NUTRITIONAL ANALYSIS OF HAUSTORIA FROM THREE VARIETIES OF COCONUT *(COCOS NUCIFERA L.)*

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Abstract
Cocos nucifera L., is the most widely recognized and one of the most economically important crops of the tropics with a wide variety of applications in different fields. Although almost every part of the palm is explored, the studies regarding its haustorium are very few. Though attempts have been made to assess the nutritional and medicinal properties of coconut haustorium, a systematic study on the nutritional and anti-nutrient composition of haustorium has not been reported so far. Thus, our study was conducted to characterize the nutritional and anti-nutritional factors of haustoria of three varieties of coconut: Chowghat orange dwarf (COD), Malayan green dwarf (MGD), and West coast tall (WCT). COD haustorium was found to have the highest amount of moisture, crude fibre, carbohydrates, reducing sugar, and total lipid. A significant amount of vitamins and minerals were present in the haustoria of three coconut varieties. COD had the highest amount of vitamin A, vitamin C, and vitamin E whereas the least amount was seen in WCT. Calcium and magnesium were the dominant macronutrients presented in all three haustoria. Of the micronutrients, manganese content was more. COD haustorium was found to be rich in manganese (155.5 ppm) and iron (518.7 ppm). Anti-nutrients such as tannin, oxalate, and phytic acid were found to be high in WCT. The activity of trypsin inhibitor was noted only in MGD. The haustorium of COD had comparatively fewer amounts of anti-nutrients. This study shows that coconut haustorium is found to be a potent nutritive source for humans.

Keywords: Coconut haustoria, Nutrition, Anti-nutrient, Proximate composition

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INTRODUCTION

Cocos nucifera L. commonly known as coconut tree is a monocot perennial member of Arecaceae (palm family), cultivated in tropical areas worldwide on account of its nutritional and medicinal attributes. It is referred to as 'kalpavriksha' (the all-giving tree) in Indian classics because of its multifarious utility. The various products obtained from the coconut palm include coconut leaves, husk fibre, tender coconut water, coconut meat (fresh and dried as copra), coir pith, coconut oil, coconut cake, coconut toddy, coconut shell, and wood -based products (DebMandal and Mandal, 2011).

One of the lesser-known edible products of the coconut palm is coconut haustorium. It is also referred to as the coconut apple. It is the soft, spongy, sweet mass of tissue formed inside the coconut during the process of germination. Haustorium consists of two distinct parts; the outer part is the oil - rich yellow portion and the inner white portion is carbohydrate-rich. Since the haustorium absorbs nutrients from the coconut water and coconut meat for nourishing the developing embryo, it is supposed that the nutrients present in the haustorium are in readily available form. Previous studies have shown that coconut haustorium contains carbohydrates, proteins, minerals, alkaloids, polyphenols, and growth-promoting substances (Manivannan et al., 2018). Though attempts have been made to assess the nutritional aspect of coconut haustorium, a systematic study on the nutritional and anti-nutritional composition of haustorium is lacking. Literature provides a little information regarding the nutritional potential of haustorium in the West coast tall variety of coconut.

In view of this, the present investigation has been conducted to compare the nutrient and anti-nutrient parameters in the haustoria of three coconut varieties.

MATERIALS AND METHODS

Plant Material

The nuts from three coconut varieties: Chowghat Orange Dwarf (COD), Malayan Green Dwarf (MGD), and West Coast Tall (WCT) were collected from a local plantation in Thiruvananthapuram, Kerala, India and dried under shade for 30 days. Nuts of each variety with identical size and weight were selected and placed in horizontal rows, two-third of each nut covered with soil, and moisture was maintained by periodical watering. The nuts were regularly monitored for germination. The appearance of shoot tip on the surface of the perianth was noted as the initial day of germination.

Sprouted nut, 60 days after germination were selected for the study. Germinated nuts were dehusked and the nuts were broken carefully to remove the haustoria from the shell and then sliced into thin pieces. The sliced samples were initially shade dried for 3-4 days and then oven- dried at 40^{o}C for 1 hour. The dried samples were ground and powdered. The powder of haustoria was labelled and stored in separate air-tight containers. These powder samples were used for the following nutritional and anti-nutritional studies.

Nutritional characterization of coconut haustoria

Proximate composition

The dried haustoria powder were analysed for moisture content, starch, carbohydrate, reducing sugar, protein, total lipid and crude fibre according to standard methods of analysis with minor modifications. Moisture and starch content was calculated according to the AOAC, 2016 (Association of Official Analytical Chemists) procedures. The carbohydrate was estimated as per the method of Hedge and Hofreiter (1962), reducing sugar as per the DNS method by Miller (1959). Lowry's method was employed for estimating the protein content of haustoria powder (Lowry et al., 1951). The total lipid content was calculated according to Bligh & Dyer method (1959). The crude fibre was determined as per Thangaraj (2016). All the experiments and analyses were conducted in triplicate. The data was statistically analyzed and expressed as mean ± standard deviation.

Vitamin Analysis

Vitamin A, riboflavin, niacin, vitamin C and vitamin E were estimated as per Srivastava and Kumar (2002), Koche (2010), Adepoju and Adeniji (2012), Sadasivam and Manickam (2008) and Lai et al. (2001) respectively. The results were the average of the three replicates.

Mineral Analysis

The concentration of calcium, magnesium, copper, iron, manganese, potassium, and zinc were determined using a flame atomic absorption spectrophotometer. Phosphorus was determined by Kitson and Mellon (1944) using a spectrophotometer.

Anti-nutritional composition

Anti-nutrients like phytic acid, oxalates, nitrates, tannins, and trypsin inhibitors were assayed as per the standard protocols (Reddy et al., 1982; AOAC, 1984; Cataldo et al., 1975; Edeoga et al., 2005; Kakade et al., 1969). All the analysis was conducted in triplicate.

RESULTS AND DISCUSSION

Nutritional characterization of coconut haustoria

Proximate composition

The haustorium from COD was found to have the highest amount of moisture, carbohydrate, reducing sugar, total lipid, and crude fibre. Starch and protein content was more in WCT. MGD had the least amount in all the parameters except moisture and total lipid content. COD showed the highest moisture content of 89.47± 0.65% followed by MGD (85.90±0.65%) and WCT (83.40 ± 0.60%). Manivannan et al. (2018) reported that the moisture content of WCT haustorium varied between 86.9-89.3% per 100 g. WCT showed highest starch content (370.23±0.93 mg/g) followed by COD (250.37± 0.57 mg/g) and MGD (210.37±0.65 mg/g).

Carbohydrate is the main source of energy for our body. COD exhibited higher amount of carbohydrate (510.30±1.25 mg/g) when compared with the other two varieties (Table 1). MGD and WCT had carbohydrate content

of 342.47 ±0.90 mg/g and 395.97±1.28 mg/g respectively. The major carbohydrates available in the haustorium are sucrose, glucose, fructose and starch (Balasubramaniam et al., 1973; Sugimura and Murakami, 1990). COD requires high sucrose concentration for germination and sugar content was found to be more in the haustorium during germination (Karun et al.,1999; Li et al., 2019) which supports the present study result that COD contains the highest amount of carbohydrate. COD haustorium possessed the highest amount of reducing sugar (441.27±0.70 mg/g) followed by WCT (265.00±1.18 mg/g) and MGD (216.63±0.57 mg/g). This finding corroborates with the report of Balachandran and Arumughan (1995) that coconut haustorium is rich in reducing sugars. According to Manivannan et al. (2018), coconut haustorium, due to its richness of simple sugars, can be used as a food supplement for lactose-intolerant children. Hence from the results of carbohydrate and reducing sugar content, it is clear that haustorium of COD is more suitable for confectionaries.

Proteins are essential nutrients needed for the growth and maintenance of the human body. The protein content in the haustorium of WCT was found to be the highest (42.57±0.40 mg/g) followed by COD (40.57±0.53mg/g) and MGD (38.03±0.45 mg/g). The total lipid content of COD haustorium was found to be the highest (110.24±0.32 mg/g) whereas MGD and WCT did not exhibit any significant difference.

Crude fibre content of coconut haustoria showed significant variation among the three varieties. The highest crude fibre content was found in COD (190.67±0.16 mg/g) followed by WCT (120.59±0.27mg/g) and MGD (90.47±0.13mg/g). Chawla and Patil (2010) described the importance of soluble dietary fibre in the reduction of blood pressure, cholesterol, control of digestive problems and control of the onset of certain cancers and increase in bioavailability of minerals. So as per the reports, COD is rich in crude fibre which can be used as dietary fibre for controlling blood glucose, cholesterol, and blood pressure.

Vitamin Analysis

Vitamins are essential for the growth and development of the body and also for good vision Vitamin A is necessary (Tanumihardjo, 2011). The amount of vitamin A showed no significant difference among the three varieties. Comparatively COD had the highest amount of vitamin A (2.35±0.41 mg/100g). Riboflavin was almost similar in MGD (1.78±0.63 mg/100g) and WCT (1.26±0.46mg/100g) and least in COD (0.16±0.03mg/100g). The quantity of niacin showed remarkable variation among the three varieties (Table 2). WCT had the highest amount (21.92±0.72 mg/100g) followed by COD (6.53±0.65 mg/100g) and MGD had the least amount (0.23±0.09 mg/100g).

Table 1: Proximate composition in three varieties of coconut haustoria

Parameters	COD	MGD	WCT
Moisture content (%)	89.47± 0.65^{a}	85.90±0.65^{b}	83.40 ± 0.60^{c}
Starch (mg/g)	250.37± 0.57^{b}	210.37±0.65^{c}	370.23±0.93^{a}
Carbohydrate (mg/g)	510.30±1.25^{a}	342.47 ±0.90^{c}	395.97±1.28^{b}
Reducing sugar (mg/g)	441.27±0.70^{a}	216.63±0.57^{c}	265.00±1.18^{b}
Protein (mg/g)	40.57±0.53^{b}	38.03±0.45^{c}	42.57±0.40^{a}
Total lipid (mg/g)	110.24±0.32^{a}	90.15±0.31^{b}	80.97±0.25^{b}
Crude fibre (mg/g)	190.67±0.16^{a}	90.47±0.13^{c}	120.59±0.27^{b}

Each value in the table is represented as mean ± standard deviation (n=3). Means not sharing the same letter are significantly different (LSD) at P < 0.01 probability level in each column.

Table 2: Vitamin analysis in three varieties of coconut haustoria

Parameters (mg/100g)	COD	MGD	WCT
Vitamin A	2.35±0.41[a]	1.93±0.16[a]	1.77±0.21[a]
Riboflavin	0.16±0.03[b]	1.78±0.63[a]	1.26±0.46[a]
Niacin	6.53±0.65[b]	0.23±0.09[c]	21.92±0.72[a]
Vitamin C	61.23±0.75[a]	48.9±0.86[b]	36.67±0.69[c]
Vitamin E	11.57±0.50[a]	9.25±0.38[b]	7.13±0.71[c]

Each value in the table is represented as mean ± standard deviation (n=3). Means not sharing the same letter are significantly different (LSD) at P < 0.01 probability level in each column.

According to Brunton et al. (2018), supplemental niacin is primarily used to treat high blood cholesterol and pellagra and found that high doses of niacin used to improve the lipid profile have been shown to elevate blood sugar by 5-10%, thereby worsening existing diabetes mellitus.

Vitamin C was found in good amounts in the haustoria of all three varieties. COD was found to have the highest amount (61.23±0.75 mg/100g) of Vitamin C followed by MGD (48.9±0.86 mg/100g) and WCT (36.67±0.69 mg/100g). Earlier reports showed that (Li and Schellhorn, 2007; Carr and Frei 1999) vitamin C is required for the biosynthesis of collagen, L-carnitine, and certain neurotransmitters; also involved in protein metabolism. Vitamin C is also an important physiological antioxidant (Frei et al., 1989) and has been shown to regenerate other antioxidants within the body, including vitamin E (Jacob and Sotoudeh, 2002). The current Recommended Dietary Allowances (RDA) for vitamin C is 90 mg and 75 mg per day for males and females respectively (Monsen, 2000). These reports showed the importance of coconut haustorium as a rich source of vitamin C. Our study revealed that haustorium of COD can be used as a good source of vitamin C.

Vitamin E is a fat-soluble vitamin with distinctive antioxidant activities (Traber et al., 2006). A significant amount of vitamin E was present in all three varieties, with the highest content in COD (11.57±0.50 mg/100g) followed by MGD (9.25±0.38 mg/100g) and WCT (7.13±0.71 mg/100g). As per the results, the vitamin C content is more in COD and it can be used as a source of the vitamin for various applications in the pharmaceutical and cosmetic industry.

Mineral analysis

Minerals are inorganic substances required as an essential nutrient by organisms to perform functions necessary for life. The amount of minerals taken should be according to the recommended values, otherwise, it leads to various health issues (Shenkin, 2006). In the present study, macronutrients like phosphorus, potassium, calcium, magnesium, and micronutrients like iron, manganese, zinc and copper were investigated (Table 3). Potassium seemed to be highest in haustoria. The results showed that calcium and magnesium were the macronutrients mainly presented in the haustoria of the three varieties. Both calcium and magnesium were dominant especially in WCT (690.0 ppm and 241.5 ppm respectively). Among the micronutrients, manganese content was more in all the haustoria samples when compared to its RDA. Our result regarding manganese content in haustoria conforms with Manivannan et al. (2018). The manganese content of COD, MGD, and WCT was155.5, 130.8, 129.2 ppm respectively, and in RDA marked as 2.3 mg/day for males and 1.8 mg/day for females (Monsen, 2000). In all these varieties, the content of iron and copper

Table 3: Mineral analysis of the three varieties of coconut haustoria

Parameters	COD	MGD	WCT
Phosphorus (%)	0.450	0.380	0.345
Potassium (%)	7.610	5.880	2.993
Calcium (ppm)	418.7	626.2	690.9
Magnesium (ppm)	87.50	87.50	241.5
Iron (ppm)	518.7	450.8	182.7
Manganese (ppm)	155.5	130.8	129.2
Zinc (ppm)	51.70	49.20	65.00
Copper (ppm)	16.20	12.40	34.00

Table 4: Anti-nutrient analysis of haustoria in the three coconut varieties

Parameters	COD	MGD	WCT
Tannin (mg/100g)	1.23 ± 0.26^{a}	0.14 ± 0.06^{b}	1.42 ± 0.26^{a}
Oxalate (mg/100g)	19.83 ± 1.54^{c}	24.13 ± 1.41^{b}	28.60 ± 0.87^{a}
Phytic acid (mg/100g)	1.65 ± 0.40^{b}	2.80 ± 0.30^{a}	2.12 ± 0.32^{ab}
Trypsin inhibitor (% inhibition)	Not detected	16.3	Not detected
Nitrates (mg/100g)	20.02 ± 1.42^{a}	3.82 ± 0.62^{c}	16.11 ± 1.04^{b}

Each value in the table is represented as mean ± standard deviation (n=3). Mean values which do not share the same letter are significantly different (LSD) at P < 0.01 probability level in each column.

were also met within RDAs (Monsen, 2000). COD haustorium was also found to be rich in iron with an amount of 518.7ppm. From the results, it is evident that coconut haustorium is rich in minerals particularly the COD variety.

Anti-nutritional composition

Anti-nutritional factors (ANFs) are natural or synthetic substances that interfere in nutrient absorption. The anti-nutrients viz., tannin, oxalates, phytic acid, nitrates and trypsin inhibitors were examined in the haustoria samples, which is shown in Table 4. Among the analysed anti-nutrients, tannin, oxalate, and phytic acid were highest in WCT haustorium. The presence of trypsin inhibitor was detected only in MGD haustorium. The haustorium of COD had a comparatively less amount of anti-nutrients.

CONCLUSION

This is a novel study on the nutritional and anti-nutritional aspects of haustorium in three varieties of Cocos nucifera L. The nutrient analysis results of the present investigation show that coconut haustorium is a good source of various nutrients. A remarkable variation was seen in the nutrient contents of haustorium of the three coconut varieties. Since a high nutritional value was seen in the COD haustorium, it could be used as a major nutrient- rich food supplement. The nutritional analysis of three haustorium varieties brought out tremendous possibilities for utilizing them

as an important nutriment. Our study focuses on the potential of coconut haustorium as a healthy, low-cost food item and must be considered as potential foodstuff for further research.

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