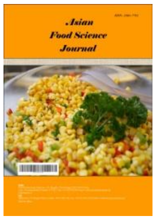

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Quantification of Nutritional Composition and Some Antinutrient Factors of Banana Peels and Pineapple Skins

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Authors' contributions

This work was carried out in collaboration among all authors. Author NFMB managed the literature review, analyses of samples, performed the statistical analysis and write the manuscript. Author ZI designed the study, write the protocol and provided the samples of study. Author AZJ conducting the analyses of sugar using the instruments and editing the manuscript. Author HH editing the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Agricultural wastes are by-products generated from growing and processing of agricultural commodities such as vegetables, fruits, meats, poultry and crops. The modernisation of agricultural practises creates huge number of wastes namely animals' carcass, seeds and skins from crop and also trace of pesticide, along the chain. If these wastes are released without proper disposal procedure, it may cause negative effects to environment and jeopardize human health. Banana and pineapple are amongst the most common crops cultivated in tropical countries. With its bright colour, juicy delicious flesh, and well-studied beneficial compounds, these two fruits are being enjoyed as fresh consumption or in the form of food products like chips and jam. Unfortunately, the peel and the skin are currently being dumped to the landfill as waste. The objective of our study was to evaluate the chemical composition of banana peel and pineapple skin, in order to explore the utilisation of these so-called wastes as food ingredients. The samples were analysed for nutritional composition, anti-nutrients level and sugar profile. Proximate analysis according to AOAC 2000 method were conducted to collect the nutritional composition of samples, antinutrients

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factors were study via spectrophotometery analysis and sugar profile were achieved by using HPLC-ELSD method. The results showed that ash, moisture, fat, protein were in the acceptable level (7.0±0.14, 7.55±1.48, 13.95±1.62, 5.0±2.82, 67.25±3.80 g/100 g respectively for banana peels and 3.49±0.02, 8.65±0.87, 0.38±0.07, 4.84±1.73 and 83.31±3.49 g/100 g for pineapple skins respectively) and acceptable levels of tannin and phytic acid for both samples. Analysis of sugar profile revealed that these high values agricultural waste contain fructose, glucose and sucrose – potentially being utilised as a good source of sweetners. Finally, we recommend that banana peels and pineapple skins should properly be processed and exploited as a high quality and inexpensive source of food ingredients.

Keywords: Banana peel; pineapple skin; nutritional composition; antinutrients factor; sugar profile.

1. INTRODUCTION

Agricultural intensification during the past decade have increased production of various farming products. This have been enhanced by state of the art agriculture technologies which been embedded as part of the industry. Due to the intensification of agricultural practise, grain production especially wheat, rice and maize, increased at a greater rate than human population [1]. Recent review indicated that demand for tropical fruits like mango, jackfruit and durian were substantially fulfilled, thanks to modernisation of agriculture [2]. In addition, looking into the current scenario of tropical waste utilization, the same author deduced that mango was the most popular tropical fruits with production of 30 million tonne, followed by pineapple with 7 million tonne and papaya 5 million tonne per year. The production value was reflected from consumer demand into these horticultural commodities. However, the notable increase of agricultural activities likewise increased its waste production. Waste production can be defined as waste material produced from agricultural activities—including residue from growing and processing of raw agricultural products such as fruits, vegetables, meat, dairy products and others [3]. A comprehensive review by Sagar et al. [4], distinguished that losses and waste of horticulture commodities happen along the food chain – from the harvesting, transporting to packaging house or market, classification and grading, storage, marketing, processing, and at home before or after processing. Furthermore, Sadh et al. [5] hold the view that most of the agro -industrial wastes were untreated and underutilized and finally ending up being burned or dumped, accumulating unplanned landfilling. This scenario leads to environmental problem such as the increase of methane gasses production, contributing directly to greenhouse effects and climate change. Hence, waste management is set to become a vital factor in agricultural industries especially exploring the potential use of these waste products [4]. Scientist have always realised that agricultural waste was high in nutritional properties, possess antimicrobial activities and could be a good source of other product formation or development. It is suggested that the potential use of agricultural wastes can briefly be divided into food application like food additives, obesity remedy and edible coating and films and non-food application such as bio sorbents, the pollution removal; biogas and also biofuel [2].

Banana (*Musaceae* family) is one of the important crops in the world due to its multifunctional properties and good taste. It has been mass cultivated worldwide. The world main producers of banana and plantain were India, China, Uganda, Ecuador, Philipines and Nigeria [6]. Production of banana in Malaysia was 330,597 tonnes with a worth value of RM 552 697 rendering banana as the second largest horticulture product in Malaysia, after the durian [7]. Banana is known for its various health benefits, making it a valuable commodity for food industries. Since banana is a huge industry, it generates enormous waste that could be explored as valuable raw materials. Recent finding showed that banana peel is an organic waste that is highly rich in carbohydrate and other basic nutrients that could potentially support microbial growth [8]. Banana peel has received much attention as it contains high amount of starch (3%), total dietary fibre (43.2-49.7%), polyunsaturated fatty acids, particularly linoleic acid, pectin and micronutrients like K, P, Ca, Mg [9].

The pineapple (*Ananas comosus*) is a popular tropical fruit with an attractive yellow flesh and tastes incredibly delicious. There are abundant reports suggesting pineapple beneficials for human health. It is packed with beneficial compounds that contain enzymes, vitamins, antioxidants and lots more nutrients which good for immune booster and healing process from surgery [10]. In 2018, about 322,460 tonnes of pineapple with a worth value of RM 600,580.85 were produced in Malaysia. Based on the above said figure, we could conclude that pineapple itself is a huge agricultural industry. Pineapples were normally consumed fresh, but the processing food industry has turned this horticulture produce into processed products such as canned food, jam, jellies, pickle etc. In turn, massive production of pineapples translates to massive waste products. Research has validated that pineapple waste contain beneficial compound as good as the fruit itself. Roda and Lambri [11] had listed the good nutrients in pineapple waste comprising insoluble fibres, simple sugars, vitamins, good enzymes such as bromelain. This review paper also concluded that pineapple waste has a great potential to be explored as a valuable substrate if appropriate processes and technologies are applied accordingly.

Regardless of the various report on potential use of the banana and pineapple waste as a potential food ingredient, previous studies have been limited to the nutritional compositions. Investigation into the antinutritional composition are still inadequate. Antinutritional factors are primarily associated compounds or substances of natural or synthetic origin, which interfere with the absorption of nutrients, and act to reduce nutrient intake, digestion, and utilization and may produce other adverse effects [12]. Nausea, bloating, and headaches were some of the symptoms associated when large quantity of antinutrients enter the body. Currently, antinutrients that could be found in grain, legumes, roots, seeds or peels include tannin, phytate, lectin and protease inhibitor. Plant tannins have become a subject of interest for researcher around the world due to its multifunctional properties for the human body. This compound display antinutrients function by impairing the digestion of various nutrients and preventing the body from absorbing beneficial bioavailable substances [13]. This compound was also reported to inhibit digestibility of protein [14]. Phytic acid is another plant constituent that have highly variable amount in seeds, legumes, grains and nuts. It is store as phosphorous which is an essential mineral information of energy and cell membranes [15]. Previous study showed that phytic acid acts by blocking the absorption of minerals such as Ca, Fe and Zn [13].

Studies in waste management and exploring the use of agricultural waste as antinutrient are most needed, as an effort to overcome both environmental pollution and seasonal food farming losses [2,4,11]. The aim of our work was to increase the current understanding on nutritional composition and level of antinutrient factors in high value agricultural waste in Malaysia. We undertook this study to acquire respective profilings of these waste compounds and to suggest its application in product formation and development.

2. MATERIALS AND METHODS

2.1 Preparation of Samples

Banana peel (variety Pisang Abu) and pineapple skin (variety MD2) were obtained from procuring whole fruits from Pasar Borong Sri Kembangan, Selangor. These two varieties were chosen as it was widely consumed among population. The fruit skins were processed by washing, air drying and peeling manually to separate its skin from the flesh. The skins were chopped into small pieces before grinding into flour prior to analysis.

2.2 Determination of Nutritional Composition

In order to investigate the nutritional composition of the samples, proximate analyses were carried out to study the level of moisture content, ash, protein, fat, carbohydrate and total energy. Procedure to determine moisture, ash, protein and fat content; were done according to the method described in Association of Official Analytical Method (AOAC) 2000 [16]. Digestible carbohydrates were calculated by the difference method. Gross energy or calories percent of the samples were calculated from the data obtained on proximate analysis by multiplying the percentage of crude protein and carbohydrate with 4.0 and crude fat with 9.0, respectively. The values were then converted to calories per 100 g of sample.

2.3 Determination of Sugar Profile

Our experimental set up is practically the same as proposed by Wilson et al. [17]. Sample preparation was initiated by dissolving 250 mg of grind sample with 25 ml distilled water and shake for 30 mins in shaker (Labwit ZHWX-304 Orbital Shaker). From the mixture, 10 ml of aliquot was removed and mixed 10 ml of methanol, followed by centrifugation at 43 000 rpm for 5 mins (Sigma 2-16K Sartorius Centrifuge). After passing the supernatant through RC filter (2μl), 2.5 ml was collected. 5 ul samples were injected into HPLC - ELSD (Waters, 2996). Sugar were separated by a carbohydrate column (Waters Spheriscorb 5 μm NH_2 4.0 x 250 mm), using a solvent of Acetonitrile: water (85:15/v:v). The flow rate was 1.0 ml min $^{-1}$. Identification and quantification of major sugars present in the samples were achieved by comparing each peak retention time and peak area with those of the standard. Sugar standards were made for glucose, fructose and sucrose. A standard curve for each sugar was prepared by injecting different concentrations of the solution and plotting HPLC peak areas versus sugar concentrations in the standards.

2.4 Determination of Antinutrient Factors

2.4.1 Determination of tannin

The experimental set up on determination of tannic acid was based on work done by Shakira et al. [18] and it was proposed by Makkar [19] with slight medification. Dried (finely ground sample, 0.2 g) was soaked in 25 ml of 70% acetone in 25 ml beaker and suspended in an iced ultrasonic water bath and subjected to ultrasonic treatment for 20 mins (2 X 10 min with 5 min break in between). The contents of the beaker were then subjected to centrifugation for 10 min at approximately 3000 rpm at 4°C (Sigma 2-16K Sartorius Centrifuge). The supernatant was filtered using Whatman No 1 filter paper and continue keeping in ice. Three concentration of filtrate was taken, made up to 0.5 ml with distilled water and put on 500 μl of Folin-Ciocalteau reagent. The mixture was then added 0.5 ml distilled water and 1.5 ml of Na_2CO_3. It was then vortexed, incubated for 40 mins at room temperature. Absorbance of sample and tannin standards was read against blank at 725 nm. Result was expressed as % tannic acid.

2.4.2 Determination of phytic acid

The procedure used was described by Latta and Erskin [20]. A 0.5 g of dried sample was weighed into 250 ml conical flask. The initial extraction was done with 2.4% 25 ml HCl, whereas sample was shake in orbital shaker (Labwit ZHWX-304 Orbital Shaker) for an hour at room temperature and then centrifuge at 3000 rmp for 30 mins (Sigma 2-16K Sartorius Centrifuge). A 3 ml clear supernatant was transferred into test tube for the phytate analysis. A 1 ml of Wade reagent (0.03% solution of $FeCl6H_2O$ containing 0.3% sulfosalicylic acid in water) to the test tube and vortex for a minute. Sample was read at 500 nm absorbance (Microplate Reader EON, Biotek) and phytate was quantified from a standard calibration curve of phytic acid (2 to 10 mg/ml). Result was expressed as phytic acid, g/100 g.

2.5 Statistical Analysis

All data collected were expressed in triplicate and reported as mean ± SD (standard deviation). Statistical analyses were performed in Statistical Analysis Software (SAS) package (version 9.1.4 of SAS Institute, Inc. Cary, NC, 2008). In case of significant effects, means were determined by one way Analysis of Variance (ANOVA) then compared using Duncan Multiple Range Test (DMRT) to determine significances between the means. Effects were considered significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Nutritional Composition of Banana Peel and Pineapple Skin

Nutritional composition of agriculture waste comprises of banana peel and pineapple skin are illustrated in Table 1. The result of nutritional compositions obtained from the proximate analysis presented a brief insight into the quality of the tested samples. The average mean for the ash and moisture content of banana peel was 7.0±0.14 g/100 g and 7.55±1.48 g/100 g. This data was in agreement with the study done by T. Happi Emaga et al. [9] (6.4 to 12.8%), Vu et al. [21] (8.33%) and Anhwange et al. [22] (8.5% and 6.70%). All studies including present study produced similarly results, in which ash and moisture content were in the same range (6-8%), respectively. Moniruzzaman et al. [23], highlighted that the ash content value could be related to the number of minerals in food, hence indicating that banana peel as a good source of minerals. Result of moisture content showed good promising usage of banana peel with minimally pretreatment needed for storing without growing moldy. The correlation between moisture content and long-term usage of sample is worth mentioning because according to Hausman et al. [24], products with lower water content, generally are less subject to degradation by microorganisms and chemical changes. For the pineapple skin, the ash content was reported as 3.49 g/100 g which is intermediate in value between work done by Pardo et al. [25] (1.5 g/100 g) and Abdullah and Hanafi Mat [26] (4 g/100 g). Furthermore, Morais et al. [27] also discovered the value for ash content in pineapple skin was 1.5 g/100 g, while indicating no significant differences between raw and processed peel. Minerals are micronutrient that are essential for maintaining human health, thus our observation support the fact that banana peel and pineapple skin as a reliable source of minerals and good for human health.

The fat content of banana peel was calculated as 13.95 g/100 g and it is correlate favourably well with P.Wachiarasiri et al [28] (13.1 g/100 g). We detected a much higher value for fat content than reported by both T. Happi Emaga et al. [9] (4.2-9.5 g/100 g) and Feumba et al [29] (8.40 g/100 g). Fat content of pineapple skin was recorded at 0.38 g/100 g and this value was almost double than reported by Abdullah and Hanafi Mat [26] (0.15 g/100 g). However, our finding contradicted with earlier work done by Kodagoda and Marapana [30] and Feumba et al. [29], which found much higher fat content in their sample 4.78 g/100 g and 5.31 g/100 g, respectively. Different type of cultivar and botanical factor such as geographical or location of the planted fruits might contribute to the differences in value. As suggested by Syarifah Khadijah et al. [31], there are no specific trend for fat content of banana peel. A lower fat content will minimise the risk of rancidity - which in turn provides good prospect for further exploration as a premium food ingredient. We found out that the protein content of the banana peel was 5.00 g/100 g samples. Our study showed consistencies with previous studies conducted by Abdullah and Hanafi Mat [26] (5.18 g/100 g), Abubakar et al. [32] (5.53 g/100 g) and Hassan and Peh [33] (5.3 g/100 g), respectively. The protein content of pineapple skin was calculated as 4.84 g/100 g. While this value was higher than study done by Pardo et al. [25] (0.75 g/100 g), it is more similar to the report by Kodagoda and Marapana [30] (5.04 g/100 g). Our finding implies that both samples, banana peel and pineapple skin contain a good level of vital nutrients like fat and protein. However, the low level of protein in sample may due to the fact that fruits is not recognized as the main source of proteins in our food pyramid. Thus, evident from this study may support the utilization of banana peel in various products. High carbohydrate content showed by both of the sample may suggest it is a good source of energy provider for any food product development particularly breakfast meal.

3.2 Sugar Profile of Banana Peel and Pineapple Skin

HPLC chromatographic profiles of banana peel showed only three types of sugar are detected i.e. fructose, glucose and sucrose as demonstrated in Fig. 1. The value content of our sample as shown in Fig. 3 were 2.2, 1.35 and 1.65 g/100gper g sample for fructose, glucose and sucrose, respectively. This result concurs well with result published by T. Happi Emaga et al. [9] where the value of three soluble sugars are in the range of 0.1% to 2.6% for fructose and 0.3% to 15.6% for glucose. Similarly, this value is also consistent with the work done by Adão and Glòria [34] (6.27, 4.63 and 0.39 g/100 g for fructose, glucose and sucrose, respectively). The content increased proportionally with increasing number of ripening days. This finding supported the previous evidence that fructose was higher than glucose in all cultivars [9]. The most significant changes that happen during banana ripening is the biochemistry transformation of starch content into soluble/simple sugars. Investigation done by Loeseck [35], indicated that the relative proportions of these constituents are depended on the stage of maturity and on the variety. Preliminary findings on the level of sugar in banana peel has considerable promise especially in gaining economical profits. Increasing demand for production of commercial sugar derived from waste, could potentially make use of banana peel into an important raw material in food industry [36]. Analysis of sugar in pineapple skin, also indicated three major types of similar sugar namely sucrose, glucose and fructose. Fig. 2 shown the chromatogram of sugar profile from pineapple skin. Fructose were dominant in the sample with level of 10.307 g/100 g, followed by glucose at 9.119 g/100 g. Our trend is similar to those of Abdullah and Hanafi Mat [26], where fructose and glucose were found to be slightly higher than sucrose in their pineapple skin sample (12.17, 8.24 and 0.00 g/100 g for fructose, glucose and sucrose respectively). The author suggested that pineapple waste can potentially be used as carbon source for organic acid fermentation due to the good level of this chemical fermentation.

Table 1. Nutritional composition of banana peel and pineapple skin

Samples	Banana peel	Pineapple skin
Ash,g/100g	7.0±0.14[a]	3.49±0.02[b]
Moisture g/100g	7.55±1.48[a]	8.65±0.87[a]
Fat, g/100g	13.95±1.62[a]	0.38±0.07[b]
Protein, g/100g	5.00 ±2.82[a]	4.84±1.73[a]
Carbohydrate, g/100g	67.25±3.80[b]	83.31±3.49[a]
Energy value, kcal/100g	415.5±9.19[a]	358.02±1.53[a]

Data was expressed as mean±SD, each value is a mean of triplicate reading (n=3), means with different lower case letters in the same row are significantly different (p = .05)

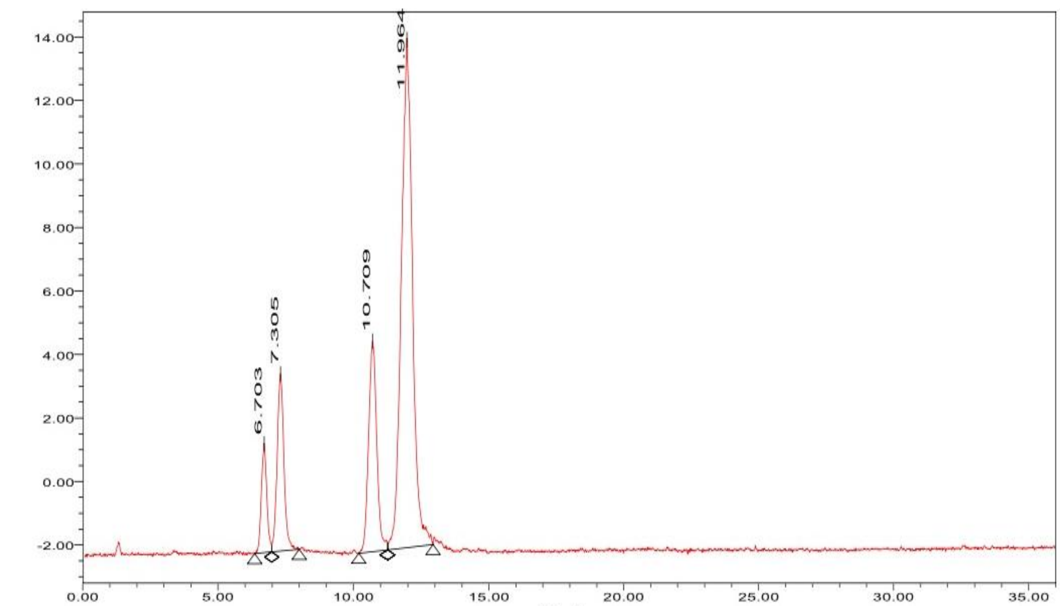

Fig. 1. HPLC chromatogram of sugar profile from banana peel

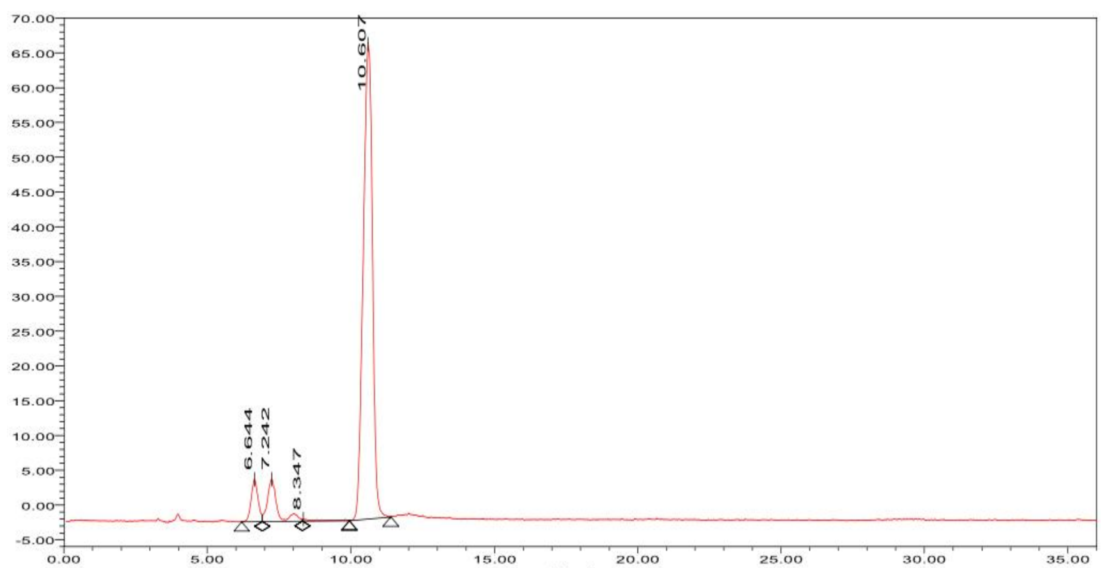

Fig. 2. HPLC chromatogram of sugar profile from pineapple skin

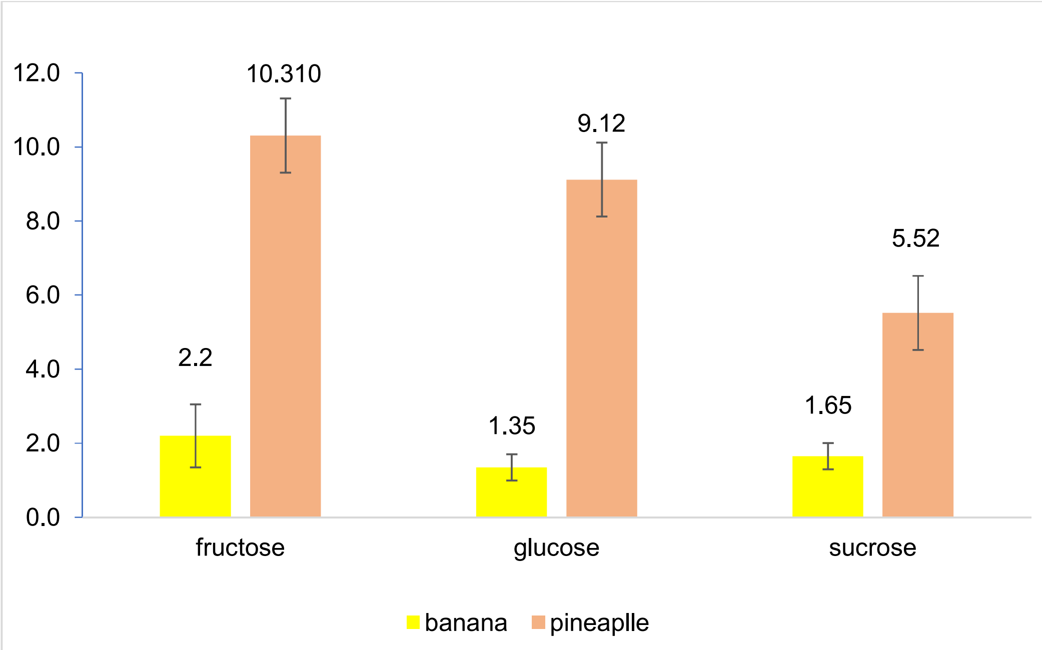

Fig. 3. Bar chart of sugar content from banana peel and pineapple skin

3.3 Antinutritional Content of Banana Peel and Pineapple Skin

Table 2 illustrated the antinutritonal content of our sample. Study on the antinutritional factor in banana peel revealed that phytic acid content was 0.79 mg/100 g. This value was higher from Anwahge et al. [22] and Adenji et al. [37] which both found the level of the phytate in their sample was 0.28 mg/100 g. Maniyan et al. [38] also discovered lower phytic acid in their sample, 0.40 mg/100 g. We found phytic acid in pineapple skin was 0.28 mg/100 g. This amount is lower than reported by Feumba et al. [29] (1.99 mg/100 g) but higher than the study done by Ukanwonko and Nwachuku [39] (0.09 mg/100 g). Determination of tannic acid in banana peel waste discovered the content of this compound was 0.083 mg/100g. This value was between 0.04 µg/ml discovered by Maniyan et al. [38] and 0.28 mg/100 g found by Anhwange et al. [22]. We found much lower value for tannic acid in our pineapple skin sample with respect for those reported by Ukanwonko and Nwachuku [39] (5.02 mg/100 g). An experiment undertaken by Sabahelkhier et al. [40] on chemical composition and effect of maturity stage on protein fractionation, discovered that level of tannic acid for 45 maturity days was 4.5 mg/100 g. Different cultivar and botanical factor of planted banana may contribute to the variability of the results. The presence of these antinutrients in the human diets may avert the digestion and bioavailability of nutrients. They reduce to mineral bioavailability and protein absorption of foods thanks to their chelating properties. The causes to micronutrient malnutrition and mineral deficiens [13]. High level of tannin reduces the digestibility of the protein, because tannin content acts as antienzymatic activity. Pre treatment on the raw material including heat processing, soaking or fermentation, should be carried out in proper manner to reduce the level of this antinutriets prior to its utilization.

Table 2. Antinutrients factor in banana peel and pineapple skin

Samples	Phytic acid (mg/100g)	Tannic acid (mg/100g)
Banana peel	0.79±0.02[a]	0.083±0.02[b]
pineapple skin	0.29±0.02[b]	1.38±0.16[a]

Data was expressed as mean±SD, each value is a mean of triplicate reading (n=3), means with different lower case letters in the same column are significantly different (p =.05)

4. CONCLUSION

As per result presented in this paper, we discovered that both agricultural wastes used in this study i.e. banana peel and pineapple skin, contain good level of nutritional value while simultaneously having levels of antinutrient below the safety threshold. The results from the nutritional value study suggest that banana peel and pineapple skin are valuable raw material with good potential to be utilized in food industry. The potential economic benefits which may arise from the utilization of this cheap material as a source of food ingredients have prompted the evaluation of this materials as a coating, thickening agent which refer to pectin, source of good dietary fibre that benefit the digestion system and also others health advantages such as anti inflammatory agent. The evidence of this study implies that banana peel and pineapple skin has potential, both from nutritional and functional properties to be applied in food processing and subsequently become commercially viable products. Future studies on how to enhance its nutritional and functional properties via various method are therefore recommended to establish the utilization of these compound in food industry.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. David Tilman. Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. Proceedings of the National Academy of Sciences. 1999;96(11):5995-6000.
2. Cheok, Choon Yoong., Mohd Adzahan, Noranizan., Abdul Rahman, Russly., et al. Current trends of tropical fruit waste utilization. Critical Reviews in Food Science and Nutrition. 2018;58(3):335-336.
3. Obi FO, Ugwuishtwu BO, Nwakaire JN. Agricultural waste concept, generation, utilization and management. Nigerian Journal of Technology (NIJOTECH). 2016; 35:957-964.
4. Sagar NA, Pareek S, Sharma S, Yahia EM, Lobo MG. Fruit and vegetable waste: Bioactive compounds, their extraction, and possible utilization. Comprehensive Reviews in Food Science and Food Safety. 2018;17(3):512-531.
5. Sadh PK, Duhan S, Duhan JS. Agro-industrial wastes and their utilization using solid state fermentation: A review. Bioresour. Bioprocess. 2018;5:1-15.
6. Padam BS, Tin HS, Chee FY, Mohd Ismail A. Banana by-products: An under-utilized renewable food biomass with great potential. J Food Sci Technol. 2014; 51(12):3527-3545.
7. Agrofood Statistics 2018. Planted area and production of selected fruits, 2013-2018. Kuala Lumpur: Policy and Strategic Planning Division, Ministry of Agricultural and Agro based Industries; 2018.
8. Ibtisam Kamal. Transformation of refuse banana waste to value-added products. Technical report; 2015.
9. T Happi Emaga, Andrianaivo RH, Wathelet B, Tchango JT, Paquot M. Effect of the stage of maturation and varieties on the chemical composition of banana and plantain peels. Food Chemistry. 2007; 103:590-600.
10. Rayman RMS. 8 impressive health benefit of pineapple. Healthline.
Accessed 26 May 2018.
Available:https://www.healthline.com/nutrition/benefits-of-pineapple
11. Roda A, Lambri M. Food uses of pineapple waste and by-products: A review. Int J Food Sci Technol. 2019;54:1009-1017.

12. Popova A, Mihaylova D. Antinutrients in plant-based foods: A review. The Open Biotechnology Journal. 2019;13:68-76.
13. Hendek Ertop M, Bektaş M. Enhancement of bioavailable micronutrients and reduction of antinutrients in foods with some processes. Food and Health. 2018; 4(3):159-165.
14. Zia-ur Rehman, Shah WH. Thermal heat processing effects on antinutrients, protein and starch digestibility of food legumes. Food Chemistry. 2005;91:327-331.
15. Jasia Nissar, Tehmeena Ahad, Naik HR, Hussain SZ. A review phytic acid: As antinutrient or nutraceutical. Journal of Pharmacognosy and Phytochemistry. 2017;6(6):1554-1560.
16. AOAC, Official methods for analysis, 14th Edn., Washington DC: Association of Official Analytical Chemists; 1984.
17. Wilson AM, Work TM, Bushway AA, Bushway RJ. HPLC determination of fructose, glucose and sucrose in potatoes. Journal of Food Science. 1981;46:300-301.
18. Shakirah OA, Lasekan O, Jinap S, Rabiha S. Physico-chemical properties, asid amino profile and antinutritional factors in seeds of three Malaysian grown jackfruit cultivars. Journal of Food, Agriculture & Environment. 2015;13(2):58-62.
19. Makkar HPS. Treatment of plant material, extraction of tannins and an overview of tannin assays presented in the manual. Quantification of tannins in tree and shrub foliage. Amsterdam: Kluwer Academic Publisher; 2003.
20. Latta M, Eskin M. A simple and rapid colorimetric method for phytate determination. J.Agr.Food Chem. 1980; 28: 1313-1315.
21. Vu HT, Scarlett CJ, Vuong QV. Effects of drying conditions on physicochemical and antioxidant properties of banana (Musa cavendish) peels. Drying Technology. 2016;35(9):1141-1151.
22. Anhwange BA, Ugye TJ, Nyiatagher TD. Chemical composition of musa sepientum (Banana) peels. Electronic Journal of Environment, Agriculture and Food Chemistry (EFAFChe). 2009;8(6):437-4442.
23. Moniruzzaman, Mohammed, Chowdhury M, Rahman Mohammad, Sulaiman, Siti Amrah, Gan Siew. Determination of mineral, trace elements and pesticide levels in honey samples originating from different regions of Malaysia compared to Manuka Honey. Biomed Res Int., Article ID 359890. Hindawi Publishing Corporations; 2014.
24. Hausmann B, Knorr KH, Schreck K, et al. Consortia of low-abundance bacteria drive sulfate reduction-dependent degradation of fermentation products in peat soil microcosms. ISME J. 2016; 10(10):2365-2375.
25. Pardo MES, Cassellies MERC, Escobedo RM, García EJ. Chemical characterisation of the industrial residues of the pineapple (Ananas comosus). Journal of Agricultural Chemistry and Environment. 2014;3:53-56.
26. Abdullah and Hanafi Mat. Characterisation of solid and liquid pineapple waste. Reaktor. 2008;12(1):48-52.
27. Morais DR, Rotta EM, Sargi SC, Bonafe, EG, Suzuki RM, Souza NE, Matsushita M, Visentainer JV. Proximate composition, mineral contents and fatty acid composition of the different parts and dried peels of tropical fruits cultivated in Brazil. J.Braz.Chem.Soc. 2017;28(2):308-318.
28. Wachiarasiri P, Siripan J, Sorada W. The effect of banana peel preparations on the properties of banana peel dietary concentrate. Songklanakarin J.Sci. Technol. 2009;31(6):605-611.
29. Feumba DR, Ashwani RP, Ragu SM. Chemical composition of some selected fruit peels. European Journal of Food Science and Technology. 2016;4(4):12-21.
30. Kodagoda KHGK, Marapana RAUJ. Analysis of proximate composition and physicochemical properties of pineapple wastes. Sri Lanka Association for the Advancement Science. Proceedings of the 73rd Annual Session. Part 1- Abstract; 2017.
31. Syarifah Khadijah S, Norlaila A, Fadhilah J. Chemical and functional properties of local banana peel flour. Journal of Food and Nutrition Research. 2018;6(8):492-496.
32. Abubakar US, Yusuf KM, Safiyanu I, et al. Proximate and mineral composition of corn cob, banana and plantain peels. International Journal of Food Science and Nutrition. 2016;1(6):25-27.
33. Hassan Pyar, Peh KK. Chemical composition of banana peels (Musa sapientum) fruits cultivated in Malaysia using proximate analysis. Res. J. Chem. Environ. 2018;22(II):108-113.
34. Adão RC, Glòria MBA. Bioactive amines and carbohydrate changes during ripening

of 'Prata' banana (Musa acuminate x M. balbisiana). Food Chemistry. 2005;90:705-711.

35. Loeseck VHW. Bananas, chemistry, physiology and technology. 2nd edition. New York: Interscience publication;1950
36. Chandraju S, Mythily R, Chidan Kumar CS. Extraction, isolation and identification of sugars from banana peels (Musa sapientum) by HPLC coupled LC/MS instrument and TLC analysis. J. Chem. Pharm. Res. 2011;3(3):312-321.
37. Adeniji TA, Barimalaa IS, Tenkouano A, Sanni LO, Hart AD. Antinutrients and heavy metals in new Nigerian Musahybrid peels with emphasis on utilization in livestock production. Fruits. 2008;63(2): 65–73.
38. Maniyan A, John R, Mathew A. Evaluation of fruit peels for some selected nutritional and antinutritional factors. Emer Life Sci Res. 2015;1(2):13-19.
39. Ukawanko AI, Nwacahuku J. Nutrient and anti-nutritional composition of crop residues and kitchen wastes fed to small ruminants in Choba, Port Harcourt. Greener Journal of Agricultural Sciences. 2017;7(2):54-59.
40. Murwan Sabahelkhier K, Saifeldin Hussain A, Ishag KEA. Effect of maturity stage on protein fractionation, *In Vitro* protein digestibility and anti-nutrition factors in pineapple (*Ananas comosis)* fruit grown in Southern Sudan. African Jornal of Food Science. 2010; 4(8): 550-552.

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