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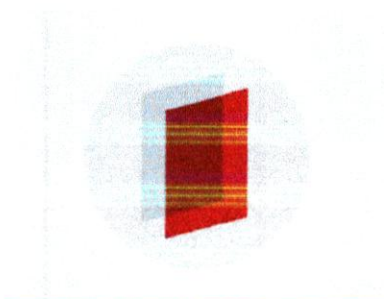
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## Fruits of *Enhalus acoroides* as a source of nutrition for coastal communities

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**Abstract.** Malnutrition in coastal areas is a widespread social and health problem in many areas of the world, with potential negative impacts on human growth, including brain development and intelligence. The root of the malnutrition problem is often the inadequate availability of foods which could provide sufficient and appropriate nutrition for a healthy body. Geographical conditions that can pose obstacles to the fulfillment of nutritional requirements in coastal areas can include sandy soils, low soil fertility, low freshwater availability, high evaporation, and high salinity or saline intrusion. These conditions limit the types of vegetation that can grow in coastal areas, including plants that can be consumed as vegetables. Therefore, coastal communities are looking to marine resources for vegetable alternatives, including the fruit of *Enhalus acoroides*. There are at least three reasons why this fruit could help fulfill human nutritional needs in tropical coastal communities: availability in nature, comparison of nutrition with other marine plants, and eligibility as a source of nutrition. The average Indonesian consumes vegetable 70.0 grams /person/ day, equivalent to 35% of the total vegetable intake recommended by WHO and balanced nutrition guidelines in Indonesia. Each *E. acoroides* fruit produces about 7.7 g of seeds per fruit so that 26 fruits would be needed to provide the daily WHO standard vegetable intake, which would require a total area of around 0.22 ha for *E. acoroides* fruit production. This vast extent can be reduced by consuming the *E. acoroides* seed pods (the thin fleshy skin of the fruit) as well as the seeds. Proximate analysis showed that, together, *E. acoroides* seeds and pods could help meet the human nutritional need for fiber, protein, phosphorus, iron, and calcium. They can also increase the body's resistance to degenerative diseases or infections. Crude fiber and carbohydrate content is higher than many other marine plants (e.g. *Eucheima cottonii*, *Caulerpa lentilifera*, and *Sargassum polycystum*). The Calcium and iron content of *E. acoroides* seed pods were higher than those of *E. cottonii*, and phosphorus content was higher than in *C. lentilifera*.

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### 1. Introduction

Nutrition plays an important role in achieving optimal growth, including brain development and intelligence, which ultimately affects the quality of human resources [1]. One factor that determines nutritional quality is food consumption patterns; these are influenced by food availability, which limits



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the type and amount of food consumed [2]. Coastal communities depend heavily on the utilization of marine resources for their livelihoods, and in much of SE Asia, including Indonesia, the food consumed is mostly in the form of animal protein in addition to rice as the main staple food.

Geographical conditions can be one obstacle to the availability of various foods. Coastal areas generally have land that is unsuitable or only marginally suitable for most crops due to sandy soils, low soil fertility, low freshwater availability, high evaporation and high salinity due to wind-blown salt and saline intrusion. This means that the types of vegetation that can grow in coastal areas are limited, including the types of plants that can be consumed as vegetables [3]. Therefore, coastal communities seek alternative vegetables from marine resources to fulfill their nutritional needs, one of which is the fruit of *Enhalus acoroides*.

*Enhalus acoroides* is the largest seagrass; it is slow growing and is widespread throughout the seas of the Indonesian Archipelago. *Enhalus acoroides* can form single species seagrass (monospecific) beds or mixed seagrass beds together with other seagrass species [4, 5]. One plant typically has 2-6 leaves, around 30-150 cm long [6, 7]. These plants are dioecious [6], with rhizomes, leaves, and roots [8]. A unique breeding system has evolved to enable *E. acoroides* to pollinate in the water (hydrophilous pollination), and after that, the developing fruits are also immersed in water. Flowers are raised to the surface of the water to pollinate, a phenomenon which is controlled by the tidal cycle. The flowers are reddish, with petal length 1.25-1.5 cm and crown length 4-5 cm, and female crowns catch male flowers that are washed away during high tide. The fruit is large and round with a thick outer surface [5]. Young fruits are bright green [9], length fruit is 12-15 mm and diameter 11-15 mm [10]. There are between 8-12 seeds in one fruit [26]. Seeds do not have a dormancy period which means that the seeds released do not need a long time to float on the surface of the water before they then sink to the bottom of the water and germinate directly [11].

The purpose of this study was to determine the potential of *E. acoroides* as a source of nutrition in coastal areas, by looking at three aspects, namely availability in nature, level of feasibility as a source of nutrition, and comparison of nutrition with other marine plants. The proximate analysis focused on *E. acoroides* as an alternative source of vegetable matter in the diet of coastal communities. The nutritional content of *E. acoroides* was compared to the recommended nutrients for dietary consumption and human health [12, 13].

## 2. Methods

This study was mostly based on secondary data on the distribution and production of *Enhalus acoroides* fruit, the direct use of seagrass fruits, and the nutritional content of *Enhalus acoroides* fruit and some other marine plants, as well as the number of nutrients needed by the human body. Primary data were collected during a preliminary survey data on Barrang Lompo Island (119°19'48" East Longitude and 05°02'48" South Latitude) during November 2016 - March 2017, and from a proximate analysis in the laboratory at Universitas Hasanuddin (major nutrients and some mineral content), following protocols in [14]. Data were analyzed descriptively and quantitatively to determine the seagrass area needed for *E. acoroides* to meet the needs of local people as a substitute for vegetables in coastal areas, and the relative quality of *E. acoroides* as a source of nutrition compared to other marine plants.

## 3. Result and Discussion

### 3.2. Availability in Nature

The World Health Organization (WHO) recommends the consumption of at least 400 g/day of vegetables and fruits to prevent disease and help fulfill the recommended dietary fiber intake requirements [15]. The minimum consumption of vegetables needed for a balanced diet is 200g/person/day [16]. Almost all Indonesian people consume some vegetables (94.8%), but the level of vegetable intake is still relatively low and the average consumption of only 70 grams/person/day can be considered inadequate, as it is equivalent to just 28% of the total vegetable intake recommended by WHO as well as by balanced nutrition guidelines in Indonesia [17]. Vegetables are limited in coastal

areas because agriculture faces challenges such as sandy soils, low soil fertility, low freshwater availability, high evaporation and high salinity due to wind-blown salt and saline intrusion [3].

The fruit of *E. acoroides* could become an alternative or substitute for vegetables to fulfill the nutritional needs of coastal communities because they are abundant in the sea, and do not need to be cultivated. Therefore, in some countries, people already use these plants as food (vegetables), and in some cases, they are sold in local markets to increase household income [18, 19, 20]. Among ASEAN countries, Indonesia has the largest area of seagrass beds (150,693.16 ha). After *Thalassia hemprichii*, the next most commonly found seagrass species in Indonesia is *E. acoroides* [21]. Indeed, in the Spermonde Islands, *E. acoroides* is found around almost all islands, including Barrang Lompo Island [22]. The seagrass beds around Barrang Lompo Island cover an area of around 58.85 ha with percentage substrate cover of around 58% [23]. These extensive meadows could help provide seagrass as a food source, especially in coastal areas where *E. acoroides* can flower throughout the year [5, 9, 24]. Flowering density increases with day length [25, 26] while fruiting density decreases with increasing seawater temperature [27]. Furthermore, the deeper the water, the lower the ability to flower because it is influenced by the presence of light [24]. Conversely, the frequently observed absence of flowers and fruit in shallow (1 m) waters can be attributed to a sudden and extensive browning process after a long flowering and fruiting season in the previous month, possibly due to the high energy costs of production [28]. A phenomenon of widespread seagrass mortality can occur after the production of flowers and fruit [29]. Seagrasses with larger shoots produce more seeds per fruit or spathe. Larger fruits produce larger seeds, so the number of seeds contained in the fruit does not increase significantly with increasing fruit size [29-31]. However, there can be substantial variation in these parameters depending on time and location. The following is a comparison of *E. acoroides* fruit production potential in the coastal/island areas of several countries:

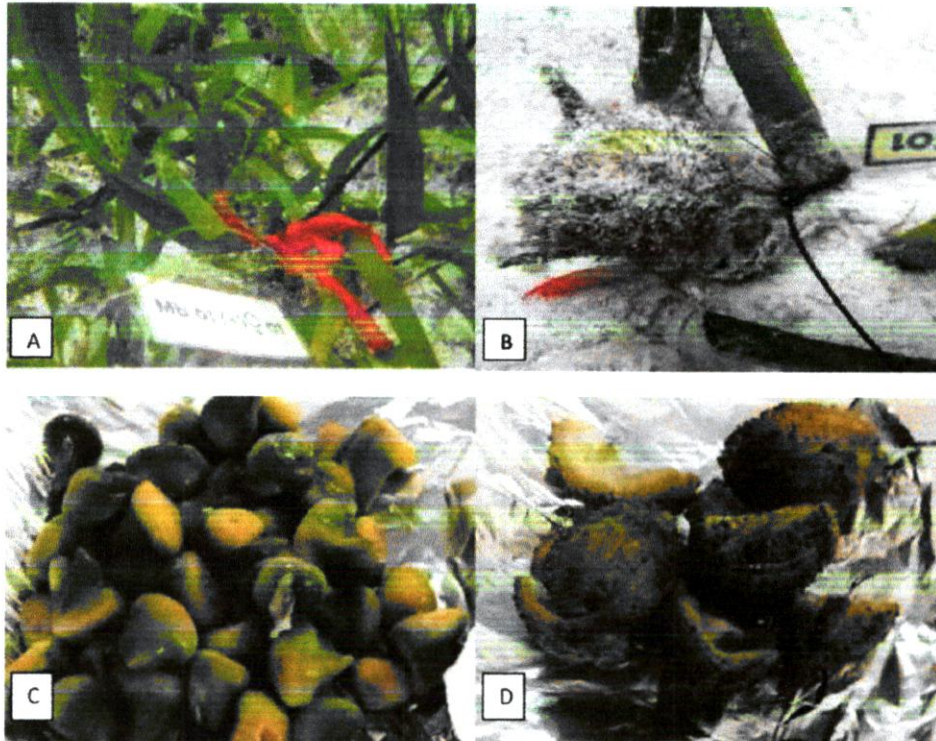
- Papua New Guinea (The Torres Strait): fruits occur throughout the year but intermittently and sparsely, with the highest flower density in spring/summer, and the lowest in autumn and winter. Fruit density in intertidal areas is very low ( $7.8 \pm 7.8$  shoots/m<sup>2</sup>) [32].
- Philippines: the peak flower density in Bolinao during February 2000 was  $0.8 \pm 0.5$  shoots/m<sup>2</sup> [33], but fruiting of *E. acoroides* in Silaki Island occurs in August-October. *Enhalus acoroides* has a flowering capacity of 2.8/shoot/year [28]. The average flower production is 1.054/shoot/year, the ratio of fruiting female flowers is 1.88/4.79, and the average fruit contains at least 9 seeds [24]. Using this data, the amount of fruit produced per square meter (with 10 shots in 0.25 m<sup>2</sup>) is approximately 16.5 fruits/m<sup>2</sup>/year or 0.045 fruits/m<sup>2</sup>/day. Each fruit produces about 6.4 g of seeds [10]. Thus, to provide vegetable intake to WHO standards for just one person, 31.25 fruits would be needed every day. Combining the density data with the amount of fruit needed to meet the recommended WHO per capita food consumption, the total area of *E. acoroides* needed for fruit production is about 694.44 m<sup>2</sup> for each person.

Different things in other regions of the Philippines, in the Visayas Middle flowering season from April to October [34], even in 1973-1982 *E. acoroides* did not flower. The deeper the water, the lower the ability to flower because it is affected by the presence of light [24].

- Indonesia (Barrang Lompo Island): *Enhalus acoroides* blooms throughout the year, but the fruiting season is only in July - April. There are no fruits in May and June. Pique interest density in August, average interest density 8.33 interest /m<sup>2</sup>. The ability to flower 1.3 times/year. The ratio of female interest (Figure 1A) to fruit (Figure 1B) is 3.16 out of 6 females. The average fruit consists of 10 seeds (Figure 1C), and the seed weight of each fruit is around 7.7 grams. Based on these data, the number of fruits produced in a year is 4.39 pieces/m<sup>2</sup>/year or 0.012 pieces/m<sup>2</sup>/day, and the amount of fruit needed to meet the needs of vegetables according to WHO standards are equivalent to 26 pieces /day. Thus the total area of *E. acoroides* seagrass that is needed for every coastal community in a day is about 2,166.67 m<sup>2</sup> or equivalent to 0.22 ha.

Based on the above—mentioned case studies from several regions, Barrang Lompo Island (Indonesia) would require more extensive *E. acoroides* seagrass beds to meet community vegetable needs compared to Silaki Island (Philippines) because the ratio of fruit to flowers around Barrang Lompo

Island is very low compared to Silaki Island. This is thought to be mainly due to anthropogenic activities such as household waste, anchor disposal, and ship propellers. Barrang Lompo is one of the most densely populated islands in the Spermonde Islands (8,896 people/km<sup>2</sup>) so that their activities tend to have a heavy impact on seagrass ecosystems [35].



**Figure 1.** *Enhalus acoroides* fruit and flowers from the seagrass meadows around Barrang Lompo Island (A. Female flower; B. Fruit. C. Seeds; D. Seed pods)

### 3.2. Comparison of Nutrition With Other Marine Plants

In order to further evaluate the extent of *E. acoroides* seagrass beds needed to meet the daily vegetable needs of the people on Barrang Lompo Island, it is necessary to determine the amount and type of nutrients contained in *E. acoroides* seeds and seed pods, and to compare these with other marine plants that are commonly consumed locally, such as farmed seaweed (*Eucheuma cottonii*) and lawi-lawi (*Caulerpa lentilifera*) (Table 1). Seed and seed pod content were analyzed separately because, besides consuming seeds, in some coastal areas in Indonesia people also consume the fleshy seed pods. The nutritional content of these pods can increase the amount of vegetable fiber and thus help in attaining balanced nutrition as recommended by the WHO.

**Table 1.** Comparison of the nutritional content of *E. acoroides* with other marine plants  
(% of sample dry weight, nr = not readable)

Nutrient type	<i>Enhalus acoroides</i> (seed) <sup>a</sup>	<i>Enhalus acoroides</i> (seed pods) <sup>a</sup>	<i>Eucheuma cottonii</i> <sup>b</sup>	<i>Caulerpa lentilifera</i> <sup>b</sup>	<i>Sargassum polycystum</i> <sup>b</sup>
Carbohydrate (%)	80.48	42.77	26.49	38.66	33.49
Protein (%)	9.61	9.47	9.76	10.41	5.40
Fat/Lipids (%)	0.76	0.69	1.10	1.11	0.29
Fibre (%)	2.38	15.48	5.91	1.91	8.47
Ash (%)	6.77	31.59	46.19	37.15	42.40
Ca (mg/kg)	2.258	4.564	3.296.9	18.747	37.921
P (mg/kg)	218	929	nr	160 <sup>c</sup>	nr
Fe (mg/kg)	56.99	54.35	26.1	213.7	682.1

This study, <sup>b</sup>[34], <sup>c</sup>[35]

The carbohydrate content of *E. acoroides* seeds and seed pods was higher than that of three edible seaweeds, the red alga (*Eucheuma cottonii*), green alga *lawi-lawi* (*Caulerpa lentilifera*) and brown alga (*Sargassum polycystum*). The protein content of *E. acoroides* seeds and seed pods was also higher than that of brown algae, but lower than that of the red alga and *lawi-lawi*. The crude fiber content of *E. acoroides* seeds pods was higher than that of the three seaweeds, while the fiber content of *E. acoroides* seeds was higher than *lawi-lawi* but lower than the red and brown seaweeds. The fat content of *E. acoroides* seeds and seed pods was lower than that of the red and green seaweeds.

Seeds and seed pods of *E. acoroides* was found to contain several minerals, especially calcium, phosphorus, and iron. However, there was almost no iodine content. Calcium content in *E. acoroides* seed pods was higher than that of the red seaweed but lower than that of *lawi-lawi*. The calcium content of the seeds was lower than that of any of the three seaweeds. The phosphorus content of *E. acoroides* seeds and seed pods was higher than that of *lawi-lawi*, while the iron content of the seeds and seed pods of *E. acoroides* was higher than that of the red seaweed *E. cottonii*.

Overall, *E. acoroides* fruit had a higher mineral content (Ca, P, Fe) than the three marine algae. The nutritional content of *E. acoroides* seeds was comparable to the nutrients found in terrestrial plants (like rice, wheat, and cassava), except for ash content; however the mineral content (including Ca, P, and Fe) in *E. acoroides* seeds was higher than that of wheat flour, cassava flour, and rice flour. Likewise, the content of calcium and iron in *E. acoroides* seeds is higher than that of *Z. marina* [10].

The function of calcium in plants includes a role in the manufacture of proteins or actively growing parts of plants, as well as in hardening stems and stimulating the formation of seeds [36]. One of the constituent elements of protein is phosphorus so that in high-protein foods, the phosphorus content will be high [37]. The roles of phosphorus in seagrasses include the storage and transfer of energy in cells and the functioning of the genetic system [38]. Iron is an essential element because it is part of certain enzymes and is part of a protein that functions as an electron carrier in the photosynthesis and respiration phases [39].

### 3.3. Eligibility as Source of Nutrition

Direct use of seagrass plants for human needs is not as common as yet, although certain types are used as food and medicine [40]. The Chwaka Village community [27] Zanzibar considers that seagrasses are very important marine plants because the roots and leaves are used as traditional medicine, for example for the treatment of muscle aches, wounds, and abdominal pain. The seagrass is sometimes also used as a medicine for fever, mixing it with spices and then burning it so that the patient inhales the smoke to reduce the fever. In Gorontalo, Indonesia, the Bajo ethnic group use *E. acoroides* leaves as an antidote to poisoning from venomous animal bites [41]. The fruit of *E. acoroides* can be used to increase the body's resistance to degenerative or infectious diseases [42], and the seeds are considered to have aphrodisiac and contraceptive properties [40, 43]. Also, seagrass productivity can exceed the productivity of wheat, corn, rice, and beet sugar as a food source in terrestrial areas [44].

One factor that affects food quality is the nutritional content [45]. In some tropical countries, a wide variety of vegetables, roots, tubers, fruits from wild plants are traditionally used because of their taste, as main food ingredients, as seasoning, or as nutritious dietary supplements [46]. Seagrass fruits can be counted among the available dietary alternatives, both as vegetables and raw food ingredients [43]; for example, coastal communities in the Philippines, Australia, and Indonesia use *E. acoroides* seeds as food [42,47]. Raw seeds taste crispy and sweet, while boiled seeds have a more starchy texture and taste like cooked sweet potatoes. However, based on Table 1 above, the nutritional content of *E. acoroides* seed pods was higher than that of *E. acoroides* seeds so that consuming the whole fruit could reduce the number of *E. acoroides* fruits collected as vegetables without reducing the intake of nutrients consumed by people in coastal areas. The following is an explanation of the nutritional content of the seeds and seedpods of *E. acoroides* and their acceptability: in human nutrition.

#### a. Carbohydrate content

Carbohydrates are one of the macro nutrients. Some carbohydrates can be digested to produce glucose and energy, while indigestible carbohydrates can be useful as dietary fiber. Carbohydrates provide around 4 Kcal of energy per gram [13]. In humans, the main function of digestible carbohydrates is to provide energy for cells, including brain cells that depend on the supply of carbohydrates in the form of glucose. Blood glucose deficiency (hypoglycemia) can cause fainting and can even be fatal; conversely, excess blood glucose causes hyperglycemia, and long-term can increase the risk of diabetes [48]. Natural carbohydrate sources include fruits, vegetables, milk, yogurt, whole grains, and nuts [12]. The composition of *E. acoroides* seeds is 80.42% carbohydrates equivalent to 804.2 g/kg, and seedpod is 42.77% equivalent to 427.7 g/kg. Humans need 225-325 g of carbohydrate per day, to provide 45-65% of the total daily calorie requirement of 2000 calories [12]. *E. acoroides* fruit is suitable as a carbohydrate source because, in addition to being classified as a grain, it tastes similar to widely acceptable vegetables such as beans.

#### b. Protein content

Protein is the main structural and functional component of every living cell. Nearly half the protein in the human body is contained in muscles and the rest in bones, cartilage, and skin. Proteins are complex molecules composed of various amino acids, nine of which are essential, cannot be synthesized by humans and therefore must be obtained from food. Proteins perform various functions as well as providing energy (4 Kcal/g). Protein requirements vary according to age, physiological status and stress. Growing infants and children, pregnant women and stressed people require more protein than average healthy adults. Animal protein comes from milk, meat, fish, and eggs, while vegetable protein comes from nuts. Animal protein is of high quality because it provides all the essential amino acids in the right proportion, while vegetable protein tends to be low in some essential amino acids [12,13]. The protein content of *E. acoroides* seed and seedpods were 9.61% (96.1 g/kg) and 9.47% (94.7 g/kg). Active humans need a protein intake of around 1.2-2.0 g/kg/day. However, in America, the Recommended Daily Allowance (RDA) for protein is 0.8 g/kg/day or about 72 g/day [12] while in India around 55-60 g/day is recommended for adults [13]. This shows that *E. acoroides* seed and seedpods can contribute to human daily protein requirements.

#### c. Fat content

Fat is a concentrated energy source that provides around 37 KJ or 9 Kcal/g. Dietary fats come from two sources: invisible fat within plants and animals, and visible fat such as lard, butter, margarine, and oil. Fats are needed for hormone and gene regulation, brain function, and as a vehicle for fat-soluble vitamins such as vitamins A, D, E and K and carotene, increasing their absorption. Fatty acid intake should be higher during pregnancy and lactation because the developing embryo and infant require body fat levels almost twice as high as adults. Adults need to limit their intake of saturated fats and cholesterol because an excess can cause obesity, diabetes, cardiovascular disease and cancer [13,49]. The fats in *Enhalus acoroides* fruits contain essential fatty acids and vitamin E, similar to plants such as grains and seafood. However, the fat content of *E. acoroides* seed and seed pods are low, at around 7.6 g/kg and 6.9 g/kg,

and thus could only make very minimal contribution to the WHO recommended 67g/day of fat per day, or not more than 30% of the total recommended energy intake of 2000 calories per day [50].

#### d. Fiber content

Dietary fiber from plants is composed of carbohydrates that can be consumed but have a high resistance to digestion and absorption in the small intestine of humans, although they do experience partial or complete fermentation in the large intestine. The main sources of dietary fiber include most vegetables, cereals, fruits, nuts and other seeds [51]. Although it does not contain nutrients, dietary fiber is important to prevent chronic diseases, such as diverticulosis, coronary heart disease, hemorrhoids, colon cancer, diabetes and obesity [13]. There are gender differences in the consumption of dietary fiber. Women tend to consume less than men because the total food and energy intake of women is generally lower than that of men. The average consumption of dietary fiber worldwide is estimated at 12 to 29 g/day [52]. Recommended fiber intake in Indonesia is higher at 30 g/day [53]. However, the WHO recommends a fibre intake of around 22-23 grams for every 1,000 Kcal/day, or 44-46 g/day on a 2,000 Kcal/day diet [54]. The fibre content of *E. acoroides* seed pods higher than seed, that is 15.48% (154.8 g/kg) and 2.38% (23.8 g/kg). This value is classified as sufficient compared to the fibre intake recommended by the World Health Organization (WHO).

#### e. Calcium content

Calcium is an important mineral for bone formation; a lack of calcium can result in reduced bone size and growth, osteoporosis and fractures [55]. Calcium also plays a role in the formation of blood clots when wounded, as well as (combined with vitamin D) the formation of bones and teeth, the muscular system and heart function [56]. The body can adapt to different calcium intake levels, so the calcium balance tends to be higher in developed countries than in developing countries. However, rates of fractures in developed countries are higher than in developing countries because of differences in the intake of limiting animal proteins and sodium and the loss of calcium through the bloodstream, all of which can reduce net calcium intake. People in developed countries tend to consume more calcium (~1-1.5 g/day) because the calcium content of milk is quite high.

On the other hand, people in developing countries on average consume less calcium (~300-600 mg/day) because the sources of calcium are mostly cereals and vegetables, especially green leafy vegetables [57]. Productive humans are advised to consume around 1,000 mg ca/day [58]. The calcium content of *E. acoroides* seed pods higher than seed, that is 4,564 mg/kg (45.64 g/kg) and 2,258 mg/kg (22.58 g/kg). This level could even meet the calcium needs of people in developed countries, as well as coastal communities in developing countries such as Indonesia.

#### f. Phosphorous content

Phosphorus is the second most common mineral in the body after calcium. Phosphorus levels that are too high or too low can cause medical complications, such as heart disease, joint pain, or fatigue. The functions of phosphorus in the body include keeping bones strong and healthy, enabling energy production and muscles movements. Phosphorus also helps to filter waste in the kidneys, maintain and repair tissues and cells, and maintain a steady heartbeat [59, 60]. Also, phosphorus serves to prevent and treat hypophosphatemia. In general, high-protein foods are also high in phosphorus [37], for example, meat, fish, milk, eggs, nuts, and seeds [60]. Phosphorous content of *E. acoroides* seed pods higher than seed, that is 929 mg/kg and 218 mg/kg. Thus, only the seed pods of *E. acoroides* could contribute to the recommended phosphorus intake for healthy humans of productive age (19-70 years old), which is around 700 mg/day [58, 60].

#### g. Iron content

Iron is needed in the human body for hemoglobin formation as well as oxygen and electron transfer [61, 62], the normal functioning of the central nervous system, and oxidation of carbohydrates, proteins, and fats [63]. However, the concentration of iron in body tissues must be strictly regulated because excessive iron causes tissue damage, as a result of the formation of free radicals. Iron metabolic disorders are one

of the most common diseases in humans and cover a wide spectrum of diseases with diverse clinical manifestations, ranging from anemia to iron overload, even neurodegenerative diseases [64].

The iron content of *E. acoroides* seeds and seedpods was 56.99 mg/kg and 54.35 mg/kg, on average. This content is relatively high when compared to daily human iron requirements. Optimum iron uptake varies with age and sex. Women of productive age (19-50 years old or pre-menopause) require more iron than productive age men or menopausal women. This is due to the need to replace iron that is lost during menstruation. Women of childbearing age need more iron (18 mg/day) than men who only need 8 mg/day [65]. Pregnant women need 30-60 mg of iron to prevent maternal anemia, low birth weight, and premature birth [66]. Postpartum women also still need additional iron for 6-12 weeks after delivery to reduce the risk of pregnancy-related anemia which is a public health problem [67].

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