Asian Journal of Research in Biosciences

Volume 6, Issue 1, Page 71-78, 2024; Article no.AJORIB.1545

The Nutritional Value of African Nutmeg (*Monodora myristica*) Seed Meal

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
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Original Research Article

Received: 26/01/2024
Accepted: 30/03/2024
Published: 03/04/2024

ABSTRACT

The African nutmeg or calabash nutmeg (*Monodora myristica*) is a terrestrial and perennial flowering plant of the custard apple family and is native to West, Central and East Africa. Its fruit is edible and the seeds are used to flavor foods, aid digestion and for medicinal purposes. This study evaluated the nutritional values or chemical composition of African nutmeg seed meal in terms of its proximate and selected vitamins, minerals, amino acids and phytochemical content. It was observed that *M. myristica* seeds contained moisture, 8.4%; ash, 2.2%; crude fat, 27.67%; crude fiber, 21.9%; crude protein, 9.4% and 30.7 % nitrogen-free extract or soluble carbohydrate. It also contained ascorbic acid, 1.6mg/100g; thiamin, 0.13mg/100g; riboflavin, 0.19mg/100g; niacin, 1.12mg/100g; Calcium (Ca), 178.3mg/100g; Magnesium (Mg), 60mg/100g; Sodium (Na), 221.7mg/100g; Potassium (K), 73.3mg/100g; and iron (Fe), 11.27mg/100g. Nutmeg seed contained B-carotene, 425 mg/100g. alkaloids, 755 mg/100g; phenols, 58.6GAE/g; flavonoids, 660 mg/100g; tannins, 830 mg/100g, terpernoids, 1360 mg/100g; cardiac glycosides, 7 mg/100g; steroids, 122 mg/100g; and antioxidants ORAC 69.57 % of inhibition. *Monodora myristica* seed meal is a good source of fibre, vitamins, minerals and useful phytochemicals with antioxidant, anti-inflammatory, and anti-bacterial properties and can be added to human and livestock feeds.

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Keywords: African nutmeg; nutritional values; phytochemicals; nutrients; analysis.

1. INTRODUCTION

"The African nutmeg or calabash nutmeg (*Monodora myristica*) is a terrestrial and perennial flowering plant that is native to West, Central and East Africa extending from Sierra Leone to Benin, Nigeria, Cameroon, the Central African Republic, Uganda, Kenya, DR Congo, Equatorial Guinea, Ghana, Sudan, Tanzania, and Angola" [www://en.m.wikipedia.org/wiki/*Monodora_myristica#*; [1]. "It belongs to the custard apple family of flowering plants called *Annonaceae* and it is widely distributed from Africa to Asia central and South America and Australia" [2]. "It grows well in the evergreen forest zone of West Africa and is most prevalent in the Southern part of Nigeria" [3]. "Its local names include: "Ehuru or "Ehiri" (Igbo), and Ariwo (Yoruba). There are different species such as Jamaica nutmeg, African nutmeg, and Calabash nutmeg. It is a medium to large-sized tree that grows up to 35m tall. It has simple, alternate leaves that are oblong to elliptical, measuring up to 45 cm long and 20 cm wide. The fruit is a large and woody berry, globose, measuring about 20 cm in diameter that contains numerous seeds in its creamy-white and smelling pulp" [4]. "The fruits and seeds are edible. The seeds have a scent similar to the nutmeg (*Myristica fragrans*) and are used to flavor foods in African and continental cuisines and medicinally to treat headaches, digestive problems, stomach ache, as stimulants in medicine and snuff, sores, eye diseases and as an insect repellent" [5-7]. "Ethnomedically, *M. myristica* is used in Ivory Coast to treat hemorrhoids, stomach aches and fibroid pain. When pulverized, the kernel is used to prepare pepper soup as a stimulant to relieve constipation and control passive uterine hemorrhage in women immediately after childbirth" [6,8,9]. "Phytochemical studies of M*. myristica* seeds have shown that it is rich in alkaloids, glycosides, flavonoids tannins, saponin and steroids" [10-12].

Due to the aforementioned uses and benefits of African nutmeg to human and farm animals as mentioned in the literature, this study hereby evaluated the nutritional values or chemical composition of African nutmeg seed meal in terms of its proximate and selected vitamins, minerals, amino acids and phytochemical contents.

2. MATERIALS AND METHODS

2.1 Source and Procurement of African Nutmeg

Monodora myristica seeds were purchased from local markets within Uyo metropolis. The seeds were cleaned and blended into powder and stored in nylon before analysis. The seed meal was divided into many portions and subjected to chemical analyses to determine the proximate, vitamins, minerals and phytochemical compositions as stated below.

2.2 Proximate Analysis

"Proximate analysis of African nutmeg for moisture, crude protein, fat, ash and fibre contents were carried out in duplicate using official methods" [13]. Nitrogen Free Extract (NFE) and total carbohydrate content were estimated from the values obtained. That is NFE = 100 – (CP + Ash + EE +CF) while the carbohydrate content is the sum of the NFE and the crude fiber content. The gross energy values were calculated from the relationship that exists between fat, crude protein and carbohydrate (i.e. 39.4EE + 23.5CP + 17.7 carbohydrates) according to Fisher [14].

2.3 Vitamin and Mineral Determination

The vitamin (ascorbic acid, thiamine, riboflavin and niacin) and mineral (Calcium, magnesium, sodium, potassium and iron) compositions of African nutmeg were analyzed using the methods of Johnson and Ulrich [15,16] as outlined by Okwu [17].

2.4 Phytochemical Analysis

The phytochemical screening of the samples for the presence and quantity of phytochemicals such as alkaloids, cyanogenic glycosides, flavonoids, B-Carotenes, phenols, steroids, terpenoids, cardiac glycosides, tannins and antioxidants present were carried out as described by AOAC [13,18,19].

2.5 Statistical Analysis

Data obtained from laboratory analysis were subjected to descriptive analysis of simple mean and percentages.

3. RESULTS

The proximate compositions of *Monodora myristica* seeds are presented in Table1 below. It was observed that *M. myristica* seeds contained moisture, 8.4%; ash, 2.2%; crude fat, 27.67%; crude fiber, 21.9%; crude protein, 9.4% and 30.7 % nitrogen-free extract or soluble carbohydrate.

Table 1. Proximate composition of *Monodora myristica* seed meal (g/100g)

Parameters	Percentage
Moisture	8.40
Crude Protein	9.40
Ether Extract (crude fat)	27.60
Ash	2.20
Crude Fibre	21.90
Soluble Carbohydrates or NFE	30.5
Total carbohydrate	52.4
Gross Energy (Kcal/kg)	2,235.82

NFE = Nitrogen-free extract.

The vitamin composition of nutmeg seed is as presented in Table 2 below. The analysis revealed that nutmeg seed contained ascorbic acid, 1.6mg/100g; thiamin, 0.13mg/100g; riboflavin, 0.19mg/100g and niacin, 1.12mg/100g.

Table 2. Vitamin composition of *M. myristica* Seed meal

Vitamins	Composition (mg/100g)
Ascorbic Acid (Vit. C)	1.6
Thiamin (Vit. B1)	0.13
Riboflavin (Vit. B2)	0.19
Niacin (Vit. B3)	1.12

Table 3. Mineral composition of *Monodora myristica* Seeds

Minerals	Composition (mg/100g)
Calcium (Ca^{2+})	178.3
Magnesium (Mg^{2+})	60.0
Sodium (Na^{+})	221.7
Potassium (K^{+})	73.30
Iron (Fe^{2+})	11.27

The mineral composition of nutmeg seed is presented in Table 3. The analysis revealed that nutmeg seed contained Calcium (Ca), 178.3mg/100g; Magnesium (Mg), 60mg/100g; Sodium (Na), 221.7mg/100g; Potassium (K), 73.3mg/100g; and iron (Fe), 11.27mg/100g.

The phytochemical composition of nutmeg seed is presented in Table 4 below. The analysis shows that nutmeg seed contained B-carotene, 425 mg/100g. alkaloids, 755 mg/100g; phenols, 58.6GAE/g; flavonoids, 660 mg/100g; tannins, 830 mg/100g, terpernoids, 1360 mg/100g; cardiac glycosides, 7 mg/100g; steroids, 122 mg/100g; and antioxidants ORAC 69.57 % of inhibition.

Table 4. Phytochemical composition of *Monodora myristica* Seeds

Parameters	Composition
B-carotene (µg/100g)	425
Alkaloids (mg/100g)	755
Phenols (GAE/g)	58.60
Flavonoids (mg/100g)	660
Tannins (mg/100g)	830
Terpenoids (mg/100g)	1360
Cardiac Glycosides (mg/100g)	7
Cyanogenetic Glycosides (mg/100g)	0.5
Steroids (mg/100g)	122
Antioxidants ORAC. (% inhibition)	69.57

GAE = Gallic Acid Equivalent; ORAC = Oxygen Radical Absorbance Capacity

4. DISCUSSION

4.1 Chemical Composition of *Monodora myristica*

The value obtained here for moisture in African nutmeg seeds (8.4%) is within the range of values (6.00 - 8.68 %) reported by Enwereuzoh et al. [20,21], though lower than 10.00, 11.20 and 13.15 % reported by Faleyimu and Oluwalana [22-24] respectively. “The difference observed may be as a result of the maturity of the seed as well as the method of analysis used. The moisture content was comparable with those of legumes and ranged between 7.0 and 11.0%” [25]. “The low moisture content is indicative of the fact that African nutmeg can be stored for a long period without deterioration in quality or microbial spoilage since microbial activity may be reduced to a minimum level. The moisture content of any food can be used as an index of its quality. Water is an important medium for most biochemical reactions. Food samples with 15% water content are more prone to high biochemical activities and therefore usually have a short shelf life” [26].

"Even though the seeds are used as spices, the carbohydrate and lipid contents as shown in Table 1 are quite appreciable and could be regarded as good sources of carbohydrates and especially essential oils for the body. The antihypertensive effect of essential oils derived from seeds of *Monodora myristica* has earlier been studied" [27]. "According to phytochemical analysis, the essential oil contains mainly monoterpenoids, which indicate that it exerts an antihypertensive activity. Essential oils derived from the cotyledons of such seeds, show high saponification value, low iodine and acid values. Therefore, it could be used for its medicinal and antioxidant properties" [28].

The ether extract with 27.6% is in line with the range of values (22.70 - 29.10 %) reported by Enwereuzoh et al. [20,22-24]. Fat is important in diets because it promotes fat soluble vitamin absorption [29]. The crude protein value of 9.4% observed in this study is not far from 12.0 % reported by Faleyimu, O. and Oluwalana [22], 10.13 % reported by Ekeanyanwu et al. [24], 9.60 % reported by Enabuleleet al. [23], but far lower than 18.69 and 22.77 % reported by Enwereuzoh et al. [20 and 21] respectively. "Such differences may arise from variations in soil micronutrients and are partly attributed to the methods of analysis". [29] "The crude protein value is relatively low when compared to protein-rich foods such as soybeans, cowpeas, pigeon peas, melon and gourd seeds which ranged between 23.1 and 33.0%" [30]. "However, it could be a good source of important enzymes which is the form found in most proteins in spices" [31]. "The recommended daily allowance for protein for children ranges from 23.0 – 36.0g and 44.56g for adults" [32]. "Apart from the significant nutritional protein as a source of amino acids, they also play a part in the organoleptic properties of food" [33].

The ash content (2.2 %) or inorganic matter obtained for *Monodora myrystica* corresponded within the range of 2.5 % reported by Enabulele et al. [23] and 3.90 % reported by Ekeanyanwu et al. [24]. "However, higher values for ash (4.90 – 8.61 %) were reported" by Enwereuzoh et al.[20,21,22]. Consequently, this could be caused by changes in the climatic factors in addition to edaphic factors. This amount of ash value was very low and slightly lower than the 8.35 % reported for *Brachetagia Eurycoma*. It has been recommended by Pomeranz and Clifton [34] that the ash content of nuts, seeds and tubers should fall within the range of 1.5 – 2.5% to be suitable for animal feeds. "Therefore, it can be recommended for animal feeds. Ash content refers to the inorganic residues that remain after either ignition or complete oxidation of organic matter in the sample and gives an overview of the mineral content of the material [26]. The high amount of ash implies high mineral content in the spices. *Monodora myristica* is not likely to be a good source of minerals in human or animal diet. Nutritionally, ash aids in the metabolism of protein, carbohydrates and fat" [35].

The crude fiber content recorded (21.9 %) corresponded to the 19.10 % report by Enabulele et al. [23], lower than the 25.90 % reported by Ekeanyanwu et al. [24], but much higher than 3.30, 5.25 and 8.33 reported by Enwereuzoh et al. [20-22] respectively. "The variation in the results may be caused by changes in climatic factors and the stage of maturity of the seed used. However, the fiber content from this study is relatively high in quantity. This implies that when this seed is incorporated into feed, it will help to prevent many metabolic or digestive disorders such as constipation and irritable bowel" [35]. "The crude fiber content was very high compared to legumes, which ranged between 5 and 6 %" [33]. "Therefore, African nutmeg is a good source of dietary fiber. Dietary fibers are generally plant polysaccharides that cannot be digested by human digestive enzymes. Dietary fibers are either soluble or insoluble, both modulate the physiological function and prevent some degenerative diseases in animals. Dietary fiber causes variations of water content in fecal, fecal bulk, transit time and elimination of bile acids and neutral sterols, which lowers the body's cholesterol pool. Therefore, dietary fiber has been shown to reduce the incidence of coronary and breast cancer" [36].

The proportion of soluble carbohydrates obtained (30.7 %) was similar to that reported by Faleyimu, O. and Oluwalana [22], but different from values (28.40, 21.20, 46.9 and 42.78 %) reported by Enwereuzoh et al. [20,21,24]. The carbohydrate content was very higher than that of cassava seed (16.81%) reported by Okaka [35] and comparable to the acceptable range of 20 – 60% for legumes based on dry weight [25]. Hence, seeds are a good source of energy for animals when they are incorporated into diet. Carbohydrate provides energy to cells, particularly the brains, which depended on the carbohydrate content [36]".

Table 2 shows the vitamin composition of *Monodora myristica* seed. The concentration of Ascorbic acid or vitamin C (1.6mg/100g) was the highest. Another study obtained a higher vitamin C content of 243.43mg/100g [37]. "The low concentration of Vitamin C content recorded in this study could be attributed to the effect of heat during seed processing. Sun-drying has been reported to cause a marked decrease in the vitamin content of food material" [38]. "Vitamin C is mainly used for the synthesis of collagen, a major protein for building connective tissues" [9]. "Also, it is generally an antioxidant that enhances iron absorption and is needed for synthesizing some hormones and neurotransmitters" [17].

"Riboflavin or Vitamin B_2 content of the seeds as reported in this study (0.19mg/100g), is not in line with the previous studies, which reported 0.06mg/100g and 0.034mg/100g" [39,40]. Additionally, the niacin or vitamin B_3 content obtained in this study (1.12mg/100g) is comparable to 0.75mg/100g reported in a previous study" by Schauss [41]. "Thiamine, riboflavin and niacin play key roles as coenzymes in energy-yielding metabolism. The recommended dietary allowance (RDA) is 1.1 – 1.2mg for thiamine, 1.1 – 1.3mg for riboflavin and 14 – 16mg for niacin. A deficiency of the three vitamins may result in a brain damage, poor nervous coordination and disorder in the gastrointestinal tract of affected animals" [42].

Table 3 shows the mineral composition of *Monodora myristica* seeds. This finding is comparable to the observation of Bouba et al. [43], who reported a calcium content of 375mg/100g and [11] who reported a calcium content of 297mg/100g in the seed. Meanwhile, some authors [24] and [23] reported calcium contents of 416.0mg/100g and 421.84mg/100g, respectively, in the seed. The calcium content found in this study is in line with the report of Okonkwo and Ogu [44]. "These differences in calcium concentration might be due to the stage of maturity of the seed used, the type and nature of the soil in which the plant was grown and the mode of seed processing. Calcium is needed for regulating most internal organs, including the heart and liver and it is needed for the integrity of most physiological functions including normal functioning of the heart and skeletal system and of cell membranes, blood clotting, nerve-signal transmission and regulation of enzymes and hormones" [17]. Calcium is required in the diet in an amount of 100mg or more per day, which implies that less than 100g of this seed is needed to provide the recommended daily intake.

The magnesium content of the seeds obtained in this study (60mg/100g) is within the range of values (56.32 – 64.52 mg/100g) reported by Okonkwo and Ogu [44] and [24], but lower than the value (132 mg/100g) previously obtained by Koche [37]. "The variations in magnesium content reported in these studies might be linked to the differences in the method of analysis and environmental factors associated with the plant source. Magnesium is required in the plasma and extracellular fluid where it helps maintain osmotic equilibrium. Additionally, magnesium is required in many enzyme-catalyzed reactions and prevents some heart disorders and low blood pressure. Magnesium and potassium support animal biochemical processes and activate enzymes for carbohydrate metabolism" [17]. A lack of magnesium is associated with abnormal irritability of muscles.

Another major mineral reported in this study is potassium, with The concentration of potassium obtained in this study (73.3mg/100g) as shown in Table 3 is comparable with the previously obtained result (79.7mg/100g) by Hemingway [45]. However, [23] found a very high potassium content (800.2mg/100g) in the seeds. The differences in mineral composition might be due to differences in soil characteristics and climatic conditions in the areas where the seeds were cultivated.

"The analysis revealed that *Monodora myristica* seeds contain sodium (221.7mg/100g) which is higher than the level (9.1mg/100g) reported by Koche [37] and 9.41mg/100g reported by Akah et al. [46]. Sodium and potassium regulate water balance, muscle contraction and nerve signal conduction. A balanced Na/K ratio controls glucose absorption and enhances the normal retention of protein during growth; it also influences glucose and lipid metabolism. However, extremely high sodium intake has been associated with fluid retention leading to hypertension, heart failure and instant death" [17].

The iron content of the African nutmeg seeds shown in table 3 (11.27mg/100g) is lower than those (21.71 – 36.70 mg/100g) reported by other studies [17,45,47]. These deviations in results might be attributed to the effect of the edaphic factor where nutrients determined are not exclusively those taken up by the plants. Iron is necessary for oxygen transport and plays an important role in animal metabolism and it facilitates the oxidation of carbohydrates, proteins and fats to control body metabolic rate,

which is a very important factor in diabetes. Iron deficiency leads to anemia.

Table 4 showed that *Monodora myristica* seed contained a high amount of steroids (122mg/100g) as corroborated by the report by Ekeanyanwu et al. [24], which showed high content of steroids in the seeds of the plant. The investigations by some researchers [23,36] did not found steroids in *Monodora myristica*. This variation could be attributed to the differences in the analytical method used. Terpenoids (1360 mg/100g) were in moderately high amounts and could partly be attributed to climatic conditions. Such a compound inhibits the release of autacoids and prostaglandins [47] and tannins (830mg/100g) were found in high and moderate contents. Such contents were in concurrence with the reports by Enabulele et al. [23,36] which found them in high and moderate amounts. Some researchers [23, 24] found a low amount of tannins in the seed while [24] did not find alkaloids in African nutmeg seeds. “Several factors could lead to this variation. The method of preparation for analysis could cause the variation in amount of alkaloid, phenol and tannin in *Monodora myristica* seeds. Alkaloids and their synthetic derivatives are used as basic medicinal agent for their analgesic, antispasmodic and antibacterial effect” [48]. “Alkaloids also bind to adhesions, enzyme inhibition, and substrate deprivation. Complex with cell wall membrane disruption, metal ion complexation” [48].

“Phenol makes intestinal mucosa more resistant and reduces secretion, stimulation against the normalization of decayed water transport across the mucosal cells and reduction of the intestinal transit, blocking the binding of the B subunit of heat-labile enterotoxin to GM. The result could suppress the symptoms of heat labile enterotoxin-induced diarrhea and astringent action. It contributed to the animal’s digestible proteins by forming protein complexes in the rumen, interfering in the generation of energy by uncoupling oxidative phosphorylation, the causes of reduction in gastrointestinal metabolism” [47]. “Due to antimicrobial and antioxidant activities of tannins, they can increase antioxidant activity, prevention against proliferation of cancer and promoting the apoptotic carcinogenic cell” [47].

The flavonoids (660mg/100g), cyanogenic glycoside (7mg/100g), and β-carotene (425mg/100g) obtained in this study were in concurrence with the report of Ekeanyanwu et al. [24] and [36] who found large amounts of flavonoids in African nutmeg seeds, but in contrast to the lower flavonoids level observed in other report 23]. This variation could be attributed to many factors, such as climatic, edaphic and time of exposure to dryness. Such differences may also arise from variations in soil micronutrients or partly attributed to the method of analysis.

5. CONCLUSION

Monodora myristica seed meal is a good source of fiber, vitamins, minerals and useful phytochemicals with promising antioxidant, anti-inflammatory, and anti-bacterial properties.

6. RECOMMENDATION

It is recommended as potential additive or supplement in human and livestock feeds.

ETHICAL APPROVAL

The experimental procedures and materials were approved by the Research Ethic committee of the Department of Animal Science, University of Uyo, Uyo, Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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