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Nutritional and antioxidant quality of Jackfruit (*Artocarpus heterophyllus*)

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Abstract

Artocarpus includes about 50 – 60 species, distributed throughout the Indo-Malayan region and Southeastern China. The species *Artocarpus heterophyllus*, known as Jackfruit, is widely consumed in Asia. Currently, it is cultivated in México, in the states of Nayarit and Michoacan. However, it is little consumed in Mexico, perhaps due to the lack of knowledge about its nutritional, nutraceutical and medicinal properties. The aim of this study was to assess the nutritional, mineral and antioxidant compounds (total phenolic compounds, flavonoids, vitamin C, and carotenes) found in jackfruit pulp. Chemical analyses showed the carbohydrates, fiber, lipids and proteins contained in the fruit pulp, as well as the minerals (Ca, K, Mg, and Fe) and antioxidant compounds. The antioxidant capacity of the fruit correlated with β-carotene of 244.84 UI and vitamin C of 6.8 mg·100 g^{-1} fresh weight (f.w.). The flavonoid content was 9.86 mg quercetin equivalents·100 g^{-1} f.w. The content of total phenolic compounds was 58.44 mg gallic acid equivalents·100 g^{-1} f.w. Jackfruit could be considered a product with nutritional quality due to carbohydrate and mineral content, as well as nutraceutical quality, derived from its levels of antioxidant compounds.

Keywords: Antioxidants, β-carotene, total phenolic compounds, vitamin C

Introduction

Artocarpus (Moraceae) includes approximately 50 species of tropical trees native to Southeast Asia and the Pacific region; most of them produce edible fruits (Nelson, 2005). *A. altilis* (Parkins) Fosb., *A. heterophyllus* Lam., *A. integer* (Thunb) Merr y *A. odoratissimus* Blanco (Love & Paull, 2011) are the four most important species. *Artocarpus heterophyllus*, known as jackfruit, is the most consumed species, mainly in Asia. Vazhacharickal et al. (2015) report Malaysia and India as center of origin of jackfruit, widely distributed around the world (Myanmar, Ceylon, China, Philippines, Australia, Kenya and Uganda). In the Americas, it is not widely cultivated, being limited mainly to Brazil, some Caribbean islands (Jamaica and Bahamas) and Florida (Vazhacharickal et al., 2015). Currently, it is also cultivated in Central America and recently in the states of Nayarit and Michoacán, Mexico for breeding and fruit production purposes.

Jackfruit was introduced in the 1960s in Mexico and its production has increased mainly to be exported to the United States (Luna-Esquivel, G., Alejo-Santiago, G., Ramírez-Guerrero, L. G., & Arévalo-Galarza., L. (2013). In 2017, Mexico had a production of 22 192 t of jackfruit, with a yield of 17.85 t·ha^{-1} and a total area allocated to the cultivation of 1 509.70 ha. The area destinated to this crop and its production have increased in the last 10 years, both at the national and state level, with Nayarit as the main producer (SIAP, 2017).

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Jackfruit, whose name comes from the Greek words *artos* (bread) and *carpos* (fruit) (Lum, T. F., Kothagoda, N., Rao, A. N., Goh, C. J., & Wee, Y. C., 2009), is a highly nutritious fruit. The edible portion is rich in carbohydrates, protein, fatty acids (palmitic, oleic, stearic, linoleic, lauric, arachidonic acid), fiber, calcium, phosphorus, iron, vitamin A, and thiamine (Adeleke & Abiodun, 2010; Swami & Kalse, 2018). The bracts of ripe fruits have high nutritional value, 100 g, in ripe state, contain 20.0–37.0 g·100 g^{-1} calcium and 191-407 g·100 g^{-1} potassium (Lengbiye et al., 2017). The fruit is consumed fresh or cooked, processed (sweets, popsicles, ice cream, jam) (Ihediohanma, N. C., Okafor, D. C. & Adeboye, A. S., 2014; Luna-Esquivel, G., et al., 2013) and as a snack (Molla, M., Nasrin, T., Islam, M., & Bhuyan, M. A .J., 2008). The seeds are consumed cooked or roasted (Vazhacharickal et al., 2015), while in dried form they are used to make sweets or consumed boiled as appetizer (Love & Paull, 2011). They are a source of starch, protein (jacalin combined with lectin) (Dasaesamoh & Seechamnanturakit, 2014), minerals and fiber. The bark has pigments (flavones), triterpene compounds and tannins; sapogenins, cycloartenol, β-sitosterol and tannins have been found in the leaves and stems. The root contains β-sitosterol, ursolic acid, betulinic acid and some flavones (Adeleke & Abiodun, 2010; Ranasinghe, R. A. S. N., Maduwanthi, S. D. T., & Marapana, R. A. U. J., 2019; Vazhacharickal et al., 2015), metabolites that could explain the different medicinal uses of the leaves and bark, whose use has been reported for the ancillary treatment of anemia, asthma, dermatosis, diarrhea, catarrh, and as an expectorant (Lengbiye et al., 2017; Vazhacharickal et al., 2015). It also has analgesic and immunomodulatory properties (Prakash, O., Kumar, R., Mishra, A., & Gupta, R., 2009), and hypoglycemic and hypolipidemic effects have been tested on mice (Omar, H. S., El-Beshbishy, H. A., Moussa, Z., Taha, K. F., & Singab, A. N., 2011). The seeds also exhibit some medicinal properties, such as anticancer, antihypertensive, antioxidant, antifungal, and antimicrobial properties (Gupta, D., Mann, S., Sood, A. & Gupta, R. K., 2011; Shanmugapriya, K., Saravana, P. S., Payal, H., Mohammed, S. P., & Binnie, W., 2011).

Jackfruit has been reported to contain various antioxidant metabolites (flavonoids, carotenoids, among others). The common denominator of most nutraceuticals is their antioxidant capacity, developed with metabolites that counteract free radicals responsible for causing membrane oxidation and DNA damage. These radicals promote diseases such as cancer, cardiovascular problems and aging (Perez, 2006; Shahidi, 2012). However, the concentrations of these metabolites can be modified by biotic and abiotic factors. Therefore, the nutritional and nutraceutical study of jackfruit grown in Mexico justify the present study. The objective was to evaluate nutritional, mineral, and antioxidant components, specifically total phenolic compounds, flavonoids, vitamin C, and carotenoids in jackfruit pulp.

Materials and Methods

Collecting plant material

Jackfruit was randomly collected without physical damage and free of pests, at physiological maturity, from "Rancho el Vergel", located near the commune "Mesas de Enandio", located in the municipality of Heroica Zitácuaro, in the state of Michoacán de Ocampo, Mexico, with geographical coordinates 100° 27' 30" W and 19° 20' 20" N. This region is located within the Transversal Volcanic Axis, with deep soils of volcanic origin and pH between 5.6 and 6.7. Its climate is predominantly temperate sub-humid with summer rainfall (Cw) (Marlés Magre et al., 2015).

Sample processing

The fruit was taken to the Biochemistry Laboratory of the Department of Agroindustrial Engineering, Universidad Autónoma Chapingo, Mexico. The fruit at consumption maturity (soft consistency, strong characteristic odor and low latex content), after harvest, was carefully washed to remove organic matter residues and dirt. The fruit was cut in half using a knife to extract the pulp. The skin and seeds were separated to determine the weight. Pulp samples were frozen by immersion using liquid nitrogen for analysis of phytochemical compounds (chemical variables) and antioxidant activity. Then, the samples were stored in Ziploc® airtight seal bags in a freezer at -20 ± 2 °C.

Quantification of Minerals

The methodology described by Alcántara & Sandoval (1999) was followed to determine Ca, Cu, Fe, K, Mg and Zn. A total of 0.5 g of dehydrated jackfruit samples, weighed separately, were subjected to wet digestion with a diacid mixture H_2SO_4:$HClO_4$, 4:1 v/v) and hydrogen peroxide. measurements were carried outin an induction coupled plasma atomic emission spectrophotometer (ICP-AES, Liberty II model, Varian, USA). Nitrogen content was determined using the colorimeter method by micro-kjeldahl digestion described by Pearson (1976).

Proximal analysis

The methods of AOAC (2000) were followed to determine moisture, ash, protein, crude fiber, fat and carbohydrate contents.

Moisture and Ash Analysis

Moisture content was quantified by the difference between the initial and final weight of a representative sample subjected to a temperature of 60 °C for 12 h in an oven with hot air convection. Ash content (%) was determined by burning the sample and then calcining it in a muffle at 60 °C for 6 h.

Determination of Carbohydrates

Total carbohydrate content was calculated by difference using the formula % TC = 100 - (% P + % L + % C + % F + % H); where TC = total carbohydrate, P = protein, L = lipid, A = ash, F = fiber, H = moisture (Audu & Aremu, 2011). The results were expressed as percentage in fresh weight.

Lipid determination

The Soxhlet method was applied, using anhydrous petroleum ether as solvent. The following equation was used to estimate lipids: [% crude fat = (M_2-M_1/ M)]100]; where: M_2 = weight (g) of the container plus sample; M_1 = weight (g) of the container with sample without fat; M=sample weight (g).

Determination of Crude Fiber

Crude fiber content was determined based on the mass loss corresponding to the incineration of the organic residue resulting from digestion with sulfuric acid and sodium hydroxide solutions under specific conditions. Crude fiber content was determined by the following formula: [% crude fiber (dry weight without fat) = ((P_s - P_p) - (P_c – P_{cp}))/M]100]; where: P_s = g of dry residue; P_p = g of filter paper; P_{cp} = g paper ash; M = g of sample; P_c = g of ash.

Determination of Total Protein

It was determined using the Kjeldahl method by adding concentrated sulfuric acid as a catalyst for the digestion of the sample. Nitrogen present in the plant tissue was converted into ammonium sulfate. Concentrated sodium hydroxide was added to release the ammonia, which was distilled into titrated hydrochloric acid for quantification by titration. Protein content was calculated according to the following equation: [% protein = V_* N_* 0.014$_*$100 /m], where: V = volume (mL) of hydrochloric acid used in titration; N = normality of hydrochloric acid 0.1; m = sample weight (g); 0.014 = milliequivalents of nitrogen.

Quantification of antioxidant compounds

Methanolic extract preparation

For each replicate, 1 g of fresh jackfruit sample (ground) was weighed and diluted in 10 mL of 80 % v/v methanol. The mixture was placed for 20 min in a sonicator (Cole-Parmer, model 08892-21, USA). Then, each sample was placed in the dark at room temperature for 24 h and centrifuged for 10 min at 1 409 × g to be used for the quantification of phytochemical compounds (Wojdylo, A., Oszmianski, J., & Czemerys, R. (2007).

Quantification of total phenolic compounds

A total of 0.5 mL of methanolic extract were taken. This extract was previously prepared by adding 0.5 mL of Folin-Ciocalteu reagent (0.2 N) and 4 mL of a 0.7 M Na_2CO_3 solution. The mixture was stirred in a vortex and incubated at room temperature and in the dark for 2 h. Finally, absorbance reading was taken with a spectrophotometer (Genesys 10s Thermoscientific, Florida, USA) at a wavelength of 765 nm. Concentration was calculated from a standard curve prepared based on gallic acid (0 - 400 $mg{\cdot}L^{-1}$; $y = 0.0068\ x + 0.0054$; $R^2 = 0.997$) as reference. Total content of phenolic compounds in methanolic extract was expressed as mg gallic acid equivalents per 100 g fresh weight (mg EAG$\cdot$100 g^{-1} f.w.) according to the modified method of Waterman & Mole (1994).

Quantification of flavonoids

Flavonoid content was quantified according to the method proposed by Chang et al. (2002). A total of 1.5 mL of 95 % (v/v) ethanol, 0.1 mL of 10 % (w/v) $AlCl_3$ solution, 0.1 mL of 1 M CH_3COOK solution, and 2.8 mL of distilled water were added to 0.5 mL of the supernatant of the previously prepared methanolic extract. The mixture was incubated for 30 min. Absorbance was read in a Genesys 10s spectrophotometer (Thermoscientific, Florida, USA) at a wavelength of 415 nm. For flavonoid quantification, a standard curve ($y = 0.0057x - 0.0098$; $R^2 = 0.9978$) was performed based on the flavone quercetin as reference. The results were expressed in mg quercetin equivalents per 100 g fresh weight (mg EQ$\cdot$100 g^{-1} p.f.).

Quantification of ascorbic acid

Ascorbic acid content was determined with the method described by Dürüst et al. (1997). Extracts were prepared by placing 0.3 g of each sample in 10 mL oxalic acid (0.4 % w/v deionized water), the mixture was sonicated for 20 min at room temperature and filtered. The following stock solutions were used: oxalic acid solution (0.4 w/v % in deionized water), ascorbic acid solution (1 000 ppm in oxalic acid solution); acetate buffer solution (300 g sodium anhydrous acetate + 700 mL deionized water + 1 000 mL glacial acetic acid), and DCIP solution (12 mg of 2,6-dichlorophenol-indophenol disodium salt in 1 000 mL deionized water). The method consisted of adjusting the spectrophotometer to zero, using deionized water, then mixing: 1 mL of oxalic acid solution + 1 mL of acetate buffer solution (sodium acetate/acetic acid) and 8 mL of DCIP solution and absorbance at 520 nm after 15 s was measured; this value was recorded as L_1 for all measurements. The instrument was reset to zero for each sample by mixing 1 mL of ascorbic acid solution (different concentrations) or extract of the solution with sample with 1 mL of acetate buffer solution and 8 mL of DCIP

solution, which led to the L2 value. The difference [L_1 L_2] was obtained and an ascorbic acid calibration curve was prepared (y = 0.0042x + 0.0011; R^2 = 0.9971). The results were expressed in milligram ascorbic acid equivalents (EA) per 100 g fresh weight sample (mg EA·100^{-1} f.w.).

Quantification of β-carotene

The method described by Nagata and Yamashita (1992) was followed to determine β-carotene. A total of 1 g of jackfruit pulp was weighed, which was shaken for 1 min with 10 mL of acetone-hexane mixed in a ratio (4:6). Later, the mixture was filtered with Whatman No. 4 paper. Absorbance of the filtrate was measured at 453, 505, 645 and 663 nm. The amount of β-carotene was calculated according to the following equation: [β-carotene (mg·100 mL^{-1}) = 0.216 A_{663} - 1.220 A_{645} - 0.304 A_{505} + 0.452 A_{453}]. The experiment was carried out in triplicate. The results were evaluated as mean (± standard deviation) and expressed as mg of β-carotene in 100 f.w.

Quantification of antioxidant capacity

ABTS method

The methodology described by Re et al. (1999) was used in this study. A total of 6.61 mg of $K_2S_2O_4$ were added to a 10 mL solution of 7 mM concentration of the $ABTS^{\cdot+}$ radical (2,2'-azino-bis(3-ethylbenzothiazolin)-6-sulfonic acid); the mixture was incubated at room temperature and in the dark for 16 h. The necessary volume of anhydrous ethanol was added to 1 mL of the $ABTS^{\cdot}$ solution until an absorbance of 0.7 ± 0.1 was obtained at a wavelength measured in a Genesys 10s spectrophotometer (Thermoscientific, Florida, USA) at 734 nm (maximum concentration of $ABTS^{\cdot+}$ radical formed). To 1 mL of the $ABTS^{\cdot+}$ solution was added 10 µL of the solution to be analyzed; the mixture was vortexed and incubated in a water bath at 30 °C in the dark for 7 min. Absorbance was measured in spectrophotometer at a wavelength of 734 nm continuously at minute one and minute seven after adding methanolic extract to the $ABTS^{\cdot+}$ solution. A standard Trolox curve (y = -0.2885 x + 0.7483; R^2 = 0.9966) was used as reference. Results were expressed as mg Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) equivalents per 100 g fresh weight (mg ET·100 g^{-1} f.w.). To calculate the percentage inhibition of the free radical $ABTS^{\cdot+}$, the following formula was used: [% inhibition = $[(A_0 - A_F)/A_0]$*100]; where: A_0 is initial absorbance of the free radical at 734 nm and A_F is final absorbance of the reaction with the sample.

Data analysis

A Pearson correlation analysis was carried out using the R program (Project for Statistical Computing). All results were expressed as mean value (± standard deviation).

Results and Discussion

Mineral analysis

Mg, Cu and Zn contents were higher than those reported for jackfruit pulp grown in other countries (Table 1). The different contents of some elements reported by other authors could be due to edaphoclimatic and genetic factors, as reported in other plant products. Rodriguez (2019) highlighted the importance of consuming foods rich in minerals, essential for cellular metabolic reactions in the organism, which control the composition of extra- and intracellular fluids and are part of enzymes and hormones, essential molecules for life. Mg is an activator of many enzyme systems and maintains electrical potential in the nervous system. K is usually found together with Ca in the body and both contribute to blood formation and provide body support structure (Al Alawi, A. M., Majoni, S. W., & Falhammar, H., 2018). Therefore, these elements, which were the most abundant in jackfruit, are involved in several vital functions of the human body.

Proximate analysis

The proximate content of jackfruit pulp is shown in Table 1 and can be compared with results obtained in other studies on *A. heterophyllus* fruit pulp grown in the United States, Brazil, Bangladesh, Pakistan and India. However, few studies report the proximate and mineral analysis of jackfruit pulp grown in the state of Michoacán, Mexico.

The carbohydrate content found in jackfruit exceeded that reported for apples (10.4 g·100^{-1} g f.w.) (US-Agriculture Department [USDA] (2002), an important variable that influences consumer preferences. The present study didn't quantify the contents of reducing and non-reducing sugars present in the pulp, those are important because they define the sweetness of the fruit as a quality attribute. In contrast, jackfruit showed lower concentrations (1.4 g·100 g^{-1} f.w.) of crude fiber, in relation to that documented in apple (2.4 g·100 g^{-1} f.w.) by the USDA (2002), an abundant and characteristic metabolite of apple. In this regard, non-digestible carbohydrates include insoluble fiber and others (resistant starch and non-digestible oligosaccharides), although these are fermented during digestion and are associated with a low glycemic response, low cholesterol levels and a decrease in risk factors for colon cancer (Reynoso-Camacho, R., Ramos-Gómez, M., & Loarca-Pina, G., 2006).

The protein content found in jackfruit was low, similar to other fruits such as apple (0.26 g ·100 g^{-1} f.w.) (USDA, 2002) and lipid content in jackfruit pulp was higher (1.61 g·100 g^{-1} f.w.) than that reported by Crane and Balerdi (2000). The content of fatty acid profile present in jackfruit is unknown, although it is a precursor of polyunsaturated fatty acids such as linoleic acid, eicosapentaenoic acid, do-

Table 1. Proximate and mineral analysis of jackfruit (*A. heterophyllus*) pulp from the present study and that reported by other authors.

Mineral composition*						
K	Ca	Mg	Fe	Cu	Zn	Reference
120.04 ± 2.27	21.98 ± 1.09	42.82 ± 1.56	0.767 ± 0.02	0.219 ± 0.00	0.287 ± 0.01	Current publication
191 - 407	20.0 -37.0	27.0	0.5 -1.1	ND	ND	Haq, 2006[a]
287–323	30.0 - 73.2	ND	0.4 - 1.9	ND	ND	Swami & Kalse, 2018[b]
234.0	11.0	40.0	0.4	0.09	0.2	Taco, 2011
Proximate analysis **						
Moisture	**Ash**	**Crude fiber**	**Protein**	**Carbohydrates**	**Lipids**	**Reference**
75.07 ± 0.11	1.17 ± 0.17	1.45 ± 0.15	0.25 ± 0.02	20.51 ± 0.18	1.61 ± 0.10	Current publication
73.0	ND	1.6	1.5	24.0	0.3	Crane & Balerdi (2000)
72 - 94.0	0.87 - 0.9	1.0 - 1.5	1.2 - 1.9	16.0 - 25.4	0.1 - 0.4	Haq (2006)[a]
76.2 - 85.2	0.9	2.6 - 3.6	2.0 - 2.6	9.4 - 11.5	0.1 - 0.6	Swami & Kalse (2018)[b]
79.62 - 84.44	0.7 - 1.11	0.51 - 0.90	0.57 - 0.97	18.36 - 25.18[c]	ND	Goswami et al. (2011)
62.39 - 76.62	0.13 - 1.97	ND	ND	ND	ND	Ibrahim et al. (2014)
75.10	0.80	2.40	1.40	22.5	0.3	Mendonça et al. (2011)

ND: not determined. [a] Fruit at consumption maturity, [b] young fruit and [c] corresponds to the sum of total simple sugars and starch. Values expressed are the mean of five replicates ± standard deviation. *mg·100 g^{-1} f.w.; **g·100 g^{-1} f.w.

cosahexaenoic acid, which are important plant metabolites for human consumption and can be found mainly in flaxseeds, oilseeds (walnuts and hazelnuts) and some fruits.

Antioxidant compounds

Phenolic compounds contents

The concentration of total phenolic compounds in jackfruit (58.44 mg EAG·100 g^{-1} f.w.) was similar (46 mg EAG·100 g^{1} f.w pulp) to that reported by Jagtap, U. B., Panaskar, S. N., & Bapat, V. A. (2010). Grapes were considered as a reference in the comparison of the content of phenolic compounds, due to high content of these metabolites. In this regard, those found in this study were used to compare that jackfruit pulp showed a concentration within the limits to those reported by Yilmaz et al. (2015) in the pulp of different white and red grape varieties (*Vitis vinfera*) (10 - 60 and 17 - 75 mg EAG·100 g^{1} f.w., respectively). Phenolic compounds are bioactive compounds found in plant-based food, with different beneficial effects on health. These metabolites constitute one of the largest phytochemical groups present in plants, standing out for their antioxidant and therapeutic properties (Chew et al., 2011; Soto-Hernández, M., Palma-Tenango, M., & Garcia-Mateos, M. del R., 2017). There is a huge structural variety of biologically active phenolic compounds containing one or more aromatic rings that are natural components of plant foods and provide, to a large extent, taste, color, and texture for these foods (Soto-Hernández et al., 2017).

Quantification of flavonoids

Jackfruit pulp had a low flavonoid content (Table 2) compared to fruits of higher content. In this regard, Marinova, D., Ribarova, F. and Atanassova, M. (2005), conducted a study where they analyzed a total of 20 fruits for the determination of these metabolites, including plum (*Prunus domestica*) and blueberry (*Vaccinium myrtilus*), which are fruits with higher content of these antioxidant compounds (136.2 and 190.3 mg EQ·100 g^{-1} in f.w., respectively), compared to the levels found in jackfruit pulp of this study. Jagtap et al. (2010) reported a concentration of 120 mg equivalents of the flavonoid rutin in 100 g f.w. pulp in jackfruit, which was not quantified in this study. Variations in levels and profile of some metabolites among varieties are due to edaphoclimatic conditions, agronomic management, and methods of analysis, as reported in other fruits and vegetables (Reynoso-Camacho et al., 2006). Variation has been attributed to the manipulation of plant material, which can generate stress situations in some species, altering plant physiology and stimulating responses that cause

Table 2. Concentration of antioxidant compounds in jackfruit (*A. heterophyllus*) pulp.

Total phenolic compounds GAE	Flavonoids EG	β – Carotene*	β–Carotene IU	Vitamine C AAE	Antioxidant Activity**	Antioxidant activity % Inhibition
58.44 ± 4.23	9.86 ±1.24	1.47± 0.07	244.84 ±12.0	6.8 ± 0.5	55.61 ± 5.22	8.16 ± 0.81

* GAE = Gallic acid equivalents·100 g^{-1} f.w.; QE Quercetin equivalents·100 g^{-1} f.w.; **mg·100 g^{-1} f.w.; IU = International retinol units; AAE = Ascorbic acid equivalents·100 g^{-1} in f.w.; *mg Trolox equivalents·100 $^{-1}$ f.w. Values expressed are the mean of five replicates ± standard deviation.

accumulation, mainly of phenolic compounds (Pirovani et al., 2009).

Quantification of vitamin C

Crane & Balerdi (2000) reported an approximate value of 6.7 mg vitamin C·100 g^{-1} f.w. pulp. The vitamin C content in the pulp determined by the method of Dürüst, N., Sümengen, D., & Dürüst, Y. (1997) was 6.8 ± 0.5 mg ascorbic acid equivalents·100 g^{-1} f.w., which was similar to the values found in this study (Table 2). The USDA (2002) reported that for every 100 g^{-1} f.w. of lemon juice (*Citrus lemon*) 53 mg of vitamin C are provided, being eight times higher in lemon than in jackfruit.

Quantification of β–Carotene

Jackfruit pulp at the edible stage of maturity shows a coloration ranging from light yellow to a deep orange color, depending on the fruit variety (Punan et al., 2000) and that hue in coloration is mainly due to the presence of carotenoids (Ranasinghe et al., 2019). In the results obtained by Crane & Balerdi (2000) and Chandrika, U. G., Jansz, E. R., and Warnasuriya, N. D. (2005), the total carotenoid content found was 297 and 470 IU (International Retinol Unit), respectively, which were higher than the present study. Chandrika, U. G., et al. (2005), in the quantification of these pigments in retinol equivalents (RE) per 100 g f.w. pulp, found lower levels in jackfruit grown in Sir Lanka (141.6 ER·100 g f.w), than in papaya (152 – 280 ER·100 g f.w.). However, the levels of these values were lower than those of jackfruit grown in Michoacan observed in the present study (Table 2). Despite the lower concentrations of this fruit compared to those of papaya, jackfruit could be considered an alternative source of these pigments. The observed differences in the β–carotene values found in jackfruit could not only be explained due to the place of origin, but also due to the degree of fruit ripening. Ong et al. (2006) reported that the value of the hue angle of jackfruit pulp increased significantly with ripening, attributed to an increase in the content of carotenes in the pulp of ripe fruit, which was also mentioned by Selvaraj and Pal (1989), who reported an increase of 200 % in the concentration of these pigments, depending on the ripening stage of the fruit.

Inhibitory quantification of free radicals ABTS

The antioxidant activity, determined by the ABTS method in fresh jackfruit pulp extract, had a low percentage in the inhibition of free radicals, in comparison with other fruits (Table 2) of higher antioxidant quality. Prior et al. (1998) reported an approximate concentration of mg ET·100 g^{-1} f.w. in blueberry (*Vaccinium myrtillus*). Wang, H., Cao, G. and Prior, R. L. (1996) reported high free radical inhibitory capacity in strawberry (375.5 mg ET·100 g^{-1} f.w.), which are also fruits with high antioxidant potential. Currently, no studies of antioxidant capacity in jackfruit with ABTS methodology have been reported. Results show a low antioxidant activity, despite its moderate content of carotenes,

Table 3. Pearson correlation of antioxidant components and antioxidant activity of jackfruit pulp.

	CFT	Flavonoids	β–Carotene	Vitamine C	AA*	% Inhibition
CFT	1.000	0.2037	-0.6123	-0.2873	-0.0363	-0.0363
Flavonoids		1.000	-0.7397	-0.8512	-0.45465	-0.45461
β–Carotene			1.000	0.9195	0.55993	0.55997
Vitamin C				1.000	0.7432	0.7433
AA					1.000	1.000
% Inhibition						1.000

CFT = total phenolic compounds; AA = antioxidant activity; % inhibition. = % inhibition of free radicals (*antioxidant activity).

vitamin C and flavonoids. On the other hand, Pearson's correlation coefficient consisted in associating antioxidant activity with the antioxidant components evaluated in the fruit. Table 3 shows a high positive correlation of antioxidant activity with vitamin C and β-carotene contents. The results are in agreement with that reported by Gardner, White, McPail, Duthie (2000), who observed a high correlation between antioxidant activity and vitamin C. The antioxidant activity of carotenes has been reported in relation to their lipophilic characteristics, which could explain the antioxidant role in the protection of cell membranes and lipoproteins against oxidative damage (Sies & Stahl, 1995).

Conclusions

The proximate analysis of the pulp showed high levels of carbohydrates, low levels of lipids and moderate fiber content. Jackfruit pulp was shown to have high concentrations of potassium, calcium, magnesium, iron and zinc. The fruit was also found to be a good source of vitamin C. It also showed a high content of β-carotene. Antioxidant activity, according to Pearson's correlation, is synergistically associated with β-carotene and vitamin C contents. Further studies are recommended in relation to shelf life, profile of metabolites and postharvest life, mainly of fruit grown in Mexico.

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