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Physicochemical and Anti-nutrients Analysis of Pasteurised and Unpasteurised Underutilised Sweet Potato Haulm Juice Powder

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***Abstract*—Under the cash-crop category, sweet potato (Ipomoea Batatas L.) has the second widest plantation area (3, 623 hectares) in Malaysia, after sweet corn. The sweet potato crop had been grown for its edible tubers, leaving behind the top parts of the plants, which led to abundant agricultural waste, around 10 tonnes per hectare. Early studies showed that haulm (unused tops of the plants consisting of stem, stalk, and leaf) from sweet potato plants are a potential source of nutritional contents, including bioactive materials and antioxidants. Suppose the haulms or other fruit and vegetable waste (FVW) are utilised as these nutrient sources benefit Malaysia in terms of consumption and economy, promoting agricultural sustainability. In this study, the sweet potato haulm undergoes slow-juicing, heat-treatment, and freeze-drying. This research focused on elucidating the physicochemical and anti-nutrients analysis of pasteurised and unpasteurised sweet potato haulm juice powder (SPHJP) (water activity, colour analysis, water solubility index, oxalic acid, and phytic acid) as a potentially edible product. Results significantly showed that pasteurised SPHJP had lower water activity (0.34 aw), lower anti-nutrients concentration (oxalic acid and phytic acid), and a higher water solubility index than the unpasteurised SPHJP ($p<0.05$). It is proven that heat treatment is crucial when utilizing green waste material, as it can reduce the availability of anti-nutrients and increase its potential as a replacement for other green vegetables. Further study must be conducted to convert this underutilised agricultural product into biofertilisers, bioplastics, biofuels, or nutraceutical products.**

***Keywords*— sweet potato; haulm; anti-nutrient; phytic; oxalic; pasteurisation**

I. INTRODUCTION

Sweet potato, which belongs to the *Convolvulaceae* family, is one of the significant tuber crops that originated from South America and has been planted mainly for its tubers [1]. Sweet potato plants grow well in various climates, such as tropical, subtropical, and temperate regions, it has grown widely in African countries such as Nigeria and Uganda, Asian countries such as China, Indonesia, Malaysia, and certain European countries [2].

Sweet potatoes' tubers come in varieties of flesh and skin colours and are edible, sweet in flavour, and have pleasant smells [3]. Sweet potato consists of a high amount of carbohydrates, proteins, fats, and fat-soluble vitamins. This contributes to using sweet potatoes as one of the main sources for food consumption, animal feed, alcohol production, and many more.

Unfortunately, the top parts of the sweet potato plant are usually discarded, burnt, or left as agricultural waste. This is due to the low utilisation of the top parts, which led to the inefficient use of the waste. Globally, the abundance of agricultural waste needs to be effectively managed to avoid environmental issues [4, 5].

Hence, studies must be conducted to benefit from this waste through valorisation. The top parts, which are the leaves and soft stems of the plants, are called haulm. Sweet potato leaves have a significant amount of other nutrients, such as vitamin B, β-carotene, calcium, zinc, and iron, apart from abundant protein and minerals [6]. Figure 1 below shows the sweet potato haulm, which consists of the leaves and soft stems of the sweet potato plant.

Figure 1: Sweet Potato Haulm

Slow juicing may provide minimal destruction to the nutrients that are heat sensitive and is chosen to extract haulm juice before the drying process. Slow juicing also aims to release chloroplast from its cell wall, increasing the bioactive compound's availability. An effective drying mechanism is needed to minimize the quality loss in plant products. Vacuum freeze-drying preserved the highest content of protein, fat, dietary fibre, and various vitamins, along with antioxidant compounds, compared to microwave and hot air drying [7]. The drying process is necessary to produce a more stable product with lower water activity and moisture content [8]. Heat processing such as pasteurisation, which is conducted at below 100˚C and is known as mild heat treatment, aims to extend the shelf-life of the food products (food preservation method). Heat processing on haulms (pea vine, sweet potato) was reported to have stable nutrients [9, 10]. Pasteurisation will inactivate enzymes and destroy vegetative and non-spore-forming pathogenic microorganisms. Pasteurisation (90˚C) reduced 22% the red colour in pomegranate juice [11]. But, in tomato juice, pasteurisation did not affect the total phenolic content [12].

Anti-nutrient are another concern in consuming agricultural products, especially green leafy vegetables, which could lessen the bioavailability of nutrients [16]. Sweet potato leaves also consist of various anti-nutrients such as oxalic acid, phytic acid, anthraquinone, tannin, saponin, cyanide, and trypsin [13-15]. Oxalates may bind to the minerals such as calcium or magnesium [17]. Oxalates could cause hypocalcemia, severe poisoning, and in some instances, the formation of calcium oxalate as kidney stones might cause renal failure [18, 19]. Phytate has been studied to reduce protein digestibility and interfere with mineral bioavailability [20, 21]. Therefore, this study aims to elucidate the physicochemical and anti-nutrients analysis of sweet potato haulm juice powder (water activity, colour analysis, water solubility index, anti-nutrient oxalic acid, and anti-nutrient phytic acid) to demonstrate the safety and suitability of sweet potato as consumable products.

II. MATERIALS AND METHODS

A. Preparation of Sweet Potato Haulm Juice (SPHJ)

Sweet potato haulm (3 kg) was collected from Perlis Sweet Potato Farm in Kangar, Perlis, in February 2021. The haulm was obtained from purple-skinned and yellow-fleshed sweet potato plants (Figure 1). Upon collection, the withered and dried leaves, stalks, and stems were removed before being stored in a container in the chiller (4˚C). On the next day, the haulm was cleaned using running tap water to remove the remaining dirt and soil, and the remaining water was discarded using a salad spinner. The haulm was cut about 2 cm long each and juiced using a slow juicer (SAVTM JE-31).

From the haulm, 1.78 kilograms of juice and 0.96 kilograms of dregs were produced. The sweet potato haulm juice (SPHJ) was divided into two batches: i) unpasteurised SPHJ for the non-heat-treated sample, and ii) pasteurised SPHJ for heat-treated sample. For the unpasteurised SPHJ, the sample was transferred into an aluminium tray and frozen (-20˚C, 48 hours) before freeze-drying.

Meanwhile, the pasteurised SPHJ was pasteurised in a jacketed beaker (85˚C, 5 min) and immersed immediately in an ice-water bath to rapidly cool the juice down to room temperature (<20˚C, 30 min). The pasteurised sample was then transferred into an aluminium tray and frozen (-20˚C, 48 hours) before freeze-drying. All samples were performed in triplicate.

Figure 2: The haulm (stem, stalk, leaves) used in this study was obtained from the purple-skin, yellow-fleshed sweet potato plant

B. Preparation of Sweet Potato Haulm Juice Powder (SPHJP)

The frozen unpasteurised and pasteurised SPHJ were freeze-dried (Freeze Dryer FD-550, Eyela) (-20˚C, 3 Pa, 48 hours) to form the sweet potato haulm juice powder (SPHJP). The unpasteurised and pasteurised SPHJP is then grounded using mortar and pestle to get homogenised powder. All SPHJP

was sieved (75 μm), vacuum-sealed in aluminium pouches, and stored at -80˚C until further analysed.

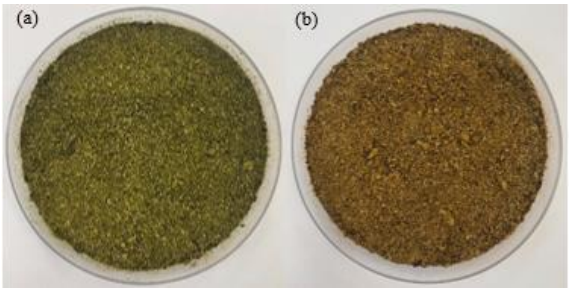


Figure 3: Unpasteurised (a) and pasteurised (b) Sweet Potato Haulm Juice Powder (SPHJP)

C. Water Activity, Colour Analysis and Physical Morphology

Water activity (a_w) was calculated using a water activity meter (AquaLab 4TE, Meter Food). Colour analysis of unpasteurised and pasteurised SPHJP was analysed using a colorimeter (LabScan XE Spectrophotometer, Hong Kong) using a CIE colour system according to the manufacturer's instructions. The physical morphology of SPHJP was analysed through Scanning Electron Microscopy (SEM) (Jeol, JSM-IT800, Japan).

D. Water Solubility Index

For warm water solubility index (WSI), a 1.0 gram of SPHJP was mixed with 12.5 mL distilled water in 50 mL centrifuge tube. The mixture was incubated in a water bath (37˚C) for 30 min before centrifuged at 10, 000 rpm (4˚C). For cold WSI, the samples did not undergo incubation and proceeded to centrifugation (30 min, 10, 000 rpm, 4˚C) (Hanil Combi, 514R, Korea). The supernatant was obtained and oven-dried (70˚C) to obtain the weight of dried solute in dry weight (dw) form [22- 24].

WSI (g/100 g dw) = Weight of dried solute/Weight of initial SPHJP × 100

E. Oxalic Acid Content

Oxalic acid content was determined based on calcium oxalate precipitation. The method involves titration of the sample's acidic aqueous extracts with a standard potassium permanganate solution [16]. SPHJP (0.5 g) was added with 25 mL distilled water, and the mixture was homogenised (8000 rpm, 3 min, 30˚C). The mixture was then purified with 6N hydrochloric acid (2.75 mL) and caprylic alcohol (2 drops), and incubated in a water bath (15 min, 95˚C). After the mixture was left overnight (16 hours, 30˚C), it was filtered using filter paper in a 50 mL falcon tube. The filtrate (25 mL) was added with tungstophosphoric acid reagent (5 mL) and left for 5 hours. The mixture was added with ammonium hydroxide (NH_4OH) until it reached pH 4.5.

The mixture was mixed with acetate buffer (pH 4.5, 5 mL) and left overnight (16 hours, 30˚C). The mixture was centrifuged (1700 rpm, 15 min, 30˚C), and the supernatant was discarded, leaving the precipitate. The precipitate was washed using cold wash liquid, and the decant process was repeated at least three times to obtain a purified precipitate. It was then dissolved with 5 mL of 10% sulphuric acid. Blank (5 mL 10% sulphuric acid) and sample were incubated in a water bath (95˚C) and titrated against 0.01N potassium permanganate ($KMnO_4$). The endpoint reading was the first persistent pink colour for more than 30 seconds. The calculation for oxalic acid content using the following formula:

Oxalic acid (mg/100 g dw) = [volume of $KmnO_4$ × 67.5 × (Net weight + 100 g)]/(Net weight × Weight of slurry)

Notes:
67.5 = 0.45 × [(30/20)] × 100 (convert to 100 mg),
0.45 = 0.45 mg anhydrous oxalic acid equivalent to 1.0 ml 0.01N $KmnO_4$

F. Phytic Acid Content

Megazyme Phytic Acid Kit and UV-Vis spectrophotometric method were used to determine phytic acid in SPHJP according to the manufacturer's instructions. This method is based on acid extraction of inositol phosphates and treatment with phytase, specifically for phytic acid (IP_6) and the lower *myo*-inositol phosphate forms (IP_2, IP_3, IP_4, IP_5). It was followed by treatment with alkaline phosphatase to release final phosphate from *myo*-inositol phosphate (IP_1) that withstands phytase action. The colourimetric method quantified the total phosphate available in the sample and expressed in milligrams of phosphorus per 100 g of sample material. UV-Vis spectrophotometer (Cary 50 Bio, UV-Vis, Malaysia) was used, and the readings were taken at an absorbance of 655 nm.

G. Statistical Analysis

The results were analysed statistically using Minitab Software for Windows (Minitab, Inc., USA). Student's t-test was used to analyse the significant difference between the nutritional concentration of unpasteurised and pasteurised SPHJP. The results were expressed in (M ± SD), with a significance level of $p<0.05$.

III. RESULTS AND DISCUSSIONS

TABLE 1. WATER ACTIVITY OF UNPASTEURISED AND PASTEURISED SWEET POTATO HAULM JUICE POWDER (SPHJP)

SPHJP	Water Activity (a_w)
Unpasteurised	0.40 ± 0.00^a
Pasteurised	0.34 ± 0.01^b

SPHJP: Sweet potato haulm juice powder, dw: dry weight basis
Values with similar letters within columns are not significantly different according to Student's t-test ($p<0.05$)
All the samples were analysed in triplicate

Table 1 shows the water activity of unpasteurised and pasteurised Sweet Potato Haulm Juice Powder (SPHJP). The pasteurised sample had a significantly reduced water activity in SPHJP by 0.06 a_w ($p<0.05$) (Table 1). Water activity is crucial in preserving the dehydrated product. The combination of heating and freeze-drying had been used to reduce free water, which indirectly reduced the deterioration of microbes in food [25].

TABLE 2. COLOUR ANALYSIS OF UNPASTEURISED AND PASTEURISED SWEET POTATO HAULM JUICE POWDER (SPHJP)

SPHJP	Colour Analysis			
	Lightness (L)	Redness (a)	Yellowness (b)	Total Colour Difference (ΔE)
Unpasteurised	32.32 ± 0.60[a]	1.40 ± 0.01[a]	22.70 ± 0.28[a]	5.98
Pasteurised	33.28 ± 0.24[a]	7.09 ± 0.09[b]	24.28 ± 0.38[b]	

SPHJP: Sweet potato haulm juice powder, dw: dry weight basis
Values with similar letters within columns are not significantly different according to Student's t-test (p<0.05)
All the samples were analysed in triplicate

TABLE 3. WATER SOLUBILITY INDEX (WSI) OF UNPASTEURISED AND PASTEURISED SWEET POTATO HAULM JUICE POWDER (SPHJP)

SPHJP	Water Solubility Index (g/100 g dw)	
	Warm	Cold
Unpasteurised	23.52 + 1.23^{Aa}	28.70 + 0.92^{Ba}
Pasteurised	24.30 + 2.83^{Ab}	31.36 + 1.75^{Bb}

Cold water solubility (no incubation, centrifuged at 10,000 rpm at 4˚C); warm water solubility (incubation at 37˚C for 30 min, centrifuged at 10,000 rpm at 4˚C)
SPHJP: Sweet potato haulm juice powder, dw: dry weight
Values with similar small letters within columns are not significantly different according to Student's t-test (p<0.05)
Values with similar capital letters between row are not significantly different according to Student's t-test (p<0.05)
All the samples were analysed in triplicate

From Figure 3, a noticeable colour change is observed between both samples. The Delta E (ΔE) value was 5.98 (Table 2), suggesting that the colour difference can be distinguished and is perceptible in a human's normal vision [26]. In our study, only lightness (L*) exhibited non-significant values between unpasteurised and pasteurised SPHJP (p>0.05). Positive a* and b* values indicated redness and yellowness of the SPHJP. Pasteurised SPHJP had a higher value of redness, which was 7.09, while unpasteurised SPHJP only had 1.40.

In food processing, enzymatic browning by polyphenoloxidase is prevented by dearaetion. Pasteurisation without deaeration to remove oxygen is known to cause losses of vitamin C and carotene [27]. Therefore, the changes of colour or browning of juice powder might be due to the absence of dearaetion prior to pasteurisation in this study. In this study, pasteurised samples can be seen in a darker colour, which might be attributed to the red or brown colour of the sample. In our study, the heat treatment applied on the SPHJP is higher than 80˚C and has shown deactivation of peroxidase enzyme activity.

However, the increasing temperature during pasteurisation without dearaetion probably causes some extent of enzymatic browning, which encourages the oxidation of phenols in pasteurised SPHJP. A low value of a* value in the unpasteurised sample also reflected a negative a* value (-a*), indicating that the sample's original green colour is preserved. Pasteurisation also significantly increased the yellowness value in SPHJP (p<0.05).

Pasteurisation is a heat treatment that can inactivate the peroxidase enzyme. However, pasteurisation can also cause discoloration in food and vegetable [28]. It can be visually seen that pasteurised sample was brownish, while the unpasteurised sample maintained a dark green colour (Figure 3). This may be due to common changes of chlorophyll to pheophytins when exposed to heat treatment and oxidation. Determining the phenolic compound in SPHJP and how it reacts to pasteurisation must also be carried out.

Table 3 shows the warm and cold Water Solubility Index (WSI) of unpasteurised and pasteurised Sweet Potato Haulm Juice Powder (SPHJP). For both warm and cold WSI, pasteurised SPHJP was more soluble than unpasteurized SPHJP (p<0.05).

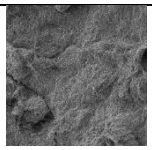
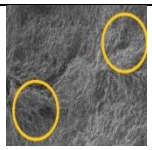
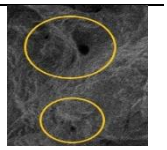
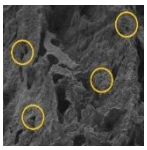
The solubility percentage for unpasteurised and pasteurised samples were higher than vacuum freeze-dried (5.71 g/100 g dw), hot air-dried (4.29 g/100 g dw), and microwave-vacuum dried (7.14 g/100 g dw) sweet potato leaves [7]. SPHJP also had a higher solubility index (g/100 g dw) in cold and warm water than purple potato flours, which were 5.8 to 20.0 g/100 g dw [29]. It could be hypothesized that heat treatment may increase the water solubility of SPHJP. Poor nutrient absorption is caused by low water solubility, which may also influence the solubility and absorption of nutrients in the lumen [30]. However, it is noteworthy that a 10% integration of low water solubility (29-38% WSI) chloroplast-rich spinach fraction in fish feed induces noticeable orange red (carotenoid) coloration in Zebra fish eggs and flesh [22, 31]. Regardless, this analysis showed that SPHJP might need additives like emulsifiers to be formulated as food and beverages that require a homogenous mixture. On the other hand, the SPHJP may be mixed as animal feed that does not dissolve easily when in direct contact with water, such as the floating fish feed.

Table 4 shows the porosity of unpasteurised and pasteurised Sweet Potato Haulm Juice Powder (SPHJP) obtained from Scanning Electron Microscopy (SEM) images. Based on Table 4, pasteurised SPHJP was more porous (marked as a yellow circle) in physical morphology than unpasteurised SPHJP. At 500x magnification, almost no or little sign of porosity could be seen in unpasteurised SPHJP, compared with the pasteurised SPHJP. The scanned images are consistent with the relation to the WSI, where pasteurised SPHJP was more soluble in water than unpasteurised SPHJP (Table 3). The microstructure of the powder is essential in determining the solubility of the substances, where a large surface area due to the porosity gives an advantage in solubility.

Pasteurised SPHJP has the potential to be utilised as a sustainable food source as it contains lower water activity and higher solubility in both warm and cold water compared to unpasteurised SPHJP. However, the determination of anti-nutritional composition in SPHJP will assess the safety aspect of SPHJP.

Anti-nutrients are natural or synthetic compounds that intervene with micronutrients' bioavailability [32]. The underutilised green leafy vegetables contained antinutritional elements such as oxalates, tannins, and saponins [33].

TABLE 4. POROSITY OF UNPASTEURISED AND PASTEURISED SWEET POTATO HAULM JUICE POWDER (SPHJP)

SPHJP	Magnification		
	500x	1000x	3000x
Unpasteurised			
Pasteurised			

Yellow circle: porous structure of the powder

Oxalic acid and oxalates exist in different amounts and levels in various plants, such as leafy vegetables. In plants, these compounds act as a mechanism for self-defence against insects, pests, and other animals and play a role in the photoremediation of toxic soils caused by heavy metals [34]. However, for humans, oxalic acid is one of the anti-nutrients that can distort mineral availability in our bodies. A high concentration of oxalates may cause the development of kidney stones. Oxalates are present in the forms of soluble and insoluble in water. Water-soluble oxalates are bound to calcium and magnesium ions, while water-insoluble oxalates are bound to sodium and potassium ions [35]. Therefore, any vegetables high in this compound should not be consumed in large amounts [35]. Phytic acid is another anti-nutritional factor that may chelate with minerals and essential nutrients. The ingestion of phytic acid through diets may lead to iron and zinc deficiency [32]. Phytic acid has a negative-charge structure, usually bound to positively charged metal ions such as iron, zinc, calcium, and magnesium, to form complexes. Therefore, phytic acid directly decreases the absorption rate of these minerals into the human body [37]. Table 5 shows the anti-nutritional content (oxalic acid, phytic acid) of unpasteurised and pasteurised Sweet Potato Haulm Juice Powder (SPHJP).

TABLE 5. ANTI-NUTRITIONAL CONTENT OF UNPASTEURISED AND PASTEURISED SWEET POTATO HAULM JUICE POWDER (SPHJP)

SPHJP	Oxalic Acid (mg/100 g dw)	Phytic Acid (mg/100 g dw)
Unpasteurised	1038.66 ± 65.18[a]	40.00 ± 0.00[a]
Pasteurised	767.89 ± 63.45[a]	10.00 ± 0.00[b]

SPHJP: Sweet potato haulm juice powder, dw: dry weight basis
Values with similar letters within columns are not significantly different according to Student's t-test (p<0.05)
All the samples were analysed in triplicate

Several heat-treatment food processing processes, such as heating and boiling, have been proven to boost nutrient bioavailability by inactivating anti-nutritional components of green vegetables and beans [38 - 40]. The amount of calcium bound to the insoluble oxalate is also higher in raw leaves than in boiled leaves, suggesting that heat treatment might reduce the formation of calcium oxalate [35].

Research on thirteen types of underutilised green leafy vegetables (non-tubers) shows the concentration of total oxalate content to be approximately 10-690 mg/100g fresh weight or 66-4599 mg/100 g dw [33]. Our study found that unpasteurised SPHJP contained 1038.66 mg/100 g dw while pasteurised SPHJP contained 767.89 mg/100 g dw of oxalic acid (Table 5), indicating that sweet potato haulm could be a better option than the underutilised green leafy vegetables studied by Gupta et al (2005) [33] for human consumption. Moreover, compared to the findings by Ooko Abong' et al. (2020) [17], leaves from Kenyan's orange-fleshed sweet potato, Kabode and Yellow sp varieties consisting of 1369.09 and 1618.71 mg/100 g dw, showed a higher number of oxalates than both SPHJP. In other studies, boiled fat hen leaves had a lower total oxalate (682.79 mg/100 g dw) than raw leaves (1112.40 mg/100 g dw).

The total amount of oxalate in blended and masticated spinach juice was much higher (3302.58-7638.27 mg/100g dw) than unpasteurised and pasteurised SPHJP [36]. Spinach is usually used as green juice because of its availability and low-priced; hence, this study provides another alternative for green spinach, with a much lower level of oxalic acid. Another reason slow-juicing methods are preferred compared to blending is the presence of oxalates in the fibre. The primary mechanism of slow juicing is to extract the juice from its main ingredient without including its pulp. In this study, haulm dregs (by-product) were not included in the juice, lowering the oxalic acid levels. It had been proved that the discarded fibre spinach juice had reduced oxalates compared to the thick blended juice [36]. Meanwhile, more analysis on the total, soluble, and insoluble oxalates in sweet potato haulm must be determined in the future. The previous study showed that insoluble oxalates do not affect the digestion system as much as soluble oxalates, as they can pass through and be discharged without being absorbed.

Based on Table 5, a significant reduction was detected in phytic acid levels of unpasteurised SPHJP (40 mg/100g dw) and pasteurised SPHJP (10 mg/100g dw) (p<0.05). This showed that the pasteurisation process could enhance the reduction in phytic acid in the sweet potato leaves. Heat treatment at 90˚C decreased the phytate level (74.6%) in the curry leaf (*Ocimum canum sims* L.) while heating at 90˚C for 15 minutes significantly caused a loss in all anti-nutrients such as oxalate, phytate, tannin, and cyanides [41]. In addition, obtained phytic acid values in both SPHJP in this study were lower than the leaves of Kenyan's orange-fleshed sweet potato, which ranged from 1.14-5.33 g/100 g dw [17]. Spinach leaf flour also contained higher phytate values than unpasteurised and pasteurised SPHJP, which are around 2.4 and 4.5 mg/g dm [42].

Other studies showed an interaction between protein and phytate where an anionic phosphate group of phytate binds with the protein cation, pH-dependent, and availability of amino acid [43 - 45]. The protein content might contribute to the decrease of phytic acid. Previous studies showed protein composition has reduced due to heat treatment, for example, pasteurisation and cooking. Cooked sweet potato leaves have a lower protein content than uncooked sweet potato leaves [46]. However, the protein content in the unpasteurised and pasteurised SPHJP was insignificant to each other [9]. Under pH 3.5, this insoluble complex will dissolve, and protein

binding sites of phytate occur at low pH [43]. Meanwhile, this protein-cation-phytate complex can solubilise in the presence of multivalent cation. Therefore, it is suggested to study the pH value of unpasteurised and pasteurised SPHJP to study the mechanism of phytate and protein interaction.

In general, pasteurised SPHJP consisted of a lower phytic acid amount ($p<0.05$) than unpasteurised SPHJP. It is suggested that sweet potato haulm should be pasteurised upon consumption due to the lower anti-nutrient availability as revealed. This study also disclosed that sweet potato haulm juice may be a substitute for spinach juice, revealing its potential as a sustainable source of nutrients from waste.

Alternatively, this plant can be grown for its consumable tubers, and its haulm can be used for nutrient extraction, useful food products, used in the industry as biofertiliser, biofuel and others, to be upcycled back to Malaysia's economy. For example, sweet potato leaves are known for the content of bioactive phytochemical compounds [19], and significantly, this waste contributes greatly to the biomedical sector. This is because turning waste into biomaterials to be used in tissue regeneration is one of the effective waste management [4]. The nature of these biomaterials as biodegradable, environmental-friendly substances allowed their utilisation in drug delivery and wound restoration, helping the financial stress faced by the healthcare system [5].

Further study should be conducted on the effect of different temperatures of juice processing on the anti-nutrient content in the SPHJP. This aims to connect information on how temperature plays a significant role in reducing oxalic and phytic acid levels, indirectly to cater to the nutrient's availability issue. It has been confirmed that anti-nutrients could become another threat to the existing beneficial nutrients. Hence, the content of other anti-nutrients, such as tannins and cyanide, should also be determined.

Meanwhile, pasteurisation process aims to establish safety precautions for food products, and the data provided in this study provides preliminary information that pasteurised SPHJP contains low water activity compared to unpasteurised SPHJP. However, it is advised to study the microbiological aspect of SPHJP to aid the safety of SPHJP to be consumed by humans or animals. The determination of calcium, potassium, magnesium, and sodium should be carried out to confirm the anti-nutrient in SPHJP will reduce the micronutrient's bioavailability. In addition, more data on the physical characteristics of powder, like hygroscopicity and dispersibility, should be set up. It is recommended to analyse antioxidant compounds such as carotenoids or flavonoids' fractions, and this can add information regarding the benefits of SPHJP.

IV. CONCLUSIONS

Although pasteurised sweet potato haulm juice powder (SPHJP) developed discolouration, it contained lower water activity and phytic acid amount and a higher water solubility index than the unpasteurised SPHJP ($p<0.05$). However, the pasteurisation process did not significantly reduce the oxalic acid level in SPHJP ($p>0.05$). On the other note, this study gave an early perception of pasteurised SPHJP to be used as safe food products.

Future research should focus on assessing the effectiveness of pasteurisation in reducing other anti-nutrients, such as tannins and cyanides in SPHJP. More understanding of the oxalic content can be done by analyzing the total, soluble, and insoluble oxalates in sweet potato haulm. This study showed that heat treatment like pasteurisation is crucial when valorising green waste. Heat treatment can reduce anti-nutrient concentration, increasing its potential to be further utilized as a replacement for other green vegetables, such as spinach, for human consumption or animal feed.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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