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Proximate composition of Malaysian local sweet potatoes

[1]Zulkifli, N.A, [1,2,]*Nor, M.Z.M., [1]Omar, F.N., [1]Sulaiman, A and [1]Mokhtar, M.N.

[1]*Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia (UPM), 43400 UPM Serdang, Selangor, Malaysia.*
[2]*Laboratory of Halal Science Research, Halal Products Research Institute, Universiti Putra Malaysia, Putra Infoport, 43400 UPM Serdang Selangor, Malaysia*

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Abstract

Sweet potato (*Ipomoea batatas* (L.) Lam) is one of the main crops worldwide. However, systematic properties characterization of this crop is still required, particularly on the Malaysian local sweet potatoes. Hence, this study aims to determine the proximate composition and the energy value of five common varieties of local sweet potato (Anggun 1, Anggun 2, Anggun 3, White, and VitAto) in Malaysia. For each variety, three different parts of the tuberous root which were the skin, the cortex, and the mixture of cambium and parenchyma were characterized. The findings indicated that VitAto exhibited the highest starch (16.95% – 17.17%) and crude protein (0.86% – 1.15%) contents in all parts as compared to other varieties, hence reflecting its potentials to be further processed for a mass starch production. Among all the parts, the skin contained the highest crude protein, crude fat, ash and crude fibre, which can be further utilized to produce by-products such as animal feed. The findings in this study serve as a baseline for the future starch and by-products production from local sweet potatoes.

1. Introduction

Sweet potato or known by its scientific name as *Ipomoea batatas* (L.) Lam, after rice, potato and wheat, is the fourth most important food crop in the world (Tortoe *et al.*, 2010). Over 145 million tons of global production has been produced in 117 countries around the world (FAO, 2018). In Malaysia, sweet potato is widely cultivated in Perak, Selangor, Kelantan and Terengganu where about 41, 244 metric tonnes of sweet potato is being produced in the year of 2017 (DOA, 2017). Sweet potato is cultivated mainly because of its tuberous roots that are sweet and tasty. It has a long and tapered structure while its smooth internal colour can be varied from deep orange, yellow, purple, violet, beige and white, depending on its varieties (Mu and Singh, 2019). There are numerous varieties of sweet potato in Malaysia such as VitAto, Gendut, 57 Tainung, Banting, Biru Jepun, Biru Johor, CH purple, CH Red, Guan, Kuala Bikam and many more (Tan, 2015; Yusof *et al.*, 2018). Besides, the Malaysian Agricultural Research and Development Institute (MARDI) has introduced another three new varieties of purple sweet potato in 2017 namely Anggun 1, Anggun 2 and Anggun 3, which have been claimed to contain more anthocyanin content, high resistance to pest and microbial attack, and higher tolerance to impoverished soil and conditions (Nurul *et al.*, 2019).

The sweet potato varieties may vary in terms of their compositions such as carbohydrates, lipids, proteins, vitamins, dietary fibres, and other bioactive compounds including anthocyanin and beta-carotene. The compositional variations may also lead to the different applications of those varieties, including the production of starch. Starch, as one of the major components in sweet potato, can be utilized in many foods and non-food industries. In the food industry, it is used as an ingredient in some bakery products such as bread, biscuits, cakes, juices and noodles (Soison *et al.*, 2015). Besides, it is used as a food additive including thickener, stabilizer, and tissue reinforcing agent to improve the food texture and quality (Mu *et al.*, 2017). Meanwhile, starch is also used in textiles, papers, fuels, adhesives, plastics, and paints productions (Mu *et al.*, 2017).

While other crops such as rice, cassava, and potato obtain wide attention among researchers and local authorities in Malaysia, sweet potato suffers improper research database management. There are very limited

*Corresponding author.
Email: *zuhair@upm.edu.my*

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literature data available on local varieties of sweet potato processing as well as nutrient contents of each variety available in Malaysia. The information on the nutritional content of different parts of the local sweet potato such as the skin and the flesh is limited and fragmented (Shaari *et al.*, 2020). Some efforts have been done by MARDI and Universiti Putra Malaysia on the cultivation of the new sweet potato variety including VitAto and Anggun (Yusoff *et al.*, 2018), but the composition of the cultivated sweet potatoes is yet to be explored. Only a recent work on the determination of phytochemical properties in the different parts of the Anggun variety has been reported (Shaari *et al.*, 2020). However, this study is lacking in terms of comparison with the other more common varieties of sweet potato in Malaysia. It is important to provide systematic data of the Malaysian local sweet potatoes to decide the future direction of this crop including for the starch and the by-products productions. Hence, this paper aims to determine the proximate composition and the energy values of five common local varieties of sweet potato in Malaysia especially related to the starch and the by-products productions.

2. Materials and methods

2.1 Materials

The sweet potato varieties of Anggun 1 (A1), Anggun 2 (A2), Anggun 3 (A3), VitAto (VA) and White (WH) (Figure 1) were bought from local sweet potato plantations at BGB Enterprise Sdn Bhd, Semenyih, Selangor and MARDI Bachok, Kelantan, Malaysia. These varieties were chosen because they are the common varieties available in the local market. The five sweet potato varieties were stored in the chiller at a temperature of 10°C before the subsequent analyses. All the chemicals used in the experiment were analytical grade unless stated otherwise. Petroleum ether, sulfuric acid, acetone and celite 545 were purchased from R&M Chemicals (Malaysia) while Kjeldahl copper catalyst tablets were obtained from Fisher Scientific (United Kingdom).

Figure 1. The local sweet potato varieties

2.2 Preparation of the samples

The whole tuber of sweet potatoes was initially cleaned and washed with running tap water to remove dirt and soils and let to be air-dried to remove excess moisture (Figure 2). Then, the tuber was manually peeled, cut, and separated into three parts, which were skin (S), cortex (C) and mix of cambium ring and central parenchyma (M) to explore their functional and nutritional values (Figure 2 and Figure 3). Each part was cut into small cubic pieces (1cm × 1cm × 1cm) for subsequent analyses.

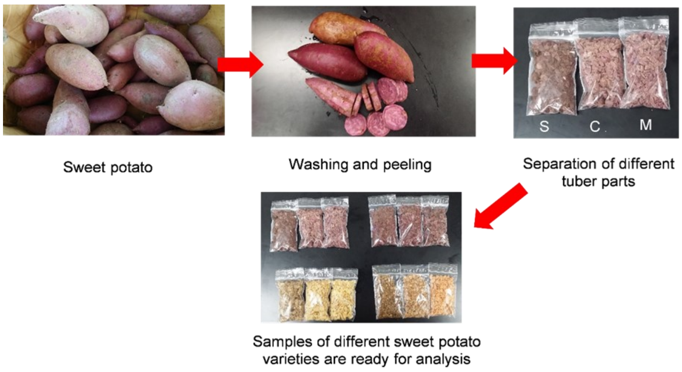

Figure 2. Sample preparation

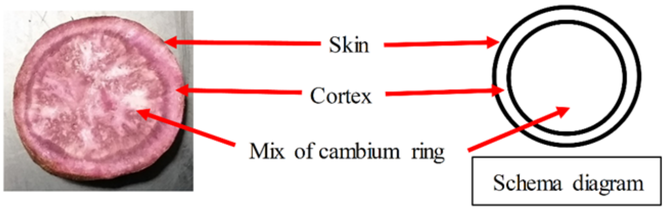

Figure 3. Different parts of sweet potato tuber

2.3 Proximate analysis of sweet potato raw samples

The raw samples of sweet potato (A1, A2, A3, WH, VA) were analyzed for moisture content using an oven (Memmert, Germany) through drying method at 105°C and following the AOAC method (AOAC, 1995). The crude fat was determined using the Soxtec extraction approach (Soxtec™ 2050, FOSS Analytical, Denmark) for 24 hrs. The crude protein content was measured (Kjeltec™ 2300, Foss Analytical, Denmark) which involved protein digestion and distillation according to Kjeldahl's method (FOSS Analytical AB., 2003). Then, the crude fibre was determined (Fibertec™ 2010, FOSS Analytical 69, Slangerupgade DK-3400 Hilleroed, Denmark) according to AACC International (1999). The ash was determined as a total inorganic matter by incineration of the samples at 600°C according to AOAC (1995). The total carbohydrate content was calculated by using the formula as in Equation (1). Total energy content was obtained using Equation (2) by referring to; Atwater conversion factors of 4, 9 and 4 for each gram of crude protein, crude fat, and carbohydrate, and expressed in calories, respectively (Dako *et al.*, 2016).

$$\text{Carbohydrate (\%)} = 100 - (\text{\% crude protein} + \text{\% total ash} + \text{\% crude fat}) \quad (1)$$

$$\text{Total energy (kcal/100 g)} = (9 \times \text{\% crude fat}) + (4 \times \text{\% crude protein}) + 4 \times \text{\% total carbohydrate}) \quad (2)$$

2.4 Total starch of sweet potato powder

The sweet potato samples (A1, A2, A3, WH and VA) were dried at 50°C in an oven for 24 hrs. The dried samples were ground using a dry mill (MX-SM1031S, Panasonic, Malaysia) and sieved (RS200, Retsch, Germany) at 250 µm to get uniform powder prior to the starch analysis. The total starch content of the samples was determined using a UV/visible spectrophotometer (Ultrospec 3100 pro, Amersham Pharmacia Biotechnology, United Kingdom) at 580 nm (Xiao *et al.*, 2006). The absorbance value was converted into a starch concentration profile using a standard calibration curve.

2.5 Data analysis

All tests were conducted in triplicate, and statistical analysis was performed using Microsoft Excel 2016 (Microsoft Corporation, USA) and Statistical Analysis System (SAS) software (Version 9.4 TS Level 1M2, SAS Institute, Inc., Cary, NC, USA). A significance level of $\alpha = 0.05$ was used throughout the analysis, and p -values larger than α ($p>0.05$) indicated that the difference between treatments was not significant. When a significant difference was found from the ANOVA results, the treatments were compared using a t-test.

3. Results and discussion

3.1 Proximate composition of five local sweet potatoes

Standard proximate compositional analyses were carried out on five varieties of local sweet potatoes at different tuber parts. Table 1 shows the moisture content of different varieties of sweet potato of different parts. Among all the sweet potato varieties evaluated in this study, Anggun 2 has the highest moisture content. Its mix cambium ring and central parenchyma part contained 76.87% moisture, higher than VitAto (73.58%), Anggun 3 (72.81%), White (67.63%) and Anggun 1 (61.07%). This variation might be affected by many factors such as the difference of the soils, the climate as well as the handling processing approaches (Dako *et al.*, 2016). Nevertheless, the moisture content of the sweet potatoes in this study was near the range of 61% – 70% reported by Ukom *et al.* (2009). Among all parts, the skin part generally has higher moisture content followed by the cortex part and the mix of cambium ring and central parenchyma part. For example, the skin of Anggun 1 contained 83.68% moisture, while its cortex contained 70.81% moisture. The mix part of cambium ring and central parenchyma has the lowest moisture content with 61.07% only. A similar trend was shown by the other sweet potato varieties. High moisture retention of the outer layer in comparison to the inner layer of the sweet potato might be due to the moisture retention in the skin cell for better respiration of the plant (Diop, 1998).

Table 2 exhibits the protein content of the local sweet potatoes. Among all the varieties, VitAto has the highest protein content (Table 2). The mix cambium ring and central parenchyma part of VitAto has 0.86% protein, followed by Anggun 3 (0.61%), White (0.47%), Anggun 1 (0.43%) and Anggun 2 (0.32%). The amount of protein content might affect the properties of the starch produced (Horstmann *et al.*, 2017). Starches with high protein content such as wheat starch, are suitable for the production of bakeries since the starch-protein mixture can provide the retention of carbon dioxide formed during fermentation, temporary binding of water required to gelatinize starch and formation of the typical

Table 1. The moisture content of five local sweet potato varieties at different tuber parts

Part	Moisture content (%) of different SP varieties				
	A1	A2	A3	WH	VA
Skin (S)	$83.68\pm0.23^{a,1}$	$89.82\pm0.63^{b,1}$	$67.00\pm0.17^{c,1}$	$78.27\pm0.32^{d,1}$	$75.92\pm0.46^{e,1}$
Cortex (C)	$70.81\pm0.83^{b,2}$	$82.68\pm0.16^{a,2}$	$70.24\pm0.56^{b,2}$	$68.51\pm1.23^{c,2}$	$70.23\pm0.64^{b,2}$
Cambium ring and central parenchyma (M)	$61.07\pm0.55^{c,3}$	$76.87\pm0.45^{a,3}$	$72.81\pm0.46^{b,3}$	$67.63\pm0.09^{d,2}$	$73.58\pm0.38^{b,3}$

Values are expressed as mean±standard deviation of triplicates. Values with different superscripts alphabets within row are significantly different ($p<0.05$) while values with different superscripts numbers within column are significantly different ($p<0.05$).

Table 2. The crude protein content of five local sweet potato varieties at different tuber parts

Part	Crude protein (%) of different SP varieties				
	A1	A2	A3	WH	VA
Skin (S)	$1.00\pm0.14^{ab,1}$	$0.77\pm 0.06^{b,1}$	$0.83\pm0.02^{b,1}$	$0.32\pm0.22^{c,1}$	$1.15\pm0.01^{a,1}$
Cortex (C)	$0.74\pm0.15^{b,12}$	$0.62\pm0.11^{bc,1}$	$0.62\pm0.01^{bc,2}$	$0.40\pm0.22^{c,1}$	$1.06\pm0.11^{a,1}$
Cambium ring and central parenchyma (M)	$0.43\pm0.15^{bc,2}$	$0.32\pm0.01^{c,2}$	$0.61\pm0.01^{ba,2}$	$0.47\pm0.19^{bc,1}$	$0.86\pm0.07^{a,2}$

Values are expressed as mean±standard deviation of triplicates. Values with different superscripts alphabets within row are significantly different ($p<0.05$) while values with different superscripts numbers within column are significantly different ($p<0.05$).

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foam structure of bread (Horstmann *et al.*, 2017). However, the protein content found in this study, were lower compared to Krochmal-Marczak *et al.* (2014) and Nascimento *et al.* (2015) with the protein contents ranging from 0.93% – 1.63% and 0.58% – 2.53%, respectively in different sweet potatoes varieties. Meanwhile, the yellow and the orange flesh sweet potatoes could be a good source of protein as compared to the white flesh sweet potatoes (Aweke and Roba, 2016). Similar to moisture content, the skin part has the highest protein following by the cortex part and the mix cambium ring and central parenchyma part (Table 2). The trend was similar to all the sweet potato varieties in this study. For example, the skin of Anggun 1 has 1% protein, which is higher compared to the cortex part (0.74%) and the mix cambium ring and central parenchyma part (0.43%). The high protein content in the skin of sweet potato has been reported by Krochmal-Marczak *et al.* (2014). This finding might reflect the potential of using the skin sweet potato in the protein extraction process and the animal feed production since the skin part is considered as a waste in the sweet potato production.

Among all the varieties, Anggun 2 has the highest crude fat content (Table 3). The mix cambium ring and central parenchyma part of Anggun 2 have 1.72% crude fat, followed by Anggun 1 (0.84%), VitAto (0.74%), Anggun 3 (0.47%) and White (0.40%). However, the crude fat content found in this study, were lower compared to the findings by Nascimento *et al.* (2015) with crude fat content ranging from 0.19% – 4.50%, respectively in different sweet potatoes varieties. Nevertheless, the low-fat content in the sweet potato may not be a major concern if the tuber was to be processed for starch production. Based on Table 3, the crude fat content of sweet potatoes at different parts showed that the skin part has the highest crude fat followed by the cortex part and the mix cambium ring and central parenchyma part. A similar trend were demonstrated by all the sweet potato varieties in this study. For example, the skin of Anggun 1 has 2.54% crude fat, which was higher compared to the cortex part (1.21%) and the mix cambium ring and central parenchyma part (0.84%).

Anggun 2 variety has the highest ash content as shown in Table 4. Its mix cambium part contained 1.10% ash, higher than White (0.98%), Anggun 3 (0.71%), VitAto (0.47%) and Anggun 1 (0.46%). These values did not differ much from the studies by Krochmal-marczak *et al.* (2014) and Nascimento *et al.* (2015) with the ash content ranging from 1.07% – 1.52% and 0.85% – 1.29%, respectively in different sweet potatoes varieties. Aweke and Roba (2016) suggested that higher ash content value indicating the variety has higher mineral and salts contents, enabling sweet potatoes to be served as good and healthy snacks and side dishes. Calcium, phosphorus, magnesium, sodium, potassium, iron, zinc and copper have been identified as the main minerals in sweet potato tubers (Aina *et al.*, 2009). Among all parts, the skin generally has a higher ash content followed by the cortex and the mix part of cambium ring and central parenchyma (Table 4). The skin of Anggun 1 contained 2.19% ash, while its cortex contained 1.88% ash. The mix part of cambium ring and central parenchyma has the lowest ash content with 0.46% only (Table 4). The ash content in the skin indicated a good source of minerals preserved and might be suitable for animal feed (Rose and Vasanthakaalam, 2011).

Table 5 exhibits the crude fibre content of all the

Table 3. The crude fat content of five local sweet potato varieties at different tuber parts

Part	Crude fat (%) of different SP varieties				
	A1	A2	A3	WH	VA
Skin (S)	$2.54±0.23^{a,1}$	$2.86±0.13^{a,1}$	$0.65±0.04^{c,1}$	$1.68±0.45^{b,1}$	$2.28±0.28^{a,1}$
Cortex (C)	$1.21±0.26^{b,2}$	$2.84±0.12^{a,1}$	$0.56±0.03^{c,12}$	$0.58±0.09^{c,2}$	$1.17±0.23^{b,2}$
Cambium ring and central parenchyma (M)	$0.84±0.32^{b,2}$	$1.72 ±0.15^{a,2}$	$0.47±0.05^{bc,2}$	$0.40±0.09^{c,2}$	$0.74±0.14^{bc,2}$

Values are expressed as mean±standard deviation of triplicates. Values with different superscripts alphabets within row are significantly different ($p<0.05$) while values with different superscripts numbers within column are significantly different ($p<0.05$).

Table 4. The ash content of five local sweet potato varieties at different tuber parts

Part	Ash (%) of different SP varieties				
	A1	A2	A3	WH	VA
Skin (S)	$2.19±0.09^{b,1}$	$2.10±0.12^{b,1}$	$2.34±0.06^{ab,1}$	$2.85±0.56^{a,1}$	$2.36±0.15^{ab,1}$
Cortex (C)	$1.88±0.15^{a,2}$	$1.40±0.17^{b,2}$	$0.95±0.01^{c,2}$	$1.38±0.15^{b,2}$	$0.78±0.07^{c,2}$
Cambium ring and central parenchyma (M)	$0.46±0.09^{b,3}$	$1.10±0.09^{a,3}$	$0.71±0.07^{b,3}$	$0.98±0.18^{a,2}$	$0.47±0.13^{b,2}$

Values are expressed as mean±standard deviation of triplicates. Values with different superscripts alphabets within row are significantly different ($p<0.05$) while values with different superscripts numbers within column are significantly different ($p<0.05$).

Table 5. The crude fibre content of five local sweet potato varieties at different tuber parts

Part	Crude fibre (%) of different SP varieties				
	A1	A2	A3	WH	VA
Skin (S)	2.78±0.24^{b,1}	2.46±0.02^{b,1}	2.22±0.11^{b,1}	11.18±0.80^{a,1}	2.94±0.11^{b,1}
Cortex (C)	1.93±0.39^{b,2}	1.55±0.07^{b,2}	1.24±0.18^{b,2}	2.92±0.65^{a,2}	2.06±0.55^{ab,2}
Cambium ring and central parenchyma (M)	1.72±0.13^{b,2}	1.45±0.07^{bc,2}	0.99±0.07^{c,2}	9.99±0.65^{a,1}	2.04±0.22^{b,2}

Values are expressed as mean±standard deviation of triplicates. Values with different superscripts alphabets within row are significantly different ($p<0.05$) while values with different superscripts numbers within column are significantly different ($p<0.05$).

Table 6. The carbohydrate content of five local sweet potato varieties at different tuber parts

Part	Carbohydrate (%) of different SP varieties				
	A1	A2	A3	WH	VA
Skin (S)	7.81±0.41^{c,3}	1.98±0.64^{e,3}	26.95±0.15^{a,1}	5.70±1.14^{d,3}	15.34±0.46^{b,3}
Cortex (C)	23.44±0.55^{b,2}	10.90±0.28^{c,2}	26.38±0.57^{a,1}	26.21±1.52^{a,1}	24.70±0.54^{ab,1}
Cambium ring and central parenchyma (M)	35.49±0.51^{a,1}	18.54±0.48^{e,1}	24.41±0.50^{b,2}	20.52±0.79^{d,2}	22.32±0.29^{c,2}

Values are expressed as mean±standard deviation of triplicates. Values with different superscripts alphabets within row are significantly different ($p<0.05$) while values with different superscripts numbers within column are significantly different ($p<0.05$).

local sweet potato varieties. Based on the table, White has the highest crude fibre content, indicating that it is more digestible than the others. The mix cambium part of White has 9.99% crude fibre, followed by VitAto (2.04%), Anggun 1 (1.72%), Anggun 2 (1.45%) and Anggun 3 (0.99%). The range of crude fibre percentage in this study was higher compared to the report by Krochmal-marczak *et al.* (2014) with 0.86% – 1.14% range. Higher crude fibre content indicates higher absorption rate by digestive systems, which is crucial in preventing digestive tract diseases and constipation among consumers (Tripathi and Tiwari, 2019) and also reducing heart disease and diabetes (Rose and Vasanthakaalam, 2011; Alam *et al.*, 2016). Similar to other properties, the skin part has the highest crude fibre followed by the cortex part and the mix cambium part (Table 5), which again might suggest the suitability of this part to be utilized for animal feed production. The trend was similar to all the sweet potato varieties in this study except for White, where the mix cambium crude fibre was higher compared to the cortex part. For example, the skin of Anggun 1 has 2.78% crude fibre, which was higher compared to the cortex part (1.93%) and the mix cambium part (1.72%).

Table 6 displays the carbohydrate content of the sweet potatoes. Among all the varieties, Anggun 1 has the highest carbohydrate content. The mix cambium ring and central parenchyma part of Anggun 1 have 35.49% carbohydrate content, followed by Anggun 3 (24.41%), VitAto (22.32%), White (20.52%) and Anggun 2 (18.54%). The range obtained in this study, however, was lower compared to the study by Nascimento *et al.* (2015) with the carbohydrate content ranging from 41.08% – 73.43%, in different sweet potatoes varieties. The carbohydrate contents in the sweet potatoes varieties in this study suggesting that they can be a good source of energy. Apart from that, these carbohydrates are crucial as they act as substrates in the production of aromatic and phenolic compounds through Shikimic pathway (Eleazu and Ironual, 2013). Besides, the production of starch from the sweet potatoes is much related to the carbohydrate content of each variety. Additionally, as expected, for all the varieties, the mix cambium ring and central parenchyma part have the highest carbohydrate followed by the cortex part and the skin part (Table 6). The mix cambium ring and central parenchyma part of Anggun 1, for instance, has 35.49% carbohydrate, which was higher compared to the cortex part (23.44%) and the skin part (7.81%).

3.2 Starch content and energy values

Starch is the main form of carbohydrates in the food system. It is one of the most predominant components in sweet potato tubers. Based on Figure 4, VitAto (VA) exhibited the highest starch content among all the varieties, revealing its suitability for the starch extraction process. The starch content is directly related to genotype and environmental settings in which the plant is cultivated, such as the variety difference of soils, the climate, and other growth factors (Nascimento *et al.*, 2015). Among the three parts of VA, the highest starch content was recorded by its cambium and parenchyma part (17.17%), followed by the cortex (17.02%) and the skin (16.95%). The starch content from sweet potato can be used for many food applications such as desserts, beverages and cookies. Besides, the starch can also be used as a thickener, water binder, emulsion stabilizer and gelling agent (Sanoussi *et al.*, 2016). VitAto has been reported to have the potential for starch production. Its

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production in Malaysia started in June 2007, to develop nutritionally more superior sweet potato varieties (Mohd Hanim *et al.,* 2014). Some applications of starch from VitAto including the production of cakes, muffins, cookies and noodles, extruded snacks, and also chiffons. Hence, the selection of VitAto out of all other varieties for commercial starch production is expected to bring advantages since it is rich in beta carotene and vitamin C, with a low glycemic index (Mohd Hanim *et al.,* 2014). However, further studies are required to characterize the VitAto starch so that its commercialization effort will be worth it.

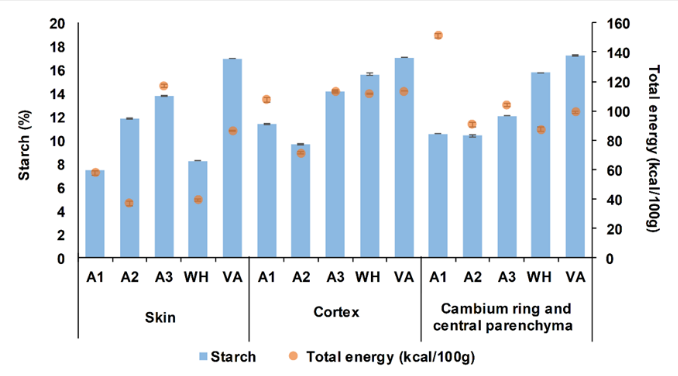

Figure 4. Starch content and total energy values of local sweet potato varieties at different tuber parts

Based on Figure 4, out of all varieties in this study, Anggun 1 (A1) has the highest energy values, with its mix of cambium ring and central parenchyma part, 151.20 kcal/100g energy. This finding was in agreement with the carbohydrate content of the variety as in Table 1. Although the values obtained in this study were much lower as compared to the report by Nascimento *et al.* (2015), the finding revealed the potential of Anggun 1 and other local varieties to be fully utilized for commercial plantation and human consumption.

4. Conclusion

The proximate analysis of the five local sweet potato varieties (A1, A2, A3, WH and VA) revealed the composition and the potential of these varieties in a wide range of industries. Among all varieties, VitAto has the highest protein and starch contents, reflecting its suitability for the production of starch at the commercial level. Although the skin part is considered as waste in sweet potato processing, it contains the highest protein, crude fat, ash and crude fibre compared to other parts. This indicates its potential to be utilized for other applications such as animal feed production. The findings in this study can be used as references for the future production of starch and by-products from the local sweet potato.

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