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COMPARISON OF PHYSICOCHEMICAL AND ANTIOXIDANT PROPERTIES OF EDIBLE FRUITS IN THE SUNDARBANS' MANGROVE FOREST, BANGLADESH

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Abstract

Ten edible fruits of the Sunderbans' mangrove forest in Bangladesh were analyzed to compare their physicochemical, nutritional and antioxidant properties. Among the fruits, the lowest pH of 4.2 was observed in *Sonneratia caseolaris* whereas the rest remains within 6.1 to 7.1. The highest electrical conductivity (596.3 µS/cm), total dissolved solid (298.2 ppm) and ash content (0.26%) were recorded in the fruit of *Phoenix paludosa*. Carbohydrate, protein, lipid and vitamin C contents were the highest in *Avicennia officinalis*, *Ceriops decandra*, *Heritiera fomes* and *Bruguiera gymnorrhiza* fruits, respectively. In these fruits, the most abundant macro and micro-elements were K and Fe, respectively. *C. decandra* showed the highest content of polyphenols (58.5 mg GAE, gallic acid equivalent/g powder), flavonoids (86.4 mg CE, (+)-catechin equivalent/g powder) and anthocyanins (0.39 µmol/g powder). *C. decandra* also showed the strongest DPPH free radicals scavenging, reducing power, and total antioxidant capacity. Noticeably, total polyphenols showed their strong correlation to total flavonoids (r^2 = 0.90), anthocyanins (r^2 = 0.81), reducing power (r^2 = 0.98) and total antioxidant capacity (r^2 = 0.88) of the fruits. Fruits of *C. decandra*, therefore, should be considered as a potential source of antioxidants followed by *H. fomes* and *P. paludosa*.

Introduction

The Sundarbans' is the single largest contiguous tracts of mangrove forest in the world which is situated in the South-Western region of Bangladesh. Among the edible fruits in the Sundarbans', *S. apetala* is consumed largely in coastal areas in Bangladesh followed by *S. caseolaris* and *N. fruticans*. Previous reports showed polyphenols, flavonoids and anthocyanins contents, nutrient compositions, antioxidant, antibacterial, antidiabetic, antidiarrheal, analgesic and cytotoxic activities in *S. apetala* fruit (Hossain *et al*. 2013, 2016, 2017). Hossain *et al*. (2013, 2016) recommended that *S. apetala* fruits should be cultivated in the tidal sea-water intruded vast tropical coastal regions of the world for the purposes of food security, primary health care, environmental protection, income generation and for preparing functional foods or dietary supplements. Fruits of *S. caseolaris* are also popular, and non-toxic (Chen *et al*. 2009), soft in texture having specific flavors, and good taste, and thus various food products, such as syrup (Abeywickrama and Jayasooriya 2010), cakes and steamed pudding (Brown 2006) have been produced from it. Brown (2006) also reported the preparation of different recipes using the fruits of *Avicennia* sp., *N. fruticans*, *B. gymnorrhiza* etc. People adjacent to the Sundarbans' also largely consume the inner endosperm of *N. fruticans*. Prasad *et al*. (2013) evaluated phenolics and antioxidant in endosperms of *N. fruticans*. Fruits of *P. paludosa* are eaten to some extent, and reportedly, they are used as a coffee substitute.

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However, little scientific attention on the edible fruits of the Sundarbans' mangrove forest has been paid till today. Edible fruits in the Sundarbans' are important resources with an untapped potential, and therefore, the current study was undertaken.

Materials and Methods

Edible fruits of *Aegiceras corniculatum* (L.) Blanco., *Avicennia officinalis* L., *Bruguiera gymnorrhiza* (L.) Lamk., *Ceriops decandra* (Griff.) Ding Hou, *Heritiera fomes* Buch.-Ham., *Nypa fruticans* Wurmb., *Phoenix paludosa* Roxb., *Sarcolobus globosus* Wall., *Sonneratia caseolaris* (L.) Engl., and *Xylocarpus mekongensis* Pierre were collected from the Sundarbans' mangrove forest, Bangladesh from July to September, 2017. Each dried fruit was pulverized into fine powder with the help of a grinder machine and stored for chemical analysis at room temperature.

Ten grams of powder of each fruit was taken in a separate airtight bottle. Then, 200 ml of methanol and ethanol mixture (1 : 1) was added to each bottle. The mixtures were vigorously shaken, and kept overnight at 30^{o}C, 150 rpm. After 20 hrs, the mixtures were filtered through Whatman No. 1 filter paper. The filtrates were then air dried, and after adjustment of volumes, the extracts were kept in a refrigerator at 4^{o}C.

Average fresh weight, diameter, and length of the fruits were measured (n = ~50). The pH of the fruits was determined using a pH meter. Electrical conductivity (EC) and total dissolved solid (TDS) were measured through EC meter. The ash, free acidity, moisture, carbohydrate, protein, lipid and vitamin C were also determined using standard methods (AOAC 1995). Mineral contents in the fruits were estimated as described by Hoenig and de Kersabiec (1996). Na and K in digested powders were determined flame photometerically and that of P was quantified by UV-visible spectrophotometric method.

The total concentration of polyphenols (TPH) in the extracts was determined according to the Folin-Ciocalteu method (Ough and Amerine 1988) with gallic acid (GA) as the standard. The total flavonoid content (Zhishen *et al.* 1999), total anthocyanin content (Padmavati *et al.* 1997), DPPH free radicals scavenging activity (Blois 1958), reducing power (Oyaizu 1986) and total antioxidant capacity (Prieto *et al.* 1999) were determined in the extract.

Results were expressed as mean of observations, n = 3 - 50. One way analysis of variance followed by LSD multiple comparison post-hoc test was used. Differences with p values < 0.05 were considered statistically significant.

Results and Discussion

The average fresh weight, diameter, length, pH, EC, TDS, ash, free acidity, and moisture of the fruits ranged from 0.6 to 83.7 g, 0.4 to 5.1 cm, 1.4 to 12.3 cm, 4.2 to 7.1, 277.9 to 596.3 µS/cm, 138.5 to 298.2 ppm, 0.08 to 0.26%, 11.5 to 85.8 meq/kg, and 42.5 to 91.3%, respectively (Table 1). Carbohydrate content was the highest in the fruit of *A. officinalis* (49.8%) followed by *N. fruticans* (32.5%). Protein content was the highest in *C. decandra* (19.1%) followed by *H. fomes* (18.6%). Lipid and vitamin C contents ranged from 0.5 to 3.1% and 55.6 to 114.1 mg ascorbic acid, AA/100 g powder, respectively (Table 2). No toxic element (Cd, Co, Cr, Ni or Pb) was found in these fruits. Among the macroelements, K was the most abundant followed by Na, P, Mg, Ca whereas in microelements Fe topped all followed by Zn, Cu and Mn (Table 2). Hence, these fruits have potentiality to be used as nutritional supplements for coastal people suffering from malnutrition. Nutritional and health promoting properties of the fruit, *S. apetala* (Hossain *et al.* 2013, 2016, 2017) from the Sundarbans' have also been reported.

The highest content of polyphenols, flavonoids and anthocyanins were recorded in *C. decandra* followed by *H. fomes* and *P. paludosa* (Table 3). The cause of relatively higher amount

Table 1. Physicochemical characteristics of the fruits.

Name of fruits	Weight (g)*	Diameter (cm)*	Length (cm)*	pH	EC (µS/cm)	TDS (ppm)	Ash (%)	FA (meq/kg)	Moisture (%)
A. corniculatum	0.6^{a}	0.4^{a}	4.6^{d}	6.1^{b}	525.2^{f}	262.5^{f}	0.22^{f}	73.5^{e}	42.5^{a}
A. officinalis	4.9^{b}	3.0^{c}	2.9^{b}	6.3^{cd}	338.5^{b}	169.3^{b}	0.11^{b}	24.5^{c}	68.9^{e}
B. gymnorrhiza	11.1^{c}	1.3^{b}	9.3^{f}	6.2^{c}	382.5^{c}	191.4^{c}	0.14^{c}	24.5^{c}	57.7^{c}
C. decandra	3.1^{ab}	0.6^{a}	12.3^{g}	6.4^{e}	587.7^{g}	293.5^{g}	0.26^{g}	24.5^{c}	54.3^{b}
H. fomes	11.1^{c}	3.1^{c}	5.2^{de}	6.2^{c}	463.3^{e}	231.5^{e}	0.18^{e}	61.3^{de}	53.6^{b}
N. fruticans	83.7^{g}	4.5^{d}	9.7^{f}	7.1^{g}	377.2^{c}	188.3^{c}	0.13^{c}	11.5^{a}	87.0^{g}
P. paludosa	0.8^{ab}	2.9^{c}	1.4^{a}	6.4^{e}	596.3^{g}	298.2^{g}	0.26^{g}	36.8^{cd}	67.1^{de}
S. caseolaris	53.0^{f}	5.1^{e}	3.5^{c}	4.2^{a}	429.5^{d}	214.8^{d}	0.16^{d}	85.8^{e}	72.0^{f}
S. globosus	44.4^{e}	5.1^{e}	5.3^{e}	6.7^{f}	277.9^{a}	138.5^{a}	0.08^{a}	23.3^{b}	91.3^{h}
X. mekongensis	34.0^{d}	4.7^{d}	3.6^{c}	6.3^{d}	394.4^{c}	197.7^{c}	0.15^{c}	24.5^{c}	66.3^{d}

EC, electrical conductivity; TDS, total dissolved solid; FA, free acidity. Values represent the mean (n = 3 ~<5; *n = 50 ~< 60). Values with different letters (a-h) within the same column differ significantly ($p < 0.05$) through one way ANOVA followed by LSD multiple comparison post-hoc test.

Table 2. Nutrient compositions of the fruits.

Name of fruits	Carbo-hydrates (%)	Proteins (%)	Lipids (%)	Vitamin C (mg AA/100g powder)	Mineral elements								
					mg/kg powder							g/kg powder	
					Ca	Cu	Fe	Mg	Mn	P	Zn	K	Na
A. corniculatum	10.1^{ce}	8.3^{cd}	2.3^{e}	87.7^{e}	45.3^{a}	5.7^{a}	138.8^{d}	261.5^{a}	4.6^{a}	992.3^{f}	8.5^{b}	12.5^{cd}	4.7^{b}
A. officinalis	49.8^{fg}	12.8^{e}	0.9^{b}	58.5^{a}	104.8^{b}	12.1^{d}	181.8^{e}	342.9^{c}	17.2^{c}	980.1^{e}	13.2^{de}	15.1^{de}	5.4^{b}
B. gymnorrhiza	8.0^{b}	5.3^{b}	0.5^{a}	114.1^{f}	266.4^{d}	6.4^{ab}	121.7^{c}	340.5^{c}	38.3^{e}	652.9^{a}	5.4^{a}	5.4^{a}	7.7^{c}
C. decandra	10.6^{de}	19.1^{f}	1.1^{c}	78.9^{d}	243.4^{c}	9.8^{c}	249.4^{g}	360.2^{e}	35.3^{e}	684.5^{b}	12.5^{cde}	7.2^{ab}	9.6^{d}
H. fomes	8.7^{bc}	18.6^{f}	3.1^{f}	87.7^{e}	52.3^{a}	10.4^{c}	83.8^{b}	332.2^{b}	8.4^{b}	953.5^{c}	10.3^{bc}	15.3^{df}	1.3^{a}
N. fruticans	32.5^{f}	2.9^{a}	0.5^{a}	64.3^{b}	817.2^{h}	5.4^{a}	293.6^{h}	937.3^{h}	187.6^{h}	1111.7^{h}	12.7^{cde}	23.6^{g}	3.4^{b}
P. paludosa	21.4^{g}	12.8^{e}	1.1^{c}	70.2^{c}	526.0^{f}	15.4^{e}	248.8^{g}	393.8^{g}	25.6^{d}	991.0^{ef}	29.0^{f}	30.4^{h}	4.0^{b}
S. caseolaris	5.2^{a}	7.3^{bd}	2.1^{d}	55.6^{a}	261.3^{d}	5.5^{a}	75.3^{a}	350.5^{d}	43.7^{f}	990.2^{ef}	10.9^{be}	10.3^{bc}	12.3^{e}
S. globosus	27.6^{h}	11.9^{e}	0.9^{b}	67.3^{bc}	338.9^{e}	7.3^{b}	84.1^{b}	382.7^{f}	60.1^{g}	968.7^{d}	32.9^{g}	32.2^{h}	8.3^{cd}
X. mekongensis	9.5^{cd}	7.3^{bc}	0.8^{b}	70.2^{c}	551.8^{g}	7.7^{b}	200.5^{f}	361.5^{e}	7.5^{ab}	1044.9^{g}	10.8^{bd}	16.5^{ef}	3.4^{b}

Values represent the mean (n = 3). AA, Ascorbic acid. Values with different letters (a - h) within the same column differ significantly ($p < 0.05$) through one way ANOVA followed by LSD multiple comparison post-hoc test.

Table 3. Polyphenols, flavonoids, anthocyanins contents, DPPH scavenging, reducing power and antioxidant capacity of the fruits.

Name of fruits	Polyphenols (mg GAE/g powder)	Flavonoids (mg CE/g powder)	Anthocyanins (µmol/g powder)	% DPPH scavenging at 50 µg powder/ml	Reducing power (OD) at 0.3 mg powder/ml	Total antioxidant capacity	
						mg GAE/g powder	mg AAE/g powder
A. corniculatum	14.9^{c}	1.8^{a}	0.25^{d}	38.5^{c}	0.33^{b}	36.9^{c}	27.4^{c}
A. officinalis	18.7^{d}	29.7^{d}	0.22^{c}	71.9^{f}	0.48^{c}	61.7^{e}	45.9^{e}
B. gymnorrhiza	21.9^{e}	9.2^{b}	0.26^{f}	76.3^{fg}	0.47^{c}	47.5^{d}	35.3^{d}
C. decandra	58.5^{h}	86.4^{g}	0.39^{g}	90.9^{h}	1.98^{g}	112.5^{g}	83.7^{g}
H. fomes	52.7^{g}	58.7^{f}	0.37^{b}	86.6^{h}	1.87^{f}	102.1^{f}	75.9^{f}
N. fruticans	3.5^{a}	1.2^{a}	0.09^{a}	8.1^{a}	0.11^{a}	7.2^{a}	5.3^{a}
P. paludosa	29.7^{f}	35.0^{e}	0.26^{h}	81.2^{g}	0.70^{e}	67.6^{e}	50.3^{e}
S. caseolaris	20.7^{e}	13.9^{b}	0.30^{e}	48.1^{d}	0.54^{d}	29.9^{b}	22.3^{b}
S. globosus	7.6^{b}	3.8^{a}	0.10^{a}	15.1^{b}	0.15^{a}	41.7^{cd}	31.1^{cd}
X. mekongensis	17.8^{d}	19.7^{c}	0.16^{a}	54.6^{e}	0.37^{b}	32.7^{bc}	24.3^{bc}

GAE, gallic acid equivalent; CE, (+)-catechin equivalent; DPPH, 1, 1-diphenyl-2-picrylhydrazyl; AAE, ascorbic acid equivalent. Values represent the mean (n = 3-5). Values with different letters (a - h) within the same column differ significantly ($p < 0.05$) through one way ANOVA followed by LSD multiple comparison post-hoc test.

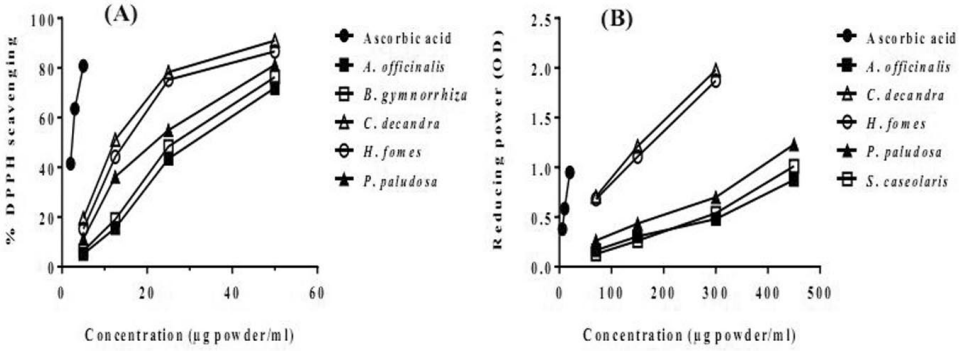

Fig.1. Dose-dependent (A) DPPH free radical scavenging activity and (B) increase of reducing power of the potential fruits.

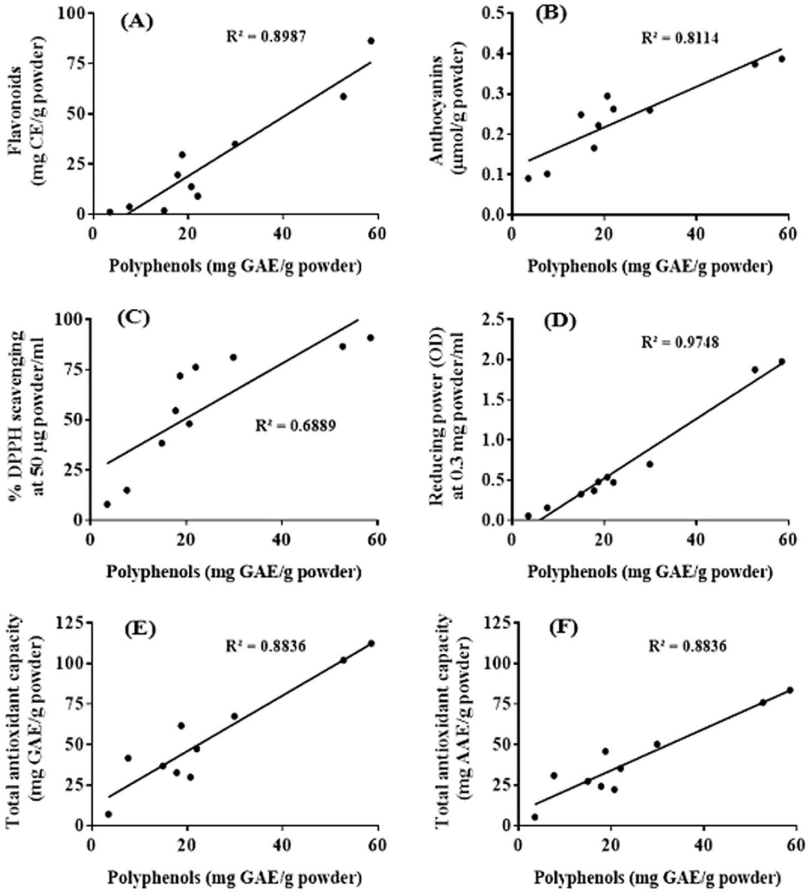

Fig. 2. Correlation of polyphenols to (A) flavonoids, (B) anthocyanins, (C) DPPH scavenging, (D) reducing power, (E) total antioxidant capacity (mg GAE) and (F) total antioxidant capacity (mg AAE) of the fruits. GAE, gallic acid equivalent and AAE, ascorbic acid equivalent.

of recorded total flavonoids than total phenolics in some fruits might be due to inefficiency of Folin-Ciocalteu method. The percentage scavenging of DPPH free radical ranged from 8.1 to 90.9% at 50 µg powder/ml. Dose-dependent DPPH free radical scavenging activities of *A. officinalis*, *B. gymnorrhiza*, *C. decandra*, *H. fomes* and *P. paludosa* showed that *C. decandra* possessed the strongest activity with the lowest IC_{50} value of 16.2 µg powder/ml, which was little larger than ascorbic acid (IC_{50} 2.4 µg/ml) followed by *H. fomes* (19.5 µg powder/ml), *P. paludosa* (26 µg powder/ml), *B. gymnorrhiza* (31.1 µg powder/ml) and *A. officinalis* (33.7 µg powder/ml) (Fig. 1A). The IC_{50} values for DPPH free radical scavenging for common edible fruits (Hossain *et al*. 2008), fruity vegetables (Hossain *et al*. 2014) and leafy vegetables (Hossain *et al*. 2015) were also reported. At 300 µg powder/ml concentration, *C. decandra* had the highest absorbance (OD 1.98) followed by *H. fomes* (OD 1.87), *P. paludosa* (OD 0.7) etc. They showed dose-dependent increase in their reducing power (Fig. 1B). It may be due to high content of polyphenols as well as hydrogen donating ability. *C. decandra* showed the highest total antioxidant capacity (112.5 mg GAE/g powder; 83.7 mg AAE/g powder) followed by *H. fomes* (102.1 mg GAE/g powder; 76 mg AAE/g powder) and *P. paludosa* (67.6 mg GAE/g powder; 50.3 mg AAE/g powder).

Total polyphenols and total flavonoids showed strong correlation ($r^2 = 0.90$), and so did total polyphenols and anthocyanins ($r^2 = 0.81$), reducing power ($r^2 = 0.98$) also total antioxidant capacity ($r^2 = 0.88$). However, moderate correlation ($r^2 = 0.69$) was found between total polyphenols and DPPH free radical scavenging (Fig. 2). This moderate correlation may be due to the fact that only phenolics with a certain structure and with hydroxyl groups at specific positions can show radical scavenging activity (Nguelefack *et al*. 2011). Since some polyphenols non-specifically bind with membrane structure, and perturb it (Hossain *et al*. 2002), clarification of proper dose of polyphenols is essential before using them for the preparation of dietary supplements, and functional foods. Among the ten edible fruits in the Sundarbans', *C. decandra* could be considered to be the best source of functional components, and antioxidants followed by *H. fomes* and *P. paludosa*.

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