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RESEARCH PAPER

Evaluations on the physical, chemical and nutritional analyses of coconut haustorium

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Abstract

Coconut haustorium is a part of the embryo embedded in the endosperm nearer to the coconut germination pores. This young sponge part will grow to form a cotyledon structure known as a haustorium. The coconut haustorium will grow and finally fill the entire coconut water cavity within 20-24 weeks after germination. A matured coconut haustorium contains a high moisture content range between 79.99-86.40% and it is rich in various nutrients and minerals. The aims of the study were to investigate the nutritional and physical properties of the local coconut haustorium. The carbohydrate, crude fat, crude protein and ash contents were recorded at 9.34-15.58%, 0.62-2.15%, 1.34-1.84% and 1.61-2.30% respectively. Coconut haustorium also has the potential to be developed as a health supplement product. In relation to that, a physical-chemical and nutritional quality study of coconut haustorium was carried out to develop MARDI coconut haustorium products. Coconut haustorium is high in lysine and other essential amino acids. Thus, fresh haustorium can be used as a high-value-added superfood ingredient for health and wellness supplements and focusing on increasing food intake (appetite), especially as a children's supplement.

1. Introduction

Coconut haustorium can be developed by matured and germinating coconuts, and it's known as a 'tombong' in Malay and also commonly known as a 'coconut apple'. It is a spongy base with a sweet taste and delicious and crunchy texture. The haustorium is a sprouting coconuts part that absorbs nutrients from the inside coconut water and endosperm to enhance the germination of the embryo and fill up the entire water cavity within 20–24 weeks after the germination stage. Figure 1 illustrates the structure of the sprouted coconut. The immature seed embryo contains plumules in the cotyledon, covered by coconut liquid endosperm. During germination, the mature seed gave a bigger haustorium and less in the coconut liquid endosperm as illustrated by Tzec-Simá *et al*. (2022).

Malaysia is one of the coconut producers in the world, especially for processed coconut products. The coconut crop production in Malaysia amounted to 568,894 tonnes as reported by Food Agriculture Organization of the United Nations (2023). There is a lack of processing of haustorium products in our local coconut industries, which means that the valuable waste of haustorium is underutilized, lacking local research and development and less utilization of the haustorium as value-added products. Manju (2021) mentioned that haustorium consists of two distinct parts; the outer part is

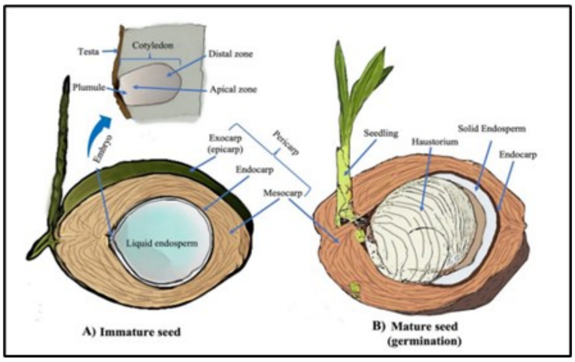

Figure 1. Structure of the coconut fruit and its components. Source: Tzec-Simá *et al*. (2022).

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the oil with a rich yellow portion and the inner part is a white portion and rich in carbohydrates. Coconut haustorium contains carbohydrates, proteins, minerals, alkaloids, polyphenols, and growth-promoting substances (Manivannan *et al*., 2018). The aqueous extract of coconut haustorium possesses significant cardioprotective and antioxidant properties during isoproterenol-induced myocardial infarction in rats as reported by Chikku and Rajamohan (2012). In relation to coconut sugar or nira sugar, a study has been done for producing a coconut syrup with yellow-brownish to brownish dark (Norma *et al.* 2021), and our new research was to develop a new sugar syrup base on the coconut haustorium milk as a diversified product with high in lysine amino acid content. Lysine cannot be synthesized by humans or farm animals and represents an indicator of other dietary essential amino acids (Cline *et al.* 2016). This amino acid is a key component of muscle and collagen and can promote the absorption and incorporation of calcium into the bone tissue, the daily need for an adult is 30 mg/kg body weight. For children 35 mg/kg body weight per day (WHO/FAO/UN (2007)). The research aims to determine the physical analysis of the oil yield extracted from the white copra of the germinated coconut, evaluation of the nutritional values; evaluations of lysine and other essential amino acid profiles of the fresh Matag coconut haustorium.

2. Materials and methods

2.1 Preparations of coconut germination and haustorium sample

The matured coconuts aged 20-24 months were collected from MARDI Kluang Station, Johore, Malaysia. The coconuts were then delivered to the Industrial Research Centre Laboratory at MARDI Headquarters, Serdang Selangor, Malaysia. The coconut was arranged on the soil (about 10 cm depth) for starting the coconut germinating study to produce haustorium. The period of coconut germinating was approximately 2.0-2.5 months. The haustorium and a white endosperm were collected by cutting its kernels and removing the endosperm water, then the coconut haustorium was collected and kept in a chiller at 5°C prior to nutritional and amino acid analyses. The fresh frozen haustorium was prepared for nutritional and amino acid analyses. The white endosperm was dried in an oven at 60°C for 24 hrs to produce a white copra, then it was cool and finally ground into powder paste to study its oil recovery.

2.2 Evaluation of coconut oil recovery and physical observation

A 10 g white copra powder was weighed into the round bottom flask. A 100 mL n-hexane was poured into the flask and the mixtures were heated under reflux for 8 hrs. The extracted mixtures were filtered through a Whatman No.1, then the filtrate was redried under a vacuum at 45°C. The physical appearance of the coconut oil was evaluated for its aroma, colour and recovery. The oil yield was determined by an in-house method of extracting the oil portion.

2.3 Determination of total solid content

The fresh haustorium was grated using a desiccated coconut machine, filtered using a muslin cloth and a sample was taken to evaluate the total solid in the haustorium milk. The total solid of the sample was determined using a Poket Atago Refractometer, Japan.

2.4 Nutritive analysis and amino acid analyses

The nutritional analyses were evaluated for protein based on (AOAC 981.10), total ash (AOAC 923.03), moisture (AOAC 950.46), protein (AOAC 923.03) and fat (AOAC 991.36) contents as referred to an Official Methods of Analysis of Association of Official Analytical Collaboration (AOAC) International. The carbohydrate was obtained by a difference of the total analyses as mentioned above (Pomeranz and Meloan, 1987). Amino acid standards include hydroxyproline - 0.00%, aspartic acid - 0.138%, serine - 0.066%, glutamic acid - 0.085%, glycine - 0.027%, histidine - 0.019%, arginine - 0.063%, threonine - 0.047%, alanine - 0.087%, proline - 5.760%, tyrosine - 9.060%, valine - 5.860%, methionine - 7.460%, lysine - 7.310%, isoleusine - 6.560%, leusine - 6.560% and phenylalanine - 8.260%. The analysis was done using acid hydrolysis and followed by an injection into an HPLC. The amino acid standards with an internal standard of AABA and haustorium amino acid extracts were prepared for the analysis. A speciality of lysine amino acid content was focused in the 4 fresh Matag haustorium samples.

2.5 Data analysis

In this work, all measurements of the nutritional value and amino acid contents were conducted in an accredited laboratory Unipeq, UKM Bangi, Malaysia. The recovery of coconut oil was conducted by triplicates in the Product Development Laboratory MARDI Serdang Selangor, Malaysia. The results are presented as average values, the standard of error of the measurements and a few analyses were under a quality assurance (QA) of the accredited laboratory. The data of each parameter analyzed were also presented in the mean ± standard mean error (SEM) format of the individual experiments.

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3. Results and discussion

3.1 Development of sprouted coconut, recovery of coconut oil and haustorium milk

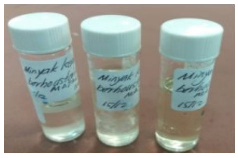
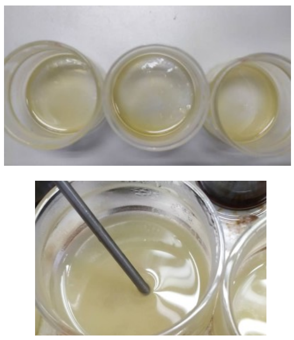
In Table 1, three coconut oils were obtained from T1, T2 and T3 white copra samples after harvesting its haustorium parts. The properties of the coconut oil such as aroma, yield and oily matter were similar to the coconut oil derived from the matured coconut from the previous research. The average of coconut oil from our T1, T2 and T3 copra samples was valued at 51.569±3.566%. In the research conducted by Konan *et al.* (2009), the germinated coconut oil recoveries fluctuated from 48.98 to 72.05%. Thus, the copra oil from our germinated coconut was within the range as mentioned above. As compared to the whole coconut copra and white copra reported by Appaiah *et al.* (2014), the oil contained 63.6% and 59.8% of fat/oil respectively as obtained from the proximate analysis. The virgin coconut oil (VCO) yield of 25.68±0.963 (natural fermentation) and 28.47±1.070 (induced fermentation, semi-controlled) were obtained and they improved the VCO yield percentages around 3% by using a probiotic organism *Lactobacillus plantarum* (Neela and Prasad, 2012). The VCO yield was lower than coconut oil obtained from solvent or pressed methods due to a natural extraction approach in producing the VCO. Thus, the copra of these germinated coconuts still contains high oil content and are edible.

3.2 Nutritional values of coconut haustorium samples

In Figure 2, coconut haustorium is high in the water reflecting its high moisture content (79.99-86.40%). The carbohydrate, crude fat, crude protein and ash contents

Table 1. Physical evaluation, oil yield and haustorium milk extracted from matured sprouted coconut.

(A) Appearance of Coconut Haustorium Developed in the Water Endosperm Site

Diversified Products from the Coconut Haustorium	Physical Data	Physical Colour	Physical Aroma	Appearance of Coconut Oil
White copra powder produced and obtained from the germinated coconuts.	51.569±3.566% oil recovery	White Clear and Oily	Coconut oil	 (B) Coconut Oil T1, T2 and T3 samples, recovered from the Germinated Coconut Endosperm
Coconut haustorium milk	73.39% Haustorium milk recovery with 7.20±0.42°Brix	Opaque liquid and similar to Milk colour	Sweet taste with young coconut aroma	 (C) New products: Coconut haustorium milk.
Coconut haustorium syrup	% syrup recoveries 12,15 and 20%	Creamish and sticky	Sweet and mild coconut taste and aroma.	 (D) New product -Coconut haustorium syrup

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were recorded at 9.34-15.58%, 0.62-2.15%, 1.34-1.84% and 1.61-2.30% respectively. The carbohydrate contents in the F2 Matag coconut samples were higher than M1 Matag coconut, these may reflect the original sweetness of the coconut water in the F2 coconut samples. According to Zhang *et al.* (2022), a larger coconut haustorium may contain more soluble sugar (47.10%) and reducing sugar (17.68%), and a small coconut haustorium contained more in ash (10.17%), protein (9.22%) and fat (5.03%) contents. All coconut haustorium was rich in potassium (4.06–4.69%) and phosphorus (0.39–0.50%). The dried samples were used for the determination of the above analysis. Other research found that coconut haustorium contained 1.05±0.2% ash, 44.2±4.6% soluble sugar, 24.5±3.2% starch, 5.50±0.3% protein, 1.99±0.9% fat, 5.72±0.4% soluble dietary fibre, 20.3±1.9% insoluble dietary fibre, and 146±14.3 mg phenolics. The findings of nutritional analyses varied to each other which may be due to the coconut varieties, locations and dry samples used in the analysis. Our findings used a fresh haustorium sample and it was recorded with a high contained water composition ranging between 79.99-86.40%.

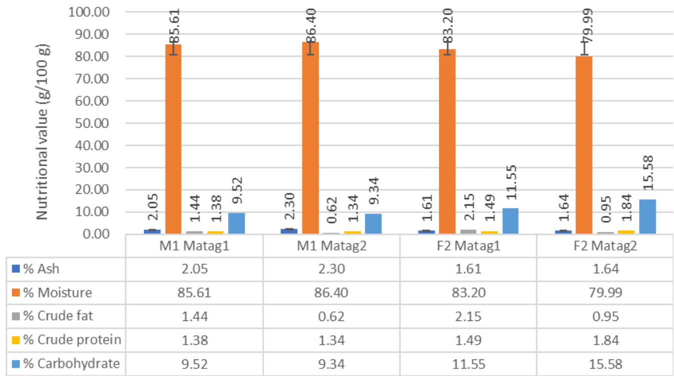


Figure 2. The nutritional analyses of matag coconut haustorium. Errors bars indicate standard mean error.

As reported by Narayanankutty *et al.* (2013), the carbohydrate, crude fat, crude protein and ash contents were at 64.2%, 1.88%, 5.7%, 0.98% and in addition of dietary soluble fibre and dietary insoluble powder analyses were reported at 5.74% and 19.25% respectively. The energy values of the fresh haustorium were calculated in the range from 483.00-782.43 kcal/100g of the proximate analyses obtained from Figure 3 above. A fresh haustorium is recommended as a great source of food for nutritional intake. For other comparisons, the nutritional value of coconut oil contains 8.92 kcal/g (892 kcal of energy per 100 g), equivalent to 3730 kJ per 100 g. A total of 99.06 g of fat was found in the 100g sample of coconut oil (Ng *et al.* 2021), this means that the energy was major derived from the fat portion.

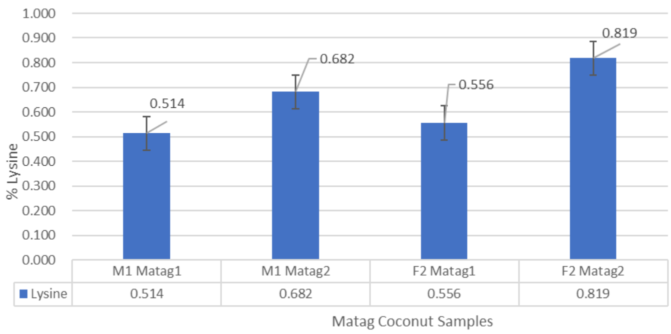


Figure 3. Percentage of the major amino acid (lysine) in the matag coconut haustorium samples.

3.3 Amino acid contents in the coconut haustorium samples

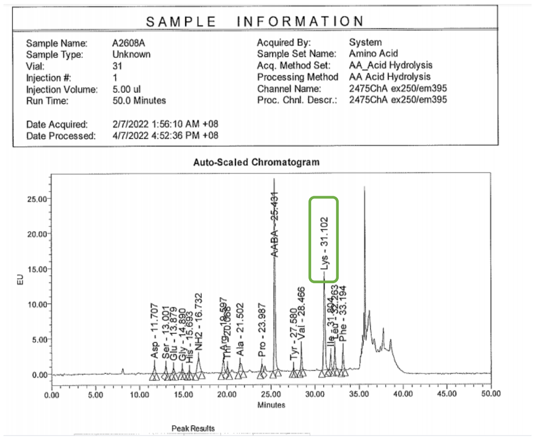
As illustrated in Figure 4, lysine was confirmed as a major amino acid in all Matag haustorium samples with amounts of 0.514±0.03 g/100g, 0.682±0.05 g/100g, 0.556±0.08 g/100g and 0.819±0.02 g/100g for M1 Matag1, M1 Matag2, F2 Matag 1 and F2 Matag2 respectively. The highest lysine content was recorded in F2 Matag2 (0.819%), followed by M1 Matag 2 (0.682%), F2 Matag 1 (0.556%) and M1 Matag (0.514%). This Lysine amino acid is an essential amino acid found in the Matag haustorium samples (Figures 3 and 4).

Figure 3 shows a marker of lysine as a major amino acid in the Matag haustorium samples that can be used to develop new value-added haustorium products such as coconut haustorium milk and coconut haustorium syrup. According to Medical Review Today (2018), the human body needs lysine amino acid for healthy functioning. It is a crucial component of proteins that play a role in helping body tissue grow and recover from damage. Other benefits of lysine include helping the body to absorb calcium, iron, and zinc; promoting collagen growth; helping produce enzymes, antibodies, and hormones and supporting the immune system.

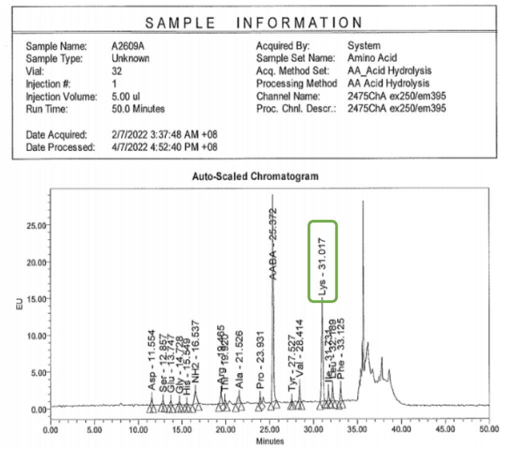
In Figure 4, a detailed comparison of lysine as a major amino acid and other essential amino acid compositions was illustrated in the four Matag haustorium samples. These amino acid profiles have fully described the profiles of essential amino acids found in the fresh haustorium.

4. Conclusion

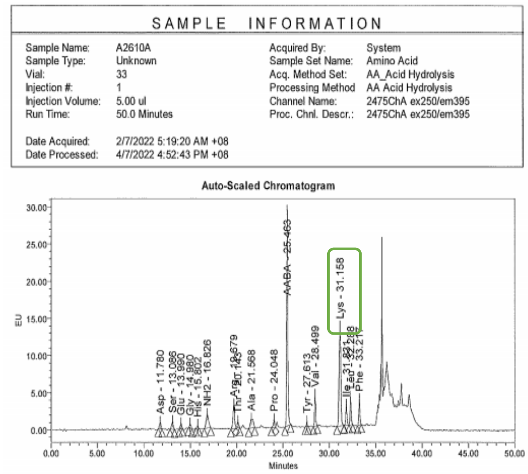
The coconut haustorium contains high minerals that are reflected by its ash content, lysine amino acids, and other nutritional values. The haustorium contained creamy plant-based milk that was found suitable for diversifying a new haustorium syrup with natural sweetness and aromatic plant syrup. In addition, copra from the germinated coconut still contains high coconut



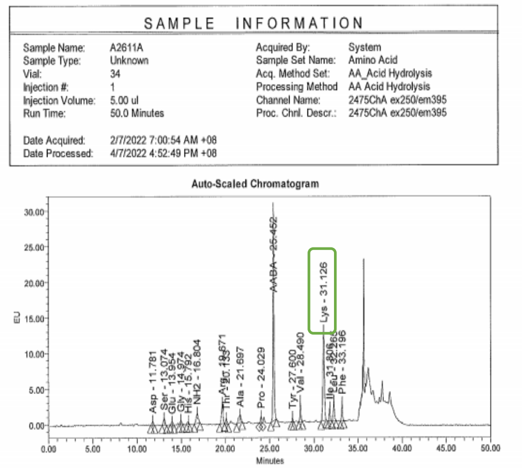
M1 Matag1 - High in lysine (0.514±0.03 g/100 g)



M1 Matag2- High in lysine (0.682±0.05 g/100 g)



F2 Matag1 - High in lysine (0.556±0.08 g/100 g).



F2 Matag2 - High in lysine (0.819±0.02 g/100 g).

Figure 4. Comparison of lysine (major amino acid) and other essential amino acid compositions in the Four Matag coconut haustorium samples.

oil that can be used for other food applications. Thus, these projects can be useful for the utilization of the coconut processing waste (haustorium) from waste to wealth.

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