academicJournals

Vol. 8(40), pp. 1013- 1020, 25 October, 2015
DOI: 10.5897/JMPR2015.5926
Article Number: 221415956085
ISSN 1996-0875

http://www.academicjournals.org/JMPR

Journal of Medicinal Plants Research

Full Length Research Paper

Determination of antioxidant, radical scavenging activity and total phenolic compounds of *Artocarpus heterophyllus* (Jackfuit) seeds extracts

Lígia Moura Burci*, Cristiane Bezerra da Silva, Maislian de Oliveira, Luciane Dalarmi, Sandra Maria Warumby Zanin, Obdúlio Gomes Miguel, Josiane de Fátima Gaspari Dias and Marilis Dallarmi Miguel

Postgraduate Program in Pharmaceutical Sciences (PPGCF), Universidade Federal do Paraná (UFPR), Av. Lothario Meissner, s/n, Jardim Botânico, 81530-900 Curitiba, PR, Brazil.

Received 12 August, 2015; Accepted 19 October, 2015

Plants and their parts are a part of life in many brazilian communities, as observed in the jackfruit. The jackfruit seeds are consumed usually as roasted, boiled, steamed, and are eaten as a snack. The present study was carried out to identify the antioxidant, radical scavenging activity and total phenolic compounds of *Artocarpus heterophyllus* seeds using different screening tests. Total antioxidant activity was determined by ferric thiocyanate method (FTC), which was shortly followed by complexing of fosfomolybdenium method (FSB) determined in sequence with total reductive capability (TRC), hydrogen peroxide scavenging activity (HPS), DPPH free radical scavenging activity, and Total phenolic content (TPC) by Folin-Ciocalteu reagent assay method. The percentage of inhibition linoleic acid peroxidation by CEE (ethanolic extract), HF (hexanic extract), CHLF (chloroform extract) and EAF (ethyl acetate extract) (90.53, 70.23, 68.72 and 92.03%, respectively), in method using prussian blue antioxidant potential for EAF (89,05%) presented antioxidant activity greater than the standard rutin (82.3%). Highest total antioxidant activity was exerted by the ethanolic extract of *A. heterophyllus* seeds, and lowest by its EAF (188.83%). In evaluating the antioxidant activity by the hidrogen peroxide scavenging activity, it was observed that the CHLF and HF extracts showed scavenging activity above 50% (83.3 and 83.5%, respectively). The EC_{50} (free radical scavenger) values of CEE, HF, CHLF and EAF were 76.71, 399.64, 534.83 and 65.51 µg/ml, respectively, and the highest total phenolic content appeared to be present in 125 µg/ml of EAF. The results of all the sources were found to be highly significant. Further investigation for isolation and identification of the phytoconstituents responsible for antioxidant activity is desirable. *A. heterophyllus* seeds in the regular diets could improve the antioxidant status of human beings.

Key words: Jackfruit, antioxidant activity, DPPH radical, radical scavenging, seeds.

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* L.) is a shrub belonging to Moraceae family and is widely distributed in tropical countries such as Brazil, Thailand, Indonesia, India, Philippines and Malaysia (Chowdhury et al., 1997). Jackfruit is composed of several berries of yellow pulp and brown seeds encased in a hard shell and are rich in carbohydrates, complex B vitamins and minerals (Silva et al., 2007). Jackfruit is 2 to 4 cm long, and a fruit can

contain between 100 to 500 seeds. The seeds are consumed usually as roasted, boiled, steamed, and eaten as a snack. However, fresh seeds have short shelf-life.

To explore the health-promoting functionalities of locally available, culturally acceptable, and economically viable Brazilian foods, it is important to focus on their bioactive compounds. Among the various bioactive substances, phenolic compounds are the most abundant antioxidants in commonly consumed foods of plant origin.Cellular oxidants, called reactive oxygen species (ROS), are constantly produced in animal and human cells and play dual role of being both deleterious and beneficial to biological systems (Rudolf, 2001). Apart from their role in the diseased conditions in the body, ROS are also known to have a role in the spoilage of food by the autoxidation of lipids, the enzymatic oxidation, during storage and processing in fats, oils and fat-containing foods (Matthaus, 2002). Antioxidants are defined as substances present at low concentration, relative to the oxidizable substrate, which significantly delay or prevent oxidation of substrate (Godfraind, 2005). In the body, antioxidants act as free radical scavengers and thus protect cells from being exposed to free radicals and further cellular damage. This is the mechanism by which they protect the human body from several diseases attributed to the reactions of radicals.

The oxidative stress leads to serious damage to macromolecules, such as proteins and DNA. However, free radical production can be eliminated by the action of endogenous enzymes, as well as by the synthetic antioxidant activity (Halliwell 1990, 1997). Antioxidants act by several mechanisms, including the prevention of transition metal ions- chelation catalysts, peroxidase decomposition and free radicals elimination (Valko et al., 2006).

The addition of jackfruit seed flour in the preparation of biscuits, sweets and breads has been investigated as an alternative use of this by-product (Aldana et al., 2011; Bobbio et al., 1978; Mukprasit and Sajjaanantakul, 2004). Therefore, in the present study, the seeds of *A. heterophyllus* were evaluated for their antioxidant activity.

MATERIALS AND METHODS

Chemicals

Linoleic acid, α-tocopherol, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), nitroblue tetrazolium (NBT), phenazine methosulphate (PMS), the stable free radical 1,1-diphenyl-2-picryl-hydrazyl (DPPH·), 3-(2-pyridyl)-5,6-bis (4-phenyl-sulfonic acid)-1,2,4-triazine (Ferrozine), trichloroacetic acid (TCA) and polyoxyethylenes orbitan monolaurate (Tween-20) were obtained from Sigma (Sigma-Aldrich, Brazil). Ammonium thiocyanate was purchased from Merck. All other chemicals used were of analytical grade and obtained from either Sigma-Aldrich or Merck.

Plant materials and extraction procedures

Seeds of *A. heterophyllus* were collected in Arapongas - Brazil, in September, 2014. The material was identified by the botanist José Tadeu Weidlich Motta of the Municipal Botanical Museum of Curitiba and the exsiccate deposited under the number 397798. After drying in the shade, 80 g of seeds were submitted to ethanol extraction, following by liquid-liquid partition with hexane, cloroform and ethyl acetate, using Sohxlet, as per methodology described in previous studies (Andrade et al., 2005, 2007; Carvalho et al., 2009). After the evaporation of the solvents under reduced pressure and temperature of 40°C, a 0.53 g of hexane fraction, 1.89 g of ethyl acetate fraction, 0.3 g of cloroform, and 0.11 g of ethanol fraction were obtained.

Total antioxidant activity determination by ferric thiocyanate method (FTC)

The antioxidant activity of ethanolic extract (CEE), hexanic extract (HF), chloroform extract (CHLF) and ethyl acetate extract (EAF) and standards was determined according to the ferric thiocyanate method, with modifications (Mitsuda et al., 1996). For preparation of stock solutions, 2 mg of each CEE, HF, CHLF and EAF was dissolved in 10 ml water. HF and CHLF was previously solubilized in methanol. Then, 250 µl of the solution, which contained concentrations of stock CEE, HF, CHLF and EAF solution (200 µg/ml) or standard samples (200 µg/ml) in 2 ml of potassium phosphate buffer (0.04 mol/L, pH 7.0), was added to 550 µl of linoleic acid emulsion in potassium phosphate buffer (0.04 mol/L, pH 7.0), ethanol (PA) 250 µl, and 900 µl of water was added. The mixed solution (3.95 ml) was incubated at 50°C in a polyethylene flask. The peroxide level was determined by reading the absorbance at 500 nm in a spectrophotometer (Bio-Crom GmbH, Zurich, Switzerland) after reaction with $FeCl_2$ and thiocyanate at intervals during incubation. During the linoleic acid oxidation, peroxides are formed, which oxidize Fe^{+2} to Fe^{+3}. The latter ions form a complex with thiocyanate and this complex has a maximum absorbance at 500 nm. Five (5 ml) linoleic acid emulsion contained 17.5 µg Tween-20, 15.5 µl linoleic acid and 0.04 M potassium phosphate buffer (pH 7.0). On the other hand, the 5 ml control was composed of 2.5 ml linoleic acid emulsion and 2.5 ml 0.04 M potassium phosphate buffer (pH 7.0). This step was repeated every 5 h until the control reached its maximum absorbance value. Therefore, high absorbance indicates a high linoleic acid emulsion oxidation. Solutions without added extracts were used as blank samples. All data on total antioxidant activity is the average of triplicate analyses. The percentage inhibition of lipid peroxidation in linoleic acid emulsion was calculated by following equation.

Inhibition of lipid peroxidation Sample Control (%) $=100 \times (A_{control} - A_{sample}) / A_{control}$

Where $A_{control}$ is the absorbance of the control reaction and A_{sample} is the absorbance in the presence of the sample of CEE, HF, CHLF and EAF or standard compounds.

*Corresponding author. E-mail: ligia.burci@gmail.com.

Total reductive capability (TRC)

The reducing power of CEE, HF, CHLF and EAF was determined by the method of Yen and Chen (1995). HF and CHLF was previously solubilized in methanol. Concentrations of CEE, HF, CHLF and EAF (200 µg/ml) in 1 ml of distilled water were mixed with phosphate buffer (2.5 ml, 0.2 M, pH 6.6) and potassium ferricyanide [$K_3Fe(CN)_6$] (2.5 ml, 1%). The mixture was incubated at 50°C for 20 min. Aliquots (2.5 ml) of trichloroacetic acid (10%) were added to the mixture, which was then centrifuged for 10 min at 1000 × g (MSE Mistral 2000, UK). The upper layer of the solution (2.5 ml) was mixed with distilled water (2.5 ml) and $FeCl_3$ (0.5 ml, 0.1%) and the absorbance was measured at 700 nm in a spectrophotometer. Increased absorbance of the reaction mixture indicates increased reducing power.

Evaluation of antioxidant activity by complexing fosfomolybdenum (FSB) method

This method, described by Prieto et al. (1999) is based on the reduction of molybdenum (VI) to molybdenum (V) which occurred in the presence of certain substances with antioxidant capacity, with formation of a complex between phosphate green/molybdenum (V), acid pH, which is determined spectrophotometrically at 695 nm. The phosphomolibdenium complex was formed by the reaction of Na_3PO_4 solution (28 ml, 0.1 mol/L) with solution of $(NH_4)6Mo_7O_{24}.4H_2O$ (12 ml, 0,03 mol/L) H_2SO_4 solution (20 ml, 3 mol/L) in an aqueous medium. The final volume was adjusted with distilled water to 100 ml, and the yellow color turned green as it reduced. For the preparation of the phosphomolibdenium complex, all reagents were transferred into a volumetric flask and the volume was completed to 100 ml with distilled water. CEE, HF, CHLF and EAF were prepared in aqueous solutions with final concentration of 200 µg/ml, using a minimum amount of methanol to dissolve the sample when necessary. Of these, 0.3 ml were taken and added to 1 ml of reagent solution fosfomolibdenio complex.

The tubes were closed and kept in a water bath at 95°C for 90 min. After cooling, the reading was carried out at 695 nm in a Shimadzu UV-1601 spectrophotometer, to obtain the absorbance, using distilled water as the blank. The antioxidant capacity of the samples was expressed relative to ascorbic acid (200 µg/ml) which was used as standard and rutin (200 µg/ml) whose antioxidant activity was considered a reference. Ascorbic acid is one of the most effective and best known biological antioxidant (Darr et al., 1996). For this test we used the following samples in triplicate: ethanol crude extract, and fractions hexane, chloroform and ethyl acetate.

The results of the evaluation of the antioxidant activity were expressed as relative antioxidant activity AAR% (ascorbic acid) and AAR% (rutin). The calculations were established by means of the equations:

$$AAR\%\ (\text{Ascorbic acid}) = 100 \times (A_{sample} - A_{blank}) / (A_{ascorbic\ acid} - A_{blank})$$
$$AAR\%\ (\text{rutin}) = 100 \times (A_{sample} - A_{blank}) / (A_{rutin} - A_{blank})$$

Hydrogen peroxide scavenging activity (HPS)

The hydrogen peroxide scavenging ability of CEE, HF, CHLF and EAF was determined according to the method of Ruch et al (1989). A solution of H_2O_2 (40 mM) was prepared in phosphate buffer (pH 7.4). Extracts (500 µg/ml) in distilled water, using as amount minimum methanol to dissolve the sample were added to a H_2O_2 solution (0.6 ml, 40 mM). The absorbance value of the reaction mixture was recorded at 230 nm. Blank solution contained the phosphate buffer without H_2O_2. The percentage of H_2O_2 scavenging of CEE, HF, CHLF and EAF and standard compounds was calculated as:

$$\%\ \text{Scavenging effect} = 100 \times (A_{control} - A_{sample}) / A_{control}$$

Where $A_{Control}$ is the absorbance of the control, and A_{Sample} is the absorbance in the presence of the sample of CEE, HF, CHLF and EAF or standards (Gülçin et al., 2003).

1,1-Diphenyl-2-picryl-hydrazyl (DPPH) free radical scavenging activity

The free-radical scavenging capacity of CEE, HF, CHLF and EAF was evaluated with the DPPH· stable radical following the methodology described by Blois (1958). This method is described extensively elsewhere (Elmastas et al., 2006), wherein the bleaching rate of a stable free radical, DPPH· is monitored at a characteristic wavelength in the presence of the sample. In its radical form, DPPH was absorbed at 517 nm, but upon reduction by an antioxidant or a radical species, its absorption decreased (Elmastas et al., 2006). Briefly, 0.1 mmol/L solution of DPPH· in ethanol was prepared and 1 ml of this solution was added to 3 ml of CEE, HF, CHLF and EAF solution in water at different concentrations (25 to 500 µg/ml). Thirty minutes later, the absorbance was measured at 517 nm. A lower absorbance of the reaction mixture indicates higher free radical scavenging activity. The DPPH· concentration (mM) in the reaction medium was calculated from the following calibration curve, determined by linear regression (R2 = 0.990):

$$\text{Absorbance} = 9.2872 \times [\text{DPPH}\cdot] + 0.097$$

The capability to scavenge the DPPH· radical was calculated using the following equation:

$$\text{DPPH scavenging} = 100 \times (A_{control} - A_{sample}) / A_{control}$$

Where $A_{Control}$ is the absorbance of the control reaction and A_{Sample} is the absorbance in the presence of CEE, HF, CHLF and EAF (Gülçin et al., 2005).

Total phenolic compounds (TPC)

The content of phenolic compounds in CEE, HF, CHLF and EAF was performed based on colorimetric Folin-Ciocalteu method (Kujala et al., 2000; Wu et al., 2005; Meda et al., 2005), with some modifications. Rates of CEE, HF, CHLF and EAF were diluted with distilled water to obtain concentrations of 25 to 100 mg/ml. To the 0.5 ml of each sample was added 0.5 ml of 2N Folin-Ciocalteau reagent and 1.0 ml of water. After a period of 2 to 5 min, to the tubes was added 0.5 ml of sodium carbonate (Na_2CO_3) at 10%. After 1 h incubation at room temperature, absorbance was measured in spectrophotometer at 760 nm using distilled water as the blank. Gallic acid (2.5 to 12.5 mg/ml) dissolved in distilled water was used for standardize the phenolic concentration curve preparation, and values were expressed as gallic acid equivalents (mg gallic acid/g sample).

Statistical analysis

All data on total antioxidant activity are the average of triplicate analyses. The data were recorded as mean ± standard deviation and analysed by Graph Pad Prism (version 6.0). Oneway analysis of variance was performed by ANOVA procedures. Significant differences between means were determined by Duncan's multiple range tests. Values of $p < 0.05$ were regarded as significant and $p < 0.01$ very significant.

Table 1. Antioxidant activity by complexing method fosfomolibdenio in the crude ethanolic extract (CCE), and hexanic (HF), chloroformic (CHLF) and ethyl acetate (EAF) extracts in *A. heterophyllus* seeds.

Parameter	AAR% rutin (x±dp)	AAR % ascorbic acid (x±dp)
CEE	701.00±4.52	219.62±1.41
HF	635.24±4.24	199.01±1.33
CHLF	607.29±4.69	190.26±1.47
EAF	602.74±2.34	188.83±0.73

RESULTS AND DISCUSSION

Results of different assays performed for all the extracts are presented in tables and graphs.

Total antioxidant activity determination by ferric thiocyanate method (FTC).

The antioxidant effects of *A. heterophyllus* seeds prevented the peroxidation of linoleic acid, as measured by thiocyanate method (Figure 1). We have found the anti-oxidative property of these four extracts (CEE, HF, CHLF and EAF). The percentage of inhibition linoleic acid peroxidation by CEE, HF, CHLF and EAF (90.53, 70.23, 68.72 and 92.03%, respectively) were simmilar with the pattern BHT (di-terc-butil metil fenol) (78.32%) as shown in Figure 1. These results demonstrate the importance of the extracts in preventing oxidation as substances such as cell membranes.

Methods to evaluate the lipid peroxidation are important since they measure the action of a free radical on cell membrane lipids, leading to destruction of its structure, the failure mechanism of exchange metabolites, and in an extreme condition, to cell death (Benzie, 1996). In the ferric thiocyanate method, the present peroxides oxidize Fe^{2+} to Fe^{3+}, which is determined by colorimetry (500 nm) as ferric chloride or thiocyanate (Silva et al., 1999). In this assay, hydroperoxides generated during the oxidation of linoleic acid react with ferrous sulfate to give ferric sulfate and then ferric thiocyanate and blood red color. The decrease in absorbance discloses interrupting the oxidation due to the unavailability of linoleic acid in the reaction medium and the appearance of secondary products derived from the degradation of hydroperoxides (Chen et al., 1996).

Total reductive capability (TRC).

The reduction of a capacity fraction serves as an indicator of its antioxidant potential. In evaluating the antioxidant activity by reducing power method (Prussian Blue), an antioxidant potential for EAF (89.05%) presenting antioxidant activity upper to the standard rutin (82.3%) was observed. The other extracts did not show 50% activity compared to Rutin, as showed in Figure 2.

Methods based on the reduction of $Fe^{3+,}$ determining the reducing power are also used to evaluate antioxidant activity. These methods assess the ability of phenolic compounds to reduce Fe^{3+}, with consequent formation of a colored complex with Fe^{2+} (Roginsky et al., 2005). The reducing power was observed by direct donation of electrons in the reduction of potassium ferricyanide $[Fe(CN)_6]^{3-}$ potassium ferrocyanide $[Fe(CN)_6]^{4-}$. The product was visualized by the addition of Fe^{3+} ions which form complex Prussian Blue, $Fe_4[Fe(CN)_6]^3$. This method is considered very effective when the substances present phenolic compounds. Thus this test is to quantify either total phenols, and to determine the antioxidant activity (Monteiro et al., 2005). *In vitro* studies indicate that phenolic compounds found in plants can effectively participate in processes that may have anti-carcinogenic implications. Among these processes, the most obvious is the antioxidant capacity of these compounds reducing power allocated to the aromatic hydroxyl group, which reduces reactive free radical, and radical fenoxila produces stabilized resonance. Antioxidant capacity of phenolic compounds is influenced by the number and position of the OH groups, as well as by glycosylation positions (Cerqueira, 2007).

The assay of reducing power becomes important in the analysis of substances for purposes of comparison with the activity of DPPH. The advantage of this test lies in the fact that trials in less soluble fractions of activity may have their particular activity. Huang et al. (2005) found that extracts obtained from edible fuits have excellent antioxidant power reduction, and considering that the reducing power of the ethyl acetate extract was superior to commercial standard rutin, it can be considered that this has a high antioxidant activity.

Evaluation of antioxidant activity by complexing method fosfomolibdenio (FSB)

Different extracts showed the total antioxidant activity in a wide range as shown in Table 1. Highest total antioxidant

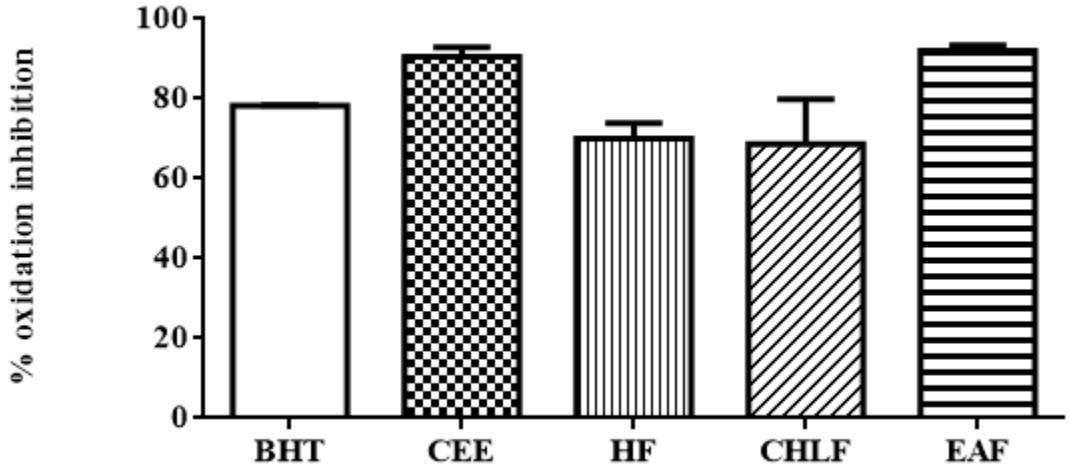

Figure 1. Antioxidant activity of standard BHT, crude ethanolic extract (CCE), and hexanic (HF), chloroformic (CHLF) and ethyl acetate (EAF) extracts in *A. heterophyllus* seeds by thiocyanate method. None of statements presented statistical difference when compared to standard bht. Dunnet test ($p < 0.05$).

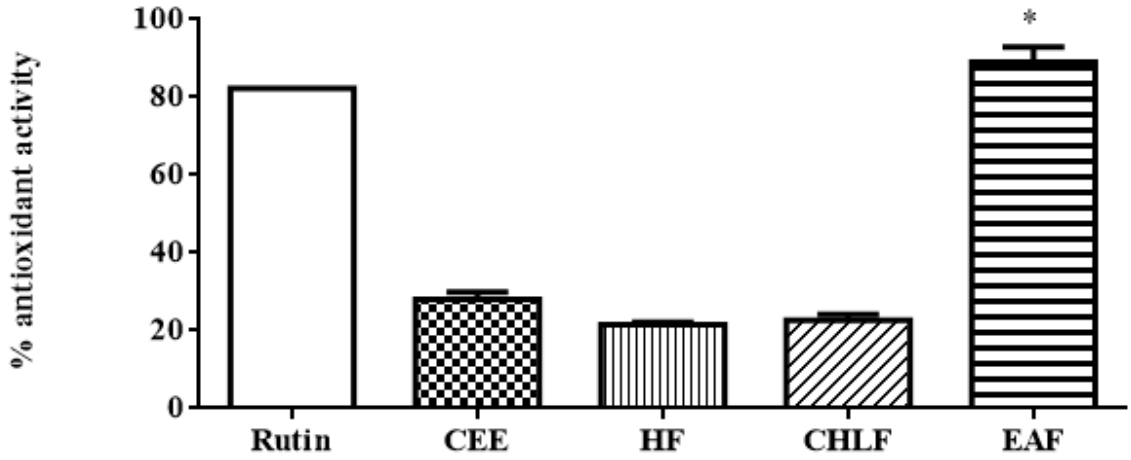

Figure 2. Antioxidant activity of pattern Rutin, crude ethanolic extract (CCE), and hexanic (HF), chloroformic (CHLF) and ethyl acetate (EAF) extracts in *A. heterophyllus* seeds by reducing power (Prussian blue). *significantly different when compared to Rutin. Dunnet test ($p < 0.05$).

activity was exerted by the ethanolic extract of *A. heterophyllus* seeds, and lowest by its EAF (188.83%). All extracts showed that close activities were all included possible antioxidants. Ascorbic acid (200 µg/ml), used as a positive control, registered an activity 100%. In the test of the antioxidant fosfomolibdenio, the results indicate that all extracts from *A. heterophyllus* seeds, to reduce the molybdenum VI to molybdenum V, can inhibit the action of xanthine oxidase. Xanthine oxidase (XO) is the enzyme responsible for processing both hypoxanthine to xanthine to uric acid, as this, in the physiological environment, is in the form of urate. The hypoxanthine and xanthine are much more soluble than uric acid and the latter may deposit as sodium urate, a major contributor to the development of the condition known as gout (Tsutomu et al., 1991). Thus, extracts and fractions which had antioxidant activity by this method may have their activities investigated in the treatment of gout disease.

Hydrogen peroxide scavenging activity (HPS)

In evaluating the antioxidant activity by the hydrogen peroxide scavenging activity, it was observed that the CEE and EAF extracts did not show activity similar to

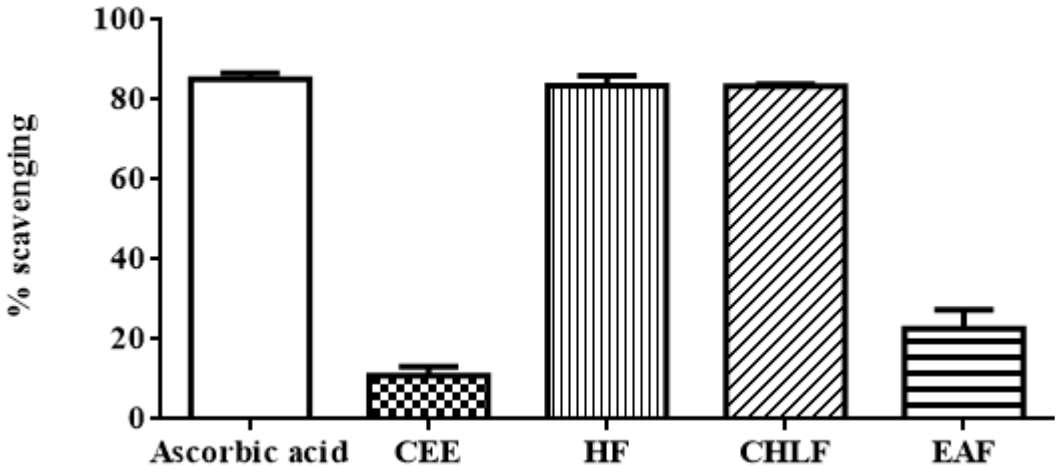

Figure 3. Antioxidant activity by , crude ethanolic extract (CCE), and hexanic (HF), chloroformic (CHLF) and ethyl acetate (EAF) extracts in *A. heterophyllus* seeds compared with Ascorbic acid by H_2O_2 scavenging method. Dunnet test ($p < 0.05$).

standard ascorbic acid. However, the CHLF and HF extracts showed scavenging activity above 50% (83.3 and 83.5%, respectively) (Figure 3). Although hydrogen peroxide is not a free radical, it is involved directly or indirectly in different pathologies. In chemical terms, H_2O_2 is poorly reactive, however it plays an important role in oxidative stress by being able to cross cellular membranes easily and generate the hydroxyl radical (•OH) (Aruoma et al., 1989). Hidrogen peroxide can readily cross cell membranes and once inside the cell, the hydrogen peroxide can react with Fe^{2+} ions to form hydroxyl radicals which may cause toxic effects. Therefore, it is advantageous to biologically cells which control the amount of hydrogen peroxide (Nagulendran et al., 2007). Thus, the fractions of CHLF and HF with higher antioxidant activity have shown to be promising in the study of antioxidant activity in the scavenging of H_2O_2.

1,1-Diphenyl-2-picryl-hydrazyl (DPPH) free radical scavenging activity

DPPH, a stable free radical with characteristics of absorption at 515 nm, was widely utilized to appraise the radical scavenging activity of extracts. Highest and lowest activity was exerted, respectively, in EAF and HF extract of *A. heterophyllus* seeds (Figure 4). Extracts prepared in polar solvents are better free radical scavengers than those prepared in less polar solvents, as evident from the fact that hexane extracts exhibited least DPPH scavenging ability. The potency of the extracts in scavenging the radicals is due to the number of hydrogens available for donation by the hydroxyl groups (Chen and Ho, 1995). Higher activity of the EAF extract may be due to the presence of high hydroxyl groups, which is proportionate to their phenolic content. Free radicals act as a trigger to a number of degenerative diseases. Therefore, samples having free radical scavenging activity can be of potent medicinal importance. The significant increase in DPPH free radical scavenging power of CEE, HF, CHLF and EAF were observed in a concentration-dependent fashion (Figure 4), confirming the free radical scavenging activity of *A. heterophyllus* seeds. The EC_{50} (free radical scavenger) values of CEE, HF, CHLF and EAF were 76.71, 399.64, 534.83 and 65.51 µg/ml, respectively. Ascorbic acid, a potent antioxidant, had lower EC_{50} value (4.92 µg/ml) than EAF. Ascorbic acid and rutin was used as a positive control.

Total phenolic compounds (TPC)

Plant phenolics present in fruits and vegetables have received considerable attention because of their potential antioxidant activity. Total phenolic content of different extracts was recorded in the range of 3.034 to 5.72 µg GAE of samples tested. The highest total phenolic content appeared to be present in 125 µg/ml of EAF. The concentrations of 25 and 50 µg/ml of the samples appeared to be poor in extracting phenolics. Fruits contain phytochemicals which have antioxidants known as polyphenols, which can strengthen the defense response in the body through different antioxidant mechanisms such as eliminating harmful free radicals in cells and likely tissues. Consequently, the antioxidant activity of a fruit is an important parameter to consider for the establishment of its nutritional value (Rice-Evan and Miller, 1996).

Epidemiological research has established an association between high intake of polyphenols derived

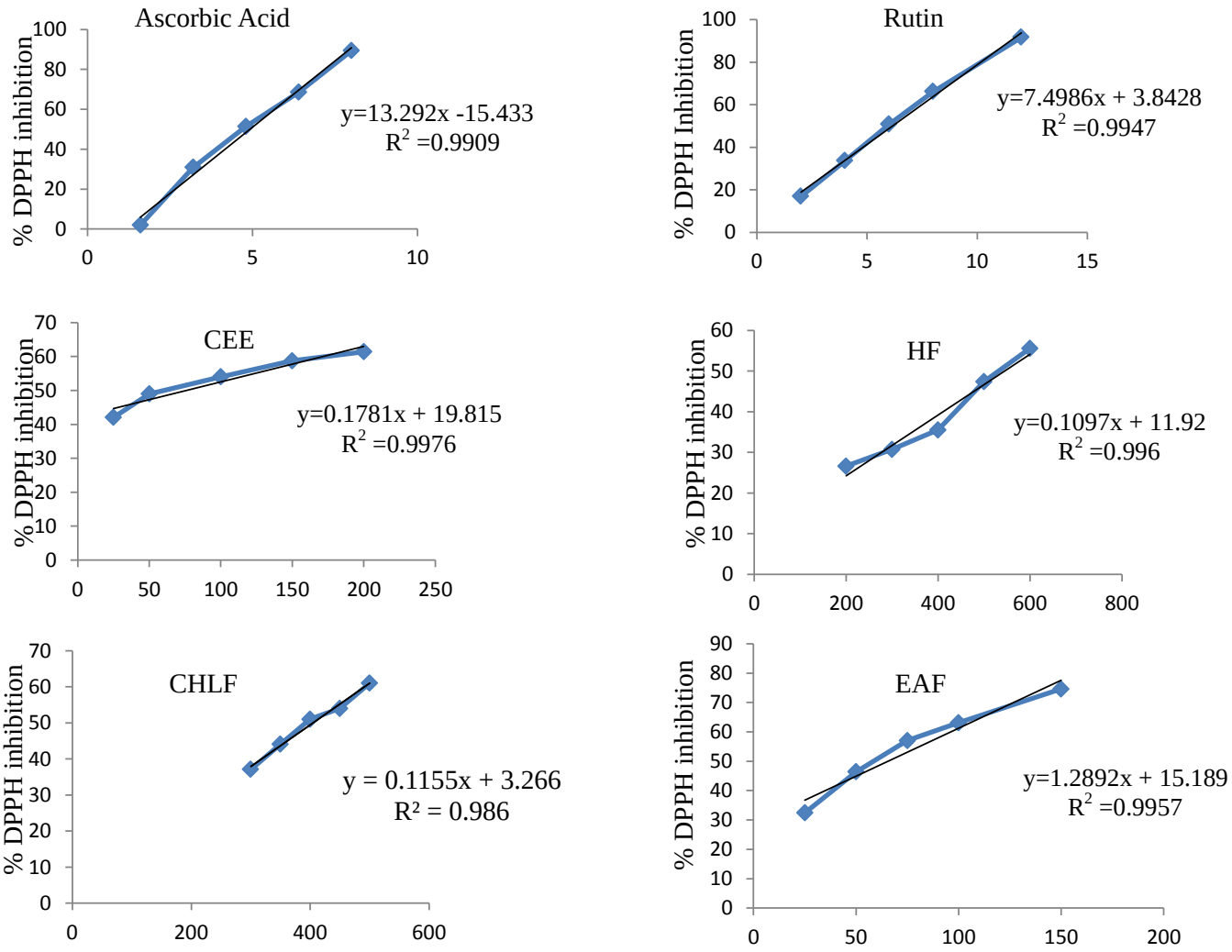

Figure 4. Curves of Ascorbic acid, Rutin, crude ethanolic extract (CCE), and hexanic (HF), chloroformic (CHLF) and ethyl acetate (EAF) extracts in *A. heterophyllus* seeds in DPPH inhibition.

from fruit and a reduced risk of certain cancers and cardiovascular disease (Fuhrman et al., 1995; Potter, 2005). These compounds exert their bioactivity of protection due to its antioxidant capacity. Polyphenols can wipe out the spread of harmful free radicals to the body, which causes cellular lipid peroxidation by transferring an equivalent electron radical. Although the role that these substances play in maintaining health are neglected in most food composition surveys. Thus, these studies show that, possibly the polyphenols present in the samples tested exert the different antioxidant activity and may act in the scavenging of H_2O_2, inhibition of peroxidation rate of lipids and inhibition of xanthine oxidase. Subsequent isolation studies and identification of chemical substances with antioxidant capacity should be investigated.

Other species of the *Artocarpus* genus have this parts studied for antioxidant activity, but the parts studied were leaves and fruit. *A. heterophylus* exhibited significant antioxidant activity studied its pulp presenting antioxidant capacity against DPPH radical, ferric reducing power and radical DMPD was studied. The jackfruit is a rich source of phytochemicals including phenolic compounds and offers opportunities for development of value-added products from jackfruit (Jagtap et al., 2010).

Conclusion

The results of the present study indicated that *A. heterophyllus* seeds showed antioxidant activity. The recorded remarkable antioxidant property in terms of reducing power, DPPH and superoxide radical scavenging activities indicate that incorporation of the seeds with food is complementary. Finally, this study has identified that CHLF and CEE extract of *A. heterophyllus*

seeds has high antioxidant activity (attributable to its high phenolic content), and EAF and CHLF extracts has high radical scavenging activity. The presence of antioxidant activity in extracts prepared in all the different solvents (which differ widely in their polarity) indicate that phytochemicals contributing to the antioxidant activity of the seeds tested belong to different groups of plant metabolites and varies widely with respect to their chemical properties. Further investigation for isolation and identification of the phytoconstituents responsible for antioxidant activity is desirable. *A. heterophyllus* seeds in the regular diets could improve the antioxidant status of human beings.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Aldana DLM, Gómez BT, Oca MMM, Ayerdi SGS, Meraz FG, Pérez LAB (2011). Isolation and characterization of Mexican jackfruit (*Artocarpus heterophyllus* L) seeds starch in two mature stages. Starch/Stärke 63:364-372.

Andrade CA, Costa CK, Bora K, Miguel MD, Miguel OG, Kerber VA (2007). Determinação do conteúdo fenólico e avaliação da atividade antioxidante de Acacia podalyriifolia A. Cunn. ex G. Don, Leguminosae-mimosoideae. Rev. Bras. Farmacogn. 17:231-235.

Andrade CA, Peitz C, Cunico M, Carvalho JLS, Abrahao WM, Miguel MD, Miguel OG, Kerber VA (2005). Avaliação da atividade antibacteriana e triagem fitoquímica das flores de *Acacia podalyriifolia* A. Cunn. ex. G. Don Leguminosae-Mimosoidea. Rev. Bras. Farmacogn. 15(1):13-15.

Aruoma OI, B Halliwell B, Laughton MJ, Quinlan GJ, Gutteridge JM (1989). The mechanism of initiation of lipid peroxidation. Evidence against a requirement for an iron(II)-iron(III) complex. Biochem. J. 258:617-620.

Benzie IF (1996). Lipid peroxidation: a review of causes, consequences, measurement and dietary influences. Int. J. Food Sci. Nutr. 47(3):233-61.

Blois MS (1958). Antioxidant determinations by the use of a stable free radical. Nature 29:1199-1200.

Bobbio FO, El-Dash AA, Bobbio PA, Rodrigues LR (1978). Isolation and characterization of the physicochemical properties of the starch of Jackfruit seeds (*Artocarpus heterophyllus*). Cereal Chem. 55:505-511.

Carvalho JLS, Cunico MM, Dias JFG, Miguel MD, Miguel OG (2009). Term-stability of extractive processes from *Nasturtium officinale* R. Br., brassicaceae for Soxhlet modified system. Quim. Nova 32(4):1031-1035.

Chen CW, Ho CT (1995). Antioxidant properties of polyphenols extracted from green and black tea. J. Food Lipids 2:35-46.

Chen H-M, Muramoto K, Yamauchi F, Nokihara K (1996). Antioxidant Activity of Designed Peptides Based on the Antioxidative Peptide Isolated from Digests of a Soybean Protein. J. Agric. Food Chem. 44(9):2619-2623.

Chowdhury FA, Rahman MA, Mian AJ (1997). Distribution of free sugars and fatty acids in jackfruit (*Artocarpus heterophyllus*). Food Chem. 60(1):25-28.

Darr D, Dunston S, Faust H, Pinnell S (1996). Effectiveness of antioxidants (vitamin C and E) with and without sunscreens as topical photoprotectants. Acta Derm. Venereol. 76(4):264-268.

Elmastas M, Gulcin I, Beydemir S, Ku¨freviog˘lu OI, AboulEnein HY (2006). A study on the *in vitro* antioxidant activity of juniper(*Juniperus communis* L.) seeds extracts. Anal. Lett. 39(1):47-65.

Fuhrman B, Lavy A, Aviram M (1995). Consumption of red wine with meals reduces the susceptibility of human plasma and low-density lipoprotein to lipid peroxidation. Am. J. Clin. Nutr. 61:549-54.

Godfraind T (2005). Antioxidant effects and the therapeutic mode of action of calcium channel blockers in hypertension and atherosclerosis. Philos. Trans. R. Soc. Lond. B Biol. Sci. 360(1464):2259-2272.

Gülçin I (2005). The antioxidant and radical scavenging activities of black pepper (*Piper nigrum*) seeds. Int. J. Food Sci. Nutr. 56:491-499.

Gülçin I, Buyukokuroglu ME, Oktay M, Kufrevioglu IO, (2003). Antioxidant and analgesic activities of turpentine of *Pinus nigra* Arn. Subsp. Pallsiana (Lamb.) Holmboe. J. Ethnopharmacol. 86:51-58.

Halliwell B (1990). How to characterize a biological antioxidant. Free Rad. Res. Commun. 9(1):1-32.

Halliwell B (1997). Antioxidants: the basics-what they are and how to evaluate them. Adv. Pharmacol. 38:3-20.

Huang D, Ou B, Prior RL (2005). The Chemistry behind antioxidant capacity assays. J. Agric. Food Chem. 53:1841-1856.

Jagtap UB, Panaskar SN, Bapat VA (2010). Evaluation of Antioxidant Capacity and Phenol Content in Jackfruit (*Artocarpus heterophyllus* Lam.) Fruit Pulp. Plant Foods Hum. Nutr. 65:99-104.

Kujala TS, Loponen JM, Klika KD, Pihlaja K (2000). Phenolics and betacyanins in red beetroot (*Beta vulgaris*) root: Distribuition and effect of cold storage on the content of total phenolics and three individual compounds. J. Agric. Food Chem. 48:5338-5342.

Matthaus B (2002). Antioxidant activity of extracts obtained from residues of different oil seeds. J. Agric. Food Chem. 50:3444-3452.

Meda A, Lamien CE, Romito M, Millogo J, Nacoulma OG (2005). Determination of the total phenolic, flavonoid and proline contents in Burkina Fasan honey, as well as their radical scavenging activity. Food Chem. 91:571-577.

Mitsuda H, Yuasumoto K, Iwami K (1996). Antioxidation action of indole compounds during the autoxidation of linoleic acid. J. Jpn. Soc. Food Nutr. 19:210-214.

Mukprasit A, Sajjaanantakul K (2004). Physico-chemical properties of flour and starch from jackfruit seeds (*Artarpus heterophyllus* Lam.) compared with modified starches. International J. Food Sci. Technol. 39:271-276.

Nagulendran KR, Velavan S, Mahesh R, Hazeena V (2007). In Vitro Antioxidant Activity and Total Polyphenolic Content of Cyperus rotundus Rhizomes. J. Chem. 4(3):440-449.

Potter JD (2005). Vegetables, fruit, and cancer. Lancet 366:527-30.

Prieto P, Pinedo M, Aguilar M (1999). Spectrophotometric quantitation of antioxidant capacity though the formation of phosphomolybdenum complex: specific application to the determination of vitamin E. Anal. Biochem. 269(2):337-341.

Rice-Evans CA, Miller JN, Paganga G (1996). Structure-antioxidant activity relationships of flavonoids and phenolic acids. Free Radic. Biol. Med. 20:933-956.

Roginsky V, Lissi EA (2005). Review of methods to determine chain breaking antioxidant activity in food. Food Chem. 92(2):235-254.

Ruch RJ, Cheng SJ, Klaunig JE (1989). Prevention of cytotoxicity and inhibition of intercellular communication by antioxidant catechins isolated from chinese green tea. Carcinogenesis 10(6):1003-1008.

Rudolf S (2001). The benefits and hazards of antioxidants: controlling apoptosis and other protective mechanisms in cancer patients and the human population. J. Am. Coll. Nutr. 20:464-472.

Silva FAM, Borges MFM, Ferreira MA (1999). Métodos para avaliação do grau de oxidação lipídica e da capacidade antioxidante. Química Nova 22:94-103.

Silva JH, Jordão Filho J, Ribeiro MLG, Silva EL (2007). Efeitos da inclusão do farelo de sementes de jaqueira *Artocarpus heterophyllus* (Lam.) na ração sobre a produção, pigmentação da gema e umidade fecal em codornas. Ciênc. Agrotec. 31:2.

Valko M, Rhodes CJ, Moncol J, Izakovic M, Mazur M (2006). Free radicals, metals and antioxidants in oxidative stress-induced cancer. Chem. Biol. Interact. 160(1):1-40.

Wu JH, Tung YT, Wang SY, Shyur LF, Kuo YH, Chang ST 2005. Phenolic antioxidants from the heartwood of *Acacia confusa*. J. Agric. Food Chem. 53:5917-5921.

Yen GC, Chen HY (1995). Antioxidant activity of various tea extracts in relation to their antimutagenicity. J. Agric. Food Chem. 43(1):27-32.