CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

EFFECTS OF THE POST-FLOWERING TIMELINES ON THE NUTRITION, PHYTOCHEMICAL COMPOUNDS AND ANTIOXIDANT ACTIVITIES OF JACKFRUIT (*ARTOCARPUS HETEROPHYLLUS* LAM.)

Chi Khang Van[1,✉], Thanh Ngan Truong[2], Thi Tuyet Lan Le[2], Trinh Thi Nhu Hang Nguyen[1], Binh An Pham[1], Cong Kha Nguyen[3]

[1]*Institute of Applied Technology and Sustainable Development, Nguyen Tat Thanh University, Ho Chi Minh City 700000, Vietnam*

[2]*Department of Natural Products, Faculty of Chemical Engineering and Food Technology, Nong Lam University, Ho Chi Minh City 700000, Vietnam*

[3] *Institute of Food and Biotechnology, Can Tho University, Can Tho City, Vietnam*

✉ *vckhang@ntt.edu.vn*

https://doi.org/10.34302/crpjfst/2024.16.3.1

Article history:
Received:
January 28th, 2024
Accepted:
August 1st, 2024

Keywords:
Jackfruit;
Artocarpus heterophyllus;
Lam;
Nutrition;
Phytochemical;
Antioxidant activities.

ABSTRACT

The nutrition, phytochemical compounds, and antioxidant activity of jackfruit (Artocarpus heterophyllus Lam.) are affected by the post-flowering timelines. Therefore, selection of appropriate harvest timing is an important factor to reduce the post-harvest losses. The objective of this study was to determine the nutritional, chemical, and antioxidant activity changes of jackfruit parts (e.g. pulp, fiber, and seed) collected from the top, middle, and bottom of the fruit at 3 different times after flowering (100 days, 110 days, and 120 days). Jackfruit parts were extracted from ethanol solvent before analysis. Results have shown that the seeds contained a high amount of starch (10.6±0.07% - 14.86±0.03%), while the sugar, total acidity (TA) and total soluble solids (TSS) are absent. The antioxidant activity was determined by three free radical scavenging methods ABTS·+, DPPH·, and phosphomolybdenum (TAC) method. At 120 days at the top of jackfruit, the highest total sugar and TSS content were 79.48 ± 2.8 (mg/gDM) and 25.25 ± 0.35% in jackfruit pulp, respectively, the highest TA content was 0.36. ± 0.02% in jackfruit fiber, the highest protein, ash and fat content in jackfruit seeds were obtained at 4.43 ± 0.01%, 1.12 ± 0.03%, 3.22 ± 0.01%, respectively. The highest carbohydrate content and pH in the jackfruit pulp at the end of the fruit at 110 days were 26.18%, 6.63 ± 0.03, respectively. The highest fiber content in jackfruit seeds at the end of the fruit at 100 days was 19.7±0.12.

1.Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the genus Artocarpus, family Moraceae (the Mulberry family, Moraceae), and is commonly grown in Vietnam. It is native to the Western Ghats of India, Malaysia, Southeast Asia and the islands of the Pacific Ocean (Prakash et al., 2009). Jackfruit tree is an important component in the livelihoods of farmers in many eco-geographic regions around the world. The tree is the main source of food and essential products for the poor. The fruit, leaves, and barks of jackfruit tree have been extensively used in traditional medicine due to their anticarcinogenic, antimicrobial, antifungal, anti-inflammatory, wound healing, and hypoglycemic effects. Jackfruit contains a wide range of nutrients such as flavonoids, phenolic acids, organic acids, carotenoids, stilbene, triterpenes, and sterols, especially prenylflavonoids (Baliga et al., 2011; de Faria et al., 2009). In addition, vitamins and minerals, especially riboflavin (B_2), potassium, and phosphorus are present in the jackfruit pulp and fiber (Moke et al., 2017). Due to several health-promoting benefits, it is necessary to analyze the phytochemical components of jackfruit. The chemical compounds and antioxidant activities have been previously reported. The chemical compounds and antioxidant activities have been previously reported. Chavez-Santiago et al., 2022 analyze the polyphenolic content, as well as the antioxidant and antifungal properties of jackfruit extract on phytopathogenic fungi. In 2020, Adan et al. studied the phytochemical composition and essential mineral profile of the unutilized parts of jackfruit, which gave rise to the significant antioxidant and antimicrobial potentials. In 2021, Juan et al. evaluated the content of nutrients, minerals, and antioxidants (e.g. synthetic phenolics, flavonoids, vitamin C, and carotenes) found in jackfruit pulp. With an attempt to produce jackfruit of high quality to meet the high demand of consumers in the world, it is essential to select the optimal harvest ripeness. This study provides an essential insights in the effects of the harvesting stage on the content of nutrients, phytochemical

compounds and antioxidant activity of the jackfruit by-products, thereby diversifying the valuable products range of jackfruit, reducing the risk of environmental pollution, and promoting the development of the food industry towards the sustainable development of the agricultural production industry. Therefore, we chose jackfruit to analyze the chemical composition, and antioxidant activity of jackfruitpulp, fiber, and seed located at the top, middle and bottom of the fruit after 100 days, 110 days, and 120 days of flowering. The knowledge of the phytochemical composition of these fruit parts would provide a cost-effective alternative source of phytochemicals and essential minerals that exhibits high biological activity for application to other fields in the future.

2.Materials and methods

2.1.Materials

Jackfruit (Artocarpus heterophyllus Lam.) was obtained at commercial farms located in Can Tho City, Viet Nam (10.0452° N, 105.7469° E). The harvested fruit were immediately transported to the laboratory.

Jackfruit takes about 20 days for the flowers to successfully undergo the anthesis process, followed by about 95 – 100 days to mature for harvesting. Three batches of fruits were harvested after100, 110, and 120 days of flowering. The dimensions and mass of the whole fruit were measured, then washed thoroughly with water and the top, middle and bottom portions were equally sectioned. The peel, and core of the fruit were removed. Each part was evaluated for several physical characteristics such as shape, mass, dimensions, and distribution ratio of the fruit parts. Finally, the samples from each fruit part were randomly selected for chemical analysis. Chemical analyses were carried out in duplicate for each batch.

2.2.Analysis methods

2.2.1. Qualitative methods

Phytochemical groups, including alkaloids, flavonoids, carbohydrates, amino acids, organic acids, phenolic and tannins, proteins, saponins were determined follwing a method by Phung, (2007).

2.2.2. Determination of nutrition

Moisture content (expressed as a percentage by weight on a wet basis) was determined using the standard official methods of analysis (AOAC 1990). This involved drying to a constant weight at 105 ^{o}C at calculated moisture as the loss in weight of the dried samples. A total of 1 g of oven-dried sample was subjected to determination of protein content in sample following the method described by Hema et al. (2016). Total nitrogen content in samples was determined by the modified Kjeldahl method, involving H_2SO_4 salicylic acid digestion, distillation and titration (Bremner & Keeney, 1965). The fat content was measured using a partial drying of a weighed sample prior to Soxhlet extraction (Nielsen & Carpenter, 2017). Dry ash contents of all jackfruit samples were determined following standard procedures (AOAC, 1977). Crude fiber is determined following the standard procedures (AOAC, 1982). The starch content of jackfruit seed was measured by the polarimetry method, as described by Subroto (2020).

The total sugar content, pH, tritable acidcity (TA), and total soluble solids (TSS) was measured in the jackfruit fiber and pulp. The total sugar was determined as previously described by Hema (2015). Total soluble solids (TSS) content was measured following TCVN 4417 – 87 by using ATAGO digital refractometer (Atago Co.Ltd , Tokyo, Japan). The titratable acidity (TA) and pH measurement method followed the procedure of Rangana (1979) with some modifications.

2.2.3. Quantitative analysis

Determination of total carotenoid content (TCC)

TCC determination followed the method described by Wellburn (1994) [15]. The absorbance spectra of chlorophyll a, chlorophyll b and total carotenoids were measured at 664 nm, 647 nm and 470 nm, respectively.

Determination of total polyphenol content (TPC)

TPC was measured by Folin-Ciocalteu assay, as previously described in Jagtap (2010), followed by absorbance measurement at 765 nm using Shimadzu UV160A UV-Vis spectrophotometer (Kyoto, Japan).

Determination of total flavonoid content (TFC)

TFC was determined following the procedure described by Park et al. (2008) [17] with some modifications, followed by absorbance measurement at 510 nn.

2.2.4. Antioxidant activity methods

Determination of total acidity capacity (TAC)

TAC was determined by using the phosphomolydenum method as previously described by Saha et al. (1970) with slight modifications. The reagent solution was prepared by mixing 0.6 M H_2SO_4 (95-97%) with 4 mM ammonium molybdate (98%) and 28 mM sodium dihydrogen phosphate using a glass rod. 3 mL of the prepared reagent was taken into separate test tubes and added with 0.3 mL of extract samples at various concentrations (100 - 500 μg/mL). Methanol was used as negative control (blank). All test tubes subjected to incubation in an oven at 95 °C for 90 min, then allowed to cool down at room temperature. The absorbance was measured at 695 nm using UV-Vis spectrophotometer (Shimadzu Corp., Kyoto, Japan). Investigation of free radical scavenging activity by DPPH· method.

The inhibitory activity of the samples against DPPH free radicals followed the previously described procedure by Sharma et al.

(2009). A total of 1.5 mL of 0.1 mM DPPH solution was mixed with 0.5 mL of sample solution of the diluted concentrations, followed by 30-min incubation without light and absorbance measurement at 517 nm. The antioxidant activity of the sample is indicated by 50% antioxidant efficiency (IC_{50}) (Miliauskas et al., 2004).

Investigation of free radical scavenging activity by ABTS·⁺ method

The antioxidant activity was determined by the ABTS free radical scavenging assay described by Nikolaos et al. (2004). ABTS·+ free radical solution was prepared by adding 10 mL of 7.4 mM ABTS·⁺ solution to 10 mL of 2.6 mM $K_2S_2O_8$ solution, then incubating for 24 h in the dark and adjusting the solution absorbance at 734 nm to 1.1 ± 0.02. 5 g of sample was diluted on 100 mL and 0.5 mL of which was drawn and placed into the test tube. Ethanol (99.5%) was used as the control. Then, 1.5 mL of ABTS·⁺ solution ($OD_{517\ nm}$ = 1.1±0.02) was added into the test tube and leave in the dark for 30 min. Absorbance measurement was measured at 734 nm using Shimadzu UV-Vis spectrophotometer (Japan). Vitamin C (ascorbic acid) was used as the standard for comparison.

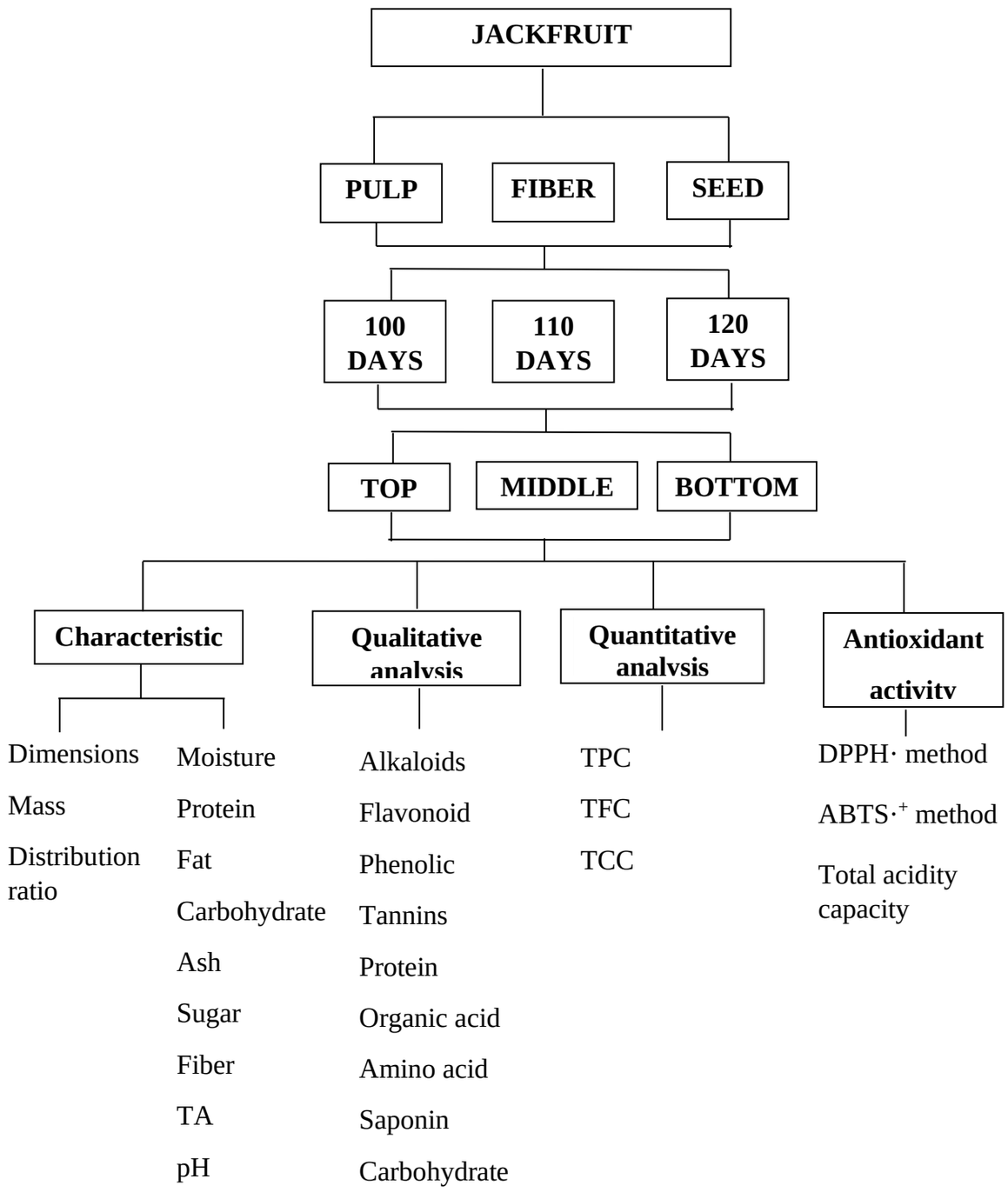

Figure 1. Schematic diagram of the experiment

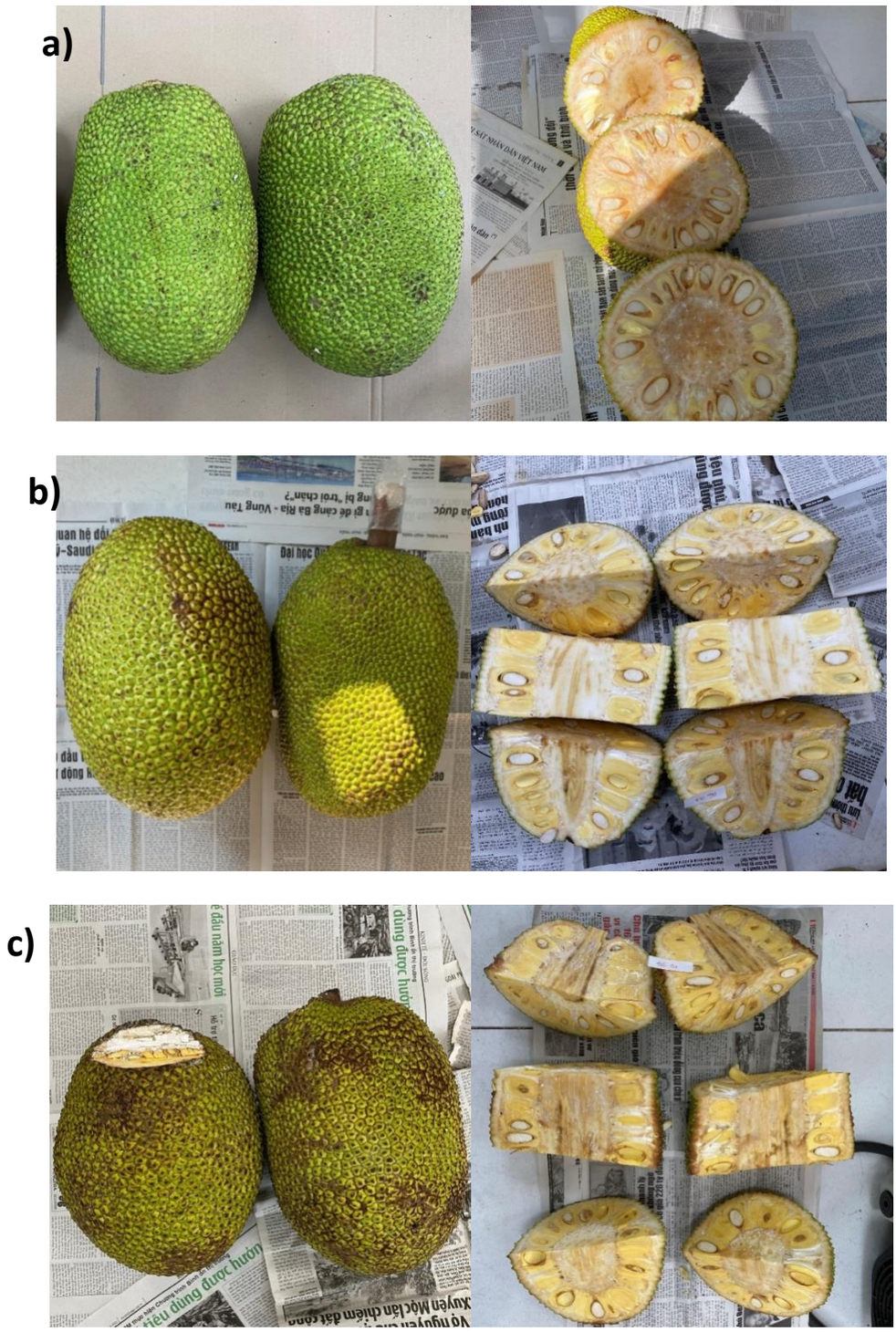

Figure 2. Jackfruit in the different days after flowering
(a) 100 days, (b) 110 days, (c) 120 days

3. Results and discussion

3.1. Determination of chemical compounds in jackfruit

The phytochemical profile of jackfruit pulp, fiber, and seed at different post-flowering timelines (i.e. 100 days, 110 days and 120 days) were shown in Table 1. Results have shown that alkaloids, flavonoids, phenolics, tannins, proteins, organic acids, carbohydrates and saponins are present in all jackfruit parts. This preliminary chemical quantification is very useful in finding the chemical components in plant materials and the quantitative part can be performed in the next indicators. Alkaloids are a large group of naturally occurring organic compounds that contain a nitrogen atom or atom in their structure and are widely used in pharmaceuticals and medicine because of their antibaterial properties (Omulokoli et al., 1997). Flavonoids and tannins are phenolic compounds, a major class of compounds that act as major antioxidants or free radical scavengers (Bhandary et al., 2012). These compounds were detected in the extract of jackfruit pulp with ethanol as a solvent, so it can be demonstrated

that jackfruit has strong antioxidant capacity. Tannins are recognized to inhibit the growth of many molds, yeasts, bacteria and viruses (Hegde et al., 2012). Secondary metabolites and other chemical constituents have been reported in the pulp. For example, saponins have antihypertensive and heart failure properties. The presence of saponins in jackfruit pulp may play a role in cardioprotective potential (Olaleye, 2007). Bhandary et al., (2012) also had a study comparing extracts from two different solvents, ethanol and methanol, to qualitatively identify chemical compounds. As a result, ethanol solvents have better extraction capacity and recover many natural antioxidants that can be applied in medicine, promoting supplements for the food industry. The ethanol extract was also selected for this study. Besides, this preliminary chemical quantification is very useful in analyzing the chemical components in plant materials, thereby performing subsequent quantification of other indicators.

Table 1. Phytochemical compounds of jackfruit portions in the different days after flowering

Portions	**Number of day** / **Compounds**	**100**	**110**	**120**
Pulp	Alkaloids	+	++	+++
	Flavonoids	+ ++	+++	+ +
	Phenolic & Tannin	+ +	++	+
	The protein	+	++	+++
	Amino Acids	+	++	+++
	Organic Acids	+	++	+++
	Carbohydrates	++	+	+
	Saponins	++	+++	+++
Fiber	Alkaloids	+	++	+++
	Flavonoids	+	++	+++
	Phenolic & Tannin	++	+ +	+
	The protein	+	++	++
	Amino Acids	+	++	+++
	Organic Acids	+	++	+++
	Carbohydrates	+ +	+	+
	Saponins	+	+	+
Seed	Alkaloids	+	+	+
	Flavonoids	+	+	+
	Phenolic & Tannin	++	+ +	+
	The protein	+	++	++
	Amino Acids	+	++	+++
	Organic Acids	+	++	++
	Carbohydrates	+ +	+	+
	Saponins	+	++	++

Table 1 describes the presence of compounds in jackfruit parts, including the pulp, fiber, seed at different post-flowering timelines 100 days, 110 days and 120 days. The phytochemical compounds include alkaloids, flavonoids, phenolics, tannins, proteins, organic acids, carbohydrates and saponins are all exist in jackfruit parts. This preliminary chemical quantification is very useful in finding the chemical components in plant materials and the

quantitative part can be performed in the next indicators. Alkaloids are a large group of naturally occurring organic compounds that contain a nitrogen atom or atom in their structure and are widely used in pharmaceuticals and medicine because of their antibaterial properties (Omulokoli et al., 1997). Flavonoids and tannins are phenolic compounds, a major class of compounds that act as major antioxidants or free radical scavengers (Bhandary et al., 2012). These compounds were detected in the extract of jackfruit pulp with ethanol as a solvent, so it can be demonstrated that jackfruit has strong antioxidant capacity. Tannins are recognized to inhibit the growth of many molds, yeasts, bacteria and viruses (Madhuri et al., 2012). Secondary metabolites and other chemical constituents have been reported in the pulp. For example, saponins have antihypertensive and heart failure properties. The presence of saponins in jackfruit pulp may play a role in cardioprotective potential (Tolulope, 2007). Bhandary et al. (2012) also had a study comparing extracts from two different solvents, ethanol and methanol, to qualitatively identify chemical compounds. As a result, ethanol solvents have better extraction capacity and recover many natural antioxidants that can be applied in medicine, promoting supplements for the food industry. The ethanol extract was also selected for this study. Besides, this preliminary chemical quantification is very useful in finding the chemical components in plant materials, from which the quantification of the next indicators can be performed.

3.2.Evaluation of the characteristics of jackfruit

3.2.1.Physical characteristics

Table 2. Physical characteristics of jackfruit at different the post-flowering timelines

The post-flowering timelines / **Indicators**		**100**	**110**	**120**
Shape		Oblong	Oblong	Oblong
Dimensions (cm)	**Length**	35	36	30
	Width	24.5	21.5	23.5
Weight (kg)		8.3	8	8.5
Outside color		Light green	Dark green	Dark green, black spots, and streaks appear
Inside color		Light yellow	Light yellow	Yellow
Aroma		No scent	Light scent	Clear scent
Taste		No taste	Light sweetness	Clear sweetness

Table 2 describes the appearance and morphological characteristics of jackfruits harvested at different post-flowering timelines (100 days, 110 days, and 120 days). The jackfruits generally have the same weight, size and color to evaluate the next indicators. These fruits are generally oblong or pear-shaped with thick green peel. The outer color and aroma increased in the post-flowering timelines. The fruit colour changes from yellowish green to yellow due to the conversion of chlorophylls, anthocyanins, and carotenoids like pigments during ripening (Ranasinghe et al., 2019). Ong et al. (2006) have shown an increase in the color of the jackfruit at days 1, 3, 5, and 6 after harvest. The strong aroma is due to the presence of aromatic compounds that are esters in the fruit (Ong et al., 2006). Sword et al. (1978) have confirmed that isopentyl isovalerate was particularly dominant in jackfruit. The taste of fruits is effected by the TSS:TA ratio (Krüger et al., 2012). Kruger et al. (2012) reported that fruit flavor is mainly determined by total acid (TA) and total soluble matter (TSS) content. Saxena et al. (2011) also reported that jackfruit had TSS greater than 25°brix and TA could be titrated

0.3% suitable for consumer taste. As for dimension and mass, the fruits selected above have a weight of 6 - 8 kg and a length of 30 - 36 cm, generally not too much difference in days. The average weight of jackfruit ranges from 2 to 20 kg, some fruits reaching up to 50 kg have been published previously (Ranasinghe et al., 2019). The differences in shape, size and weight are due to factors such as variety, soil, fertilizers, weather, crops, cultivation and storage.

Table 3. Mass of jackfruit parts as percentages of total weight at different the post-flowering timelines

Jackfruit part weights (%)			
	100 days	**110 days**	**120 days**
Pulp	26.54	30.50	27.69
Fiber	16.05	12.50	17.69
Seed	14.81	13.25	14.62
Peel	17.28	25.00	16.92
The other	22.22	18.75	23.08

Table 3 describes the weight of jackfruit parts as percentages of total weight, including peel, fiber, pulp, seed, and the other at different the post-flowering timelines. According to the results, jackfruit pulp had the highest distribution rate in 100 days, 110 days and 120 days at 26.54%, 30.5% and 27.69%, respectively. Besides, the weight of fiber, seed, peel, and other parts fluctuated from 12.5% to 17.69%, from 13.25% to 14.81%, from 16.92% to 25% and from 18.75% to 23.08% respectively. The means followed by the different superscript letters in the same row within the column of each individual portion are significantly different ($p < 0.05$ by Duncan's multiple range test).

3.2.2.Nutritional characteristics

3.2.2.1.Moisture

Moisture is an important parameter affecting the quality and appearance of fruit, and the post-flowering timelines and portions significantly affect moisture content ($p<0.05$). In general, the moisture content tended to increase gradually on different days of ripening, yet decrease slightly at the top, middle, and bottom parts. Similar results were alo reported by Ong et al. (2006). This can be explained by the fact that the ripening process of the jackfruit proceeds from the top to the bottom, so the first ripening part contained higher moisture than the remaining. The highest moisture content was found in the fiber (from 72.87 ± 0.3% to 88.52 ± 0.22%), followed by the pulp (from 72.23 ± 0.06% to 79.54±0.08%), and seed (from 50.96 ± 0.71% to 69.87 ± 0.25%).

This result of the pulp was similar to the study by Goswami et al. (2011) (from 79.62% to 84.44%). However, the obtained results were different from Ranasinghe's study, which was from 70.94 to 89.21% (Ranasinghe & Marapana, 2019). The differences can be attributed to the differences in internal factors (e.g. genus, and varieties) and external factors (e.g. environment, and cultivation) that affected the tested subjects. ANOVA results showed that the fruit parts, portions and the post-flowering timelines significantly affect moisture content at 95% confidence level ($p<0.05$).

3.2.2.2.Fat

The fat contents of pulp, fiber, and seed tended to increase as the fruits ripened, yet decreasing from the top to the bottom part of the fruit. This change could be explained based on the ripening process of jackfruit The seed had the highest fat content (from 0.44 ± 0.01 to 3.22 ± 0.01%), followed by the pulp (from 0.37 ± 0.01 - 1.52 ± 0.06%) and fiber (from 0.3224 ± 0.09 to 2.2498 ± 0.03%). The fat content of the pulp tended to increase as the ripening proceeded, which was similar to the results of Shamla et al. (2019). In addition, ANOVA results also showed that the fruit parts, portions and the post-flowering timelines significantly affected fat content ($p<0.05$).

3.2.2.3.Protein

Similar to the fat content, the protein content was also significantly affected by the post-flowering timelines and fruit parts ($p<0.05$). The fiber had the lowest value, as compared to the pulp and seed. The protein values of pulp, fiber and seed were reported to increase from 0.48± 0.12 to 1.22 ± 0.02%, 0.81 ± 0.01 to 1.11 ± 0.02% and 3.95 ± 0.014 to 4.44 ± 0.01%, respectively. This value of the pulp is similar to the study of Goswami et al. (2011). Sabahelkhier et al. (2010) reported that the albumin, globulin and protein content increased proportionally with the mature stage in pineapple.

3.2.2.4.Ash

The ash content of the pulp, fiber and seed were 0.61 ± 0.03 - 0.97 ± 0.03%, 0.67 ± 0.03 - 0.88 ± 0.03%, and 0.78 ± 0.02 - 1.12 ± 0.03%, respectively (Table 4).

Table 4. Nutritional characteristics change at different days after flowering in different portions of jackfruit parts

		Top			Middle			Bottom		
		100 days	**110 days**	**120 days**	**100 days**	**110 days**	**120 days**	**100 days**	**110 days**	**120 days**
Pulp	**Moisture (%)**	73.65^{cdh}±0.04	75.14^{ceh}±0.02	79.54^{cfh}±0.00	73.19^{bdh}±0.01	73.65^{beh}±0.04	78.47^{bfh}±0.06	72.41^{adh}±0.08	72.23^{aeh}±0.08	74.11^{afh}±0.02
	Sugar (mg/gDM)	15.87^{cdg}±2.04	39.17^{ceg}±1.18	79.48^{cfg}±2.8	16.77^{bdg}±0.77	35.42^{beg}±1.77	76.82^{bfg}±0.05	16.50^{adg}±0.01	33.06^{aeg}±0.01	75.93^{afg}±0.06
	Protein (%)	0.65^{cdg}±0.1	1.1^{ceg}±0.03	1.22^{cfg}±0.02	0.6^{bdg}±0.06	0.98^{beg}±0.05	1.19^{bfg} ±0.05	0.48^{adg}±0.12	0.82^{aeg}±0.04	1.05^{afg}±0.03
	Ash (%)	0.67^{cdh}±0.03	0.87^{ceh}±0.02	0.97^{cfh}±0.03	0.66^{bdh}±0.02	0.82^{beh}±0.03	0.93^{bfh}±0.03	0.61^{adh}±0.03	0.78^{aeh}±0.02	0.92^{afh}±0.02
	Fat (%)	0.28^{cdh}±0.04	0.76^{ceh}±0.11	2.34^{cfh}±0.06	0.26^{bdh}±0.06	0.67^{beh}±0.07	2.24^{bfh}±0.17	0.32^{adh}±0.09	0.50^{aeh}±0.09	2.25^{afh}±0.03
	Fiber (%)	10.18^{adh}±0.22	8.89^{afh}±0.15	7.93^{aeh} ±0 .03	11.42^{bdh}±0.13	9.36^{bfh}±0.07	8.15^{beh}±0.04	12.14^{cdh}±0.06	9.96^{cfh}±0.05	8.23^{ceh}±0.1
	Carbohydrate (%)	24.76	22.14	15.93	25.29	23.88	17.17	26.18	25.67	21.67
	TA (%)	0.11^{cdg}±0.02	0.19^{ceg}±0.01	0.23^{cfg}±0.02	0.09^{bdg}±0.01	0.16^{beg}±0.01	0.19^{bfg}±0.01	0.08^{adg}±0.01	0.15^{aeg}±0.01	0.18^{afg}±0.01
	pH	6.08^{afh}±0.04	5.73^{aeh}±0.01	5.50^{adh}±0.02	6.52^{bfh}±0.02	5.95^{beh}±0.04	5.55^{bdh}±0.03	6.63^{cfh}±0.03	5.93^{ceh}±0.02	5.60^{cdh}±0.02
	TSS (%)	6.55^{cdh}±0.07	14.00^{ceh}±0.00	25.25^{cfh}±0.35	5.38^{bdh}±0.07	12.85^{beh}±0.49	23.75^{bfh}±1.06	4.70^{adh}±0.14	11.90^{aeh}±0.14	21.70^{afh}±0.42
Fiber	**Moisture (%)**	74.49^{cdi}±0.31	79.16^{cei}±0.24	88.52^{cfi}±0.22	73.64^{bdi}±0.27	78.48^{bei}±0.33	87.17^{bfi}±0.34	72.87^{adi}±0.3	76.22^{aei}±0.21	85.41^{afi}±0.13
	Sugar (mg/gDM)	14.28^{cdh}±1.27	16.77^{ceh}±0.77	27.92^{cfh}±0.59	13.02^{bdh}±0.00	16.5^{beh}±0.39	24.07^{bfh}±0.8	12.23^{adh}±0.38	15.04^{aeh}±0.57	21^{afh}±1.17
	Protein (%)	0.87^{xdh}±0.01	0.99^{ceh}±0.02	1.11^{cfh}±0.02	0.84^{bdh}±0.01	0.95^{beh}±0.02	1.06^{bfh}±0.02	0.81^{adh}±0.01	0.91^{aeh}±0.01	1.02^{afh}±0.02
	Ash (%)	0.68^{cdg}±0.02	0.77^{ceg}±0.03	0.88^{cfg}±0.03	0.68^{bdg}±0.02	0.77^{beg}±0.028	0.88^{bfg}±0.03	0.67^{adg}±0.03	0.76^{aeg}±0.03	0.87^{aeg}±0.02
	Fat (%)	0.48^{cdg}±0.10	0.86^{ceg}±0.00	1.52^{cfg}±0.06	0.48^{bdg}±0.01	0.86^{beg}±0.00	1.52^{bfg}±0.06	0.37^{adg}±0.01	0.69^{aeg}±0.02	1.39^{afg}±0.04
	Fiber (%)	9.79^{adg}±0.05	7.61^{afg}±0.14	6.40^{aeg}±0.15	10.84^{bdg}±0.00	7.55^{bfg}±0.14	7.07^{beg}±0.03	10.8^{cdg}±0.21	7.57^{cfg}±0.06	7.07^{ceg}±0.03
	Carbohydrate (%)	23.48	18.23	7.98	24.48	19.12	9.52	24.48	19.12	9.52
	TA (%)	0.15^{cdh}±0.01	0.26^{ceh}±0.04	0.36^{cfh}±0.02	0.13^{bdh}±0.01	0.20^{beh}±0.01	0.34^{bfh}±0.02	0.10^{adh}±0.01	0.17^{aeh}±0.02	0.29^{afh}±0.01
	pH	5.59^{afg}±0.04	5.30^{aeg}±0.02	4.98^{adg}±0.02	5.66^{bfg}±0.03	5.34^{beg}±0.02	5.18^{bhg}±0.02	5.77^{cfg}±0.02	5.39^{ceg}±0.04	5.23^{cdg}±0.04
	TSS (%)	5.52^{cdg}±0.25	8.2^{ceg}±0.28	17.50^{cfg}±0.14	4.75^{bdg}±0.49	8.20^{beg}±0.28	16.30^{bfg}±0.42	3.95^{adg}±0.07	6.80^{aeg}±0.28	11.60^{afg}±0.28
Seed	**Moisture (%)**	54.49cdg±0.20	62.39ceg±0.12	69.87cfg±0.25	54.66^{bdg}±0.55	61.07^{beg}±0.24	69.45^{bfg}±0.20	63.05^{adg}±0.21	59.84^{aeg}±0.87	50.96^{afg}±0.71
	Protein (%)	3.98^{cdi}±0.01	4.19^{cei}±0.01	4.43^{cfi}±0.01	3.97^{bdi}±0.01	4.19^{bei}±0.01	4.43^{bfi}±0.00	3.95^{adi}±0.01	4.18^{aei}±0.00	4.43^{afi}±0.01
	Ash (%)	0.83^{cdi}±0.03	0.99^{cei}±0.02	1.12^{cfi}±0.03	0.8^{bdi}±0.02	0.97^{bei}±0.02	1.1^{bfi}±0.03	0.78^{adi}±0.02	0.95^{aei}±0.02	1.02^{afi}±0.02
	Fat (%)	0.57^{cdi}±0.00	2.47^{cei}±0.00	3.22^{cfi}±0.01	0.45^{bdi}±0.01	1.84^{bei}±0.03	2.62^{bfi}±0.07	0.44^{adi}±0.01	1.61^{aei}±0.04	2.61^{afi}±0.04
	Fiber (%)	17.97^{adi}±0.21	15.21^{afi}±0.21	2.861^{aei}±0.02	18.11^{bdi}±0.09	15.23^{bfi}±0.04	2.93^{bei}±0.01	19.7^{cdi}±0.12	15.45^{cfi}±0.07	3.02^{cei}±0.09
	Carbohydrate (%)	20.99	17.2	11.68	21.6	19.36	13.38	22.43	21.04	17.83
	Starch (%)	10.6^{ad}±0.07	15.01^{af}±0.02	14.02^{ae}±0.00	11.1^{bd}±0.07	15.4^{bf}±0.02	14.75^{be}±0.00	11.38^{cd}±0.10	15.71^{cf}±0.06	14.86^{ce}±0.03

The means followed by the different superscript letters in the same row within the column of each individual portion are significantly different ($p < 0.05$

The ash content of jackfruit samples followed a similar trend with the protein and fat contents, which increased as the fruit ripened and decreased from the top to the bottom part of jackfruit.This result was similar to the report of by Shamla et al. (2019), in which prolonging ripening time would increase the ash content from 0.59 ± 0.02% to 1.86 ± 0.06%. ANOVA results showed that the fruit parts, portions and the ripening time of the fruit significantly affected the ash content ($p<0.05$).

3.2.2.5.Fiber

In contrast to the contents of fat, protein and ash, the fiber content tended to decrease from 100 to 120 days after flowering, while increasing from the top to the bottom part of jackfruit. The fiber content of the pulp, fiber, and seed were from 7.93 ± 0 .03 to 12.14 ± 0.06%, from 6.30 ± 0.12 to 10.90 ± 0.07%, from 2.861 ± 0.02 to 19.70 ± 0.12%respectively. However, this result is different from the study of Shamla et al. (2019), which reported that the fiber content of the pulp was recorded from 3.97 ± 0.03% to 0.96 ± 0.10%. This difference could be due to several factors such as breed, environment, and preservation. ANOVA results showed that parts, portions and the post-flowering timelines significantly affect fiber content at 95% confidence level ($p<0.05$).

3.2.2.6.Carbohydrate

Similar to the conclusion of fiber content, total carbohydrate content also tended to decrease gradually at the different post-flowering timeline and increase in the different portions, that due to the maturation of fruit. The highest value was recorded in the pulp that were to be 15.93 – 26.18%, the fiber and the seed had values from 7.98 to 24.48% and 11.68 to 22.43% respectively. This result is similar to the report of Shamla et al. (2019) that recorded the carbohydrate value from 18.37±0.26% to 61.34±0.09%.

3.2.2.7.Starch

Total starch content was only in the seed. Starch was measured lowest at the beginning of 100 days (10.6±0.07%) and highest at the end of 120 days (14.86±0.03%). There is a tendency to gradually increase at 100 and 110 days then decrease at 120 days. The reason is jackfruit seeds are not fully developed at 100 days, leading to lowest starch content. At 110 – 120 days, jackfruit seeds convert starch into sugar, so the slight decrease in starch content. The results obtained were different from previous studies, including jackfruit seed starch (26.13%), corn starch (22.20%) and potato starch (25.2%) (Alvani et al., 2011; Tulyathan et al., 2002). ANOVA results showed that parts, portions and the post-flowering timelines significantly affect starch content ($p<0.05$).

3.2.2.8.Sugar

Table 4 shows the sugar content of the pulp and the fiber that was ranged from 15.87 to 79.54 mg/g DM and 12.23 to 27.92 mg/g DM respectively. The pulp had the value was higher than the fiber, but there was none in the seed. The sweetness of fruit is largely dependent on the amount of sugar that is inversely proportional to the acidity. Therefore, the sugar content is increase that usually imparts sweetness to the fruit, which means decreasing acidity by decreasing in organic acid and phenol content. The total sugar content of jackfruit parts also tended to increase gradually at the different timelines and decreasing at the top, middle, and bottom. This trend was also reported by Ong et al. (2006) and Ranasinghe & Marapana (2019). ANOVA results showed that parts, portions and the post-flowering timelines significantly affect total sugar content at 95% confidence level ($p<0.05$).

3.2.2.9. pH and total acidity (TA)

Table 4 shows the pH and total acid (TA) values of jackfruit parts (pulp, fiber, seed) at the portions (top, middle, bottom) and the post-flowering timelines (100, 110 and 120 days). They had an opposite trends: the pH values of pulp, fiber decrease from 6.63±0.03 to 5.50±0.02, 5.77±0.02 to 4.98±0.02 respectively; the TA values of pulp, fiber increase from 0.10±0.01 to 0.36±0.02, 0.08±0.01 to 0.23±0.02% respectively. This trend was similar to the results of Ong et al. (2006) that had pH values were highest in unripe jackfruit and significantly decreased in all parts of the fruit (top, middle, bottom) while TA increased significantly, fluctuating in the range of 0.3-0.9%. The increase in acidity during ripening can be attributed to formation of acid by degradation of polysaccharides and oxidation of reducing sugars or by breakdown of pectic substances and uronic acid (Ranasinghe & Marapana, 2019). The results of ANOVA analysis showed that parts, portions and the post-flowering timelines significantly affected on the acidity and pH at the 95% confidence level ($p<0.05$).

3.2.2.10.Total soluble solids

The highest TSS values of the pulp, fiber were reported at the top of 120 days and the lowest values were at the bottom of 100 days jackfruit after flowering (4.70±0.14-25.25±0.35% and 3.95±0.07-17.50±0.14%) That means the TSS was tended to increase in the post-flowering timlines and decrease at the portions. The increase in TSS during ripening may be due to the conversion of starch into sugar (Deepthi, 2017; Shamsudin et al., 2009). The recorded value of pulp is similar to the study of Ong et al. (2006), from 1.33±0.52% to 20±1.26%. Several studies have shown that TSS content of guava (Deepthi, 2017; Mercado-Silva et al., 1998) and sweet peppers (Tadesse et al., 2002) also had a similar trend during the ripening process. ANOVA results showed that the fruit parts, portions and the post-flowering timelines significantly affect TSS at 95% confidence level ($p<0.05$).

3.3.Quantification of chemical components in jackfruit parts

3.3.1.TCC

TCC plays an important role in determining the characteristic yellow color of all fruits, particularly in jackfruit. As shown in Table 5, TCC increased at different post-flowering timelines and decreased in the different fruit portions. The highest value was reported in the pulp and the lowest was in the seed. When the fruits ripens, the temperature, moisture, and pressure all decrease. For the reason, this reduces environmental influences and the relationships between fatty acids and carotenoids leading to carotenoid production. Carotenoids are used to increase the protective power of fruits, so they are important for recovery and protection from the effects of solar radiation (De Azevedo & Rodriguez-Amaya, 2005). The TCC values of the pulp, fiber, seed were to be 0.30±0.00 - 0.63 ±0.01 µg/mL, 0.19±0.00 - 0.44±0.00 µg/mL, and 0.11±0.01 - 0.30±0.03 µg/mL, respectively. This result is similar to some previous reports: TCC of the pulp from 0.06 to 0.63 µg/g published by Shamla et al. in four different ripening stage (Shamla et al., 2019), TCC value of tropical jackfruit pulp is 0.3±0.00 mg/100g reported by Barreto et al. (2009). ANOVA results showed that parts, portions and the post-flowering timelines significantly affect total carotenoid content at 95% confidence level ($p<0.05$).

3.3.2.TPC

Meanwhile, TPC tended to decrease from 100 to120 days, yet increase from the top to the bottom portions of the fruit. TPC of the seed had the highest value (from 0.13 ± 0.02 to 0.28 ± 0.04 mgGAE/g DM) due to the presence of an antioxidant compound, followed by pulp (from 0.12 ± 0.02 to 0.25 ± 0.04 mgGAE/g DM) and fiber (from 0.07 ± 0.02 to 0.23 ± 0.02 mgGAE/g DM).(Table 5). When the fruits ripen, TPC decreased since the polyphenols were degraded into small molecules by the enzymatic reactions (Krüger et al., 2012). The obtained results were relatively similar to Jagtap et al. (2010), which reported that the ripe Brazilian jackfruit samples extracted from ethanol solvent exhibited a TPC of 34.1±1.0 mg GAE/100 g DM. ANOVA results showed that the post-flowering timelines and different fruit parts significantly affected total polyphenol content of jackfruit extract ($p<0.05$).

3.3.3.TFC

Similar to TPC, TFC was reduced due to enzymatic reactions as the fruits ripe. TFC also decreased from 100 to 120 days. The values of the pulp, fiber, seed were to be 0.10±0.00 - 0.31±0.01 mgQE/g DM, 0.15±0.04 - 0.44±0.02 mgQE/g DM, 0.03±0.01 - 0.06±0.02 mgQE/g DM (Table 5). In there, the pulp had the highest value. The results were similar to the studies of Barreto et al. (2009), Jagtap et al. (2010b). However, the results obtained were lower than those of Shamla et al. (2019) (1,744 – 0.302 mg QE/g DM). ANOVA results showed that parts, portions and the post-flowering timelines significantly affect total flavonoid content at 95% confidence level ($p<0.05$).

3.4.Evaluation of antioxidant activity in jackfruit parts

3.4.1.DPPH· method

Results have shown that the DPPH scavenging activity of jackfruit pulp, fiber and seed extracts tends to decrease as the post-flowering pprolonged from 100 to 120 days, as indicated by the increasing IC_{50} values from 108.59 ± 9.75 to 202.34 ± 17.40 µg/mL, from 4.28 ± 0.53 to 367.33 ± 4.72 µg/mL, from 3.29 ± 0.37 to 19.55 ± 1.30 µg/mL, respectively. This can be explained that the jackfruit extractcontains antioxidants which are capable of converting hydrogen molecules into free radicals to get antioxidant capacity. This result was according to Li et al. (2021), the published IC50 value is 2.871 mg/mL that was different to this result. ANOVA results showed that parts, portions and the post-flowering timelines significantly affect IC50 value of DPPH· at 95% confidence level ($p<0.05$).

3.4.2.$ABTS^{\cdot+}$ method

Similar to DPPH· method, the results of $ABTS^{\cdot+}$ free radical scavenging capacity were shown in Table 6 The lower the OD value measured at 734 nm, the higher the free radical scavenging capacity of the antioxidant. IC50 of $ABTS^{\cdot+}$ radical of pulp, fiber, seed extractions tended to increase in the post-flowering timelines which recorded at 56.60±6.33 - 81.54±3.04 µg/mL, 3.70±0.15 - 287.07±18.78 µg/mL, 2.96±0.07 - 19.55±1.30 µg/mL. The increased IC50 value means the antioxidant capacity of jackfruit in the post-flowering timelines 100 days, 110 days, 120 days will be decrease. This can be explained by the increased respiration capacity as jackfruit ripens, leading to reduced antioxidant activity due to enzymatic reactions or external factors (such as oxidation or high temperature) affecting enzyme production (Quirós-Sauceda et al., 2019). The IC50 value was similar to that recorded in the Brazilian ripe jackfruit (9.39±0.18 mg/100 g) but they was lower than the value of IC50 was published by Z.Li (0.259 mg/mL) (Barreto et al., 2009; Li et al., 2021).

3.4.3.Phosphomolybdenum method

The total antioxidant capacity of the jackfruit parts and its portions were measured spectrophotometrically through the phosphomolybdenum method, which is based on the reduction of Mo (VI) to Mo (V) by the sample analyte and the subsequent formation of green phosphate/Mo (V) complex with maximum absorption at 695 nm. The antioxidant capacity of jackfruit parts and its portions was found to decrease in 100 days < 110 days < 120 days and increase in order top > middle > bottom.

Table 5. TCC, TPC, and TFC change at different days after flowering in different portions of jackfruit parts

		Top			Middle			Bottom		
		100 days	**110 days**	**120 days**	**100 days**	**110 days**	**120 days**	**100 days**	**110 days**	**120 days**
Pulp	**TCC (mg/mL)**	0.31^{cdi}±0.00	0.44^{cei}±0.01	0.61^{cfi}±0.01	0.29^{bdi}±0.02	0.41^{bei}±0.00	0.63^{bfi}±0.01	0.30^{adi}±0.00	0.33^{aei}±0.01	0.53^{afi}±0.01
	TPC (mgGAE/g DM)	0.2^{afh}±0.02	0.14^{aeh}±0.02	0.12^{adh}±0.02	0.24^{abfh}±0.02	0.16^{abeh}±0.05	0.14^{abdh}±0.04	0.25^{bfh}±0.04	0.19^{beh}±0.06	0.14^{bdh}±0.02
	TFC (mgQE/g DM)	0.23^{afh}±0.02	0.18^{aeh}±0.05	0.10^{adh}±0.00	0.25^{bfh}±0.00	0.24^{beh}±0.05	0.15^{bdh}±0.01	0.31^{cfh}±0.01	0.29^{ceh}±0.05	0.19^{cdh}±0.03
Fiber	**TCC (mg/mL)**	0.24^{cdh}±0.00	0.24^{ceh}±0.00	0.44^{cfh}±0.00	0.20^{bdh}±0.00	0.21^{beh}±0.00	0.33^{bfh}±0.01	0.19^{adh}±0.00	0.21^{aeh}±0.00	0.32^{afh}±0.02
	TPC (mgGAE/g DM)	0.18^{afg}±0.02	0.14^{aeg}±0.00	0.07^{adg}±0.02	0.21^{abfg}±0.03	0.14^{abeg}±0.01	0.08^{abdg}±0.00	0.23^{bfg}±0.02	0.19^{beg}±0.05	0.11^{bdg}±0.01
	TFC (mgQE/g DM)	0.27^{afh}±0.01	0.18^{aeh}±0.05	0.15^{adh}±0.04	0.32^{bfh}±0.09	0.21^{beh}±0.09	0.16^{bdh}±0.00	0.44^{cfh}±0.02	0.24^{ceh}±0.06	0.16^{cdh}±0.02
Seed	**TCC (mg/mL)**	0.11^{cdg}±0.02	0.15^{ceg}±0.01	0.30^{cfg}±0.03	0.11^{bdg}±0.02	0.15^{beg}±0.01	0.30^{bfg}±0.03	0.11^{adg}±0.01	0.14^{aeg}±0.01	0.30^{afg}±0.01
	TPC (mgGAE/g DM)	0.25^{afi}±0.04	0.22^{aei}±0.00	0.13^{adi}±0.02	0.27^{abfi}±0.05	0.23^{abei}±0.00	0.14^{abdi}±0.04	0.28^{bfi}±0.04	0.24^{bei}±0.02	0.14^{bdi}±0.03
	TFC (mgQE/g DM)	0.04^{afg}±0.01	0.03^{aeg}±0.01	0.03^{adg}±0.01	0.05^{bfg}±0.01	0.05^{beg}±0.01	0.04^{bdg}±0.01	0.06^{cfg}±0.02	0.05^{ceg}±0.00	0.04^{cdg}±0.00

The means followed by the different superscript letters in the same row within the column of each individual portion are significantly different ($p < 0.05$)

Table 6. IC50 of DPPH·, IC50 of $ABTS^{\cdot+}$, and TAC change at different days after flowering in different portions of jackfruit parts

		Top			Middle			Bottom		
		100 days	**110 days**	**120 days**	**100 days**	**110 days**	**120 days**	**100 days**	**110 days**	**120 days**
Pulp	**IC50 $ABTS^{\cdot+}$ (µg/mL)**	58.65^{afh}±8.48	77.32^{aeh}±1.18	81.54^{adh}±3.04	58.61^{bfh}±11.27	75.36^{beh}±0.33	78.55^{bdh}±0.56	56.60^{cfh}±6.33	71.40^{ceh}±7.08	77.64^{cdh}±4.23
	IC50 DPPH· (µg/mL)	128.29^{cdh}±2.37	135.10^{ceh}±4.61	202.34^{cfh}±17.40	116.52^{bdh}±3.16	124.23^{beh}±4.66	170.21^{bdh}±8.22	108.59^{adh}±9.75	114.08^{aeh}±5.30	165.16^{afh}±1.39
	TAC (mgGAE/g DM)	87.21^{afh}±4.94	32.80^{aeh}±1.59	29.15^{adh}±0.69	93.13^{bfh}±7.38	36.71^{beh}±2.04	34.65^{bdh}±7.37	113.52^{cfh}±10.33	44.02^{ceh}±2.17	35.90^{cdh}±7.33
Fiber	**IC50 $ABTS^{\cdot+}$ (µg/mL)**	122.91^{afi}±33.88	130.06^{aei}±18.15	287.07^{adi}±18.78	97.55^{bfi}±16.78	108.82^{bei}±3.66	264.97^{bdo}±12.41	3.70^{cfi}±0.15	3.89^{cei}±0.07	4.23^{cdi}±0.01
	IC50 DPPH· (µg/mL)	311.03^{cdi}±15.37	315.86^{cei}±4.72	367.33^{cfi}± 4.72	294.79^{bdi}±4.42	304.60^{bei}±3.11	366.62^{bfi}±3.08	4.28^{adi}±0.53	11.51^{aei}±0.29	19.55^{afi}±1.30
	TAC (mgGAE/g DM)	110.80^{afi}±14.33	62.56^{aei}±3.78	42.87^{adi}±15.83	115.40^{bfi}±8.47	80.09^{bei}±20.18	48.43^{bdi}±18.62	123.67^{cfi}±12.70	88.11^{cei}±16.82	56.03^{cdi}±14.82
Seed	**IC50 $ABTS^{\cdot+}$ (µg/mL)**	3.70^{afg}±0.15	3.89^{aeg}±0.07	4.23^{adg}±0.01	3.23^{bfg}±0.25	3.44^{beg}±0.27	4.13^{bdg}±0.10	2.96^{cfg}±0.07	3.24^{ceg}±0.36	3.43^{cdg}±0.35
	IC50 DPPH· (µg/mL)	4.28^{cdg}±0.53	11.51^{ceg}±0.29	19.55^{cfg}±1.30	3.99^{bdg}±0.21	9.45^{beg}±1.13	17.29^{bfg}±2.18	3.29^{adg}±0.37	8.39^{aeg}±0.35	11.24^{afg}±0.40
	TAC (mgGAE/g DM)	23.47^{afg}±6.40	16.44^{aeg}±4.01	13.04^{adg}±0.13	31.33^{bfg}±2.41	20.42^{beg}±0.79	16.05^{bdg}±3.14	35.28^{afg}±1.73	32.16^{aeg}±2.06	17.84^{adg}±3.80

ANOVA results showed that parts, portions and the post-flowering timelines significantly affect IC50 value of $ABTS^{\cdot+}$ at 95% confidence level ($p<0.05$).

However, the bottom portions of 100-day and the top portions of 120-day showed the highest and lowest antioxidant capacities respectively (Table 6). In there, the seed had the lowest values were to be 13.04±0.13 - 35.28±1.73 mgAAE/g DM and the pulp, fiber were recorded at 29.15±0.69 - 113.52±10.33 mgAAE/g DM, 42.87±15.83 - 123.67±12.70 mgAAE/g DM.This change may be due to a decrease in antioxidant compounds such as phenolic acids and flavonoids. As jackfruit ripens, these compounds are degraded leading to reduced antioxidant capacity. Kumari et al. (2013) also showed the decrease of TAC in lemons at different mature stage and they reported the unripe lemons had a higher TAC than ripening (0.178 and 0.127 mg/mL).

The antioxidant capacity of jackfruit pulp was determined based on the ABTS·$^{+}$, DPPH· free radical scavenging methods and phosphomolybdenum method (TAC). Both ABTS·$^{+}$ and DPPH· free radical scavenging methods can use the IC50 value to calculate the free radical scavenging level, but the TAC method cannot achieve the IC50 value. The TAC method was found to be inappropriate in determining the antioxidant capacity of jackfruit pulp in this study. The IC50 value of the DPPH· free radical scavenging method (108.59±9.75 - 202.34±17.40 µg/mL) was higher than the IC50 value of the capture method. ABTS·$^{+}$ free radicals (56.60±6.33 - 81.54±3.04 µg/mL). Therefore, ABTS·$^{+}$ method was better than DPPH· and phosphomolybdenum method. This difference can be explained by the type of antioxidant used as the standard. Antioxidants include endogenous (enzymes and nonenzymes) and exogenous (vitamin E, vitamin C, β-carotene, flavonoids, Se minerals, vitamin D and vitamin K3) (Biochem et al., 2011). In which vitamin E (Trolox) and vitamin C (ascorbic acid) were selected as standard substances in methods to determine the antioxidant capacity of jackfruit. In this study Trolox was used as a standard in the DPPH· and ABTS·$^{+}$ free radical scavenging methods, and ascorbic acid was used in the phosphomolybdenum (TAC) method. Borut and Peter (2008) compared these two antioxidant compounds and reported that Trolox has many advantages over the other, while the auto-oxidation of ascorbic acid produces a quantity of H_2O_2 that prevents the determination of determine the antioxidant capacity of the compound. This may explain the poor free radical scavenging ability of the TAC method. The ABTS·+ free radical scavenging method is better than DPPH· because ABTS·+ free radicals are detected at 734 nm far from the visible region (with wavelengths from 380 to 760 nm), while DPPH· radicals are detected at 517 nm wavelength may be attenuated due to potential interference. Another advantage of the ABTS·+ method is that antioxidants in the aqueous and oily phases can both capture ABTS·+ free radicals, while only lipophilic antioxidants can capture DPPH· radicals in the environment field (Arnao et al., 2001).

4.Conclusion

The effects of post-flowering timelines (i.e. 100 days, 110 days and 120 days) on the nutritional, chemical, and antioxidant values of jackfruit parts (pulp, fiber, and seed) were analyzed to gain useful insights in determining the optimal harvesting time to obtain high-quality jackfruit. Results have shown that most of the nutritional values of the tested jackfruit parts increased as the post-flowering timelines prolonged and decrease gradually from the top to the bottom. The value of fiber and carbohydrate content tended to be the opposite. In particular, increasing TSS, sugar content and TCC provides a better palatability for the ripened fruit, thus improving consumer tastes. Meanwhile, chemical constituents, TPC, TFC, and antioxidant activity tended to decrease from 100 to 120 days and increased from the top to the bottom part of jackfruit due to enzymatic reaction. The results also showed that 120 days is the most appropriate harvesting time to obtain jackfruit with high nutritional content. Further studies are required to optimize the antioxidant activity to exploit the biological potentials and extend the applications of jackfruit.

5. References

Adan, A. A., Ojwang, R. A., Muge, E. K., Mwanza, B. K., & Nyaboga, E. N. (2020). Phytochemical composition and essential mineral profile, antioxidant and antimicrobial potential of unutilized parts of jackfruit. *Food Research*, 4(4), 1125–1134. https://doi.org/10.26656/fr.2017.4(4).326

Alvani, K., Qi, X., Tester, R. F., & Snape, C. E. (2011). Physico-chemical properties of potato starches. *Food Chemistry*, 125(3), 958–965. https://doi.org/10.1016/j.foodchem.2010.09.088

Arnao, M. B., Cano, A., & Acosta, M. (2001). The hydrophilic and lipophilic contribution to total antioxidant activity. *Food Chemistry*, 73(2), 239–244. https://doi.org/10.1016/S0308-8146(00)00324-1

Baliga, M. S., Shivashankara, A. R., Haniadka, R., Dsouza, J., & Bhat, H. P. (2011). Phytochemistry, nutritional and pharmacological properties of Artocarpus heterophyllus Lam (jackfruit): A review. *Food Research International*, 44(7), 1800–1811. https://doi.org/10.1016/j.foodres.2011.02.035

Barreto, G. P. M., Benassi, M. T., & Mercadante, A. Z. (2009). Bioactive compounds from several tropical fruits and correlation by multivariate analysis to free radical scavenger activity. *Journal of the*

Brazilian Chemical Society, 20(10), 1856–1861. https://doi.org/10.1590/S0103-50532009001000013

Baur, F. J., & Ensminger, L. G. (1977). The Association of Official Analytical Chemists (AOAC). *Journal of the American Oil Chemists' Society*, 54(4), 171–172. https://doi.org/10.1007/BF02670789

Bhandary, S. K., Bhat, V. S., Sharmila, K. P., & Bekal, M. P. (2012). Preliminary phytochemical screening of various extracts of Punica granatum peel, whole fruit and seeds. *Journal of Health and Allied Sciences NU*, 2(04), 34–38. https://doi.org/10.1055/s-0040-1703609.

Biochem, A., Pisoschi, A. M., & Negulescu, G. P. (2011). Biochemistry & Analytical Biochemistry Methods for Total Antioxidant Activity Determination: A Review. *Biochem Anal Biochem*, 1(1), 1–10. https://doi.org/10.4172/2161-1009.1000106.

Borut, P., & Peter, R. (2008). The antioxidant and pro-oxidant activity of vitamin C and trolox in vitro: a comparative study. *Journal of Applied Toxicology: An International Journal*, 28(2), 183-188.

Bremner, J. M., & Keeney, D. R. (1965). Steam distillation methods for determination of ammonium, nitrate and nitrite. *Analytica Chimica Acta*, 32(C), 485–495. https://doi.org/10.1016/S0003-2670(00)88973-4.

Chavez-Santiago, J. O., Rodríguez-Castillejos, G. C., Montenegro, G., Bridi, R., Valdés-Gómez, H., Alvarado-Reyna, S., Castillo-Ruiz, O., & Santiago-Adame, R. (2022). Phenolic content, antioxidant and antifungal activity of jackfruit extracts (Artocarpus heterophyllus Lam.). *Food Science and Technology (Brazil)*, 42, 4–10. https://doi.org/10.1590/fst.02221.

De Azevedo, C. H., & Rodriguez-Amaya, D. B. (2005). Carotenoid composition of kale as influenced by maturity, season and minimal processing. *Journal of the Science of Food and Agriculture*, 85(4), 591–597. https://doi.org/10.1002/jsfa.1993

de Faria, A. F., de Rosso, V. V., & Mercadante, A. Z. (2009). Carotenoid composition of jackfruit (Artocarpus heterophyllus), determined by HPLC-PDA-MS/MS. *Plant Foods for Human Nutrition*, 64(2), 108–115. https://doi.org/10.1007/s11130-009-0111-6.

Deepthi, P. (2017). Physiological and Biochemical changes during fruit growth, maturity and ripening of guava: A review. *Journal of Postharvest Technology*, 5(2), 1–16.

Goswami, C., Hossain, M. A., Kader, H. A., & Islam, R. (2011). Assessment of Physicochemical Properties of Jackfruits' (Artocarpus heterophyllus Lam) Pulps. *Forestry and Biotechnology*, 15(3), 26–31.

Hegde, C. R., Madhuri, M., Nishitha, S. T., Arijit Das, A. D., Sourav Bhattacharya, S. B., & Rohit, K. C. (2012). Evaluation of antimicrobial properties, phytochemical contents and antioxidant capacities of leaf extracts of Punica granatum L. *ISCA J of Biological Sciences*, 1(2), 32-7. https://www.cabidigitallibrary.org/doi/full/10.5555/20133055646.

Hema, J., Ahiduzzaman, M., & Hossain, M. (2016). Development of Nutritious Dried Powder From Jackfruit Bulb and Seed. *International Journal of Business, Social and Scientific Research*, 4(May), 189–195.

Jagtap, U. B., Panaskar, S. N., & Bapat, V. A. (2010a). Evaluation of antioxidant capacity and phenol content in jackfruit (Artocarpus heterophyllus Lam.) fruit pulp. *Plant Foods for Human Nutrition*, 65(2), 99–104. https://doi.org/10.1007/s11130-010-0155-7

Jagtap, U. B., Panaskar, S. N., & Bapat, V. A. (2010b). Evaluation of antioxidant capacity and phenol content in jackfruit (Artocarpus heterophyllus Lam.) fruit pulp. *Plant Foods for Human Nutrition*, 65(2), 99–104. https://doi.org/10.1007/s11130-010-0155-7

Krüger, E., Josuttis, M., Nestby, R., Toldam-Andersen, T. B., Carlen, C., & Mezzetti, B. (2012). Influence of growing conditions at different latitudes of Europe on strawberry growth performance, yield and quality. *Journal of Berry Research*, 2(3), 143–157. https://doi.org/10.3233/JBR-2012-036

Kumari, S., Sarmah, N., & Handique, A. K. (2013). Antioxidant activities of the unripen and ripen Citrus aurantifolia of Assam. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(9), 4811–4816.

Li, Z., Lan, Y., Miao, J., Chen, X., Chen, B., Liu, G., Wu, X., Zhu, X., & Cao, Y. (2021). Phytochemicals, antioxidant capacity and cytoprotective effects of jackfruit (Artocarpus heterophyllus Lam.) axis extracts on HepG2 cells. *Food Bioscience*, 41(February), 100933. https://doi.org/10.1016/j.fbio.2021.100933.

Mercado-Silva, E., Benito-Bautista, P., & De los Angeles García-Velasco, M. (1998). Fruit development, harvest index and ripening changes of guavas produced in central Mexico. *Postharvest Biology and Technology*, 13(2), 143–150. https://doi.org/10.1016/S0925-5214(98)00003-9.

Miliauskas, G., Venskutonis, P. R., & Van Beek, T. A. (2004). Screening of radical scavenging activity of some medicinal and aromatic plant extracts. *Food Chemistry*, 85(2), 231–237. https://doi.org/10.1016/j.foodchem.2003.05.007.

Moke, L. E., Ngbolua, K., Bongo, G. N., Messi, L. M., Noté, O. P., Mbing, J. N., & Mpiana, P. T. (2017). Artocarpus heterophyllus Lam.

(Moraceae): Phytochemistry, Pharmacology and Future Directions, a mini-review. *Journal of Advanced Botany and Zoology*, 5(3), 1–8.

Murwan Sabahelkhier, K., Hussain, A. S., & Ishag, K. E. A. (2010). Effect of maturity stage on protein fractionation, in vitro protein digestibility and anti-nutrition factors in pineapple (Ananas comosis) fruit grown in Southern Sudan. *African Journal of Food Science*, 4(8), 550–552.

Nielsen, S. S., & Carpenter, C. (2017). Fat Content Determination. *Food analysis laboratory manual*, 121–129. https://doi.org/10.1007/978-3-319-44127-6_12.

Nikolaos N., Lan-Fen Wang., Maria Tsimidou, A. H.-Y. Z. (2004). Estimation of scavenging activity of phenolic compounds using the ABTS•+ assay. *Journal of agricultural and food chemistry*. 52(15), 4669-4674. https://doi.org/10.1021/jf0400056.

Olaleye, M. T. (2007). Cytotoxicity and antibacterial activity of methanolic extract of Hibiscus sabdariffa. *Journal of Medicinal Plants Research*, 1(1), 9–13.

Omulokoli, E., Khan, B., & Chhabra, S. C. (1997). Antiplasmodial activity of four Kenyan medicinal plants. *Journal of Ethnopharmacology*, 56(2), 133–137.

Ong, B. T., Nazimah, S. A. H., Osman, A., Quek, S. Y., Voon, Y. Y., Hashim, D. M., Chew, P. M., & Kong, Y. W. (2006). Chemical and flavour changes in jackfruit (Artocarpus heterophyllus Lam.) cultivar J3 during ripening. *Postharvest Biology and Technology*, 40(3), 279–286. https://doi.org/10.1016/j.postharvbio.2006.01.015

Park, Y. S., Jung, S. T., Kang, S. G., Heo, B. G., Arancibia-Avila, P., Toledo, F., Drzewiecki, J., Namiesnik, J., & Gorinstein, S. (2008). Antioxidants and proteins in ethylene-treated kiwifruits. *Food Chemistry*, 107(2), 640–648. https://doi.org/10.1016/j.foodchem.2007.08.070

Phung, N. K. P. (2007). Method for isolating organic compounds. Vietnam National University, Ho Chi Minh City – VNU-HCM.

Prakash, O., Kumar, R., Mishra, A., & Gupta, R. (2009). Artocarpus heterophyllus (Jackfruit): An overview. *Pharmacognosy Reviews*, 3(6), 353.

Madhuri, M., Nishitha, S. T., Arijit, D., Sourav, B., & Rohit, K. C. (2012). Evaluation of Antimicrobial Properties , Phytochemical Contents and Antioxidant Capacities of Leaf Extracts of Punica granatum L. *ISCA J of Biological Sciences*. 1(2), 32–37.

Ranasinghe, R. A. S., & Marapana, R. (2019). Effect of maturity stage on physicochemical properties of jackfruit (Artocarpus heterophyllus Lam.) flesh. *World Journal of Dairy & Food Sciences*. 14 (1), 17-25. https://doi.org/10.5829/idosi.wjdfs.2019.17.25

Ranasinghe, R. A. S. N., Maduwanthi, S. D. T., & Marapana, R. A. U. J. (2019). Nutritional and Health Benefits of Jackfruit (Artocarpus heterophyllus Lam.): A Review. *International Journal of Food Science*. 2019(1), 4327183. https://doi.org/10.1155/2019/4327183.

Ranasinghe, R. A. S. N., & Marapana, R. A. U. J. (2019). Effect of Maturity Stage on Physicochemical Properties of Jackfruit (Artocarpus heterophyllus Lam.) Flesh. *World Journal of Dairy & Food Sciences*, 14(1), 17–25. https://doi.org/10.5829/idosi.wjdfs.2019.17.25

Rangana, S. (1979). Manual of analysis of fruit and vegetable products. Tata McGraw-Hill.

Saha, M., Hasan, S., Akter, R., Hossain, M., Alam, M., Alam, M., & Mazumder, M. (1970). In vitro free radical scavenging activity of methanol extract of the leaves of Mimusops elengi Linn. *Bangladesh Journal of Veterinary Medicine*, 6(2), 197–202. https://doi.org/10.3329/bjvm.v6i2.2336

Quirós-Sauceda, A. E., Sañudo-Barajas, J. A., Vélez-de la Rocha, R., Domínguez-Avila, J. A., Ayala-Zavala, J. F., Villegas-Ochoa, M. A., & González-Aguilar, G. A. (2019). Effects of ripening on the in vitro antioxidant capacity and bioaccessibility of mango cv.'Ataulfo'phenolics. *Journal of food science and technology*, 56, 2073-2082. https://doi.org/10.1007/s13197-019-03685-x.

Saxena, A., Bawa, A. S., & Raju, P. S. (2011). Jackfruit (Artocarpus heterophyllus Lam.). In Postharvest Biology and Technology of Tropical and Subtropical Fruits: Cocona to Mango. *Woodhead Publishing Limited*. https://doi.org/10.1533/9780857092885.275.

Shamla, L., Heeba, S., Jose, N., & Nisha, P. (2019). Change in chemical composition during maturation of Artocarpus heterophyllus and its effect on acrylamide formation in deep-fried jackfruit chips. *Journal of Food Processing and Preservation*, 43(9), 1–9. https://doi.org/10.1111/jfpp.14099.

Shamsudin, R., Ling, C. S., Ling, C. N., Muda, N., & Hassan, O. (2009). Chemical compositions of the jackfruit juice (Artocarpus) cultivar J33 during storage. *Journal of Applied Sciences*, 9(17), 3202–3204. https://doi.org/10.3923/jas.2009.3202.3204.

Sharma, O. P., & Bhat, T. K. (2009). DPPH antioxidant assay revisited. *Food Chemistry*, 113(4), 1202–1205. https://doi.org/10.1016/j.foodchem.2008.08.008

Subroto, E. (2020). Review on the Analysis Methods of Starch, Amylose, Amylopectinin Food and Agricultural Products. *International Journal of Emerging Trends in Engineering Research*, 8(7), 3519–3524. https://doi.org/10.30534/ijeter/2020/103872020.

Swords, G., Bobbio, P. A., & Hunter, G. L. K. (1978). Volatile constituents of jack fruit (Artocarpus heterophyllus). *Journal of food science*, 43(2), 639-640. https://doi.org/10.1111/j.1365-2621.1978.tb02375.x.

Tadesse, T., Hewett, E. W., Nichols, M. A., & Fisher, K. J. (2002). Changes in physicochemical attributes of sweet pepper cv. Domino during fruit growth and development. *Scientia Horticulturae*, 93(2), 91–103. https://doi.org/10.1016/S0304-4238(01)00317-X.

Tolulope, M. (2007). Cytotoxicity and antibacterial activity of Methanolic extract of Hibiscus sabdariffa. *Journal of Medicinal Plants Research*, 1(1), 9–013.

Tulyathan, V., Tananuwong, K., Songjinda, P., & Jaiboon, N. (2002). Some physicochemical properties of jackfruit (Artocarpus heterophyllus Lam) seed flour and starch. *Science Asia*, 28(1), 37–41.

Wellburn, A. R. (1994). The Spectral Determination of Chlorophylls a and b, as well as Total Carotenoids, Using Various Solvents with Spectrophotometers of Different Resolution. *Journal of Plant Physiology*, 144(3), 307–313. https://doi.org/10.1016/S0176-1617(11)81192-2.

Acknowledgements

This research was supported by Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam and the Department of Science and Technology of Can Tho City, Vietnam