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Research Article

Nutritional Composition and Anti-Nutrient Content of Elephant Foot Yam (*Amorphophallus campanulatus*)

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Abstract

Background and Objective: The nutrient and anti-nutrient compositions of a foodstuff affects its utilization as food or feed. The nutrient contents of food ingredients are affected by the environmental conditions in which the plant was grown and oxalate in a foodstuff limits its utilization and exerts a negative effect on consumers. The aim of this study was to evaluate the nutrient value, minerals and anti-nutrient values in *Amorphophallus campanulatus (A. campanulatus*). **Materials and Methods:** The *A. campanulatus* tubers were collected from East Nusa Tenggara, Indonesia and then cleaned, peeled, chopped, sun-dried for 2 days (at 30-32°C), milled into powder and then analyzed for the proximate and anti-nutrient contents. **Results:** The nutrient content of *A. campanulatus* flour included crude protein (1.126±0.101%), crude fat (1.173±0%) and crude fiber (3.447±0.142%). The detected minerals included P (1443.33±34.185 mg kg^{-1}), Ca (8535.76±543.75 mg kg^{-1}) and Mg (1512.39±89.28 mg kg^{-1}). Anti-nutrient analysis indicated the presence of oxalates (318.51±3.2 mg kg^{-1}), tannins (0.46±0.04%), cyanide (35878±0.402 ppm) and phytates (0.165±0.015%). **Conclusion:** These results revealed that *A. campanulatus* was high in mineral content but low in anti-nutrient content, so it can be used for food or feed.

Key words: *Amorphophallus campanulatus*, oxalate, tannin, cyanide, phytate, nutritional value

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Amorphophallus campanulatus is synonymous with *Amorphophallus paeoniifolius* (*A. paeoniifolius*) and is commonly known as the elephant foot yam and also called as maek in East Nusa Tenggara, Indonesia. The plants are herbaceous and belong to the Araceae family, which is a native crop of South Asia that is widely distributed in India, Malaysia, the Philippines, Bangladesh, Indonesia and Southeast Asia[1-4].

Elephant foot yam has been cultivated as an intercrop plant along with ginger under coconut or banana trees in India. The production yield of the elephant foot yam is 50-80 t ha^{-1}, thus, this plant has a low rate of production and is an underutilized crop in Indonesia[4]. The production of *Amorphophallus muelleri* (*A. muelleri*) in East Java is 6-10 t ha^{-1}/year[1] of fresh tuber. In East Nusa Tenggara, this plant is not cultivated (i.e., it is a wild plant), which is the cause of its low productivity. Elephant foot yam tubers are usually eaten as vegetables after boiling[1]. The tubers have been used as traditional food sources in Malaysia, Philippines, Bangladesh, Indonesia and India[1-3] as traditional medicine[1] and animal feed[2]. Elephant foot yam tubers contain P (34 mg/100 g), calcium (50 mg/100 g), vitamin A (434 IU/100 g)[1], crude protein (2.14%), fat (0.46%), calcium (32.1 mg/100 g) and crude fiber (1.68%)[5]. The tuber also contains anti-nutrient factors, such as oxalate and phytate. The level of oxalic acid in the elephant foot yam is 1.3%[2]. The nutrient compositions of elephant foot yam tubers vary according to where they are grown, the soil, the season, the water and climate situations[6]. This study was conducted to evaluate the nutrient and anti-nutrient compositions of wild elephant foot yams from East Nusa Tenggara, Indonesia.

MATERIALS AND METHODS

Materials: Elephant foot yam tubers were collected from Kupang District of East Nusa Tenggara, Indonesia. The tubers were cleaned, peeled, chopped to 7 cm in length, sun-dried for 2 days at 30-32°C and milled into powder.

Nutrient contents: The flour of elephant foot yam tubers was analyzed for proximate, energy, mineral contents and the anti-nutrient factors, such as hydrogen cyanide, oxalate, tannins and phytate.

The proximate and mineral compositions were determined according to the AOAC[7] methods. First the samples were oven dried at 105°C to assess the moisture content (method 934.01), the Kjeldahl method, which consists of digestion, distillation and titration (method 990.02) was utilized to assess the crude protein (nitrogen$\times$6.25) content and extraction in acid and alkali solutions (method 978.10) was used to assess the crude fiber. The mineral contents, including calcium (Ca), magnesium (Mg) and phosphorus (P), were measured by dissolving ash samples in acids (a mixture of HCl and HNO_3). Subsequently, Ca and Mg were assessed using the AAS (method 942.05) and P was determined using spectrophotometry method (method 965.17). The gross energy value was determined with a bomb calorimeter.

Anti-nutrient contents: The anti-nutritional factor oxalic acid was assessed by HPLC according to the methods of Savage *et al.*[8]. Phytate was evaluated with spectrophotometry method according to Vaintraub and Lapteva[9], tannins were determined according to the method of Burns[10] and hydrocyanic acid (HCN) content was determined using the alkaline titration method (method 915.03)[7].

Statistical analysis: Three independent analyses were performed for nutritional components, minerals and anti-nutrient contents. The results are expressed as the means and the standard deviation values (mean$\pm$SD).

RESULTS AND DISCUSSION

Nutritional composition: Elephant foot yam is wild crop in East Nusa Tenggara and its nutritional content is presented in Table 1. Protein content of the tuber was 1.126%, which falls within the range of 0.84-2.6% of the protein contents of cultivar tubers of elephant foot yams in India as reported by Chattopadhyay *et al.*[6]. Paul *et al.*[2] reported that elephant foot yams are rich in minerals but poor in proteins. The elephant foot yams examined in this experiment contained a higher content of crude fat than the elephant foot yam cultivars in India (0.01-0.4%) as reported by Chattopadhyay *et al.*[6].

The phosphorus content of the yams was 1443.33 mg kg^{-1}. Chattopadhyay *et al.*[6] reported a similar value for elephant foot yams in India (20.89- 247 mg/100 g). The calcium content was found to be 8535.76 mg kg^{-1} and the magnesium content of this tuber was 1512.28 mg kg^{-1}. Paul *et al.*[2] reported that elephant foot yams are rich in minerals, such as calcium (950 mg/100 g), phosphorus (934 mg/100 g) and iron (0.6 mg/100 g). The elephant foot yam is a good source of minerals that can supply a large portion of the daily requirements of minerals in food or feed. Calcium and phosphorus are the major minerals that the body requires in large quantities. Minerals have functions in the

Table 1: Analysis of the composition of *Amorphophallus campanulatus*

Components	Values
Crude protein (%)	1.126±0.1010
Crude fat (%)	1.173±0.0180
Crude fiber (%)	3.447±0.1420
Ash (%)	6.627±0.1680
Phosphorus (mg kg^{-1})	1443.330±34.185
Calcium (mg kg^{-1})	8535.760±543.754
Magnesium (mg kg^{-1})	1512.385±89.276
Calories (cal g^{-1})	3356.500±15.306

The values are presented as the means±the standard deviations of three determinations

Table 2: Anti-nutrient content of *Amorphophallus campanulatus*

Components	Values
Oxalate (mg kg^{-1})	318.510±3.210
Tannin (%)	0.456±0.045
Hydrogen cyanide (ppm)	35.878±0.402
Phytate (%)	0.165±0.015

The values are presented as the means±the standard deviations of three determinations

body that include as enzymatic regulation, acid-base processes, bone growth and muscle stimulation.

Anti-nutrient content: Anti-nutrient factors can influence animals in several manners, including directly intoxicating the animals, causing mortality or decreased production[11] and decreasing feed intake[12]. The mean anti-nutrient concentrations in the elephant foot yams in this study are provided in Table 2. The oxalate concentration was 31.851 mg/100 g, which is higher than that reported for cultivars in India (2.91-18.50 mg/100 g)[6]. The oxalate content in plants is affected by many factors, including the season, soil, water, climatic conditions and where the plant is grown[13]. Oxalic acid is strongly oxidized and exhibits mineral chelating activity. Oxalates react with calcium to produce insoluble calcium oxalate, which reduces calcium absorption[11]. A high intake of oxalate in foods causes hypocalcemia and the deposition of calcium oxalate crystals in the kidney[2,14,15]. Oxalic acid ingestion results in gastric hemorrhaging, corrosion of the mouth and gastrointestinal tract and renal failure[16]. Soluble oxalate ingestion of less than 2% for ruminants and 0.5% for non-ruminants might be acceptable[14]. Cattle and sheep are less affected because of the degradation of oxalate in the rumen[17]. In humans, the minimum dose of oxalate that can cause death in adults is 40-50 mg[14]. Cooking and fermenting can decrease the oxalate contents of soybean and soybean products[18]. Sun drying processes can also decrease the oxalate content by 26-35% in the false yam tuber.

Tannins are plant polyphenols that have the ability to form complexes with metal ions and macromolecules such as proteins and polysaccharides[19]. The tannin content in the elephant foot yams was 0.456% (Table 2). *A. paeoniifolius* extract contains flavonoids, tannins, proteins and carbohydrates[20]. Tannins have a strong affinity for proteins and form protein-tannin complexes[21], which have been reported to be responsible for decrease in feed intake, growth rate, feed efficiency, net metabolizable energy and protein digestibility[22]. At the levels of 100-120 g kg^{-1}, tannins reduce gastrointestinal parasitism in lambs[23] and inhibit the growth of fiber-degrading bacteria in the digestive tracts of ruminants[24]. Vohra *et al.*[25] reported that chicks fed tannins at dietary levels of 0.64-0.84% and 1.0-2% exhibited depressed growth, egg production and an increase in the content to >3% caused mortality. Tannin levels can be reduced by fermentation processes. Ridla *et al.*[26] studied fermented *Chromolaena odorata* in rumen content and found that putak meal can reduce tannin levels.

Hydrogen cyanide was observed at a level of 35.878 ppm in the elephant foot yams (Table 2). Hydrogen cyanide (HCN) is widespread in the plant kingdom and mainly exists in the form of cyanogenic glucosides[21]. The cyanide concentration of the elephant foot yam is lower than that of the cassava root in which the level varies from approximately 75-350 ppm[27] but can reach 1000 ppm or more[21] depending on the variety, plant age, soil conditions, fertilizer application, weather and other factors[11]. High levels of HCN have been implicated in cerebral damage and lethargy in animals and humans. Cyanide toxicosis is caused by the inhibition of cytochrome oxidase, which is a terminal respiratory enzyme in all cells. When cytochrome oxidase is inhibited, the cells suffer from rapid ATP deprivation. Signs of cyanide toxicosis include labored breathing, excitement, gasping, staggering, convulsions, paralysis and death. Blood is bright red due to its high oxyhemoglobin content[11]. Highly toxic hydrocyanic acid (HCN) is released from cyanogenic glucosides during hydrolysis by the enzyme linamarase, which is present in the root peel of the cassava[27]. The lethal dose of HCN for humans is between 0.5 and 3.5 mg for an adult, depending on body weight and nutritional status and is between 30 and 210 mg kg^{-1} body weight[21], while the lethal dose of HCN for cattle and sheep is 2.0-4.0 mg kg^{-1} body weight[11]. Cyanogens can be removed by drying, soaking and fermentation processes[21]. Hay and silage should be properly cured to ensure the loss of a majority of their cyanogenetic contents before being fed to livestock[28]. Phytic acid acts as strong chelator that forms protein and mineral compounds and is a common storage form for phosphorus in seeds[21]. Phytic acid chelates with minerals to produce phytates[29]. In elephant foot yams, the phytate content is 0.165%, which is higher than that of cassava root chips (0.09%) and sweet potatoes (0.1%)[30] but lower than that in some seeds, such as sorghum (5.9-11.8 mg g^{-1}), soybeans (9.2-16.7 mg g^{-1})[31] and the false yam tuber (0.39%)[32]. Phytic acid has a strong affinity for binding metal ions, such as phosphorus and zinc ions and this leads to interference in the absorption of these minerals in the small intestine and affects various metabolic processes[21]. The phosphorus in phytic acid is not nutritionally available to monogastric animals. Dietary phytate forms insoluble phytate-mineral complexes and reduces the bioavailability of minerals. The small intestine of the human is devoid of phytate-degrading enzymes and the microbial population in the upper part of the digestive tract is also limited[31]. A phytate intake of 4-9 mg/100 g of food can decrease the Fe absorption by 4-5 fold in humans. The mean phytate level in the elephant foot yams was lower than the recommended level of 25 mg/100 g in food[33]. The phytate in the vegetables can be reduced by increasing temperature and heating time and the phytate content is reduced by 51% in sun-dried false yams[32] and by 11-25% in *Pterocarpus mildbraedii* following heating at 90°C[33].

CONCLUSION

According to the described results, the elephant foot yam is a good source of minerals and has a high caloric content. Thus, the elephant foot yam can be used for food or feed but because of its antinutritional value, it must be processed before consumption.

SIGNIFICANCE STATEMENT

This study reveals that the nutrient and anti-nutrient contents of the foodstuff like *A. campanulatus* indicate that this plant could serve as a nutritionally beneficial food-/foodstuff. This study will help researchers to uncover critical aspects of the nutrient composition of *A. campanulatus*, which is grown in East Nusa Tenggara, Indonesia, that many researchers have not previously been able to explore. Thus, new information about the nutrient and anti-nutrient contents of *A. campanulatus* may be discovered.

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