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IMPACT OF MATURITY STAGE ON ANTIOXIDANT ACTIVITY AND PHYTOCHEMICAL PROPERTIES OF DIFFERENT PARTS FROM PAWPAW: CARICA PAPAYA L. VAR SOLO 8

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Abstract: *The purpose of this paper has been to study the antioxidant activities and phytochemical compounds at different stages of maturity from papaya (Carica papaya L. var solo 8) peel, pulp and seeds in order to understand the correlation throughout these parameters. Thereby, three parts of papaya such as peel, pulp and seeds were sampled fresh, dried in an oven at 45 °C for 48 hours, ground and analyzed according to standard procedures. Carica papaya L. var solo 8 peels, seeds and pulps were specifically rich in phytochemical content around 1/8 and ¼ advanced stage of maturity before decreasing at advanced maturity stage. Results showed high level of total phenolic (434.36 ± 0.10 mg (GAE)/100 g DW), flavonoids (23.74 ± 0.01 mg (QE)/100 g DW) and tannins (89.33 ± 0.06 mg (TAE)/100 g DW) respectively in seeds and peels. The DPPH, FRAP and ABTS assays of methanolic extracts from this papaya (Carica papaya L. var solo 8) showed that the antioxidant activity measured was high for the peels followed by pulp and seeds at immature stage. These data indicated that the whole parts of this papaya (Carica papaya L. var solo 8) could constitute a potential good source of natural antioxidant for local population.*

Keywords: *Antioxidant activity, papaya Variety solo 8, Phytochemical composition, Maturity stage*

1. Introduction

Papaya is compared with other fruit such as the banana or the apple, it has been found a good natural source of macronutrients (carbohydrates and proteins) and macronutrients (vitamin A and vitamin C) [1]. There is also a strong relationship between the intake of these antioxidant-containing plants and reduced mortality caused by diseases [2]. Indeed, natural antioxidants warrant further scientific scrutiny given their activity against free radicals, which contribute to chronic degenerative diseases [3]. Medicinal plants play important roles in preventing various diseases and have received much attention from many researchers over the last few decades. Studies on the antioxidant contents of fruits and vegetables are increasing because natural antioxidant consumption has been found to be related to decreased risk for cancer and heart diseases [4]. Papaya contains a broad spectrum of phytochemicals including enzymes (in the latex), carotenoids (in fruits and seeds), alkaloids (in leaves), phenolics (in fruits, leaves, and shoots), and glucosinolates (in seeds and fruits).

During maturation, several variations (biochemical, physiological, and structural) take place and determine the fruit's quality [5].

To our knowledge there are no reports in one study about the influence of maturity stages on phytochemical content and antioxidant activity from different parts of *C. papaya* L. var solo 8. So, the goal of this work was to study the differences in amount and composition of phenolic compounds, total carotenoids, vitamin C and to estimate the antioxidant activities of *C. papaya* L. var solo 8 fruit harvested in Côte d'Ivoire with respect to different stages of maturity (Immature, 1/8 Advanced, 1/4 Advanced and Advanced) and fruit parts (Peel, pulp and seeds). The result of this study will form the basis of advising consumers and the biological world, when and how best to utilize this fruit.

2. Material and methods

Biological material

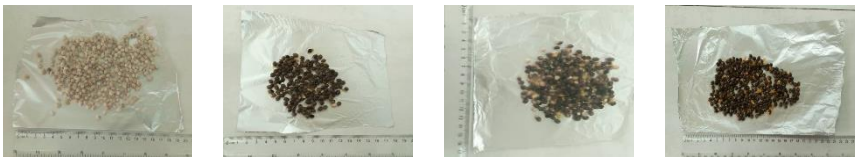
Biological material is composed of the peel, epicarp and seeds of harvested *Carica papaya* L. var solo 8 at four stages of maturity which are immature, 1/8 advanced, 1/4 advanced and advanced yellow skin (Figures 1 to 3). These stages follow those proposed by Yao [6] to investigate pectinolytic activities. The fruits were harvested from a farm near Thomasset (Azaguié), a village located at about 50 km north of Felix Houphouet Boigny Airport, Abidjan, Cote d'Ivoire.

Immature 1/8 Advanced 1/4 Advanced Advanced

Fig. 1. *Carica papaya* L. var solo 8 peels at different stages of maturity

Immature 1/8 Advanced 1/4 Advanced Advanced

Fig. 2. *Carica papaya* L. var solo 8 pulps at different stages of maturity



Immature 1/8 Advanced 1/4 Advanced Advanced

Fig. 3. *Carica papaya* L. var solo 8 seeds at different stages of maturity

Methods

Collection and sampling from different parts of papaya

The sampled papaya fruits were previously washed and rinsed with bleach and separated according to the stage of maturity. The peel, pulp and seeds were then separated from each other using a knife, peeler, and spatula. A quantity of 500 g of each part of the papaya (peel, pulp, and seeds) at the various stages of ripeness was spread out on aluminium film and then dried in a ventilated MEMMERT oven at 45 °C for 2 days. After drying, the parts were crushed in a mill type Mill IKA (Germany/Deutschland). The resulting grind of each sample formed the papaya powder (flour) used at different analyses. These grindings were then packaged in glass bottles which were previously dried in an oven at 45 °C and then stored in a desiccator.

Phytochemical Composition

Extraction of phenolic compounds

Extraction of phenolic compounds was determined using Singleton *et al*. method [7]. A sample (10 g) of fine dried papaya sample flour was extracted by stirring with 50 ml of methanol 80 % (v/v) at 25 °C for 24 hours and filtered through Whatman n°4 paper. The residue was then extracted with two additional 50 ml portions of methanol. The combined methanolic extracts were evaporated at 35 °C (rotary evaporator HEILDOLPH Laborata 4003 Control, Schwabach, Germany) until 25 ml, prior to phenolic compound contents determination.

Determination of total phenolic compounds content

Contents of total phenolic compounds were estimated according to the Folin-Ciocalteu method [7]. A volume of 1 ml of methanolic extract of each sample was added to 1 ml of Folin-Ciocalteu solution in a test tube. After 3 minutes, 1 ml of 20 % sodium carbonate solution was added to the mixture and adjusted to 10 ml with distilled water. The mixture was let to stand at room temperature in a dark environment for 30 min. Absorbance was measured against the blank reagent at 725 nm. Gallic acid was used for the calibration curve with a concentration range of 50 - 1000 µg/ml.

Results were expressed as mg gallic acid equivalent (GAE)/100g DW (Dry Weight).

Determination of tannins:

Tannin content was determined using the method described by Bainbridge *et al*. [8]. A volume of 1 ml of each methanolic extract was collected and mixed with 5 ml of reaction solution [vanillin 0.1mg/ml in sulphuric acid 70 % (v/v)]. The mixture could stand at room temperature in a dark environment for 20 min. The absorbance was measured at 500 nm against a blank (without extract).

Tannic acid was used for the calibration curve with a concentration range of 0 - 100 µg/ml.

The results were expressed as mg of tannic acid equivalents (TAE)/100 g DW.

Determination of total flavonoid content

The total flavonoids content was determined using the Dowd method [9]. 5 ml of 2 % aluminum trichloride ($AlCl_3$) in methanol was mixed with the same volume of the methanolic extract solution (0.4 mg/ml). After ten minutes the absorbance was measured at 415 nm using PerkinElmer UV-VIS Lambda. Blank sample consisting of a 5 ml extract solution with 5 ml methanol without $AlCl_3$. The total flavonoid content was determined using a standard curve with catechin (0 – 100 mg/l) as the standard.

Total flavonoids content is expressed as mg of catechin equivalents (CE)/100 g DW.

Determination of total carotenoid content (TCC) and estimation of vitamin C

The TCC and vitamin C was determined using the spectrophotometric method as described by these authors [10]. Optical density was measured at 450 nm and 491 nm respectively in a spectrophotometer with the appropriate blank (PE:DE: 2:1, v, v). The amount of carotenoid and vitamin C in mg/100 g of dry weight (DW) was calculated using LambertBeer equation (as described in Rocheford's Lab protocol).

Antioxidant Activities

DPPH Assay

The *antioxidant* activity of the extracts was evaluated by *DPPH* radical scavenging *assay* which was described by [11].

DPPH is solubilized in absolute ethanol to have a solution of 0.3 mg/mL. Different ranges of concentrations in the order of the microgram of each extract are prepared (2 mg/ml, 1 mg/ml, 0.25 mg/ml, 0.125 mg/ml, 0.0625 mg/ml). Absolute ethanol was used as the dilution solvent. In dry, sterile tubes, 2.5 mL of extract solution to be analyzed and 1 mL of DPPH solution are added. After stirring, the tubes are placed in the dark for 30 min and the absorbance of the mixture is measured at 517 nm against a blank of 2.5 mL pure ethanol and 1 mL DPPH solution. The percentage of inhibition of DPPH radical formation is calculated as follows according to the formula:

$I = [(A_b – A_s) / A_b] \times 100$

With I, the percentage of inhibition,

A_b, the absorbency of blank

A_s, the absorbance of the sample.

ABTS Assay

The Trolox Equivalent Antioxidant Capacity (TEAC) test described in [11] was used to assay the antioxidant activities. The ABTS + radical cation was produced by mixing a solution of ABTS (8 mmol. L^{-1}) and a solution of $K_2S_2O_8$ (3 mmol. L^{-1}) (1 / 0.5, v / v). The mixture was then incubated for 16 h in the dark at room temperature (25 °C). Then, 0.1 mL (standard or extract) diluted in methanol (1/10, v / v), was added to 3.9 mL of the diluted ABTS solution. The mixture was vigorously vortexed for 2 min following by incubation for 6 min in the dark at room temperature (25 °C). The absorbance of the mixture was read in the Jasco V-530 UV-visible spectrophotometer at 734 nm. The results were expressed in µmol. g^{-1} TE (Trolox Equivalents). The percent degradation of ABTS by Trolox was compared to that of the sample. Percentage degradation A (%) of ABTS was expressed by using following mathematical formula,

$$A\ (\%) = \frac{A(\text{blank}) - A(\text{extract})}{100} \times A(\text{blank})$$

A(blank) = blank absorbance after incubation.

A(extract) = extract absorbance at 734 nm after incubation

FRAP Assay

Reducing Power Determination

The ferric reducing capacity of extracts was investigated by using the potassium ferricyanide-ferric chloride method [11]. Briefly, 0.2 mL of each of the extracts at different concentrations, 2.5 mL of phosphate buffer (0.2 M, pH 6.6), and 2.5 mL of potassium ferricyanide $K_3Fe(CN)6$ (1 %) were mixed and incubated at 50 °C for 20 min, to reduce ferricyanide into ferrocyanide. The reaction was stopped by adding 2.5 mL of 10 % (w/v) trichloroacetic acid followed by centrifugation at 1000 rpm for 10 min.

Finally, 2.5 mL of the upper layer was mixed with 2.5 mL of distilled water and 0.5 mL of $FeCl_3$ (0.1 %) and the absorbance was measured at 700 nm.

Statistical Analysis

All the chemical analyses and assays were performed in triplicate, unless otherwise indicated. The results were expressed as mean values • ± standard deviation (SD).
Analysis of variance (ANOVA) followed by Duncan's test was performed to test the differences between means by using Kyplot (version 2.0 beta 15, c1997-2001, Koichi Yoshioka) statistical software.

3. Results and discussion

Phenolic contents

Estimation of polyphenol, flavonoids, and tannins

Phenolic compounds, as secondary metabolites, are a large group of molecules widely distributed in fruits and vegetables.
They are considered the main actors for the antioxidant capacity of plants and have also many benefits for human health, as free radical scavenger. Recently, universal importance is given to the identification of maturity stages with the best levels of polyphenols targeting increased functional properties of fruits and vegetables. But it is hard to estimate the real content of the phenolic compounds, due to the fact that the phenolic content of fruits and vegetables is largely influenced by many factors, such as biotic and abiotic stress, senescence, cultivar, tissue, harvesting time, post-harvest treatment and also extraction techniques [11]. The maturity stage is an important factor that influences the compositional quality and the quantity of fruits.
Table 1 shows the content of estimated polyphenols, flavonoids, and tannins in different parts of *Carica papaya* L. var solo 8 fruits harvested at several stage of maturity.

Polyphenols: The levels of total phenolic content (TPC) in the evaluated parts of the papaya fruits varied significantly from 149.85 to 434.36 mg GAE / 100 g of dry weight (DW). The seeds contained the highest phenolic content (434.36 ± 0.10), followed by the peel (350.34 ± 0.68) and the pulp (254.41 ± 0.04) at immature to 1/8 advanced stage. Obviously, seeds have higher content at the stage of ¼ advanced maturity followed by peel and pulp with a peak at 1/8 and ¼ of advanced maturity, respectively. Decrease is observed for all the parts of fruits at advanced maturity stage.
Nonetheless, in comparison with several studies, *Carica papaya* Linn var. solo 8 seemed to have the highest level of total phenolic compound ([12]; [13]).
These high contents of phenolic compounds found in papaya (*Carica papaya* L. var solo 8) could constitute interesting data for population nutrition since it is well-known that these bioactive compounds found in human diet act as the antioxidant compounds and play a role in stabilizing lipid peroxidation [14].

Flavonoids: The peel and seeds have important level respectively at 1/8 advanced maturity and immature stage, followed by pulp at ¼ advanced maturity one.
Accumulation of flavonoids in investigated parts from papaya fruits ranged from 9.46 to 23.74 mg (QE) / 100 g DW. A high level of flavonoids was determined in the peel accounting for 23.74 ± 0.01, followed by 23.28 ± 0.01 and 16.61 ± 0.05 mg (QE) / 100 g DW in the seeds and the pulp, respectively. The lowest flavonoid accumulation was determined for the pulp (9.46 ± 0.02 mg (QE) / 100 g DW) at immature stage. However, no significant

difference was observed at risk ($p < 0.05$) between peel and seeds flavonoids content at 1/4 advanced maturity. Considering these data, consuming pulp at immature stage is not interesting due to the known beneficts of flavonoids. Fortunately, people consume papaya pulp beyond the immature stage.

It is well known that flavonoids endow a wide range of pharmacological and biochemical properties, such as antimicrobial activities, anti-inflammatory, and inhibition of platelet aggregation [14]. There was a significant variation in the accumulation of total flavonoids.

Tannin: The condensed tannin amount determined was significantly different through the maturity stages besides the investigated parts in the fruits of *Carica papaya* L. var solo 8. High level was observed for the peel (89.33 ± 0.06 at ¼ advanced maturity) and the seeds (87.92 ± 0.02 at immature stage) with no significant difference at the level $p < 0.05$. Tannin content of the peel remains interesting during the maturation process (immature to advanced mature) accounting from 75.05 to 56.70 mg (TAE) / 100 g DW. Whereas the peel, pulp and seeds have lower tannin levels at ¼ and advanced maturity stage with 18.32 to 13.09 and 17.73 mg (TAE) / 100 g DW, respectively.

Indeed, regardless of fruit parts and maturity stage, our results confirmed that fruits of *C. papaya* were an excellent source of phenolic compounds when comparing to other varieties, Maradol variety [15].

Table 1

Polyphenol, flavonoid and tannin compounds in *C. papaya* L. var solo 8

Parameters	Analyzed parts of the fruits	Stage of maturity			
		Immature	**1/8 Advanced**	**1/4 Advanced**	**Advanced**
Polyphenols	**Peel**	235 ± 1.01^{d}	350.34 ± 0.68^{g}	266.74 ± 3.24^{e}	261.23 ± 1.15^{e}
	Pulp	149.85 ± 0.75^{a}	203.03 ± 0.48^{b}	254.41 ± 0.04^{e}	218.74 ± 0.42^{c}
	Seeds	211.73 ± 0.11^{c}	240.44 ± 1.51^{d}	434.36 ± 0.10^{h}	339.2 ± 0.23^{f}
Flavonoids	**Peel**	19.79 ± 0.05^{d}	23.74 ± 0.01^{f}	21.62 ± 0.01^{e}	19.18 ± 0.03^{d}
	Pulp	9.46 ± 0.02^{a}	16.32 ± 0.02^{c}	16.61 ± 0.05^{c}	12.29 ± 0.01^{b}
	Seeds	23.28 ± 0.01^{f}	18.93 ± 0.01^{d}	21.57 ± 0.02^{e}	19.82 ± 0.05^{d}
Tannins	**Peel**	75.05 ± 0.03^{g}	79.70 ± 0.17^{g}	89.33 ± 0.06^{h}	56.70 ± 0.05^{d}
	Pulp	25.98 ± 0.07^{c}	68.61 ± 0.02^{f}	18.32 ± 0.01^{b}	13.09 ± 0.01^{a}
	Seeds	87.92 ± 0.02^{h}	69.29 ± 0.01^{f}	62.29 ± 0.01^{e}	17.73 ± 0.02^{b}

Values are expressed as mean ± standard deviation (n = 3). Means with different letters within a column were significantly different at the level $P < 0.05$.

Total carotenoids and vitamin C contents

Estimation of total carotenoid and vitamin C

C. papaya L. var solo 8 is a red-fleshed papaya. During fruit maturity process, the most visible change of papaya is the color of exocarp turning from green to yellow whilst the pulp and seeds changing from

white to orange red and black (Figures 1 to 3).

The content of major carotenoids was determined during the ripening of papaya fruit (Table 2). A large amount of carotenoid, as well as a small amount of lycopene was detected in the peel. The highest content was observed in the peel (93.50 ± 0.41 mg /100 g DW) and the pulp (91.50 ± 0.64 mg /100 g DW) followed by the seeds (72.49 ± 0.61 mg /100 g DW) at ¼ , immature and 1/8 advanced stage of maturity, respectively. An important content of ß-carotene, as well as small amount of lycopene were detected in the pulp at advanced stage of maturity. The content of lycopene increased, while and the content of ß-carotene decreased in the peel during papaya ripening. The highest content was 8.03 ± 0.27 mg /100 g DW for the pulp at ¼ advanced stage of maturity whereas the lowest amount occurred at advanced stage of maturity with the seeds accounting 0.03 ± 0.03 mg /100 g DW.

The results were in contrast with those obtained by the variety Maradol by some authors [16, 17, 18]. Indeed, ß-carotene accumulation from *C. papaya* L. var solo 8 is still higher than lycopene, which content remained important [19]. The positive health benefits of lycopene contained in different fruits and vegetables have been widely reported, including reduction of cardiovascular problems [20]. Therefore, the possible benefits of papaya consumption fruit could be compared to those reported by other vegetables rich in lycopene such as tomatoes. However, the concentration of other phytochemical present in these products that contribute to health needs is to be considered.

Vitamin C, measured by spectrophometer at 491 nm, both in the peel, the pulp and the seeds was higher in peel than in the pulp at ¼ advanced maturity stage, and seeds at 1/8 advanced maturity (Table 2).

Significant differences ($P \leq 0.05$) were found in vitamin C between different parts. The largest amount of vitamin C in the peel was 22.5 ± 0.04 mg/100 g DW (at ¼ advanced maturity) and it remained stable. However, pulp had lower vitamin C values with 07.50 ± 0.02mg/100 g DW (at 1/8 advanced maturity satge) papaya fruit. In previous reports, papaya vitamin C content was higher than in this study and ranged from 60 to 84 mg/100 g [21]. Solo type (Kapoho or Sunrise) papayas obtained from retail markets were analyzed in those studies.

The content of vitamin C could vary, mainly because of the type of fruit cultivation, type of soil, weather and level of fruit ripeness [21]. Vitamin C or ascorbic acid is a powerful hydrosoluble antioxidant that protects body against oxidative stress, due to its ability of trapping hydroxyl and superoxide radicals. In addition, a regular daily intake of vitamin C ranged from 250–500 mg reduces oxidative damage by removing free radicals [22]

Antioxidant activities

In this study, three complementary tests were used to assess the antioxidant activity of *Carica papaya* L. var Solo 8 from different fruit parts harvested at several stages of maturity: DPPH free radical-scavenging activity, Trolox equivalent antioxidant capacity (TEAC) and reducing power assays. Antioxidant activity is a complex procedure usually happening through several mechanisms and is influenced by many factors, which cannot be fully described with one single method. Therefore, it is essential to perform more than one type of antioxidant capacity measurement to consider the various mechanisms of antioxidant action [11; 12].

Estimation of DPPH

As summarized in Table 3, the rank order of antioxidant potency was the same for all assays, namely stage, in decreasing order, immature, followed by 1/8 advanced, ¼ advanced, and advanced stage of maturity. All the extracts were able to reduce the stable, purple coloured radical DPPH into yellow-coloured DPPH-H. The water extract obtained from seeds at a concentration of 2 mg/mL exhibited a percentage inhibition of 90.03 ± 0.45 % at ¼ advanced stage of maturity. On the other hand, the lowest capacity to reduce DPPH was observed in pulp water extract (I = 23.01 ± 0.44 %) by immature stage.

Table 2

Total carotenoid and vitamin C compound in *C. papaya* L. var solo 8

Parameters	Analyzed parts of the fruit	Stages of maturity			
		Immature	**1/8 Advanced**	**1/4 Advanced**	**Advanced**
Carotenoids	Peel	35.10± 0.58^{b}	40.51 ± 0.31^{c}	93.50 ± 0.41^{h}	52.50 ± 0.61^{d}
	Pulp	91.50 ± 0.64^{h}	86.43 ± 0.11^{g}	74.04 ± 0.22^{f}	31.60 ± 0.73^{a}
	Seeds	72.49 ± 0.61^{f}	70.18 ± 0.05^{f}	61.17 ± 0.65^{e}	29.30 ± 0.65^{a}
Lycopene	Peel	3.15 ± 0.15^{d}	2.56 ± 0.04^{c}	1.06 ± 0.03^{b}	3.20± 0.10^{d}
	Pulp	1.93 ± 0.33^{c}	2.81 ± 0.03^{d}	8.03 ± 0.27^{f}	4.06± 0.05^{e}
	Seeds	3.02 ± 0.26^{d}	2.22 ± 0.03^{c}	1.54± 0.02^{c}	0.03 ± 0.03^{a}
β-carotene	Peel	7.02± 0.02^{d}	4.34± 0.06^{b}	21.07 ± 0.08^{g}	17.38 ± 0.09^{f}
	Pulp	3.35± 0.04^{a}	25.01 ± 0.03^{g}	18.24 ± 0.06^{f}	91.75 ± 0.06^{j}
	Seeds	5.62 ± 0.04^{c}	40.15 ± 0.04^{i}	30.03 ± 0.06^{h}	10.12 ± 0.04^{e}
Vitamin C	Peel	11.67 ± 0.06^{e}	15 ± 0.12^{f}	22.5 ± 0.04^{g}	11.25 ± 0.05^{d}
	Pulp	10 ± 0.07^{c}	07.50 ± 0.02^{a}	12.5 ± 0.01^{e}	08.33 ± 0.06^{a}
	Seeds	9.17 ± 0.06^{b}	12.5 ± 0.01^{e}	10.02 ± 0.09^{c}	10.23 ± 0.11^{c}

Values are expressed as mean ± standard deviation (n = 3). Means with different letters within a column were significantly different at the level *P < 0.05.*

Table 3

Effet of maturity stage on antioxidant measured by DPPH assays from different parts of *C. papaya* L. var solo 8

Stages of maturity	**Evaluated parts of fruits**	**DPPH**					
		C 0.0625	**C 0.125**	**C 0.25**	**C 0.5**	**C 1**	**C 2**
Immature	Peel	31.52 ± 0.66^{c}	36.43 ± 0.63^{e}	44.06 ± 0.88^{i}	49.10 ± 0.57^{k}	65.25 ± 0.45^{m}	84.01 ± 0.93^{p}
	Pulp	23.01 ± 0.44^{a}	31.64 ± 0.33^{d}	39.22 ± 0.49^{f}	42.33 ± 0.38^{h}	60.17 ± 0.48^{n}	81.05 ± 0.61^{o}
	Seeds	29.29 ± 0.68^{b}	34.26 ± 0.74^{d}	41.09 ± 0.14^{g}	45.22 ± 0.43^{j}	62.01 ± 0.97^{n}	82.53 ± 0.55^{o}
1/8 Advanced	Peel	38.22 ± 0.61^{d}	41.1 ± 0.37^{e}	49.08 ± 0.32^{h}	53.72 ± 0.39^{i}	69.25 ± 0.28^{k}	85.66 ± 0.58^{n}
	Pulp	36.16 ± 0.83^{c}	39.26 ± 0.83^{d}	45.17 ± 0.53^{f}	49.26 ± 0.66^{h}	54.11 ± 0.57^{i}	72.24 ± 0.49^{l}
	Seeds	31.63 ± 0.57^{a}	35.07 ± 0.95^{b}	46.01 ± 0.89^{g}	46.29 ± 0.78^{g}	64.21 ± 0.76^{j}	80.24 ± 0.52^{m}
1/4 Advanced	Peel	35.45 ± 0.35^{b}	37.74 ± 0.49^{c}	41.26 ± 0.75^{e}	47.18 ± 0.34^{g}	50.02 ± 0.63^{i}	60.21 ± 0.89^{k}
	Pulp	35.47 ± 0.71^{b}	39.32 ± 0.76^{d}	41.44 ± 0.98^{e}	46.74 ± 0.64^{g}	50.01 ± 0.34^{i}	55.17 ± 0.51^{j}
	Seeds	34.19 ± 0.51^{a}	39.04 ± 0.61^{d}	48.09 ± 0.45^{h}	50.03 ± 0.59^{i}	68.29 ± 0.65^{l}	90.03 ± 0.45^{m}
Advanced	Peel	28.01 ± 0.58^{a}	30.56 ± 0.36^{b}	40.61 ± 0.59^{f}	45.29 ± 0.48^{i}	48.76 ± 0.44^{k}	58.06 ± 0.75^{o}
	Pulp	35.47 ± 0.71^{d}	39.32 ± 0.76^{e}	41.44 ± 0.98^{g}	46.74 ± 0.64^{j}	50.01 ± 0.34^{k}	55.17 ± 0.51^{n}
	Seeds	32.28 ± 0.40^{c}	36.11 ± 0.31^{i}	39.88 ± 0.66^{e}	43.21 ± 0.14^{h}	48.68 ± 0.61^{k}	52.24 ± 0.48^{m}
Trolox		45.43 ± 0.66^{a}	59.76 ± 0.11^{b}	69.43 ± 0.27^{c}	82.01 ± 0.19^{d}	85.08 ± 0.51^{e}	92.29 ± 0.41^{f}

Tests: n=3; means ± standard deviation with different lowercase letters on the same line are significantly different at p<0.05 in Duncan's test.

Table 4
Effet of maturity stage on antioxidant measured by ABTS assays from different parts of *C. papaya* L. var solo 8

Stages of maturity	Evaluated parts of fruits	ABTS					
		C 0.0625	C 0.125	C 0.25	C 0.5	C 1	C 2
Immature	Peel	44.62 ± 0.58^{c}	49.34 ± 0.38^{e}	56.03 ± 0.92^{h}	61.9 ± 0.74^{i}	64.19 ± 0.94^{j}	70.22 ± 0.46^{k}
	Pulp	41.24 ± 0.16^{b}	47.01 ± 0.47^{d}	49.36 ± 0.28^{e}	54.29± 0.28^{g}	60.74 ± 0.45^{i}	61.02 ± 0.18^{i}
	Seeds	40.97 ± 0.29^{a}	44.19 ± 0.98^{c}	46.21 ± 0.11^{d}	51.11 ± 0.24^{f}	57.62 ± 0.49^{h}	60.17 ± 0.90^{i}
1/8 Advanced	Peel	47.21 ± 0.80^{c}	49.64 ± 0.51^{e}	54.33 ± 0.92^{g}	59.88 ± 0.17^{j}	63.74 ±0.54^{m}	66.14 ± 0.99^{o}
	Pulp	45.41 ± 0.91^{b}	49.35 ± 0.77^{e}	51.86 ± 0.26^{f}	56.67 ± 0.42^{h}	61.59 ± 0.80^{l}	64.28 ± 0.23^{n}
	Seeds	44.82 ± 0.85^{a}	48.23 ± 0.76^{d}	54.18 ± 0.14^{g}	57.71 ± 0.46^{i}	60.07 ± 0.30^{k}	61.47 ± 0.31^{l}
1/4 Advanced	Peel	46.90 ± 0.14^{a}	47.67 ± 0.34^{b}	49.53 ± 0.43^{e}	53.92 ± 0.12^{f}	57.09 ± 0.89i	61.78 ± 0.26^{l}
	Pulp	46.67 ± 0.32^{a}	49.09 ± 0.19^{c}	53.21 ± 0.84^{f}	57.10 ± 0.13^{i}	58.41 ± 0.27^{j}	60.01 ± 0.20^{k}
	Seeds	47.59 ± 0.56^{b}	48.54 ± 0.42^{c}	54.02 ± 0.24^{g}	55.61 ± 0.42^{h}	57.29 ± 0.15^{i}	58.94 ± 0.13^{j}
Advanced	Peel	49.75 ± 0.47^{f}	47.19 ± 0.27^{d}	49.21 ± 0.26^{f}	54.39 ± 0.25^{j}	57.43 ± 0.26^{k}	59.07 ± 0.26^{l}
	Pulp	44.82 ± 0.39^{b}	46.66 ± 0.28^{c}	48.64 ± 0.36^{e}	50.42 ± 0.59^{g}	52.61 ± 0.37^{i}	54.18 ± 0.81^{j}
	Seeds	43.56 ± 0.50^{a}	46.15 ± 0.20^{c}	48.38 ± 0.27^{e}	50.02 ± 0.11^{g}	51.84 ± 0.29^{h}	52.24 ± 0.27^{h}
Trolox		75.15 ± 0.05^{a}	79.76 ± 0.09^{b}	84.56 ± 0.13^{c}	89.10 ± 0.19^{d}	90.21 ± 0.21^{e}	92.08 ± 0.17^{e}

Tests: n=3; means ± standard deviation with different lowercase letters on the same line are significantly different at $p<0.05$ in Duncan's test.

Estimation of ABTS

The method described gives a measure of the antioxidant activity of the range of peel, pulp and seeds at different stages of maturity, fruit extract antioxidants, determined by the decolorization of the ABTS, through measuring the reduction of the radical cation as the percentage inhibition of absorbance at 734 nm. The results given in the table 4 remain like DPPH inhibition. Peel had the highest level of ABTS antioxidant (70.22 ± 0.46 %) at immature stage. Infact the used methods have different reaction mechanisms [23].

For instance, DPPH and ABTS assays are based on electron and H atom transfer, while the FRAP assay is based on electron transfer reaction [23; 24]. However, the three methods clearly indicated that the studied plants possess considerable antioxidant and antiradical activities. Furthermore, well-pronounced correlations were observed between these methods which confirm that the three assays were all suitable and reliable to assess the total antioxidant capacities of plant extracts.

Estimation of FRAP

As depicted in table 5, immature stage of fruits showed the highest radical TE values. At all extract concentrations, peel had the highest TE value where it ranks a percentage inhibition of 87 ± 7.79 %. The lowest value of 28.60 ± 1.60 % was shown by seeds.

FRAP assay measures the tendency of an antioxidant which acts as a reducing agent and brings a single electron to the Fe^{3+} in a redox-linked colorimetric reaction based on the breaking of the free-radical chain in order to stabilize and finish the radical chain reactions [24]. This will cause an increase in absorbance; however, it is limited to only hydrophilic antioxidants or water-soluble antioxidants [25].

Table 5

Effet of maturity stage on antioxidant measured by FRAP assays from different parts of *C. papaya* L. var solo 8

Stages of maturity	Evaluated parts of fruits	FRAP					
		C 0.0625	C 0.125	C 0.25	C 0.5	C 1	C 2
Immature	Peel	42.00 ± 1.40^{f}	49.00 ± 3.40^{h}	54.20 ± 2.03^{j}	60.80 ± 4.13^{k}	79.60 ± 2.36^{m}	87.00 ± 7.79^{n}
	Pulp	32.00 ± 0.03^{b}	36.40 ± 2.49^{c}	40.20 ± 1.11^{e}	53.20 ± 5.33^{i}	60.40 ± 3.67^{k}	60.80 ± 6.69^{k}
	Seeds	28.60 ± 1.60^{a}	33.80 ± 5.07^{b}	36.60 ± 3.55^{c}	48.20 ± 5.18^{g}	60.60 ± 2.43^{k}	64.60 ±1.70^{l}
1/8 Advanced	Peel	38.80 ± 0.12^{c}	44.80 ± 3.94^{e}	49.60 ± 2.83^{g}	59.40 ± 4.39^{h}	66.20 ± 2.80^{i}	73.40 ±5.19^{l}
	Pulp	38.60 ± 2.20^{c}	38.00 ± 2.30^{c}	40.40 ± 3.36^{d}	48.20 ± 5.29^{f}	68.80 ± 5.29^{j}	66.80 ± 3.8^{i}
	Seeds	34.00 ± 0.13^{a}	35.40 ± 5.60^{b}	36.60 ± 4.01^{b}	40.60 ± 2.10^{d}	69.40 ± 2.50^{k}	74.40 ±4.10^{m}
1/4 Advanced	Peel	38.20 ± 2.80^{d}	43.40 ± 4.93^{g}	50.20 ± 6.82^{j}	57.80 ± 2.50^{l}	60.80 ± 3.22^{m}	69.60 ±5.05^{p}
	Pulp	36.80 ± 4.19^{b}	41.60 ± 3.33^{f}	45.00 ± 5.44^{h}	54.60 ± 4.52^{k}	67.40 ± 7.27^{o}	64.20 ±5.38^{n}
	Seeds	33.40 ± 5.60^{a}	37.00 ± 3.12^{c}	40.00 ± 3.89^{e}	46.80 ± 6.29^{i}	79.80 ± 9.34^{q}	79.40 ±6.82^{q}
Advanced	Peel	37.80 ± 3.82^{c}	42.60 ± 3.90^{e}	49.20 ± 7.07^{g}	54.00 ± 5.24^{h}	57.80 ± 8.77^{i}	66.80 ± 6.88^{l}
	Pulp	35.60 ± 4.10^{b}	39.40 ± 5.26^{d}	46.80 ± 6.35^{f}	49.00 ± 6.42^{g}	63.60 ± 3.55^{k}	62.20 ±7.03^{j}
	Seeds	32.20 ± 4.99^{a}	35.00 ± 3.94^{b}	38.40 ± 5.07^{d}	41.80 ± 4.71^{e}	64.20 ± 3.40^{k}	51.60 ± 5.12^{g}
Trolox		40.21 ± 0.09^{a}	55.43 ± 0.04^{b}	70.55 ± 0.07^{c}	81.78 ± 0.31^{d}	85.77 ± 0.29^{e}	90.13 ±0.52^{f}

4. Conclusion

The results presented in this work clearly demonstrate that the amounts of phenolic compounds and the antioxidant capacities of papaya (*Carica papaya* L. var solo 8) were affected by maturation stages. It was shown that peel has a notable antioxidant activity at immature stage and it is found to be a good source of antioxidants. These findings confirm the antioxidant potential of papaya (*Carica papaya* L. var solo 8) and increase focus on the impact on health promoting antioxidative compounds in all parts of the fruit during the four maturation stages.

The papaya (*Carica papaya* L. var solo 8) peel flour could be used as a potential source for functional food ingredients and, in addition, it could be further processed into therapeutic functional food products, at immature stage. However, pulp and seeds are good for consumers from 1/8 to ¼ of advanced maturation.

5. References

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