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INVESTIGATION OF SUSTAINABLE SOURCE OF NUTRIENTS FROM FRESH AND PASTEURISED SWEET POTATO HAULM JUICE POWDER

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Abstract: The push for modernisation in agriculture involves food-based plants as a buffer for more profitable returns. In Malaysia, the second widest cash-crop plantation is for sweet potato (*Ipomoea batatas* L.), occupying 3, 623 hectares of agricultural land. Furthermore, its haulms are discarded as waste. There are limited studies on the macronutrients of sweet potato stalk, stem and leaves, collectively known as the haulm. This study investigates the proximate nutritional composition of fresh and pasteurised sweet potato haulm juice powders (SPHJPs). The pasteurisation process has significantly reduced carbohydrate content (39.33 g/100g dry weight (dw)) and increased mineral content (13.24 g/100g dw) compared with fresh SPHJP ($p<0.05$). The fresh and pasteurised SPHJP had a minimum percentage of protein (35.23 g/100g dw), fibre (7.72 g/100g dw) and fat (2.42 g/100g dw), revealing that the haulm from sweet potato has the potential to be transformed into a sustainable source of nutrients and as an innovative plant-based protein. The current information is crucial in imparting dietary recommendations on utilising sweet potato haulm as part of human or animal diet. Future studies that emphasise on the micronutrient and antinutrient contents of the haulm are recommended.

Keywords: Sweet potato, haulm, fresh juice, pasteurised juice, sustainable nutrients. Abbreviations: Sweet potato haulm juice (SPHJ), sweet potato haulm juice powder (SPHJP).

Introduction

The sweet potato plant is ranked as the sixth most significant crop globally, following rice, wheat, potato, maize and cassava (CIP, 2017). In Malaysia, sweet potato crops cover about 3, 623 hectares of agricultural land, with 58,034 metric tonnes being produced in 2020 (The Department of Agriculture, 2020). The sweet potato is a favoured cash crop due to its abundant yield of harvest (tubers), its delicate flavour and pleasant smell (tubers), it can be easily grown, is resistant to pests and is able to adapt well in various environments (Šlosár *et al.,* 2016).

Green plants are high in chloroplast organelles that are nutrient-dense (Wattanakul *et al.*, 2019). Although the top parts of the plants, consisting of green leaves, stems and stalks, are nutritious and edible, it is underutilised and discarded due to low consumer demand. The unused top parts of the plants, or haulms, are considered as "fruit and vegetable waste (FVW)" (Plazzotta *et al.,* 2017).

Research has shown that the concentrations of anthocyanin in orange-fleshed and white-fleshed sweet potatoes are higher than purple-fleshed sweet potatoes. There are no anthocyanins found in the stems of the plant (Su *et al.,* 2019). Furthermore, the anthocyanin concentration in the stem of yellow-fleshed sweet potato leaves or haulms are not reported. Generally, the total antioxidant capacity, total phenolic acids and total carotene of sweet potato leaves are 10.36 mg AAE/g dw, 5.29-8.37 mg/g dw and 1.17-2.37 mg/g dw, respectively (Tang *et al.,* 2021; Gunathilake & Ranaweera, 2016; Alam *et al.,* 2016). The total phenolic compounds in sweet potato leaves are higher than in its roots (Abong *et al.,* 2020). The leaf part of sweet potatoes was proven to contain an abundance of protein, ascorbic acid, α-tocopherol and antioxidant compounds (Tang *et al.,* 2021; Alam *et al.,* 2016; Awol, 2014; Conrad *et al.,* 2014), there are limited studies on the macronutrients and micronutrients of sweet potato stalks, stems and leaves, collectively known as the haulm.

Utilisations of the haulms or other FVW can provide economic contributions. This is done by upcycling the economic potential back to the producer rather than simply sending it to a waste disposal facility (Widodo *et al.,* 2015). This action also converts the agricultural waste into a sustainable source of nutrient to realise the food security chain, especially in Malaysia (Yunus *et al.,* 2020).

To date, there is no scientific data on the macronutrients of the fresh and heat-treated juice obtained from yellow-fleshed sweet potato haulms. Hence, the main objective of this study is to determine the proximate nutritional composition of fresh and pasteurised juice of sweet potato haulm juice powders (SPHJPs) as a sustainable source of nutrients.

Materials and Methods

Preparation of Sweet Potato Haulm Juice (SPHJ)

A total of 3 kg of sweet potato haulms were collected from Kangar, Perlis (Perlis Sweet Potato Farm) in February 2021. The haulms were obtained from purple-skinned and yellow-fleshed sweet potato plants (Figure 1). The haulms were cleaned using a running tap water to remove the remaining dirt. The haulms were cut for about 2 cm long each and juiced using a slow juicer (SAVTM JE-31). From the haulms, 1.784 kg of juice and 0.955 kg of dregs were produced. The sweet potato haulm juice (SPHJ) was divided into two batches of (i) fresh SPHJ and (ii) pasteurised SPHJ. For the fresh SPHJ, the samples were transferred into an aluminium tray and kept frozen (-20℃, 48 hours) before freeze-drying. Meanwhile, the pasteurised SPHJ was pasteurised in a jacketed beaker (85°C, 5 minutes) and immersed immediately in an ice-water bath to rapidly cool the juice down to room temperature (<20℃, 30 minutes). The pasteurised sample was then transferred into an aluminium tray and kept frozen (-20℃, 48 hours) before freeze-drying.

Preparation of Sweet Potato Haulm Juice Powder (SPHJP)

The frozen fresh and pasteurised SPHJs were freeze-dried (Freeze Dryer FD-550, Eyela) (-20℃, 3 Pa, 48 hours) to form the sweet potato haulm juice powder (SPHJP). The fresh and pasteurised SPHJPs are then grounded using mortar and pestle to get a homogenised powder. All SPHJPs were sieved (75 μm), vacuum-sealed in aluminium pouches and stored at -80℃ until further analysed.

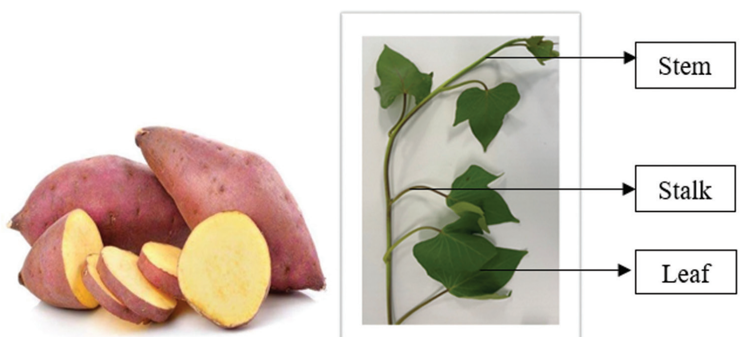

Figure 1: The haulms (stems, stalks, leaves) used in this study were obtained from purple-skin, yellow-fleshed sweet potato plants

Proximate Analysis and Crude Fibre Analysis of SPHJ Powder (SPHJP)

The macronutrient composition, such as moisture, fat, ash, protein and carbohydrate contents was analysed following the AOAC method (AOAC, 2005). Moisture analysis was calculated based on the moisture loss in the samples after drying, while the ash content was based on the remaining incinerated samples. The determination of fibre was done using the FibreTherm automated instrument. The crude protein content was determined using the Kjeldahl method and the percentage of protein was calculated by multiplying the nitrogen value with 6.25. The crude fat content was determined using the Soxhlet method by extracting fat using petroleum ether. The total carbohydrate content was obtained by subtracting 100 with the percentage of macronutrients. All analysis were performed in triplicate.

Statistical Analysis

The results were analysed statistically to one-way analysis of variance (ANOVA) using the Minitab software to analyse significant differences between the nutritional concentration of fresh and pasteurised SPHJPs. The results were expressed in (M ± SD) and the $p<0.05$ was considered to indicate a statistically significant difference.

Results and Discussion

Proximate analysis is the analysis of macronutrients quantitatively, where it consists of the mass percentage of the moisture, ash, fat, protein and carbohydrate contents. In this study, proximate analysis was performed on the fresh and pasteurised SPHJPs dried using the freeze-drying technique (Figure 2).

In this research, the carbohydrate content of the fresh and pasteurised SPHJP samples are statistically significant ($p<0.05$) (Table 1). The reduction of the carbohydrate content in the pasteurised SPHJP may be due to the thermal processes that degraded the starch of the haulms.

The ash content in pasteurised SPHJ was significantly higher than fresh SPHJP (Table 1) ($p<0.05$). It has been suggested that minerals, such as zinc and iron, are very stable under low heat conditions. However, low volatility minerals may contribute to high ash content upon exposure to heat during ashing or drying (Siti Mahirah *et al.,* 2018; Morris *et al.,* 2004).

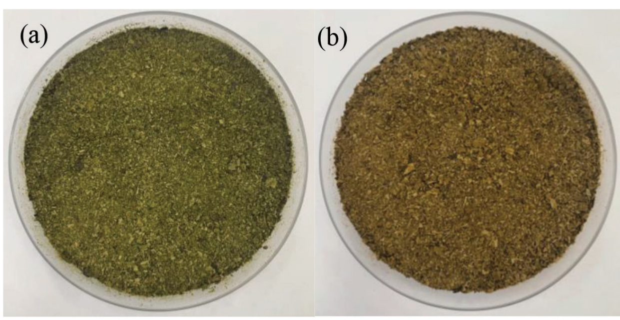

Figure 2: Images of the (a) fresh and (b) pasteurised sweet potato haulm juice powders

Table 1: Nutritional composition of fresh and pasteurised SPHJPs

g/100g dw	Carbohydrate	Protein	Ash	Moisture	Fibre	Fat
Fresh	42.18±0.70[a]	35.23±0.28[a]	10.57±0.02[a]	9.59±0.52[a]	8.44±0.41[a]	2.42±0.27[a]
Pasteurised	39.33±0.42[b]	35.26±0.47[a]	13.24±0.10[b]	9.43±0.18[a]	7.72±1.88[a]	2.68±0.06[a]

SPHJP: Sweet potato haulm juice powder, dw: dry weight basis
Values with similar letters within columns are not significantly different (Tukey's test, $p<0.05$)

Higher concentrations of ash and mineral (iron, calcium and potassium) in boiled cassava leaves compared with non-processed leaves have been reported (Achidi *et al.,* 2005). The loss of moisture and other nutrients, such as fibre, may also contribute to the higher concentration of ash in pasteurised SPHJP than in fresh SPHJP. Other than that, the fresh haulm samples in this study have a lower ash percentage than the fresh sweet potato leaves (Ethiopia) (Awol, 2014), mostly due to the collective analysis on the stalk, stem and leaves of the haulms.

An increase in certain nutrients after cooking could be demonstrated by water reduction, explaining the inverse relationship between moisture and other nutrients (Ersoy & Özeren, 2009). Thermal treatments, such as boiling, steaming, dry roasting and microwaving have increased cassava leaves' crude fat content (Ekpo & Baridia, 2020). In our study, the difference between the protein, fibre and fat content of fresh and pasteurised SPHJP was insignificant (Table 1).

There was no significant difference for the protein percentage in the fresh and pasteurised SPHJP, suggesting that heat treatment given to the pasteurised sample (85℃, 5 minutes) did not change the protein content in SPHJP ($p>0.05$). Chirwa-moonga (2020) supported this finding, which reported that the crude protein in purple sweet potato leaves was not affected by steaming (95℃, 10-15 minutes). A high amount of protein was detected mainly in sweet potato and cassava leaves (21.85 to 24.53 g/100g dw), with essential amino acids, such as glutamate, leucine, aspartate and lysine (Iyaka *et al.*, 2015). But the amino acid content of SPHJP has not yet been determined. It was suggested that thermal blanching might cause the leaching of water-soluble protein from the sample into the surrounding water (Xiou *et al.,* 2017; Lee, 1958). In our study, the macronutrients of the juices were contained within the close-jacketed pasteuriser and dried using freeze-drying method. Therefore, protein loss due to leaching was successfully avoided.

Mechanical abruption and juicing are crucial pre-processing steps to release chloroplast organelles from the cell wall (Torcello-Gómez *et al.,* 2019). There is a 0.72 g/100g dw difference in the fibrecontent of the SPHJPs, whereby 8.44 g/100g dw of fresh SPHJP consisted of fibre, compared with pasteurised SPHJP which had 7.72 g/100g dw of fibre. It has been suggested that the modification of total dietary, soluble and insoluble fibre are highly dependent on processing temperatures. Heat treatments, such as boiling and pressure cooking, also increased soluble fibre in barley (Bader Ul Ain *et al.,* 2019).

In the study conducted by Ishida *et al.* (2000), sweet potato leaves mainly contributed to the soluble fibre (5.94 - 6.90 g/100g dw), while its stems are made up of insoluble fibre (10.40 – 11.30 g/100g dw). The insoluble fibre in the haulms may have turned into soluble fibre in the presence of heat (85℃), which is demonstrated by the pasteurisation of aloe vera fillet at 85℃ for 15 minutes that resulted in a lower cell wall polymer (0.268 mg/g dw) than the fresh fillet (0.345 mg/g dw) (Rodríguez-González *et al.,* 2011). As the temperature increased, the rate of breaking glycosidic bonds in polysaccharides is also increased, contributing to the release of oligosaccharides (Yi *et al.,* 2014). Soluble dietary fibre could provide health benefits by forming a gel and increase gut health by slowing down digestion, delaying gastric emptying, preventing constipation and creating the sensation of fullness (Axelrod & Saps, 2018; Li & Komarek, 2017). Hence, further study must be conducted to determine the concentrations of soluble and insoluble fibre contents of SPHJP.

Both freeze-dried SPHJP in this study had slightly higher moisture content (9.43-9.59 g/100 dw), compared with freeze-dried basil leaves (7.99 g/100g dw) (Siti Mahirah *et al.,* 2018). The moisture content being higher than 7% may suggest that the freeze-drying process applied in this study could be enhanced to reduce the moisture content of SPHJP further. Moreover, a hygroscopicity test is suggested to confirm the physical characteristic of SPHJP at room temperature.

Preventive actions, such as pasteurisation, should be applied to minimise or avoid biological hazards in food (FSMA, 2011). Pasteurisation of *Justicia secunda* leaves has seen them maintain nutrient retention and quality (Neba *et al.,* 2020). On top of that, heat treatment at 85℃ can deactivate the plant's enzyme and preserve the quality of nutrients, like carotenoids and galactolipids, in peavine haulm powder (Wattanakul *et al.,* 2020). In our study, the heat treatment applied on the SPHJP is higher than 80℃ and has been shown to deactivate peroxidase enzyme activities, which may provide a stable shelf-life and safer food consumption. It was proven that pasteurisation can reduce the microbial load in food and juice samples such as *Listeria monocytogenes* and other vegetative pathogens (Rodrigues *et al.,* 2021; Peng *et al.,* 2017). Further study to analyse the microbial safety of SPHJ should be done to understand the impact of pasteurisation on the sample.

In response to the current trend to go green, wholesome, and consume plant-based products, the high percentage of carbohydrate (39.33 g/100g dw), protein (35.23 g/100g dw), fibre (7.72 g/100g dw), ash (10.57 g/100g dw) contents in both the fresh and pasteurised SPHJPs could be the key to sustainable food nutrients and production. These nutrients could be converted or further fermented into novel sugar and act as a new source of plant protein. Furthermore, carbohydrates help avoid the oxidation of polyphenol (Wang *et al.,* 2016) and this is linked to the leaves antioxidant abilities. Leaves were found to scavenge free radicals better than the skin and flesh of sweet potatoes (Makori *et al.,* 2020). The leaf extracts can be utilised in food products, such as juice, ice cream or pasta, and functional food, as it is directly associated to the human health as anti-diabetic, anti-cancer and to improves cardioprotective effect (Alam, 2021). This showed that the data and information on the haulms are needed to ensure that the haulms can be fully utilised and provide a sustainable nutrient. However, further study must be conducted to determine its mineral compounds, soluble and insoluble dietary fibre, and amino acid concentration in the SPHJP samples. Investigations into the antioxidant and antinutrient properties of the haulms should also be set up.

Conclusion

Throughout this study, fresh and pasteurised sweet potato haulm juice powders (SPHJPs) had a minimum percentage of carbohydrate (39.33 g/100g dry weight (dw)), protein (35.23 g/100g dw), fibre (7.72 g/100g dw) and fat (2.42 g/100g dw) contents, revealing that the haulms of sweet potato hae the potential to be transformed into a sustainable source of nutrients and an innovative plant-based protein. The exposure of SPHJP to pasteurisation has decreased the carbohydrate content and significantly increased the ash content of the haulm powder (p<0.05). Further study must be conducted to analyse the concentration of mineral compounds, soluble fibre, insoluble dietary fibre, amino acids, antioxidant, antinutrient and hygroscopicity of the powder. Assessment of the microbial aspect of the SPHJP is recommended to evaluate the efficiency of pasteurisation used to cater to food safety issues.

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