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# Proximate composition, minerals profile, and predominant sugars by ion chromatograph along the physiological development of jabuticaba var. *Pingo de mel*

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**Abstract**

The objective of this study was to characterize jabuticaba fruits for their proximate composition, minerals profile, and predominant sugars during fruit physiological development. The fruits were harvested ten days after anthesis (DAA) until maturity, at intervals of four days between collections. The period between anthesis and maturity was 34 days. An increase in moisture was observed, as for protein and lipids up to 18 DAA, with subsequent reduction until ripening, while an opposite behavior was observed for ash and carbohydrates levels. In general, minerals decreased throughout the fruit development. Regarding the carbohydrates profile, fructose showed the highest concentration, followed by glucose and sucrose, respectively, with an increase during ripening for all sugars. Whereas the sweet taste of fruit is a major factor for both consumption *in natura* and processing, we observed that jabuticaba fruits harvested 34 days after anthesis presented the best results.

**Keywords:** anthesis; fructose; glucose; *Myrciaria* sp.

**Pratical Application:** Studying the physiological development of jabuticaba fruits to determine the optimum harvest point.

## 1 Introduction

Fruits are one of the fastest growing agricultural markets in Brazilian agriculture, and jabuticaba tree (*Myrciaria* sp) stands out among the native species. Jabuticaba fruits are presented in the form of globular berry, smooth skin, with up to 3 cm in diameter, bright green to dark violet depending on the ripening stage, whitish pulp, mucilaginous, bitter-sweet, tasty, often containing one small seed, but may be up to four (Donadio, 2000; Boari Lima et al., 2008). The sweet taste and acidity of jabuticaba fruit is due to sugars, organic acids, and terpenes in its composition (Plagemann et al., 2012).

Among the existing varieties, the *Pingo de Mel* variety stands out, being widely cultivated in the region of Goiás, with fruit production once a year, for three months. However, it is a very perishable fruit, with shelf life of up to three days after harvesting, which hinders its commercialization *in natura*.

Knowledge about the development pattern of a fruit from flowering allows determining the maturity indices, especially regarding the optimum maturity stage for the commercial harvest, and is essential to determine agricultural practices (Coombe, 1976). When the pattern of growth and development of fruit is well known, agricultural practices such as irrigation, application of phytorregulators and pesticides, and bagging of fruits can be carried out effectively at the right time. However, few studies are found in literature about the behavior of the different maturity stages.

Assessing the proximate composition of foods is very important, since it shows the nutritional value and the proportion of components in 100 g of product (edible portion). Given the above, the objective of this study was to characterize the jabuticaba fruits var. *Pingo de Mel* for proximate composition, mineral profile, and free sugars by ion chromatograph over the physiological development.

## 2 Materials and methods

The experiment was performed from September to October 2014, at the *Fazenda & Vinícula Jabuticabal* in New Fatima, district of Hidrolândia-GO (16° 55' 32.35" S, and 49° 21' 39.76" W), 35.6 km from Goiânia-GO. Seventy trees were selected at random, homogenous as to the size and age, and branches were marked at

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the time of anthesis, with different colored wool yarn. The first harvest occurred at ten days after the anthesis, at intervals of four days until 34 DAA (days after the anthesis), when the fruits reached maturity, characterized by the black-violet color of the bark and the beginning of fruit fall, totaling 7 collection points. About 300 g of the jabuticaba fruits var. *Pingo de mel* were collected in the morning at random, among the 70 previously selected trees, and transported to the laboratory. Samples were collected 10, 14, 18, 22, 26, 30 and 34 DAA, being collected 300 g of the fruit each stage of development. Fruits were selected for the presence of defects or pests, and washed in tap water to remove surface dirt. In the days of harvest the fruits were frozen at -18 °C until the time of analysis.

### *2.1 Determinations*

*Proximate composition*

The proximate composition was determined every 8 days. Moisture was determined as described by Association of Association of Official Analytical Chemists (2010), Total nitrogen was determined by Kjeldahl method, considering the conversion factor of 6.25 for crude protein, according to Association of Official Analytical Chemists (2010); Total lipids were determined by the method of Bligh & Dyer (1959); Ash content was determined according to the methodology of Association of Official Analytical Chemists (2010). Calorie values were estimated by the ATWATER coefficients (carbohydrates = 4.0 kcal $g^{-1}$; lipids = 9.0 kcal $g^{-1}$; and protein = 4.0 kcal $g^{-1}$ (Merrill & Watt, 1973).

*Minerals*

The determination of the minerals phosfhorus, calcium, magnesium, potassium, iron, manganese, zinc, and copper was performed by the method of nitroperchloric digestion according to methodology proposed by Malavolta et al. (1997). Results were expressed as mg 100 $g^{-1}$ of fruit.

*Sugar profile*

The concentrations of sucrose, glucose, and fructose were determined by the method described by Metrohn (2015). Ion chromatography system 930 Compact IC Flex (Metrohm, Herisseau, Switzerland) was used, with column Metrosep Carb 1 (150/4.0) and sodium hydroxide as a mobile phase (100 mmol.$L^{-1}$). Samples were diluted in pure water and filtered using 0.45 uM filter. The running conditions were: injection volume 0.25 uL, flow rate 1.0 mL.$min^{-1}$, oven temperature 35 °C, and run time 9 minutes. The results were compared with a calibration curve using standard solutions from 1 and 1000 mg.$L^{-1}$ (glucose and fructose) and 1 to 100 mg.$L^{-1}$ (sucrose).

### *2.2 Statistical analysis*

The experiment was conducted in a completely randomized design (DIC), and the treatments were arranged in a factorial scheme composed by seven harvest points (10, 14, 18, 22, 26, 30 and 34 DAA), except for proximal composition, with four stages (10, 18, 26 and 34 DAA). Variables were submitted to polynomial regression analysis as a function of the harvest season. Sisvar software was used to fit the regression models to the F test at 5% probability to measure the importance of the model. All analyses were carried out in four replicates.

## 3 Results and discussion

The development stage of jabuticaba fruits was 34 days from flowering to harvest, represented by the growth, maturity, and ripening stages. According to Donadio (2000), jabuticaba fruit matures within three weeks after flowering. However, this period can vary according to the variety, climate, soil, temperature, among other factors, and the variety *Pingo de Mel* presented a higher development cycle.

During the 34 days of fruit development, significant differences ($p < 0.05$) were observed for all physicochemical determinations (Table 1). The initial moisture (10 DAA) of jabuticaba fruit was 74.50 g.100 $g^{-1}$ of fruit, with an increase up to 18 DAA, and further decrease to 34 DAA, with moisture content of 80.87 g.100 $g^{-1}$ of fruit (Figure 1). According to Awad (1993), this increase in moisture in the initial stages of fruit development is due to the expansion of cell wall after cell division, followed by influx of water into the vacuole. As a result, there is water accumulation into the cells during pulp development. In contrast, the lower moisture can be due to the transpiration, resulting in loss of turgor of the fruit.

Significant changes were observed for ash content of the fruits during growth and ripening (Figure 2). Until 18 DAA, the values remained stable, followed by a decrease at 26 DAA, with further increase up to 34 DAA. Minerals are essential for fruit metabolism, and mineral levels are dependent on several factors, such as soil fertility, climatic factors, and mainly the ability of the plant to absorb these elements from soil (Chitarra & Chitarra, 2005). Thus, the differences in mineral levels of jabuticaba fruits can be due to climatic variations and availability of mineral elements in the soil during the life cycle of the fruit.

An increase in protein content was observed up to 18 DAA with subsequent reduction to 34 DAA, corroborating the results obtained by Tlili et al. (2014), who studied *Rhus tripartitum* fruit grown in two locations and three maturity stages, and found similar protein behavior. According to Chitarra & Chitarra (2005), the synthesis of nucleic acids and proteins is more pronounced in the early maturation stages, thus justifying the behavior of this macronutrient in jabuticaba fruits. In contrast, the protein reduction in the later stages may be due to its utilization in metabolism processes, including enzymatic activities (Silva, 2009).

Similar behavior was observed for the lipid content when compared to proteins (Figure 2). Silva et al. (2007) evaluated papayas at different maturity stages, and also observed a reduction of lipid content in the pulp and seeds. This fat reduction has been associated with the action of lipoxygenase, which contributes to a reduction of lipid components, since this enzyme has some activity during ripening and senescence of fruit (Ferrie et al., 1994; Hildebrand, 1989; Palyiath & Droillard, 1992). Total carbohydrates were calculated by difference, and an opposite behavior was observed when compared to proteins and lipids, with a reduction up to 18 DAA, followed by an increase to full maturity (Figure 2).

**Table 1**. Mean values and standard deviation of the content moisture (g.100 $g^{-1}$ of fruit), ash (dry basis - g.100 $g^{-1}$ of fruit), potassium (mg.100 $g^{-1}$ of fruit), phosphorus (mg.100 $g^{-1}$ of fruit), calcium (mg.100 $g^{-1}$ of fruit), magnesium (mg.100 $g^{-1}$ of fruit), copper (mg.100 $g^{-1}$ of fruit), iron (mg.100 $g^{-1}$ of fruit), manganese (mg.100 $g^{-1}$ of fruit), zinc (mg.100 $g^{-1}$ of fruit), proteins (dry basis - g.100 $g^{-1}$ of fruit), lipids (dry basis - g.100 $g^{-1}$ of fruit), carbohydrates (dry basis - g.100 $g^{-1}$ of fruit), glucose (g.100 $g^{-1}$ of fruit), fructose (g.100 $g^{-1}$ of fruit) e sucrose (g.100 $g^{-1}$ of fruit) during the physiological development of jabuticaba variety *Pingo de Mel* harvested in the *Fazenda & Vinícula Jabuticabal*, Nova Fatima-GO.

| Analyses | Days after anthesis (DAA) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 10 | 14 | 18 | 22 | 26 | 30 | 34 |
| Moisture | 74.50 ± 1.302 | - | 87.66 ± 0.122 | - | 84.28 ± 0.962 | - | 80.87 ± 0.789 |
| Ash | 3.21 ± 0.147 | - | 3.16 ± 0.133 | - | 2.80 ± 0.226 | - | 3.85 ± 0.076 |
| Potassium | 5818.27 ± 0.001 | 5580.09 ± 0.003 | 7394.72 ± 0.003 | 5861.49 ± 0.002 | 4582.52 ± 0.002 | 4430.92 ± 0.001 | 4059.22 ± 0.001 |
| Phosphorus | 283.49 ± 0.001 | 290.22 ± 0.001 | 250.51 ± 0.002 | 260.51 ± 0.001 | 193.42 ± 0.001 | 176.06 ± 0.002 | 153.38 ± 0.001 |
| Calcium | 239.56 ± 0.001 | 253.12 ± 0.001 | 136.52 ± 0.001 | 165.78 ± 0.001 | 74.39 ± 0.001 | 115.20 ± 0.002 | 110.18 ± 0.001 |
| Magnesium | 106.87 ± 0.002 | 123.68 ± 0.001 | 122.30 ± 0.001 | 115.45 ± 0.002 | 98.20 ± 0.001 | 91.57 ± 0.001 | 86.98 ± 0.001 |
| Copper | 5.90 ± 0.001 | 1.35 ± 0.001 | 9.12 ± 0.001 | 0.56 ± 0.001 | 1.10 ± 0.001 | 0.41 ± 0.002 | 2.06 ± 0.001 |
| Iron | 3.50 ± 0.001 | 2.19 ± 0.002 | 2.19 ± 0.000 | 1.81 ± 0.002 | 1.49 ± 0.001 | 1.03 ± 0.002 | 1.10 ± 0.001 |
| Manganese | 2.85 ± 0.001 | 2.82 ± 0.001 | 1.96 ± 0.001 | 1.48 ± 0.001 | 0.95 ± 0.001 | 0.83 ± 0.001 | 0.87 ± 0.001 |
| Zinc | 0.84 ± 0.002 | 0.74 ± 0.003 | 0.77 ± 0.002 | 0.68 ± 0.002 | 0.67 ± 0.001 | 0.65 ± 0.001 | 0.68 ± 0.002 |
| Proteins | 26.04 ± 0.011 | - | 44.42 ± 2.298 | - | 27.53 ± 3.231 | - | 14.88 ± 1.347 |
| Lipids | 6.53 ± 0.264 | - | 13.89 ± 1.640 | - | 8.74 ± 0.098 | - | 5.11 ± 0.175 |
| Carbohydrates | 64.21 ± 0.379 | - | 38.53 ± 0.814 | - | 60.92 ± 3.123 | - | 76.14 ± 1.482 |
| Glucose | 0.29 ± 0.036 | 1.82 ± 0.099 | 5.02 ± 0.128 | 14.69 ± 0.765 | 16.68 ± 0.169 | 26.03 ± 0.102 | 27.83 ± 1.002 |
| Fructose | 1.60 ± 0.152 | 7.95 ± 0.058 | 11.87 ± 0.274 | 22.48 ± 1.006 | 23.17 ± 0.314 | 33.31 ± 0.683 | 34.98 ± 0.721 |
| Sucrose | 0.52 ± 0.093 | 0.22 ± 0.073 | 1.66 ± 0.396 | 0.25 ± 0.041 | 0.83 ± 0.262 | 3.50 ± 0.044 | 2.65 ± 0.338 |

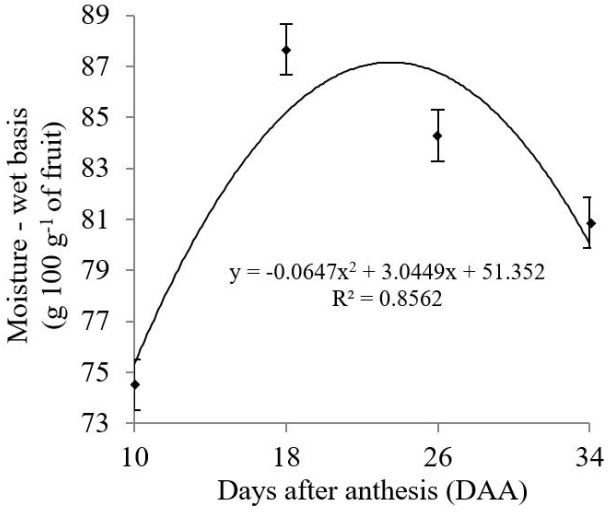


**Figure 1**. Mean values and standard deviation of the moisture content (wet basis) during development stage of jabuticaba variety *Pingo de Mel*, harvested in the *Fazenda & Vinícula Jabuticabal*, Nova Fatima-GO.

The concentration of macro and micro minerals decreased during growth and ripening of the fruits, with the exception of potassium and copper, with a peak at 18 DAA, as shown in Figure 3. According to Galho et al. (2007), this reduction during ripening is due to dilution of these minerals during the development stages.

Potassium stood out among the macro minerals, with values greater than all other minerals throughout the life cycle, which can be explained by Vieira et al. (2010), who reported that potassium along with sucrose is the main component of osmotic phloem sap. Furthermore, potassium is an important regulator of neuromuscular activity, for example, fatigue, weakness, and cramps, and promotion of cell growth (Marques et al., 2010). Phosphorous was the second most abundant mineral in jabuticaba, followed by calcium and magnesium. Lower levels of these macro minerals were found in araca fruits by Galho et al. (2007), with values maximum the 250 mg.100 $g^{-1}$ of potassium, 150 mg.100 $g^{-1}$ of calcium, 30 mg.100 $g^{-1}$ of magnesium and 20 mg.100 $g^{-1}$. Lima et al. (2011) studied the mineral composition of jabuticaba fruits and fractions of two different genotypes, and found that potassium, calcium, and magnesium were in higher concentrations in the fruit peel than in other parts.

Within the universe of trace minerals in jabuticaba fruits (Figure 3), the highest concentration was observed for copper, followed by iron, manganese, and zinc. According to Franco (2003), although copper is a trace element, it is essential in several metabolic functions with iron mobilization for hemoglobin synthesis, besides being a component of many enzymes, including cytochrome C-oxidase, superoxide dismutase, and monoamine oxidase.

Sugar composition is one of the most important parameters for the assessment of fruit quality, since it determines the consumption and the post-harvest storage conditions (Zhu et al., 2013). Sucrose, glucose, and fructose was detected by ion chromatograph in all samples (Figure 4), and fructose was found in higher concentrations, followed by glucose and sucrose, respectively, corroborating Lima et al. (2011) and Silva et al. (2017). Although sucrose is the most common transport sugar in plants, when reaching the non-photosynthetic tissues like fruits, it is degraded into hexoses through different metabolic pathways, aimed at regulation of gene expression and plant development (Ruan et al., 2010; Koch, 1996).

Maximum concentrations of reducing sugars (glucose and fructose) and sucrose were observed at 30 and 34 DAA.

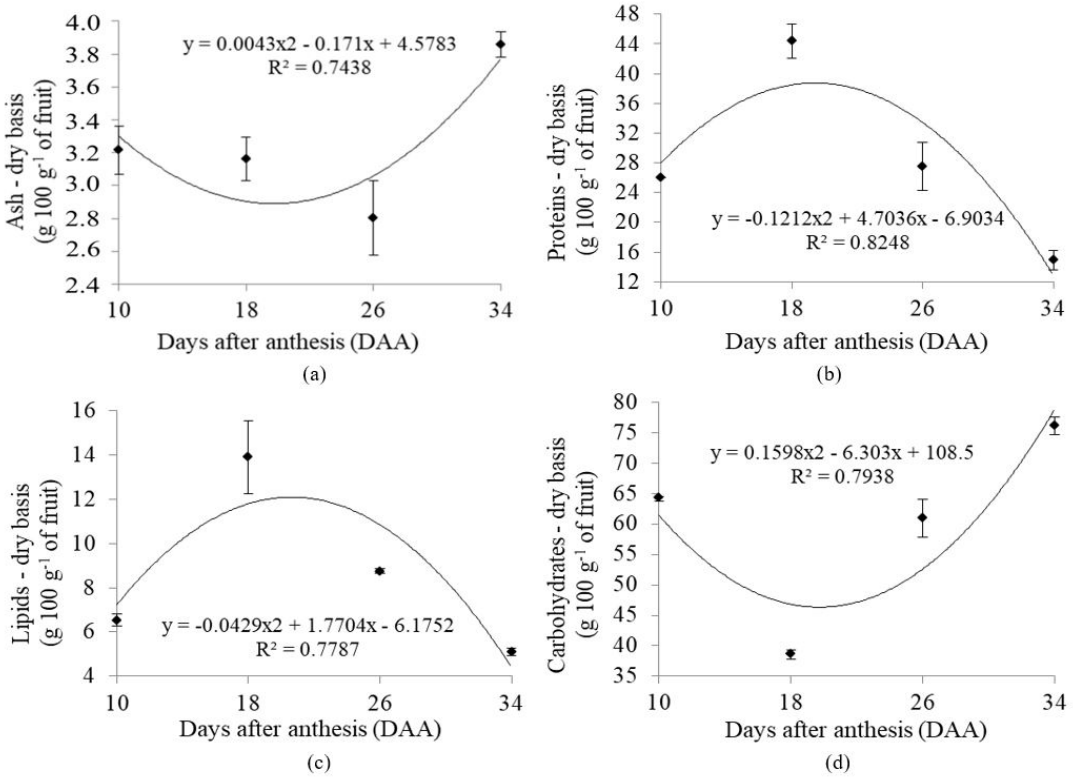


**Figure 2**. Mean values and standard deviation of ash (a), proteins (b), lipids (c), and carbohydrates (d) on a dry basis during the physiological development of jabuticaba variety *Pingo de Mel* harvested in the *Fazenda & Vinícula Jabuticabal*, Nova Fatima-GO.

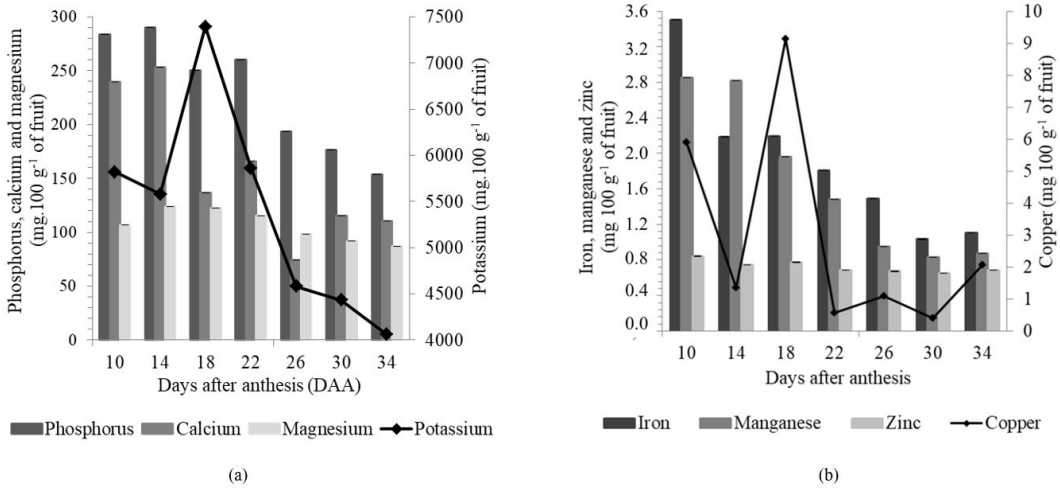


**Figure 3**. Mean values and standard deviation of micro (a) and macro minerals (b) during the physiological development of jabuticaba variety *Pingo de Mel* harvested in the *Fazenda & Vinícula Jabuticabal*, Nova Fatima-GO.

Lima et al. (2011) studied two mature jabuticaba genotypes (*Paulista* and *Sabara*), and found similar values for glucose and sucrose. With respect to jabuticaba *Paulista*, glucose and fructose concentrations were 38.25 ± 4.57 g.100 $g^{-1}$ of fruit and 32.87 ± 3.25 g.100 $g^{-1}$ of fruit, respectively, while the genotype *Sabará* presented 32.96 ± 2.68 g.100 $g^{-1}$ of fruit and 26.40 ± 0.60 g.100 $g^{-1}$ of fruit for fructose and glucose, respectively. However sucrose levels were quite discrepant between genotypes, with values of 9.87 ± 0.27 g.100 $g^{-1}$ of fruit and 11.69 ± 0.21 g.100 $g^{-1}$ of fruit for *Paulista* and *Sabara*, respectively, probably due to weather conditions and preparation of samples for analysis.

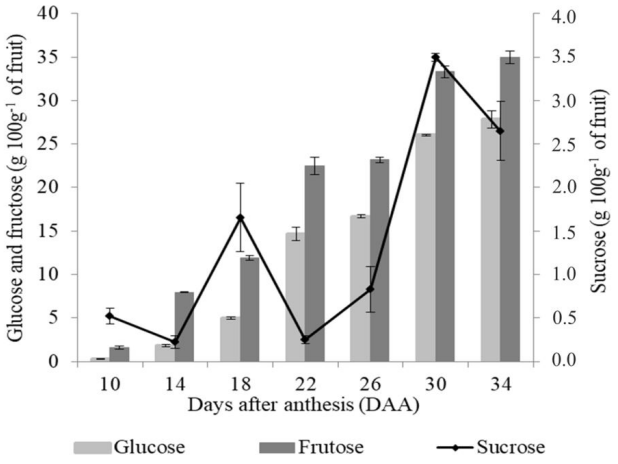


**Figure 4**. Mean values and standard deviation of glucose, fructose, and sucrose during the physiological development of jabuticaba variety *Pingo de Mel* harvested in the *Fazenda & Vinícula Jabuticabal*, Nova Fatima-GO.

## 4 Conclusion

The jabuticaba fruits variety *Pingo de Mel* exhibited a decrease in moisture, proteins, lipids, and minerals during the physiological development, while an increase in sugar levels was observed up to 34 DAA. Whereas the sweet taste of fruit is a major factor for both consumption *in natura* and processing, we observed that jabuticaba fruits harvested 34 days after anthesis presented the best results.

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