Assessment of nutritional value and potential metal toxicity in fruit of *Artocarpus altilis* (Parkinson) Fosberg (seedless) in India

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ABSTRACT

Artocarpus altilis (Parkinson) Fosberg, commonly known as Breadfruit (seedless), is one of the economically important trees, which is being used for food, fodder, fuel, timber, starch as adhesives, gum, and dye for textiles, paper, cordage and medicine; however, its fruits are reported as staple food. In the present investigation the ethanolic extract of *Artocarpus altilis* fruit pulp (EAFP) were analysed for their proximate and mineral content in matured unripe fruit. Proximate analysis of the unripe edible fruit showed that it is rich in carbohydrate (70.81%) when compared to ash (1.45%), protein (3.10%), fat (3.34%) and fibre (9.52%). The lower moisture levels in this study are suggestive of longer shelf life for the breadfruit flours. The bread flour could replace wheat, maida, etc. for pastries and confectionary process. In this investigation, more elements contributing to the mineral composition were determined in EAFP than in the majority of papers published to date. The order of the concentrations of the trace and heavy elements in the EAFP sample was Fe >Ni > Cu > Cr > Mn > Zn > Mo >Co and Al > V > Pb > Cd > As >Hg respectively. EAFP contain the highest level of Al, a toxic metal, as well as the essential microelement Fe. The fruits analyzed did not contain mineral concentrations exceeding the recommended values. Therefore, EAFP can act to provide the needed energy, mineral nutrition, pharmaceuticals and help combat malnutrition.

Keywords: EAFP, proximate, mineral, Breadfruit (seedless)

INTRODUCTION

Over one billion people throughout the world are believed to gain part of their entire livelihood from the utilization of wild food. In nutrition, food security and income generation, plant resources play a significant role stated by agro pastoral societies in Africa Edmonds, J. Et.al., (1995); Faruq, U., (2002) Funtua, I., (1999). Furthermore, FAO report, wild foods are used nearly one billion people in their diet. About 150 wild plants species were identified as sources of emergency food in India, Malaysia and Thailand (Burlingame, B., 2000). To nutritionally marginal or vulnerable groups within populations become beneficial by the incorporation of edible wild and semi-cultivated plant resources, especially in developing countries where poverty and climatic changes are causing havoc to the rural population. Some of these wild plants that are used by people which serve as food and sources of nutrients are fruits, because they provide some of the minerals that are essential for body building and regulating some body functions. Plants growing in heavy metal contaminated soils would pose a severe risk to humans as accumulation of heavy metals may cause long-term adverse health effects whilst accumulation can also be facilitated through the plant-animal-human food chain (Berto, A. et.al., 2015; Bello, M.O., et.al. 2008; Jaishankar M et.al. 2014 and Okieimen FE et.al.,2011). Obesity, diabetes, cardiovascular problems, hypertension, osteoporosis, and cancer diseases are based on diets rich in fat, salt and sugar, and poor in complex carbohydrates, vitamins and minerals.

For a healthy life, fruit consumption has increased because of health benefits, taste, disease prevention due to the presence of nutraceutical like vitamins, minerals, fiber and other bioactive compounds required by the body (Guo, C. et.al.,.2003; Hossain, M. A, et.al., 2011 and Ribeiro, A. B. et.al., 2013). Breadfruit is a great versatile food source has drawn attention because of its abundance throughout tropical regions and low cost. Minimal inputs of labour, little attention and materials make breadfruit trees to grow easily in a wide range of ecological conditions (NTBG, 2009).

Artocarpus altilis (Parkinson) Fosberg plant, known as Breadfruit (seedless), is one of the oldest domesticated crops in Oceania (Fosberg, F.R. et.al., 1941 & 1960). *Artocarpus altilis* trees are monoecious, a syncarpus, composed of 1500-2000 flowers attached to the fruit axis or core. Numerous latex tubes and large vascular bundles in the core discolour rapidly upon cutting, due to oxidation of enzymes. Persistent perianth of each flower fused together except at the base develop into bulk of the fruit which grows vigorously and becomes fleshy at maturity, forming the edible portion of the fruit. Fruits globose to oblong, yellowish-green, light green or yellow skin, creamy white or pale yellow flesh; smooth to slightly bumpy or spiny surface with individual disks ranging from areolate, to slightly raised and flattened, to widely conical up to 3 mm high and 5mm across at the base, to narrowly conical up to 5 mm long (Ragone, D., 2007; Singh, H., et.al., 2009 & Ragone, Diane. 1997).

It is high yielding with an average sized tree producing 400-600 fruits per year. Yield 150 to 200 kg of fruits with a single tree. It is superior to other starchy staples producing plant. It can be eaten raw at the soft, sweet ripe stage and at mature unripe starch stage eat as boiled, baked, roasted, pickled, steamed or fried. Utilized as local food crops in developing tropical countries is of great interest. This is especially true for those that are produced abundantly, economically, and are well liked by the locals. A gluten-free starch contains a high percentage of carbohydrates, and also a rich source of fiber, vitamins such as vitamin C, minerals especially high microelements, and phytochemicals such as flavonoids. Although breadfruit contain low quantity of protein but its quality is excellent. Breadfruit meets these criteria and provides an excellent source of calories for the diet. Heavy metals, due to their toxicity, are considered a significant risk to the environment. Breadfruit has been cultivated for years to use as food, fodder, fuel, timber, starch as adhesives, gum, and dye for textiles, paper, textiles, cordage and medicine (Jones, A.M.P. et.al., 2010& Zerega, N. et.al., 2006)

Breadfruit has reported to be a good source of nutrients; however still there is a huge dearth of information to promote its cultivation, knowledge of its nutritional composition to use as food and medicine need to be generated. Therefore, it is imperative to intensify investigations aimed at evaluating the potentiality of proximate and mineral composition of ethanolic extract of *Artocarpus altilis* fruit pulp (EAFP) found in India.

MATERIALS AND METHOD

Chemicals

All chemicals and reagents were analytical or HPLC grade.

Sample preparation

The fruits of *Artocarpus altilis* (Parkinson) Fosberg, (Breadfruit) of the family *Moraceae* were collect from Gobichettipalayam, Erode, Tamilnadu, India. The plant was authenticated by Botanical Survey of India, Coimbatore; letter No BSI/SRC/5/23/2017/Tech/1610. The dried powdered fruit pulp of A. altilis was defatted with n-hexane and extracted with ethanol at room temperature by cold maceration. Evaporation of ethanol gave a dark brown solid. A relatively simple better yield method is cold maceration. Ethanol, a polar solvent easily penetrates cellular membrane of plant material to extract secondary metabolites of our interest. In our previous study, among five extracts ethanol showed more pharmaceutically worth phytochemicals in the plant material. So, in this study, we have a chance to check the nutraceutical extraction efficiency of ethanol. The powdered ethanolic extract of *Artocarpus altilis* fruit pulp (EAFP) were used for further analysis except for the moisture content determination, which was based on fresh weight.

Proximate analysis

The methods recommended by the Association of Official Analytical Chemists (AOAC, 2005) for proximate analysis of ethanolic extract of *Artocarpus altilis* fruit pulp (EAFP) was adopted. Micro-Kjeldahl method used to determine nitrogen as described by Pearson (1976). The Crude protein was calculated from percentage Nitrogen by multiplying. All determinations were performed in triplicates (n=3).

Determination of Ash: Ash content in powder was determined as described by AOAC (2005). Cleaned, heated to about100^{0}C, cooled and weighed porcelain crucible were added with 2 Gms of powdered sample. The crucible with its content was placed in a mufle furnace for about four hours at about 600^{0}C. It then cooled in a desecrator and weighed. To ensure completion of ashing, the crucible was again heated in the mufle furnace for half an hour, cooled and weighed again. This was repeated till two consecutive weights were the same and the ash was almost white in colour.

Determination of Moisture: Standard IUPAC method used to determine Moisture content (1977). I n previously treated porcelain crucible contain sample of 2 Gms were weighed. The sample containing crucible was heated at 105^{0}C for about six hours in an electrical oven and then cooled in desiccators and weighed again. The percentage moisture in the oil cakes was calculated from the formula:

Moisture = 100(W1- W2)/W2 %,

Where, W1 = Original weight of the sample before drying; W2 = Weight of the sample after drying.

Estimation of fat: Fat determination is one of the key analyses used for food labelling and quality control. Fat content was determined based on Jinadasa 2010. For the present study 5 g of finely ground sample was taken in a motor and anhydrous sodium sulphate of twice the weight of the sample was added into it. Then the mixture was ground until a free-flowing powder was obtained. Then the powder was transferred to a thimble and sealed the end. Extraction thimble with the sample was placed in the Soxhlet apparatus and fixed a previously dried and weighed round bottom flask. 200 mL of extracting solvent (petroleum ether) was added to the flask containing pumice chips. Then the Flask and the condenser were connected to the Soxhlet extractor. Sample was allowed to reflux for about five hours. After the extraction flask was removed from the apparatus and kept in the water bath and then in the oven. Then the flask was cooled and weight was taken.

Estimation of protein: The crude protein was assessed by micro-Kjeldahl method (AOAC 2005). It was calculated from percentage Nitrogen by multiplying. The samples were digested by heating with concentrated sulphuric acid (H_2SO_4) in the presence of digestion mixture, Potassium sulphate (K_2SO_4) and copper sulphate ($CuSO_4$). By adding 40 % NaOH mixture becomes alkaline. Ammonia gas was collected in 4% boric acid solution and titrated against standard HCl which was released due to Ammonium sulphate formed. The percent nitrogen content of the sample was calculated the formula given below. Total protein was calculated by multiplying the amount of percent nitrogen with appropriate factor (6.25).

1.4 X (mL HCl - mL blank) X Conc. of HCl

% N = Weight of sample (g)

% Protein = % N X Factor (6.25)

Estimation of total carbohydrate: Anthrone method as described by Sadasivam and Manickam (2008) was followed for carbohydrates. The powder sample 100 mg were hydrolyzed with 5 ml of 2.5 N HCl in boiling water bath for 3 hours. The acid digested sample was cooled to room temperature and neutralized by adding sodium carbonate. The final volume is made to 100 ml with distilled water and centrifuge at 5000 rpm for 15 min. The supernatant was then collected and 0.5 and 1ml aliquots were taken for analysis of total carbohydrates. The green colour developed in reaction mixture was read at 630 nm using Spectronic-20 UV Visible spectrophotometer (Thermo Scientific, USA). D-glucose at the concentration of 100 µg ml-1 was used to prepare the standard curve. The amount of carbohydrate present is calculated by following formula.

Amount of carbohydrate present in 100 mg of the sample= 100- (%Moisture + % Fibre + % Protein + % Lipid + % Ash)

Mineral composition

Analysis of metals in ethanolic extract of *Artocarpus altilis* fruit pulp (EAFP) by atomic absorption spectrophotometer (Eng-Shi *et al*., 2000 and Sahito*et al*., 2001).

Determination of Elements: All the atomic measurements are carried out with PerkinElmer model 400/HGA 900/AS 800 coupled with Mercury Hydride System-15 (MHS-15) and Flame Photometer. The Hallow cathode lamps (HCL) for Fe, Cu, Mn, Zn, Mg, Mo etc., and Electrode less Discharge Lamp (EDL) for Cd, Pb, Hg and As analyses are used as a light source to provide specific wavelength of the elements to be determined and high purity (99.999 %) Acetylene and Nitrous oxide are used to provide constant thermal energy for atomization process and Argon gas used for carrier gas removal purposes for Graphite furnace.

Standard Certified Reference (SRM) of National Institute of Standard and Technology (NIST) was used for day-to-day for the evaluation of methods of analysis or test and for long-term quality assurance of measurements. A reagent blank reading was taken and necessary corrections are made during the calculation of concentration of various elements.

Atomic Absorption Spectrophotometer (AAS): After calibrating the instrument with prepared working standard, a quantum of 10 ml of digested liquid sample is pipette out to a specific container of Mercury Hydride system analyser and then by adding 1.5% HCl of 10ml as diluents for each flask and blank, 3 % of $NaBH_4$ solution in 1% of NaOH is run through the reaction flask to quartz cell without heating against the calibration curve obtained from Absorbance versus concentration of the prepared known concentration on the day of the analysis.

STATISTICAL ANALYSIS

All the results obtained were as means ± SD. One-way analysis of variance (ANOVA) was used to determine the significant differences for multiple comparisons which was completed using Duncan test at $\alpha = 0.05$. All of these were done using SPSS statistical package (ver.17.0).

RESULT AND DISCUSSION

Proximate composition

Proximate composition includes moisture, ash, fat, protein, crude fibre and carbohydrate were analysed from the ethanolic extract of *Artocarpus altilis* fruit pulp of are shown in Table 1.

TABLE 1. Proximate composition.

S.NO	Parameters	EAFP value
1	Ash	1.45 ± 0.03
2	Moisture	4.72 ± 0.05
3	Total Fiber	9.52 ± 0.03
4	Soluble Fiber	7.78 ± 0.03
5	Insoluble Fiber	1.73 ± 0.03
6	Fat	3.34 ± 0.04
7	Protein	3.10 ± 0.19
8	Carbohydrate	70.81 ± 0.20
9	Lipid	1.27 ± 0.03

Results are expressed as mean ± standard deviation of triplicates followed by Duncan test.

Moisture content of the sample was 4.72% which is lower than fermented (10.57 %) and unfermented (9.11 %) pulp flour of *Artocarpus altilis* of Ghana region reported by F. Appiah et al., *A.communis* (Breadfruit) belongs to the location of Ifewara (9.63%), Mamu (9.68%) and Noforija (9.35%) reported in Bakare, H.A.et al.,. The moisture content of the flours was within the recommended range (10-14%) for flours. This study suggested that longer shelf life for the breadfruit flours based on the lower moisture levels. Generally, increased moisture levels in flours are known to encourage the growth of micro-organisms and consequently microbial spoilage (Oduro I. et. al, 2009) depending on packaging that will exclude atmospheric moisture uptake. According to Celestino, products with lower moisture content, generally, are less subject to degradation by microorganisms and chemical changes. Hence, the ethanolic flour increases shelf life.

The carbohydrate content was 70.81 % in the EAFP. It had the highest concentration of carbohydrates compared to both the pulp and peels close to 60% and about 50% reported in Bakare, H.A.et al., respectively but lower than reported by F. Appiah et al., The decrease in carbohydrate content with fermentation was marginal. The high carbohydrate content observed indicates that *A. altilis* pulp flour could be a good source of energy. This probably explains its use as a staple in the Caribbean (Roberts-Nkrumah, L.B., 2005). Changes occur in individual sugars such as fructose, glucose and sucrose were the major sugars, with only trace amounts of ribose and maltose during maturation. As maturation progressed, level of Fructose, predominant sugar in less mature fruits was decreased compared to sucrose and glucose. Carbohydrates are good sources of energy and help provide bulk and impart the needed pastiness for necessary mouthfeel. Deterioration and softening of fruit cause browning which may due to reducing sugars comprise in the soluble sugars; this occurs as a result of Maillard reaction between reducing sugar and protein contents of the fruit (Akintayo, E.T., et.al. 2002).

The amount of ash in the sample was 1.45 % generally lower than *A.communis* (Breadfruit) belongs to the location of Ifewara (2.77%), Mamu (4.35%) and Noforija (3.74%) reported in Bakare, H.A.et al., and Ghana location *Artocarpus altilis* pulp flour had ash content ranging from 2.37% and 2.38%. reported by F. Appiah et al., but higher than cassava (1.0%; Aryee et al., 2006). Ash content varied significantly with respect to the region, part of the fruit as well as with variety. The quantity of minerals present in the samples is directly proportional to the amount of ash present (Coimbra, M.C. et.al., 2011).

As regards the fat content, the value was 3.34 %. This was higher than that the 0.47- 0.65% reported for *A. communis* [25] and *A. altilis* pulp flour (2.36%; F. Appiah et al.) [24]. The unfermented flour had significantly higher crude fat content than the fermented. To minimize rancidity and the associated storage stability and acceptability problems we need knowledge of its fatty acid composition. As per Wootton and Tumaalii (1984) report, 41% and 64% of saturated and unsaturated acids as total percentage of the total fatty acids in breadfruit. The low fat content of *A. altilis* suggests it may not be a good source of oil.

Generally, the protein content of flour gives an indication of the nutrient quality of the flour. Flours are usually fortified with high protein flours to provide needed nutrition (Zhao, W., et.al., 2004). Protein content varied considerably between the pulp and the peels, and within the pulp varieties. The protein content (3.10%) of the EAFP was lower than the reported for *A. communis* pulp and peel flour (3.12%-5.66%; Bakare, H.A.et al., 2012) and *A. altilis* pulp flour (3.80%; F. Appiah et al.). On comparison, the protein content of the pulp flour was also lower than pearl millet (11.4%; Oshodi *et al*., 1999), wheat flour (9.8%; Akubor and Badifu, 2004) and as well as *Dioscera alata* (water yam; 4.7-15.6%) reported by Treche and Agbor-Egbe (1995). Contrary to values reported by Graham and De- Bravo (I981), the pulp had significantly higher protein content than the peels. The heart (core) of the fruit was milled with the pulp to prevent loss of protein in flour. Adewusi *et al*. (I995) had reported high crude protein content in the core of the fruit. These differences could be due to geographical location or soil nutrient levels since soil nitrogen level could influence protein levels (Blumenthal *et al*., 2008). Although breadfruit contain low quantity of protein but its quality is excellent.

As for fibre content, the samples generally contain1.73%, 7.79%and 9.52% of insoluble, soluble and total fibre respectively. Nevertheless, actual dietary fibre available in the samples was only indicated (Heller, S.N. and Hackler, LR., 1978). The fiber content of the breadfruits was higher than the reported for *A. communis* pulp and peel flour (6.32%-9.04%; Bakare, H.A.et al., 2012) and lower than A. *altilis* pulp flour (3.12%; F. Appiah et al.). Fibre is reported to have beneficial effects on preventing cancer (Shankar and Lanza, 1991). *A. altilis* pulp is thus a better source of fiber than the nuts. *Artocarpus altilis* flour could therefore be used to fortify low-fiber flours such as cassava flour in the bread industry to increase its fiber content.

MINERAL ANALYSIS

Among the micronutrients found in fruits, minerals represent a class of inorganic substances that is present in all kinds of fruits. In order to function properly the human body needs about twenty different minerals (Williams 2006). These elements can be classified into macro, micro minerals and heavy elements. Minerals are needed in amounts higher than 100 mg/day are Macro which include calcium (Ca), chloride (Cl), sulphur (S), sodium (Na), magnesium (Mg), phosphorus (P) and potassium (K). Minerals are needed in amounts lower than 100 mg/day and very very minute are Micro and heavy which include elements such as iron (Fe), zinc (Zn), iodine (I), selenium (Se), manganese (Mn), boron

(B), cobalt (Co), silicon (Si), chromium (Cr), copper (Cu), molybdenum (Mo), fluorine (F), aluminium (Al), arsenic (Ar), tin (Sn), lithium (Li) and nickel (Ni) (Mahan and Escott-Stump 2005). Minerals, in ionized form are essential for proper functioning of the body, and a deviation from the appropriate amounts can cause numerous diseases, clinical syndromes, and illnesses associated with the deficient intake, as well as overuse over time or at a certain time period of life.

Trace element and heavy metal composition analysis of EAFP is scarce and some important trace and heavy elements (essential and non-essential) for many metabolic and physiological functions, like, Hg, As, Cd, V, Al, Pb, Co, Cr, Cu, Fe, Mn, Mo, Ni and Zn are present in EAFP at parts per million (ppm) level evaluated in this study are given in table 2 &3 and statistically analysed. To stipulate the mineral levels that will meet the needs of healthy human individuals reference values are established and reviewed periodically. The average daily reference values of recommended dietary allowances (RDA) for adults established by USA National Institute of Health (NIH) 26 for men and women, from 19 to 70 years, are given in table 2 & 3. In general, the order of the concentrations of the trace and heavy elements in the EAFP samples is Fe >Ni > Cu > Cr > Mn > Zn > Mo >Co and Al > V > Pb > Cd > As >Hg respectively.

TABLE 2. Trace Elements.

Sl. No.	Elements analyzed	Amount of elements (in ppm)	RDA
		EAFP	mg / day
1	Iron (Fe)	0.7521	8-14
2	Copper (Cu)	0.2568	4- 9
3	Manganese (Mn)	0.2016	1.8-2.3
4	Zinc (Zn)	0.1896	8-11
5	Nickel (Ni)	0.7452	0.6-1.0
6	Cobalt (Co)	0.0845	5-40
7	Chromium (Cr)	0.2384	0.025-0.035
8	Molybdenum (Mo)	0.1589	34-45 µg/day

Among the essential micro-minerals, the EAFP analyzed contained Fe, Ni, Cu, Cr, Mn, Zn, Mo and Co in ppm: 0.7521, 0.7452, 0.2568, 0.2384, 0.2016, 0.1896, 0.1589 and 0.0845 are within the RDA values respectively. Fe was present in sufficient amount in EAFP compared with unfermented flour (3.91%) fermented flour (1.56%) of *A. altilis* and cassava 32 mg/100 g (FAO and IFAD, 2004). Especially in anaemia parts of the world, the high level of iron might be of nutritional importance where Fe deficiency is relatively rampant. Consuming unfermented *A. altilis* pulp could help provide the daily requirement for iron. Iron is an important constituent of haemoglobin found in blood. De Villota *et al*. (1981) emphasized the importance of iron in oxygen carriage in blood. In plants growing naturally higher contents of Mn and Zn were detected. Manganese is an essential element and is bound to a number of essential enzymes, for example, the activity of superoxide dismutase is suppressed by low Mn status (Li C, Zhou HM., 2011). Fe, Zn, and Mn are also identified to be potential antioxidants (Talwar H. S., 1989) which involve in the strengthening of immune system. Apart from its function as a biocatalyst, Cu is necessary for body pigmentation, for the maintenance of a healthy central nervous system, and for the prevention of anaemia, and it is interrelated with the function of Zn and Fe in the body (Zhi et.al.,2003).Cu is vital for human body especially for the nervous and cardiovascular systems, besides that, Cu plays an important role in thyroid gland metabolism, specifically in hormone production and absorption (S. S. Abdrabo et.al., 2015and S. B. Swamiet.et.al., 2012). Through soil contamination Cu can be accumulated in plants, considered essential in low concentrations, (Palmieri et al., 2005). Nickel has also been reported to be a carcinogenic element (Cassaret, A., & Doull's, D., 1996). Cr is an essential mineral for human metabolism but this mineral can be toxic and carcinogenic depends on its structural form. Co is an essential part of vitamin B12 (cyanocobalamin), and its deficiency can cause pernicious anaemia. Ingestion of foods containing these compounds is must since the human body is unable to synthesize vitamins. By increasing the production of red blood cells, this compound can prevent or treat anaemia, as well as improve the absorption of iron by the body. Considered to be an essential element for human beings, exposure to high doses can cause toxic effects (Agency for Toxic Substances and Disease Registry, 2001). It can be suggested that EAFP can be a valuable dietary source of these trace elements.

Heavy metals are required for biochemical and physiological functions and necessary for maintaining health throughout life. Some deleterious heavy metals elements are such as Lead (Pb), Cadmium (Cd), Mercury (Hg), Vanadium (V) and Arsenic (As) are transmitted into fruits and other farm produces. Most of them are converted into high toxic compound. Keeping in view of the potential toxicity, there is necessary to test and analyze the food items to ensure that the levels of these heavy metal contaminants meet the agreed international requirements (Sajib M. A., 2014).

TABLE 3. Heavy Elements.

Sl. No.	Elements analyzed	Amount of elements (in ppm)	PTMI
		EAFP	
1	Aluminum (Al)	7.2184	1 mg/kg bw
2	Vanadium (V)	2.3654	*1.8* µg/kg bw
3	Mercury (Hg)	0.0019	4 µg/kg bw
4	Arsenic (As)	0.0047	2.1 µg/kg bw
5	Cadmium (Cd)	0.1288	25 µg/kg bw
6	Lead (Pb)	0.2566	25 µg/kg bw

The results obtained in the heavy element analysis was expressed as parts per million for the elements shown in Table 3. In this can be seen that the chemical element of greater concentration is Aluminium and the element with lower content is Mercury. Lead is one of the representative metals whose concentration represents a reliable index of environmental pollution (Community Nutrition Mapping Project, 2009). The organic form of arsenic is less toxic than inorganic form of arsenic which educates toxicity of arsenic depends on its chemical form (FDA, 2003). Gastrointestinal tract injuries and cardiac disorders mar be caused by arsenic. Absorbed and incorporated mercury into tissue proteins can cause detrimental effects on health. Cadmium may accumulate in the human body, leading to renal dysfunction, bone diseases, and reproduction problems (Sobral et al., 2006). An excessive amount of Al may be related to a variety of neurodevelopment disorders, including encephalopathy, Parkinson's disease, and Alzheimer's disease (Sobral et al., 2006). Depending on the chemical forms, duration, time and route of exposure and concentration of the exposed metals determine the bioaccessibility and bioavailability of the exposed heavy metals. Our analysis determined that the concentration of these minerals in EAFP was within the acceptable range stated in daily recommended dose, suggesting that they may not impose any health risk.

CONCLUSION

Based on the findings of proximate composition and mineral contents of ethanolic extract of Artocarpus altilis fruit pulp (EAFP) one can infer that nutritious breadfruit flour may be a possible solution to helping alleviate hunger in underdeveloped areas, where the crop is indigenous. Carbohydrate present at an appreciable amount while components such as ash, protein, fat and fibre present at low amount. This study suggested that longer shelf life for the breadfruit flours based on the lower moisture levels. *A. altilis* pulp flour is a good source of carbohydrate and therefore could be useful in providing the energy requirements of its consumers. The bread flour could replace wheat, maida, etc. for pastries and confectionary process. In this investigation, more elements contributing to the mineral composition were determined in EAFP than in the majority of papers published to date. The order of the concentrations of the trace and heavy elements in the EAFP sample was Fe >Ni > Cu > Cr > Mn > Zn > Mo >Co and Al > V > Pb > Cd > As >Hg respectively. EAFP contain the highest level of Al, a toxic metal, as well as the essential microelement Fe. The fruits analyzed did not contain mineral concentrations exceeding the recommended values. The use of *A. altilis* pulp flour as food could provide mineral nutrition, needed energy and help combat malnutrition.

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