

Anti-Bacterial, Anti-Diarrheal, and Cytotoxic Activities of Edible Fruits in the Sundarbans Mangrove Forest of Bangladesh

M. Zakir Hosen, Anirban Biswas, M. Rabiul Islam, and Sheikh Julfikar Hossain

Biotechnology and Genetic Engineering Discipline, Life Science School, Khulna University, Khulna 9208, Bangladesh

ABSTRACT: This study evaluated anti-bacterial, anti-diarrheal, and cytotoxic activities of ten edible fruits (*Aegiceras corniculatum*, *Avicennia officinalis*, *Bruguiera gymnorrhiza*, *Ceriops decandra*, *Heritiera fomes*, *Nypa fruticans*, *Phoenix paludosa*, *Sarcolobus globosus*, *Sonneratia caseolaris*, and *Xylocarpus mekongensis*) in the Sundarbans mangrove forest of Bangladesh. Highest anti-bacterial activity was shown for ethanol : methanol (1:1) extracts of *S. caseolaris* (2 mg/disc), which demonstrated inhibition zones of 16.7, 17.0, 14.7, 15.7, and 15.7 mm against *Escherichia coli*, *Klebsiella* sp., *Shigella boydii*, *Shigella sonnei*, and *Staphylococcus aureus*, respectively. In mice with castor oil-induced diarrhea, *S. caseolaris* extract (250 mg/kg body weight) showed the highest inhibition (87.7%) and delayed the onset time (273 min) of diarrheal episodes, followed by *A. corniculatum* extract (inhibition, 83.6%; delayed onset time, 187.4 min). *S. caseolaris* and *A. corniculatum* fruit powders were successively fractionated into *n*-hexane, diethyl ether, chloroform, ethanol, and methanol. Antidiarrheal activity significantly increased with increasing polarity of these fractions. In brine shrimp lethality assay, *S. globosus* extract demonstrated the highest cytotoxicity (59.2 µg/mL), followed by *H. fomes* (74.1 µg/mL) and *C. decandra* (116.7 µg/mL); however, lowest cytotoxicity was shown for *A. corniculatum*, *A. officinalis*, and *S. caseolaris* extracts. Mice treated with *A. corniculatum* extract did not experience any acute toxicity. These results demonstrate that *S. caseolaris* and *A. corniculatum* fruits have potential to treat diarrhea and may act as useful nutraceuticals.

Keywords: anti-bacteria, anti-diarrhea, cytotoxicity, mangrove fruits, the Sundarbans

INTRODUCTION

The Sundarbans, the world's largest mangrove forest, is located on the South-Western region of Bangladesh and borders the Bay of Bengal. Mangrove refers to the ecosystem of diverse groups of plants that adapt to the intersection of land and marine conditions. Various secondary metabolites are produced inside mangrove plants that enable them to adapt to this stressful environment, such as high salinity, tidal inundation, and intense sunlight. Secondary metabolites that are produced in the edible parts of the mangrove plants may be used to treat metabolic and infectious diseases in humans without inducing any toxic or hazardous effects. Previous reports have described physicochemical and antioxidant properties of the edible fruits *Aegiceras corniculatum*, *Avicennia officinalis*, *Bruguiera gymnorrhiza*, *Ceriops decandra*, *Heritiera fomes*, *Nypa fruticans*, *Phoenix paludosa*, *Sarcolobus globosus*, *Sonneratia caseolaris*, and *Xylocarpus mekongensis*, which are present in the Sundarbans mangrove forest (Hosen et al., 2020).

Moreover, studies have reported phytochemical and health promoting bioactivities of *Sonneratia apetala* fruits in the Sundarbans (Hossain et al., 2013; Hossain et al., 2016; Hossain et al., 2017). These edible fruits grow abundantly along the coast of Bangladesh, especially in and around the Sundarbans. Local habitants readily consume these fruits, with the highest amount of *S. apetala*, *S. caseolaris*, and *N. fruticans*. Due to the nutritional and health benefits of *S. apetala* fruits, it has been recommended that these fruits should be cultivated in the vast tropical coastal regions worldwide to help ensure food security, primary health care, environmental protection, and income generation, as well as for use as functional foods and as dietary supplements (Hossain et al., 2013; Hossain et al., 2016). Several studies have also reported consumption of mangrove fruits as foods and as major components in various food preparations (Brown, 2006; Chen et al., 2009; Abeywickrama and Jayasooriya, 2011).

Metabolic and infectious diseases are leading health challenges of the world (Hossain et al., 2007). Many of

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Correspondence to Sheikh Julfikar Hossain, Tel: +88-2-477734416, E-mail: sjhossain_ku@yahoo.com

Author information: M. Zakir Hosen (Graduate Student), Anirban Biswas (Graduate Student), M. Rabiul Islam (Researcher), Sheikh Julfikar Hossain (Professor)

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the diseases are caused by insufficient amounts of phytochemicals in diet. Dietary phytochemicals consist of an array of chemical compounds that have multiple targets of action, thereby generating synergistic beneficial effects on physiological health. Of phytochemicals consumed as part of the human diet, polyphenols are the most abundant with more than 7,000 reported. Various polyphenols have been shown to possess anti-oxidant, anti-microbial, anti-diarrheal, anti-diabetic, anti-cancer, anti-inflammatory, anti-aging, anti-neurodegenerative, and cardioprotective properties (Schuier et al., 2005; Pandey and Rizvi, 2009; Daglia, 2012). Bioactive polyphenols, such as caffeic acid, (+)-catechin, (–)-epicatechin, ellagic acid, gallic acid, and quercetin, have been reported in *S. apetala* fruit (Hossain et al., 2016), and *S. apetala* extracts strongly inhibit common pathogenic bacteria (Hossain et al., 2013; Hossain et al., 2017). Arif et al. (2014) reported that antidiabetic medicinal plants containing a high polyphenol content have strong antibacterial activities. Furthermore, earlier reports have showed that several common edible fruits in Bangladesh possess anti-amylase, anti-glucosidase, and antiallergic effects (Hossain et al., 2008), and (+)-catechin and its derivatives demonstrate anti-hyperglycemic effects (Hossain et al., 2002).

Intestinal bacteria and rotaviruses are major causes of diarrhea. Diarrhea accounts for more than 5~8 million deaths each year (Victoria et al., 2000; Shoba and Thomas, 2001) and is the second leading cause of death for children. Antidiarrheal agents should contain rehydration substances and agents to inhibit of causal microorganism(s). Dietary substances such as ginger, cardamom, cocoa, and black and green tea have also been used to treat diarrhea (Dillinger et al., 2000; Bruins et al., 2006; Chen et al., 2007; Rahman et al., 2008). People living in tropical coastal regions are highly dependent on forest products for their food security, primary health care, and income generation. However, meagre scientific attention has been paid on edible mangrove fruits to date. To enhance food security and primary health care of vulnerable coastal people, it is crucial to explore multipurpose uses of the coastal fruits, especially edible mangrove fruits in the Sundarbans forest. Therefore, the present research was conducted.

MATERIALS AND METHODS

Chemicals and reagents

Folin-Ciocalteu's phenol reagent and gallic acid were purchased from Sigma-Aldrich Co. (St. Louis, MO, USA). Chloroform, diethyl ether, dimethyl sulfoxide (DMSO), ethanol, *n*-hexane, hydrochloric acid, methanol, and Tween-80 were obtained from Merck KGaA (Darmstadt, Germany). Nutrient broth and nutrient agar media were

purchased from HiMedia Laboratories Pvt. Ltd. (Mumbai, India).

Fruit samples

Edible fruits of *A. corniculatum* (L.) Blanco., *A. officinalis* (L.), *B. gymnorhiza* (L.) Lamk., *C. decandra* (Griff.) Ding Hou, *H. fomes* Buch.-Ham, *N. fruticans* Wurm., *P. paludosa* Roxb., *S. globosus* Wall., *S. caseolaris* (L.) Engl., and *X. mekongensis* Pierre were collected from the Sundarbans mangrove forest, Bangladesh from July to September, 2017. After being washed in distilled water, the edible parts were separated, and shed dried. Then, each dried fruit was pulverized into fine powder using a grinding machine, and stored in air tight containers at room temperature.

Extraction

Ten grams of powder of each fruit were placed into separate air tight bottles. Then, 200 mL of methanol and ethanol mixture (1:1) was added to each bottle. Mixtures were vigorously shaken (150 rpm) at 30°C for 20 h, then filtered through Whatman No. 1 filter paper (pore size 11 µm). The filtrates were air dried and the extracts stored in a refrigerator at 4°C.

Fractionation

Ten grams of powder of each fruit were successively fractionated with solvents. First, powders were fractionated by vigorously shaking (150 rpm) with 200 mL of 100% *n*-hexane at 30°C for 20 h in an air tight bottle. The fraction was then filtered using Whatman no. 1 filter paper, air dried, and then transferred into screw cap vials. Vials were labeled and stored at 4°C as *n*-hexane fraction (HEX). Diethyl ether, chloroform, ethanol, and methanol fractions (DEE, CHL, ETH, and MET, respectively) were successively prepared from residue on the filter paper.

Determination of total polyphenol content

Total polyphenol content in extracts (methanol : ethanol, 1:1) was determined according to the Folin-Ciocalteu method (Ough and Amerine, 1988) using gallic acid as the standard, expressed as mg gallic acid equivalents (mg GAE)/g of powder. One milliliter of diluted extract was mixed with 1 mL of Folin-Ciocalteu's reagent and vortexed for 5 s. Then, 1 mL of a 10% (w/v) sodium carbonate aqueous solution was added, the mixture was incubated at room temperature for 1 h, and the absorbance at 700 nm was measured by a spectrophotometer. Each experiment was conducted three times.

Antibacterial activity assays

The bacterial strains *Escherichia coli*, *Klebsiella* sp., *Shigella boydii*, *Shigella sonnei*, and *Staphylococcus aureus* were obtained from International Centre for Diarrheal Disease Research' Bangladesh (ICDDR'B), Dhaka, Bangladesh.

Bacteria were sub-cultured in nutrient agar medium at least three times with 24 h intervals before use. Ten microliters of culture were then transferred into a 10 mL nutrient broth medium and incubated at 37°C for 24 h.

For susceptibility tests, nutrient agar plates were seeded by pouring culture broth to create a bacterial lawn. The bacterial population was adjusted through comparing with 0.5% McFarland standards to make 5×10^6 CFU/mL. The extracts/fractions were dissolved in respective solvents to prepare the stock and added to paper discs (6 mm) using a micropipette. Discs impregnated with the extracts/fractions were placed at proportionate distances from each other using sterile needles. The plates were incubated overnight (20 h) at 37°C then assessed for clear zones of inhibition around the discs.

Animals

Young Swiss-albino mice (16~22 g) of either sex were purchased from the ICDDR'B. Mice were provided with ICDDR'B formulated food and tap water *ad libitum*, and maintained in polypropylene cages (6 mice in each cage of 30 cm×15 cm×15 cm dimension) with a natural day-night cycle. All experiments were conducted in isolated and noiseless conditions in an animal house in accordance with the guidelines of the Animal Ethics Committee, Khulna University, Khulna, Bangladesh, which adheres to the EU Directive 2010 for animal experiments (Research Ref. No.: KUAEC-2017/07/02).

Antidiarrheal activity assays

Castor oil-induced diarrhea was studied as described by Shoba and Thomas (2001). Animals fasted with water for 18 h were randomly divided into control, positive control, and test groups (each n=6). Mice were placed into individual cages, the floors of which were lined with absorbent paper. Suspensions of extracts/fractions were prepared in water containing 0.1% Tween-80. The control group received distilled water containing 0.1% Tween-80; the positive control group received loperamide hydrochloride [3 mg/kg body weight (b.w.)]; the test groups received the extracts/fractions. After 1 h, each mouse was given 0.5 mL of castor oil with the help of a feeding needle for mice. The time elapsed between administration of castor oil and excretion of the first diarrheal stool was measured. In addition, the total numbers of characteristic diarrheal droppings were noted every half hour for 5 h. Dose-dependent antidiarrheal effects of potential fractions were studied.

Cytotoxicity tests

Brine shrimp (*Artemia salina*) lethality bioassay was used to assess cytotoxicity, as described by McLaughlin (1991). The eggs of *A. salina* were collected from Fisheries and Marine Resource Technology Discipline, Khulna Univer-

sity, Bangladesh. Eggs were hatched into larva in the larger compartment of a rectangular tank of two unequal compartments containing artificial sea water (20 g of NaCl and 18 g of table salt in 1 L of distilled water). Larva were then moved to the small compartment by being attracted to the light, where they were collected to investigate the cytotoxicity of the extracts. Different concentrations ($\mu\text{g/mL}$) of the extracts were tested in triplicate. Extracts were dissolved in distilled water with the assistance of DMSO, ensuring that the final concentration of DMSO did not exceed 1%. Vincristine sulphate (Cipla Ltd., Mumbai, India) was used as a positive control, and 1% DMSO in distilled water was used as the negative control. Survivors were counted after 24 h, and the percentage mortality was calculated. Lethal concentrations [in which 50% (LC_{50}) of the larvae died] were determined from best-fit linear lines plotting concentration verses percentage mortality.

Acute toxicity tests

Acute toxicity tests were carried out as described by Lorke (1983), with slight modifications. Young Swiss-albino mice aged 6~8 weeks (20~30 g) were randomly divided into different groups each consisting of 6 mice. The control group (G-I) received distilled water containing 0.1% Tween-80 and the test groups received the extract at different concentrations (500, 1,000, and 2,000 mg/kg b.w. for G-II, G-III, and G-IV, respectively) with the help of a feeding needle. Mice were observed individually for any clinical signs of toxicity or mortality for 14 days.

Statistical analysis

Statistical analysis was performed using SPSS (version 16, SPSS Inc., Chicago, IL, USA). Results were expressed as mean±standard deviation (SD) for a given number of observations, n=3~10. One way analysis of variance (ANOVA) followed by least significant difference multiple comparison post-hoc tests were used to analyze statistical differences. Differences with *P*-values <0.05 were considered statistically significant.

RESULTS AND DISCUSSION

Total polyphenols content

The fruits of *A. corniculatum*, *A. officinalis*, *B. gymnorhiza*, *C. decandra*, *H. fomes*, *N. fruticans*, *P. paludosa*, *S. globosus*, *S. caseolaris*, and *X. mekongensis* were composed of 14.9, 18.7, 21.9, 58.5, 52.7, 3.5, 29.7, 7.6, 20.7, and 17.8 mg GAE/g powder, respectively. To date, no studies have shown that the barks or leaves of these edible fruit-producing plants are consumed directly or after processing. However, significantly smaller amounts of polyphenols have been re-

ported in some edible fruits (e.g., berries and pomegranates) than their leaves (Teleszko and Wojdyło, 2015; Amri et al., 2017). The concentration of polyphenols is inversely related to the pathogenesis of various metabolic and infectious diseases (Pandey and Rizvi, 2009; Daglia, 2012). The content of polyphenols in *C. decandra* and *H. fomes* were similar to that in *S. apetala* (48 mg GAE/g powder) but less than that in *Embllica officinalis* fruit (89 mg GAE/g powder), an edible non-mangrove (data not published).

Antibacterial activity

The disc diffusion method was used to assay antibacterial activity of the extracts (methanol : ethanol, 1:1) of edible mangrove fruits. Clear zones around the discs indicated inhibition of growth of the test bacteria (measured in mm). *S. caseolaris* extract (2 mg/disc) strongly inhibited the bacteria, producing clear zones diameters of 16.8, 17.0, 14.7, 15.6, and 15.7 mm against *E. coli*, *Klebsiella* sp., *S. boydii*, *S. sonnei*, and *S. aureus*, respectively. At the same concentration, *X. mekongensis* extract showed prominent effects against *S. aureus* and *S. sonnei*, indicating clear zone diameters of 16.4 and 13.3 mm, respectively. However, the other extracts demonstrated minimal inhibitory effects. The HEX, DEE, CHL, ETH, and MET fractions of *S. caseolaris* strongly inhibited bacterial growth. The highest degree of inhibition was seen for the ethanol fraction (clear zone diameters of 16.3, 17.4, 18.5, 16.8, and 17.5 mm against *E. coli*, *Klebsiella* sp., *S. boydii*, *S. sonnei*, and *S. aureus*, respectively, at 2 mg/disc). However, *S. caseolaris* methanol extracts of the different parts of the plant exhibited antibacterial activity against both Gram-positive and Gram-negative bacteria (Yompakdee et al., 2012). Potential antibacterial effects of fruit of *S. apetala* were also reported (Hossain et al., 2013; Hossain et al.,

2017), which may be due to their high content of polyphenols, especially caffeic acid, (+)-catechin, (–)-epicatechin, ellagic acid, gallic acid, and quercetin in seeds (Hossain et al., 2016). *C. decandra*, *H. fomes*, and *P. paludosa* extracts had high contents of polyphenols but exhibited low antibacterial effects; however, Arif et al. (2014) showed that extracts contained high polyphenol contents had strong antibacterial activities. These differences may have arisen from different interactions between polyphenols and the surfaces of bacterial cells that determine the antibacterial activity of polyphenols (Bouarab-Chibane et al., 2019).

Antidiarrheal activity

All the mangrove fruit extracts (methanol : ethanol, 1:1) at a dose of 250 mg/kg b.w. significantly ($P < 0.05$ vs. control) inhibited castor oil-induced diarrhea in mice (Fig. 1A). The highest antidiarrheal activity was demonstrated for *S. caseolaris* extract (87.7%) followed by *A. corniculatum* extract (83.6%). At 250 mg/kg b.w., *S. caseolaris* extract showed the longest delay of diarrhea onset (273 min), followed by *A. corniculatum* extract (187 min) and *N. fruticans* extract (151.5 min) (Fig. 1B). Since *S. caseolaris* and *A. corniculatum* extracts strongly inhibited the frequency of and onset of diarrheal episodes, the extracts were fractionated into HEX, DEE, CHL, ETH, and MET fractions. In mice, the inhibitory effects of these fractions at 250 mg/kg b.w. on diarrhea are shown in Fig. 2A. These data indicated that the majority of their antidiarrheal components were polar and slightly non-polar. At 250 mg/kg b.w., the ethanol fraction of *S. caseolaris* showed the highest antidiarrheal activity (84.4%) followed by the methanol fraction (77.8%). However, for *A. corniculatum*, highest inhibition of diarrhea was shown for the methanol fraction (75.6%) followed by the etha-

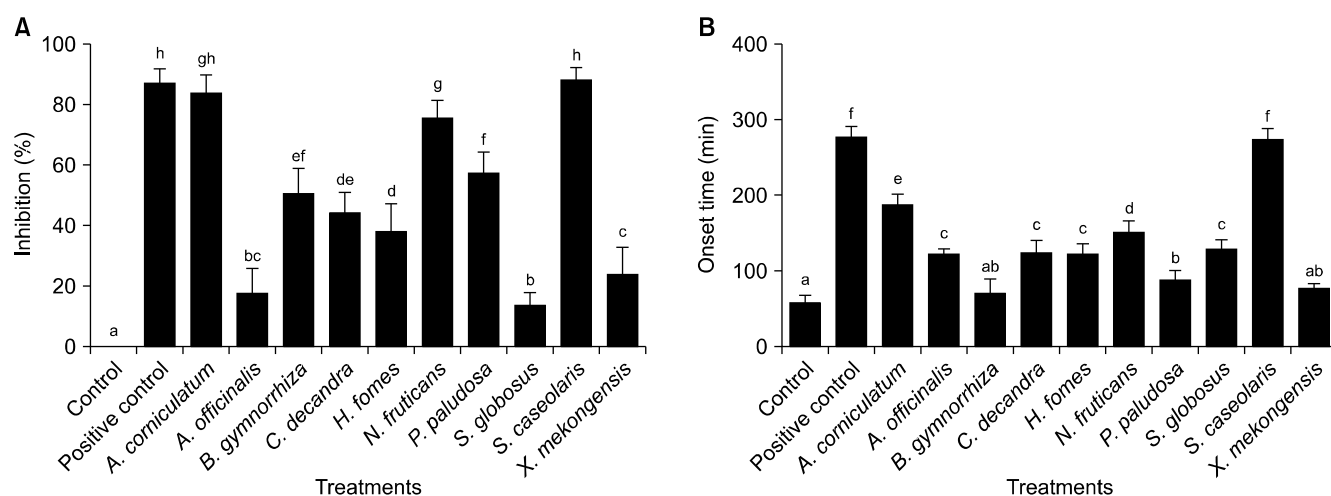


Fig. 1. Effects of edible mangrove fruits on castor oil-induced diarrhea in mice. (A) Inhibition (%) and (B) onset time (min) of diarrhea in different treatment groups at 250 mg extract/kg body weight (b.w.). Data are expressed as mean \pm SD ($n=6$). Different letters (a-h) indicate significant differences compared with each other group using one way ANOVA at $P < 0.05$. Positive control, loperamide 3 mg/kg b.w..

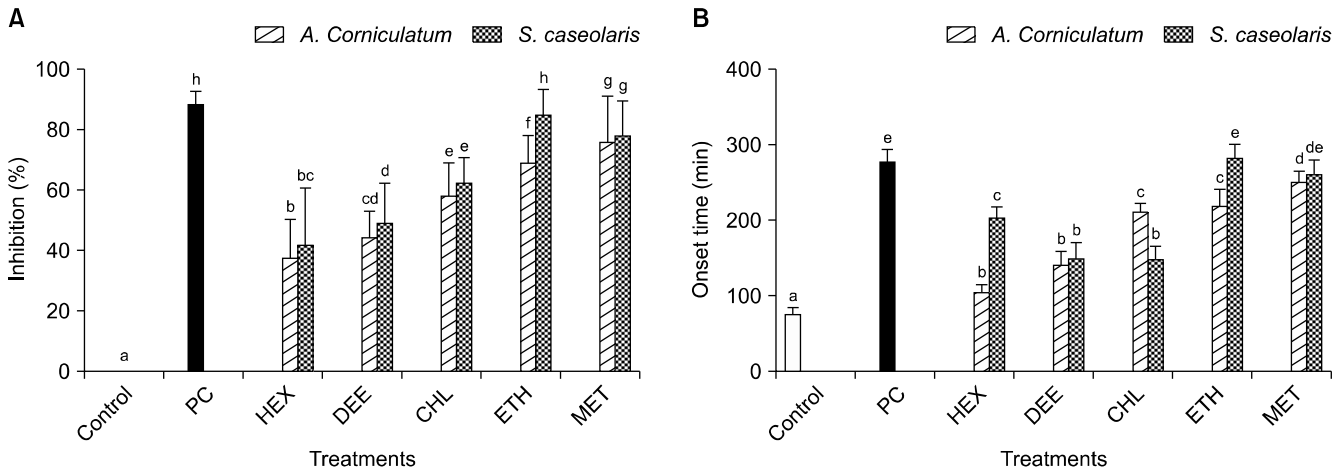


Fig. 2. Effects of different solvent [*n*-hexane (HEX), diethyl ether (DEE), chloroform (CHL), ethanol (ETH), and methanol (MET)] fractions of the fruits on castor oil-induced diarrhea in mice. (A) Inhibition (%) and (B) onset time (min) of diarrhea in different treatment groups at 250 mg fraction/kg b.w.. Data are expressed as mean \pm SD (n=6). All data were significant compared with the control, and different letters (a-h) indicate significant differences compared to each other group using one way ANOVA at $P < 0.05$. PC, positive control, loperamide 3 mg/kg b.w..

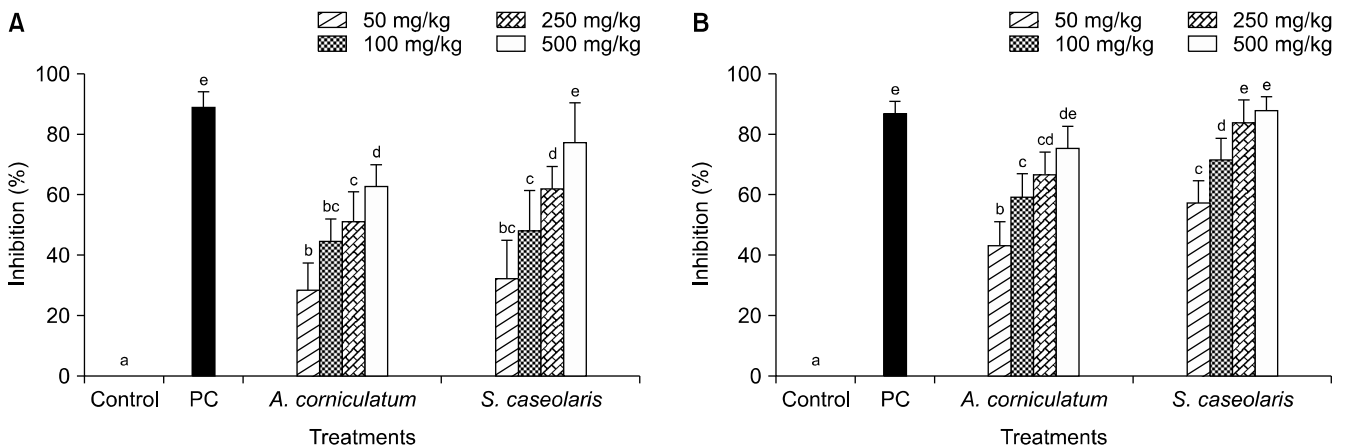


Fig. 3. Dose-dependent inhibitory effects of (A) chloroform and (B) ethanol fractions of *Aegicerias corniculatum* and *Sonneratia caseolaris* on castor oil-induced diarrhea in mice. Data are expressed as mean \pm SD (n=6). All data were significant compared with the control, and different letters (a-e) indicate significant differences compared to each other group using one way ANOVA at $P < 0.05$. PC, positive control, loperamide 3 mg/kg b.w..

nol fraction (69.0%). The effects of these fractions on diarrhea onset are shown in Fig. 2B. Both the methanol and ethanol fractions strongly delayed the onset of diarrheal episodes. Dose-dependent inhibition of diarrhea using ETH and CHL fractions of *S. caseolaris* and *A. corniculatum* fruits are shown in Fig. 3.

Extracts from other parts of *A. corniculatum* and *S. caseolaris* plants have previously been shown to exhibit significant antidiarrheal activity (Ahmed et al., 2007a; Ahmed et al., 2007b; Bose et al., 2010). Furthermore, *S. apetala* fruit juice is used as tonic and to treat diarrhea-like diseases in coastal Bangladesh (Hossain et al., 2013). In addition, Hossain et al. (2017) reported potential antidiarrheal activity of different fractions of *S. apetala* seeds. Since ricinoleic acid in castor oil was responsible for prostaglandin-mediated diarrhea in this mice model (Pierce et al., 1971), polar and slightly non-polar compounds of

the fruits were strongly involved in inhibition of prostaglandin biosynthesis and reduction of gastrointestinal motility and secretion. However, tannins, flavonoids, and reducing sugar/glycosides have been reported as potent antidiarrheal agents (Palombo, 2006). In addition, polyphenol extracts from apples have been shown to dose-dependently inhibit cholera toxin-induced diarrhea, with fractions containing polymerized catechins most effectively inhibiting toxin-mediated fluid secretion (Saito et al., 2002).

Cytotoxicity

Brine shrimp lethality bioassay results are indicative of cytotoxicity (McLaughlin, 1991), therefore were used to determine cytotoxicity of extracts (ethanol : methanol, 1:1). The extracts of the *A. corniculatum*, *A. officinalis*, *B. gymnorrhiza*, *C. decandra*, *H. fomes*, *N. fruticans*, *P. paludosa*,

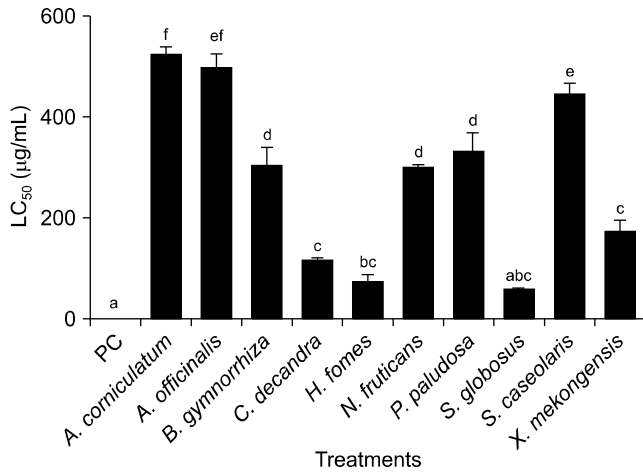


Fig. 4. LC₅₀ values of cytotoxic activity of different edible mangrove fruits on brine shrimp nauplii. Different letters (a-f) indicate significant differences compared to each other group using one way ANOVA at $P < 0.05$. PC, positive control, vincristine sulphate (0.45 µg/mL).

S. globosus, *S. caseolaris*, and *X. mekongensis* fruits demonstrated LC₅₀ values of 524.0, 497.0, 304.5, 116.7, 74.1, 299.3, 331.4, 59.2, 444.3, and 172.0 µg/mL, respectively, compared with 0.45 µg/mL for the positive control vincristine sulphate (Fig. 4). However, Ahmed et al. (2007b) reported *A. corniculatum* leaf ethanol extract show LC₅₀ of 10 mg/mL. Rieser et al. (1996) postulated that extracts with LC₅₀ values <250 µg/mL were significantly active and show potential for further investigation. Therefore, *C. decandra*, *H. fomes*, *S. globosus*, and *X. mekongensis* fruits are potential sources of new cytotoxic compounds. In a previous study, different *S. apetala* seed fractions showed LC₅₀ values <250 µg/mL (Hossain et al., 2017). Various flavonoids, alkaloids, tannins, and saponins have been shown to exert cytotoxic effects (Lim et al., 2007; Podolak et al., 2010; Dey et al., 2019). However, some polyphenols non-specifically bind to membrane structures and destroy cells (Hossain et al., 2002; Hossain et al., 2007).

Acute toxicity

Since *S. caseolaris* and *A. corniculatum* fruits showed potential for treating diarrhea in addition to low toxicity in brine shrimp, we determined their acute toxicity. *S. caseolaris* fruits are readily consumed in coastal areas, although no abnormal effects on human health have yet been identified. However, *A. corniculatum* fruits are rarely eaten. Therefore, the *A. corniculatum* fruit extract (methanol : ethanol, 1:1) was used in acute toxicity test in mice. No mortality or signs of toxicity were observed within 6 h of continuous observation, after 24 h, or after consecutive 14 days of oral administration at different doses (0.5, 1.0, and 2.0 g/kg b.w.). Morphological characteristics (fur, skin, eyes, and nose) and body temperature of mice appeared to be normal. No salivation, diarrhea, lethargy, and unusual behavior were observed. Body weight gain and food and water consumption (Fig. 5) were similar to the control group, thus extracts may not affect carbohydrate, protein, or fat metabolism. In a previous study, Auletta (1995) reported that alterations in body weight gain reflect the toxicity of toxic substances. Therefore, we concluded that *A. corniculatum* fruits are non-toxic.

Of the ten edible fruits in the Sundarbans mangrove forest of Bangladesh, *S. caseolaris* showed potential to inhibit common pathogenic bacteria. *A. corniculatum*, and *S. caseolaris* fruit extracts (250 mg/kg b.w.) demonstrated antidiarrheal activity similar to that of loperamide (3 mg/kg b.w.). These two fruits showed low cytotoxicity in brine shrimp lethality bioassay, therefore showing potential to be used for the prevention and treatment of bacterial and diarrheal diseases. However, the dose of loperamide available in Bangladeshi markets is 2 mg, which was equivalent to 167 mg of the extract produced from 1.5 and 2.2 g fresh fruits of *A. corniculatum* and *S. caseolaris*, respectively. These results suggest that consumption of only a few grams of the mangrove fruit may provide health and medicinal benefits for humans. Further attempts should be taken to isolate and identify potential

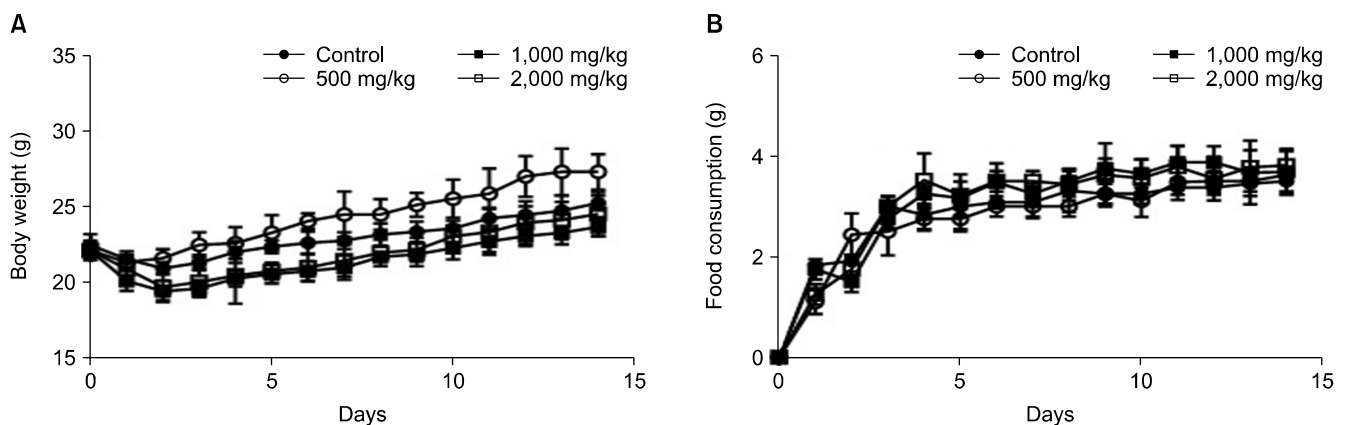


Fig. 5. Effect of different doses of *Aegiceras corniculatum* fruit extract (ethanol : methanol, 1:1) on (A) body weight gain (g) and (B) food consumption (g) of mice. The control group showed non-significant differences compared to the extract-treated groups (mean±SD; n=6) using one way ANOVA at $P < 0.05$.

health promoting compound(s) from these fruits. In addition, integrated measures are necessary to promote cultivation of the fruits in the vast tropical coastal regions of the world to meet food security and primary health care demands of coastal populations.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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