixed oils are a mixture of lipid substances, usually extracted from seeds. Most fixed oils are liquid at room temperature and can be used in medicines, cosmetics and food. Oils can be extracted from various parts of the vegetable, with the largest amount found in the seeds. Its obtainment can be carried out through hydraulic presses with or without heating. When it does not involve heating, the oil is called "virgin oil" or "cold pressing oil" (ROBBERS et al., 1997).

In the fixed oil of *Dipteryx alata* Vogel a high degree of unsaturation was identified, and oleic and linoleic acids were the fatty acids found in greater quantities, corresponding to approximately 77% of the total composition (SIQUEIRA et al., 2016; SILVA et al., 2015, MARQUES, 2014; BORGES, 2013).

Oleic and linoleic acids are considered essential, not being synthesized by humans, but ingested from the diet. These compounds have benefits related to the prevention of several diseases, such as heart disease, hypertension, type 2 diabetes and others (BRENNER, 1987). In addition to oleic and linoleic acid, palmitic, stearic acid have also been identified (SIQUEIRA et al., 2016; MARQUES, 2014, TAKEMOTO et al, 2011, VALLILO; TAVARES; AUED, 1990), behenic, arachidic (TAKEMOTO et al, 2011, VALLILO; TAVARES; AUED, 1990), gadoleic, lignoceric (MARQUES, 2014, TAKEMOTO et al, 2011), linolenic (SIQUEIRA et al., 2016, MARQUES, 2014), myristic and erucic (MARQUES, 2014).

The interference of temperature in relation to the concentration of tocopherols is noticeable. The oil obtained from raw almonds obtained a concentration of 27.90mg/100g, while the oils obtained with almonds heated for 25 and 35 seconds with a temperature of 150°C obtained 29.19 and 29.93 mg/100g. In addition to the total levels of tocopherols, it was found that α-tocopherol corresponds to most of the composition and that its concentration also suffers interference from temperature, obtaining 49.06% for the oil extracted from raw almonds, 70.71 and 65.98% for the oils extracted from heated almonds (MARQUES, 2014). At high temperatures, vegetable oils with high oxidative stability are used, however, each oil has different characteristics depending on the composition of tocopherols and fatty acids (TABBE et al., 2008).

Dipteryx alata oil has a content of α-tocopherol and fatty acids similar to peanut oil and the high degree of unsaturation favors its use for food, pharmaceutical and oleochemical purposes (TAKEMOTO et al., 2001).

The heating of the fixed oil in microwaves and fryers are not indicated, as it can cause changes in the concentration of tocopherols and fatty acids, reduction of antioxidant activity and the formation of oxidation products, being recommended the use without heating (BORGES, 2013).

Quality control tests were performed and it was found that the use of different presses did not cause changes in the physicochemical characteristics of the oil, maintaining values within the permitted standards (SIQUEIRA et al., 2016; MARQUES et al., 2015). Table 1 presents the values obtained for iodine, peroxide and acidity index.

Table 1 - Physicochemical characteristics of fixed baru oil extracted by hydraulic pressing and continuous screw.

	Hydraulic press (Siqueira *et al.*, 2016)	**Hydraulic press** (Marques *et al.*, 2015)	**Continuous screw press** (Marques *et al.*, 2015)
Iodine content (g/100g)	72.9 ± 2.2	89.88 ± 4.42	89.44 ± 2.59
Peroxide content (meq/kg)	1.61 ± 0.05	1.61 ± 0.05	1.36 ± 0.05
Acidity index (mg KOH/g)	0.28 ± 0.05	0.41 ± 0.01	0.30 ± 0.01

Source: (MARQUES et al., 2015; SIQUEIRA et al., 2016).

6 THE VOLATILE FRACTION OF BARU OIL

Volatile oils can be defined as a complex mixture of volatile substances, ranging from 20 to 200 components. They can also be called essential oils, ethereal oils or essences. Unlike fixed oils, they present volatility at room temperature and in most cases, characteristic pleasant aroma. They are colorless or slightly yellowish, do not have a rancid aspect, but when exposed to luminosity and air, they can oxidize and acquire resinous characteristics (SIMÕES et al., 2017; ROBBERS et al., 1997).

Volatile oils consist mainly of terpenes and phenylpropanoids. However, the extractive process interferes in the composition of the mixture, and the volatile oils, from distillation, are mostly made up of monoterpenoids and sesquiterpenoids. While oils extracted with solvents or by supercritical fluid have diterpenoids (SIMÕES et al., 2017; ROBBERS et al., 1997). In addition, the enantiomer compounds may present differences in aroma and flavor (ROBBERS et al., 1997).

The components of volatile oils can be classified according to the percentage present in the mixture. The majority ones present from 20 to 95%, the secondary ones from 1 to 20% and trace components when less than 1% (SIMÕES et al., 2017). Generally, plant species from different locations have the same constituents, however, they differ in the percentage of the mixture (ROBBERS et al., 1997).

The chemical composition, aroma and physicochemical characteristics of volatile oils may vary according to the botanical family and organs. These substances can be found in the flowers (roses, orange trees), leaves (lemongrass, bay leaf), fruits (fennel, fennel), seeds (nutmeg), wood (sandalwood, rosewood), stem bark (cinnamon), roots (vetiver) and rhizomes (ginger, turmeric). Even if a volatile oil is extracted from the same organ of a certain species, its composition may be influenced by the vegetative cycle and extrinsic factors, such as seasonality, climatic conditions, temperature, circadian rhythm and others (SIMÕES et al., 2017; ROBBERS et al., 1997).

In vegetables, volatile oils can perform different and important biological and ecological functions, such as protection against herbivores, against water loss and temperature increase, pollinator attraction, communication between individuals of the same species and allelopathic effect. While humans use the volatile oils or even the plants that store these substances as medicines, spices and in the manufacture of cosmetics. The antimicrobial, expectorant and rubefaciente activities are attributed to most volatile oils (SIMÕES et al., 2017).

In addition to volatility and chemical composition, essential oils differ from fixed ones in relation to extraction methods, which can be flowering, distillation, hydrodistillation, water vapor dragging, cold pressing, solvent extraction and supercritical fluid (SIMÕES et al., 2017).

In the literature, the only information we have about the volatile constituents of *Dipteryx alata* are the works of Marques et al. (2015) and Oliveira-Alves et al. (2020). The terpenes and sterols present in the fixed oil obtained from different forms of pressing were identified. There is a decrease in the number of volatile compounds (terpenes) in the fixed oil obtained by pressing with heating of 60°C. The β-caryophyllene, γ-elemene, β- elemen, α-caryophyllene and limonene were identified (MARQUES et al., 2015). These volatile compounds are related to biological activities as antioxidant, anti-inflammatory, antibiotic and antitumor (SIMÕES et al., 2017; ROBBERS et al., 1997).

Oliveira-Alves et al. (2020) identified 32 volatile compounds present in roasted almonds, the majority being hexanal (71.18%), 2.5-dimethyl-pyrazine (9.43%), 3-methyl-1-butanol (3.12%), methylpyrazine (2.07%), D-limomen (1.91%) and nonanal (1.46%).

7 THE BIOLOGICAL POTENTIAL OF BARU

Natural products can have toxic effects that are often unknown to the population. With this, toxicity must be investigated so that its use is considered safe (LIMA, 2014). In this sense, there are several biological assays that can be used to present a scientific proof and ensure the safety of the health of the population. Depending on the purpose of the study, several assays can be used such as Artemia salina, antimicrobial, antifungal and anticholinesterase activities and others.

The lethality test against Artemia salina is widely used in research of natural products (HIROTA et al., 2012), due to its simplicity of handling, speed and low cost (NASCIMENTO et al., 2008).

Artemia salina is a species of marine microcrustacean in the order Anostraca. An adult Artemia measures about 10 mm in length, while cysts have an average diameter of 250 µm and newly hatched nauplii are on average 450 µm long (IGARASHI, 2008). Figure 5 shows the microscopic image of Artemia salina.

Figure 5- Microscopic image of Artemia salina in adulthood.

Source: From the author himself.

It is known as saltwater shrimp and has been an important object of study, because it has high sensitivity to a variety of compounds, a large amount of larvae obtained at hatching and the durability that its eggs present when stored (CEPLEANU, 1993). A characteristic of this test that makes it a viable practice is the similarity of the toxic effects produced by the microcrustacean with those produced by humans (AMARAL; Smith, 2008).

Bacteria are present everywhere and are important to humans and animals, serving as a lining for the skin, mucous membranes and intestinal tract. They can be beneficial or harmful to host organisms (humans, animals, and plants). Generally, they do not bring risk to healthy individuals, due to low virulence. They act in the protection of pathogens and diseases. However, opportunistic bacteria can generate infections in people with weakened organism (SANTOS, 2004; ANVISA, 2004).

Gram-positive drugs such as Staphylococcus aureus and Staphylococcus epidermidis can cause diseases such as respiratory tract infections, skin infections and meningitis (ANVISA, 2004). Gram-negative ones, such as Klebsiella pneumoniae and Escherichia coli are capable of generating enteric and extra-intestinal diseases, such as moderate and severe diarrhea (SOUZA et al., 2016).

As a result of bacterial resistance, the number of researches that seek natural compounds with antimicrobial activities has grown more and more (DEL FIO, 2000). When the compound inhibits bacterial growth, it is considered bacteriostatic, while when it occurs to bacterial destruction, it is termed as bactericide (SCHECHTER; MARANGONI, 1998). Candida albicans and Candida tropicalis are one of the biggest causes of fungal diseases such as urinary infections, onychomycosis, oral candidiasis, vulvovaginal and others. They are pathogens responsible for the high mortality rate of people with compromised immune systems, such as AIDS patients, transplanted or affected by cancer (SANTOS et al., 2018; ZUZA-ALVES et al., 2017; MAHERONNAGHSH et al., 2016; PFALLER; DIEKEMA, 2010). They are one of the pathogens causing candidemia, which is when the fungal infection comes into contact with the bloodstream.

Bacteria, fungi and viruses cause hospital-acquired infections. In Brazil, fungi are responsible for approximately 8% of hospital infections (ANVISA, 2004). Candida albicans is responsible for approximately 40.9% of infections, while Candida tropicalis for 20.9%, Candida parapsilosis for 20.5% and Candida glabrata for 4.9% (NUCCI et al. , 2010). It is observed that Candida albicans is responsible for most fungal diseases, however, in recent years there has been a growth of diseases caused by other Candida species (SANTOS et al., 2018).

Agar diffusion and microdilution to determine the minimum inhibitory concentration (MIC) are the most widely used methods to determine antifungal and antimicrobial activity due to their low cost, simplicity and reliability (OSTROSKY et al., 2008).

The classification of the degree of activity performed by a plant compound may vary according to the literature. Holetz et al. (2002) define strong, moderate, weak and inactivity activity according to values of minimum inhibitory concentration (MIC), minimum bactericidal concentration (CMB) and minimum fungicide concentration (CMF), while Aligians et al. (2001) define strong, moderate and weak activity only based on IMC values, as shown in table 2.

Table 2- Classification of antimicrobial and antifungal activity based on IMC, AMC and CMF values.

Activity	Values of IMC, AMC and CMF (µg/mL) (Holetz *et al*., 2002)	IMC values (µg/mL) (Aligianns *et al*., 2001)
Strong	< 100	< 500
Moderate	100 to 500	600 to 1500
Weak	500 to 1000	> 1600s
Inactive	> 1000	-

Source: Holetz et al., (2002); Aligianns et al., (2001).

In health, obtaining compounds with antimicrobial, antifungal, anticholinesterase, antioxidant, anti-inflammatory and antitumor properties has extreme relevance, considering that the share of the population affected by degenerative diseases of motor and cellular order such as Alzheimer's, neoplasms, some types of infections and even the consequences of aging by exposure to reactive forms of oxygen is growing. This physiological mechanism can lead to the development of Alzheimer's. Alzheimer's is a neurodegenerative, irreversible and progressive disease that causes changes in memory and cognitive abilities (FORLENZA, 2005). One of the causes attributed to Alzheimer's is cholinergic dysfunction, due to the abnormal rate of degradation of acetylcholine by the enzyme acetylcholinesterase (AChE) (BIAZOTTO, 2014; KONRATH, 2011) Anticholinesterase, AChE inhibitors, prolong the degradation of acetylcholine (ACh) and are responsible for providing an increase in the amount of neurotransmitters in the synaptic cleft, delaying the symptoms of Alzheimer's disease (SANTOS and GONSALVES, 2016). The use of baru-based bioproducts for neurodegenerative diseases could be a significant field of research for healthcare.

8 FINAL CONSIDERATIONS

Given the above, most of the references used for this analysis are related to the nutritional potential of baru and its use for other purposes such as logging, for example. Despite being a food in energy, fiber, protein and carbohydrates, it can be consumed pure or added to other preparations such as cakes, cookies and cereal bars, which greatly favors the food industry.

However, the literature also brought the biological properties that make baru and its derivatives such as fixed oil, volatile oil and almond, products of importance for the pharmaceutical area, under the pharmacotechnical and pharmacological aspects.

Thus, the incentive to invest in the production chain of the baru becomes salutary, since this species is native to the Cerrado and responsible for generating income for families that inhabit the Cerrado domains. It is considered a promising species for cultivation, due to its multiple use, establishment of seedlings and high germination rate.

For now, sustainable and rational extractivism contributes to the conservation of the species, to the ecological balance and conservation of the biome.

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