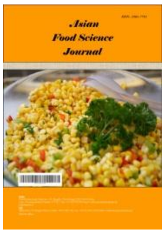

Asian Food Science Journal

20(8): 96-105, 2021; Article no.AFSJ.70841
ISSN: 2581-7752

Effect of Extrusion and Steam Pressure on Fiber and Nutritional Properties of Pineapple Peels

Zuwariah Ishak[1*], Noor Fadilah Mohd Bakri[1], Syahida Maarof[1], Hadijah Hassan[1], Rodhiah Razali[1] and Mohd Fakhri Hashim[1]

[1]Food Science and Technology Research Centre, MARDI HQ, 43400 Serdang, Selangor, Malaysia.

Authors' contributions

This work was carried out in collaboration among all authors. Author NFMB managed the literature review, analyses of samples, performed the statiscal analysis, provided the samples of study and write the manuscript. Authors NFMB, SM, RR and MFH analysed the samples and help in samples preparation. Author HH conducting the experimental design in preliminary studies. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2021/v20i830334
Editor(s):
(1) Dr.Surapong Pinitglang, University of the Thai Chamber of Commerce, Thailand.
Reviewers:
(1) Abdela Befa Kinki, Ethiopia Institute of Agricultural Research, Ethiopia.
(2) Subhashree S., Stella Maris College (Autonomous), India.
Complete Peer review History: https://www.sdiarticle4.com/review-history/70841

Original Research Article

Received 03 May 2021
Accepted 13 July 2021
Published 20 July 2021

ABSTRACT

Research finding on modification of pineapple peel through extrusion and steam pressure have led to increasing fiber and nutritional properties of the pineapple powder. The objective of the present study was to investigate the effect of extrusion processing and steam pressure on soluble and insoluble fiber contents, antioxidant activities, sugar profile and proximate contents. The extrusion of Morris pineapple peel increased soluble dietary fiber (SDF-2.8 folds), insoluble dietary fiber (IDF-1.2 folds) and total dietary fiber (TDF-1.3 folds). Steam pressure treatment also show the same trends of fiber modification in Morris peel (SDF-3.4 folds, IDF-1 folds, TDF-1.2 folds). The sugar profile showed that fructose and glucose increased after fiber modification. Total phenolic content (TPC), ferric reducing antioxidant power (FRAP) assay and 2,2-diphenyl-1-picrylhydrazyl (DPPH test) had been used to determine antioxidant activity in both processing method. The results of the proximate analysis showed that protein, crude fiber and moisture content affected by extrusion and steam pressure process of pineapple peel. It can be conclude that modification of fiber through extrusion and steam pressure is able to alter fiber and nutritional properties of pineapple peel.

**Corresponding author: Email: zuwariah@gmail.com, zuwariah@mardi.gov.my;*

Keywords: Fiber; extrusion; steam pressure; antioxidants; sugar; proximate.

1. INTRODUCTION

Extrusion and steam pressure is predominantly a thermomechanical processing and its able to alter the physicochemical properties of the DF, increase their solubility and improve their physiological properties. Extrusion process involved mechanical stress which are responsible for breaking of glycoside bonds of insoluble polysaccharides. The soluble fiber was reported increased after extrusion [1]. It also has the potential to release phenolic associated with cell walls, and increasing the content of bioactive compounds and antioxidant capacity of the extruded product [2]. In steam pressure procedure, the saturated steam under high pressure was released and this led to the mechanical separation of fibers. The latter processed was also achieved by sudden evaporation of condensed moisture from the pressure release. Mechanical breakdown of lignocellulosic, oligosaccharides and monosaccharides are also happened during this procedure. Thus, many studies were conducting nowadays in inventing new by-products applications and functional food properties from particular peel. The finding of this study seems very interested to turn them into useful products. Therefore, it is crucial to study the effect of extrusion and steam pressure on fiber and nutritional properties of pineapple peels.

In Malaysia, Pineapple industry has gain important impact on socio-economic development. Report done by Malaysian Pineapple Industry Board (MPIB) [3] cited that 412,665 metric tonnes of pineapples were produced in 2014. According to MPIB [3], the market segment for pineapple products was canned, juice and fresh consumption. Pineapple plant is considered not profitable after the fruit has been harvested because there is lack of knowledge about the potential of the plants after the fruit has discarded [4]. The pineapple industries used 22.5 to 35% of the edible portion and discard the peel, stems, crowns and pineapple core as a waste. The large quantities of pineapple solid and liquid wastes contributed to a serious environmental problem. The pineapple canning industry utilized pineapple biomass as a vinegar, or sell to feedstock industries and biofertilizer. Approximately 35% of pineapple peels produced during processing and there is worthwhile to exploit this biomass as a functional fiber instead of animal feed or biofertilizer. The pineapple peels are agroindustrial byproduct derived from pineapple food industries, created waste management issue to be overcome.

Pineapple peels contain dietary fibre and antioxidant compound, therefore it can be converted into highly valuable products. High fibre food products being considered as a functional food because fibres can acts as interference in the metabolism of lipids and carbohydrates and also play important role against constipation [5]. Beside that, pineapple peels also rich in vitamin and minerals and also loaded with antioxidants. Healthy antioxidants may reduce oxidative stress, next it may reduce the risk of chronic diseases such as heart disease, diabetes and certain cancers.

The objective of the study is to investigate effect of extrusion and steam pressure on fiber and nutritional properties of pineapple peels.

2. MATERIALS AND METHODS

2.1 Preparation of Samples

The pineapple peels (variety Moris) were collected from Pasar Pagi market Section 16 Shah Alam Selangor. Moris variety peels were used to produce the pineapple powder. The peels were washed in filtered water and manually separated before cut into sizes of approximately 2 cm^2 and divide into three group (Fig. 1).

i) Control (CPP)

Dried in oven dryer (Memmert, Germany) at 60ºC for 17h.

ii) Extrusion process (EPP)

The dried peels were ground and treated by extrusion, single screw extruder (Brabender, Germany) at 140°C at 8% moisture with a die opening of 6 mm and a screw speed of 80 rpm.The temperature of the first (feed) zone was set to 80ºC, while the second (metering) was set to 135ºC and at the third (compression) zone were set to 150ºC respectively.

iii) Steam pressure process (SPP)

The small sliced pineapple peels were heated with high temperature pressure (2$kgcm^{-2}$), 121ºC for 30 min (SP). Then were dried in the oven dryer (Memmert, Germany) at 60ºC for 17h.

All the samples were ground well into a fine powder by using a mixer grinder (Panasonic MX900M). They were stored in aluminium pack at room temperature prior to analysis.

2.2 Determination of Fiber

The content of total dietary fiber (TF), soluble (SF) and insoluble (IF) fractions were determined according to enzymatic-gravimetric method 991.43 [6].

2.3 Determination of Antioxidant Activity

2.3.1 Determination of total phenolic content (TPC)

The TPC was determined by using Folin–Ciocalteu reagent [7] and expressed in gallic acid equivalents (g per 100 g samples). Estimation of the phenolic compounds was carried out in triplicate.

2.3.2 Determination of 2, 2-diphenyl-1picrylhydrazyl (DPPH) assay

The evaluation of antioxidant capacity in each fruit has been carried out using two different methods [8]. The free radical scavenging effect was determined based on the 2, 2-diphenyl-1picrylhydrazyl (DPPH) assay. About 1.0 ml sample extracts were added with 2.0 ml freshly prepared methanolic DPPH solution (20 ppm). The mixture was then thoroughly vortex-mixed and left to stand for 30min in the dark. By using a UV-VIS spectrophotometer (Hitachi U-2800 Japan) against methanol as a blank for auto-zero, the absorbance was recorded at 517nm and the percentage of inhibition of the DPPH radical was expressed by the antioxidant activity and calculated as below:

$$\%\ \text{Scavenging activity} = \frac{\text{Abs control} - (\text{Abs sample} - \text{Abs blank})}{\text{Abs control}} \text{ X } 100$$

Where Abs control is the absorbance of DPPH solution without sample extracts and Abs blank is the absorbance of sample extracts without DPPH solution.

2.3.3 Ferric reducing antioxidant power assay (FRAP)

The ability of the antioxidant as a reducing agent was determined using ferric reducing antioxidant power assay (FRAP). About 40 µl sample extract was mixed with 3.0 ml FRAP reagent. The mixture was left in the dark for 30 min at 37°C and by using distilled water, the absorbance was determined at 593nm against blank. By mixing 2.5 ml of 10 mM 2,4,6-tris(1-pyridyl)-5-triazine (TPTZ) solution in 40 mM HCl with 2.5 ml of 20 mM $FeCl_3$ and 25 ml of 0.3 M acetate buffer (pH 3.6), FRAP reagent should be freshly prepared. A calibration curve using ferrous sulphate ($FeSO_4$) was prepared. FRAP value was expressed as g $FeSO_4$/100g on a dry basis.

2.4 Total Sugar, Fructose, Sucrose and Glucose Content

Total sugar content was determined according to Association of Official Analytical Chemists (AOAC) (982.14 or 977.20) [6].

A: Fresh pineapple peel (Moris variety) **B: Extrusion process (EPP) of pineapple peel before ground** **C: Steam pressure process (SPP) of pineapple peel**

Fig. 1. The picture of fresh and treated pineapple peel

2.5 Statistical Analysis

All data were expressed as mean ± standard deviation and were done in triplicate independent analyses. Data were analyzed using SAS 9.3 (SAS Institute Inc., USA) for ANOVA.

3. RESULTS AND DISCUSSION

3.1 Nutritional Composition of Extrusion and Steam Pressure Pineapple Peels Powder

Table 1 showed the proximate composition in all samples. CPP and SPP have the highest moisture content (7 to 9% respectively). However EPP has lowest moisture content significantly and probably because it has undergo two times dehydration process. Oven drying with extrusion method can reduce moisture content more than other samples because high barrel temperatures can affected moisture content. The correlation between moisture content and long-term usage of sample is noteworthy because according to Hausmann et al. [9], products with lower water content, generally having longer shelf life due to less subject of microorganisms degradation and chemical changes.

The ash content in the samples is an important indicator of mineral of the products. Total ash content varied from 4.45 to 5.65%. This variation may be due to steam pressure process penetrating the pineapple peel, debranch reactions process and release inorganic mineral elements of the samples [10,11,12]. Thus, mineral acid might be leaching out from the biomass and decreased the mineral content.

There was no significant difference at P> 0.05 between all samples for carbohydrate, fat, fructose and glucose but CPP showed the highest content of sucrose. According to Morrison et al. [13] and Sun et al. [14] they found that sucrose is the major sugar in raw forms. From the Table 1, SPP decreases the sucrose content significantly if compared to CPP. Heat exchange technique allows movement of soluble substance and it will cause solutes move from high concentration to low concentration [15]. CPP initially high in sucrose and consequently after steam pressure process the sucrose content moved from the samples to the steam. Glucose and fructose content was not significantly affected by the different method treatments (SPP and EPP), although the levels were generally higher compared to CPP. The steaming process in SPP samples could reduce sucrose content more than CPP and EPP. This is because the effect of temperature, time, and pressure on sugar content depends on the treatment method. Based on this experiment, the highest level of fructose and glucose could be produced from the SPP treatment. In general, thermal treatment resulted in the conversion of lignocellulosic biomass of pineapple peel to various types of sugar including glucose, fructose, xylose, galactose, arabinose, mannose, and sucrose [16]. Increasing heating temperature over a time frame caused the increase of starch degradation [13]. According to Simkovic et al. [17] and Chan et al. [18], higher temperatures resulted in sucrose caramelization, a phenomenon, which results in the conversion of sucrose to oligomers and polymers. Hence, the reduction of sucrose in SPP may be associated with this effect.

EPP and SPP have highest protein content compared to CPP. Extrusion process and steam pressure resulted protein denaturation and inactivation of enzyme inhibitor, thus affected the protein content. Our finding of protein content for the extruded samples are hardly distinguishable from Rivera-Mirón et al. [19] which found the protein content was in the range of 1.87 to 6.61g/100g. According to Maria et la. [20] steam pressure treatment on plant cell wall will destroy the cell wall, thus increase the protein content. Non-protein nitrogen compound in the plant cell wall are separated from crude fiber when treated by steam pressure. Therefore, the non protein nitrogen will be considered as crude protein, resulted total amount of protein increased.

CPP showed the highest crude fiber. The crude fiber in CPP decline after extrusion and steam pressure process from 23.5% to 17% (EPP) and 20% (SPP), respectively. It was indicated that high pressure process during extrusion and steam pressure capable to destroyed part of crude fiber in cell wall. Studies have found that [21,22] steam pressure changes the chemistry structure of cell wall and destroy of crude fiber composition like ligno-celluloses and modify the hemicelluloses become more soluble component.

Table 1. Proximate composition and sugar profile of extrusion and steam pressure pineapple peels powder

Treatment	Protein (g/100 g)	Fat (g/100 g)	Carbohydrate (g/100 g)	Ash (g/100 g)	Moisture (g/100 g)	Energy (Kcal)	Crude fiber (g/100 g)	Fructose (g/100 g)	Sucrose (g/100 g)	Glucose (g/100 g)
Control moris (CPP)	2.3 ± 0.28b	0.25 ± 0.07 a	73.85 ± 1.20a	4.45 ± 0.49b	7.75 ± 0.07a	311.5 ± 0.71c	23.5 ± 0.71a	5.2 ± 3.11a	14.85 ± 4.03a	4.95 ± 3.46a
Steam Pressure (SPP)	6.65 ± 1.06a	1.25 ± 1.20a	77.25 ± 4.45a	5.8 ± 0.28a	9.05 ± 1.91a	347 ± 2.83b	20 ± 0.85b	9 ± 2.26a	3.85 ± 1.20b	8.65 ± 1.77a
Extrusion (EPP)	7.2 ± 0.14a	1.3 ± 0.28a	81.8 ± 0.28a	5.65 ± 0.35ab	4.2 ± 0.14b	368 ± 2.83a	17.0 ± 0.14c	7.5 ± 0.71a	8.3 ± 0.28ab	5.4 ±0.57a

Values are the mean ± SD (n=3); means that do not share a same letter are significantly different (p<0.05) as measured by Duncan test

3.2 Fiber and Total Sugar of Pineapple Peels Powder

The extrusion process generally enhances soluble dietary fiber [23]. This statement correlates favorably well with our discovery where there was an increase in the soluble dietary fiber content and reduction in total sugar in all samples extruded and steam pressure. Depolymerization of polysaccharides during extrusion probably affected the sugar content of samples [24]. SPP showed the highest values for soluble fiber (up to 3.4 times) (Fig. 2). From the graph, it can be concluded that the total dietary fiber had a significant influence on the process, explaining that there was a redistribution of insoluble dietary fiber and soluble dietary fiber after mechanical stress during processing. Extrusion can increase total dietary fiber, insoluble dietary fiber and alter the physicochemical properties of fiber [25]. Heat process affected the starch as referring to Stojceska et al. [26]. Vasanthan et al. [27] reported that the possibility of the formation of insoluble dietary fiber could be attributed to the formation of retrograded amylose. This scenario could also contribute to the formation of covalent interactions between macronutrients leading to components that are insoluble and not hydrolyzed by digestive enzymes. These indigestible glucans may be Maillard reaction products likely resulting from chemical reactions between starch and proteins present within the dietary fiber-containing matrix [28]. On the other hand, the steam pressure and extrusion process significantly affected the total sugar content. Panpea et al., [15] reported that the solubility and the accumulation of total sugars were highly affected by the temperature, ratio of water per biomass (pineapple peel), and heat. The volume of water was not being applied in this study. Thus, the total sugar was reduced in SPP and EPP.

3.3 Antioxidant Activity of Pineapple Peels Powder

Phenolic compounds have a strong correlation with antioxidant activity. From Table 2, it was found that the TPC of EPP was significantly higher (3.70 g GAE/100g) than CPP (1.42 g GAE/100g) and SPP (1.58 g GAE/100 g). The results of total phenolic content in this study (1.42 to 3.70 g/100 g GAE) were higher than pineapple peel waste studied by Saraswaty et al. [29], which is 0.54 to 1.26 g/100 GAE. However, Alothman et al. [8] found that the TPC of pineapple peels is higher (34.7 mg GAE / 100g) than that of banana (Musa Paradasiaca) (27.0 mg GAE/100 g FW). Ti Li et al. [30] reported that polyphenols content in pineapple (Bali, China) peels were lower than some fruits which have been studied, including grapes, apples, and teas. Many researchers found that TPC of red grape, apple, and black tea was 201.0 mg GAE/g FW, 296.3 mg GAE/g FW, and 62 to 107 mg GAE/g DW in ranged, respectively [31,32]. Besides, many researchers also reported that the major phenolic compound is highest in the peel of fruit than in flesh [8,33,34]. According to Alothman et al. [8] the antioxidant activity will be affected the most by the drying process of pineapple waste, as well as it would degrade the compounds. In contrast, Table 2 shows that EPP had the highest total phenolic content followed by SPP and CPP. The extrusion process affected the phenolic content, and these findings were the same trend with dry beans extrudates (Rawela cultivar) studied by Korus et al. [35]. They found that the beans extruded at a lower temperature (120°C) can retain a higher amount of phenolic content up to 14% if compared with the beans extruded at 180°C. Besides, the small losses in phenolic were observed in the samples of higher initial moisture. It was suggested that water probably protects the phenolic compounds during extrusion. The results obtained in this study reveals that after the extrusion process the amount of phenolic content in CPP or dried pineapple peel risen by 20% in EPP. It might be attributed to initial moisture content (8%) and extrusion process temperature ranged 80°C to 150°C. Ismail and Zahran [36] and Korus et al. [37] observed that the retention of chemical compounds was affected by the initial moisture.

However, the steam pressure treatment did not significantly affect the phenolic content in SPP. Even the total phenolic compounds did not change during steam pressure treatment, the antioxidant capacity values were still being affected.This was probably a result of the degradation of antioxidant compounds other than the phenolic compounds. Table 1 shows the DPPH content in CPP samples exhibiting the highest DPPH values (92.37% scavenging), followed by SPP (90.93 % scavenging) and EPP (85.53% scavenging). The DPPH value of SPP and EPP were decreasing from control pineapple peel to steam pressure and extrusion treatment. The radical scavenging activity of all the treatments from pineapple peel decreased as heat treatment involved during processing. The reduction may be attributed due to the high extrusion temperature or steam pressure. Silva et al. [38] also found the same trend of antioxidant activity of pineapple peel. They found that the treated pineapple peel, banana peel, lychee peel, and papaya peel were significantly higher in DPPH content than the peel flours. They found that the antioxidant capacity of apple, mango, papaya [38], starfruit [39] and tomato [40] were decreased after various treatments. Therefore, the result obtained is in the same agreement with the studies found by Chong et al. [39], Shofian et al. [40] and Komiloglu et al. [41]. Heat treatment is related to the degradation of biologically active compounds at high temperatures, due to chemical, enzymatic or thermal decomposition [42]. Natural antioxidant from fruit is affected by several factors, including environmental aspects, ripening, fruit variety, type of extraction solvent, and extraction conditions [43]. Almeida et al. [44] pointed out that the antioxidant potential of fruits is also influenced by the action of different antioxidant compounds with synergistic and antagonistic effects between them.

The FRAP values of these pineapple peel samples ranged from 1.02 g/100g to 2.66 g/100g, with EPP exhibited the highest values, followed by SPP and CPP. Hafiz et al. [45] reported on fruit peel antioxidant, for example, Grapefruit peel exhibited the highest FRAP reducing power with 9.22 mg AAE/g, followed by mango peel (6.19 mg AAE/g), avocado peel (3.65 mg AAE/g), and apple peel samples (3.20 mg AAE/g), while the FRAP reducing power from dragon fruit, melon, passion fruit, pear, and plum peels were relatively low as compared to other fruit peels. However, FRAP assay by other researchers using different methods would give different results because they are based on different principles [46,47]. Other than that, the antioxidant activity of fruits could be influenced by the geographical origin, cultivar, and harvest or storage time [48].

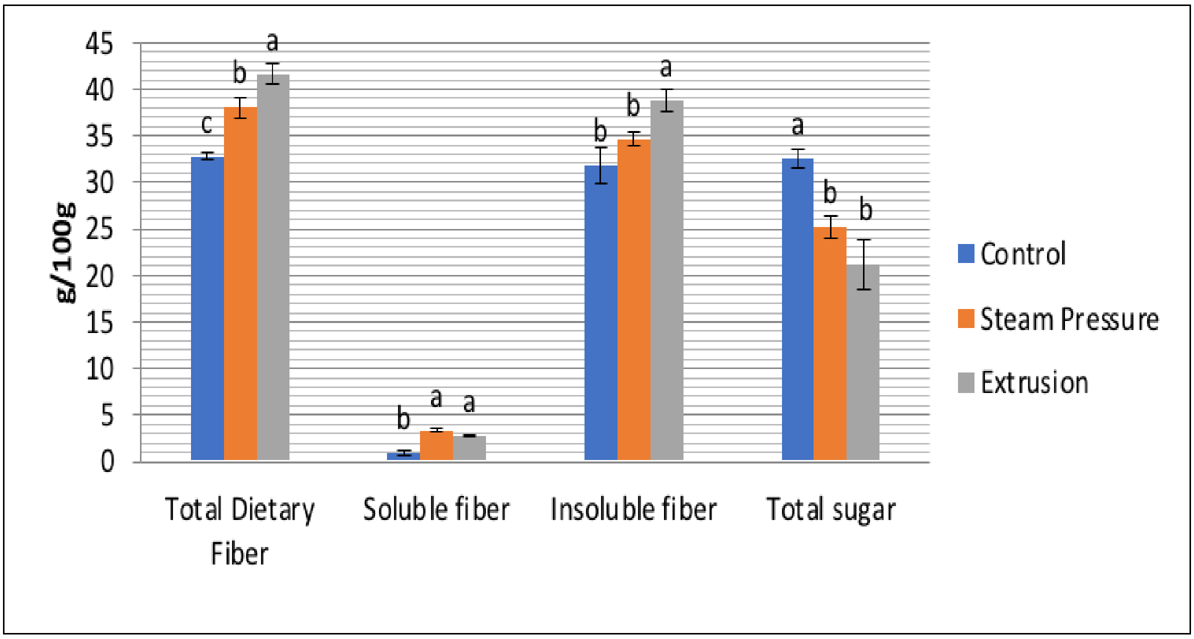

Fig. 2. Fiber and total sugar of pineapple peels powder

Values are the mean ± SD (n=3); means that do not share a same letter are significantly different (p<0.05) as measured by Duncan test

Table 2. Antioxidant content of extrusion and steam pressure pineapple peels powder

Sample	FRAP (g/100g $FeSO_4$)	DPPH (% scavenging activity)	TPC (g/100 g GAE)
Control (CPP)	1.02±0.01 b	92.37±0.18 a	1.42±0.05 b
Steam Pressure (SPP)	1.06±0.02 b	90.93±0.31 b	1.58±0.07 b
Extrusion (EPP)	2.66±0.06 a	85.53±0.17 c	3.70±0.09 a

Values are the mean ± SD (n=3); means that do not share a same letter are significantly different (p<0.05) as measured by Duncan test.

4. CONCLUSION

The findings of this study indicated that the extrusion and steam pressure process significantly influence the fiber, total sugar and antioxidant content of pineapple peels. The increasing of 3.4 folds soluble fiber during steam pressure process stipulated that, pineapple peels powder has potential to manage blood sugar levels and cholesterol in our body. The release of polyphenols during extrusion and steam pressure process reported it potential to lower type 2 diabetes, inflammation, heart diseases and obesity. Further study should be conducted to explore the application pineapple peels powder in food products, with inclusion of limits studies to assess the safety level of designate products. This could produce a wholesome package of new inventive premium products.

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.

ACKNOWLEDGEMENT

The authors would like to acknowledge the financial support provided by Projek Pembangunan MARDI, MOA.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Macagnan FT, da Silva LP, Hecktheuer LH. Dietary fibre: The scientific search for an ideal definition and methodology of analysis, and its physiological importance as a carrier of bioactive compounds. Food Research International. 2016;85:144–154.
2. Brennan C, Brennan M, Derbyshire E, Tiwari BK. Effects of extrusion on the polyphenols, vitamins and antioxidant activity of foods. Trends in Food Science and Technology.2011;22(10):570–575.
3. Malaysian Pineapple Industry Board. Pineapple industry information. Johor, Malaysia; 2015.
   Accessed 10 June 2021.
   Available:http://www.mpib.gov.my/en/download/?lang=en
4. Zainuddin, Muhammad Fakhri. Development of pineapple waste pellets and In vitro digestilibility study for herbivore. Masters thesis, Universiti Putra Malaysia; 2015.
5. Slavin J. Fiber and prebiotics: Mechanisms and health benefits. Nutrients. 2013;5:1417-1435.
   DOI: 10.3390/nu5041417
6. Association of Official Analytical Chemists. Official methods of analysis. 19th ed. Virginia: AOAC; 2012.
7. Lim YY, Lim TT, Tee JJ. Antioxidant properties of several tropical fruits: A comparative study. Food Chemistry. 2007;103(3):1003-1008.
   Available:https://doi.org/10.1016/j.foodchem.2006.08.038
8. Alothman M, Bhat R and Karim AA. Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. Food Chem. 2009;115:785–788.
9. 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.
10. Glasser WG, Wright RS. Steam assisted biomass fractionation. II. Fractionation behavior of various biomass resources. Biomass Bioenergy.1998;14(3):219-235.
11. Qing Q, Yang B, Wyman CE. Xylooligomers are strong inhibitors of cellulose hydrolysis by enzymes. Bioresource Technol. 2010;101(24):9624-9630.
12. Selig MJ, Knoshaug EP, Adney WS, Himmel ME, Decker SR. Synergistic enhancement of cellubiohydrolase performance on pretreated corn stover by addition of xylanase and esterase activities. Bioresource Technol. 2008;99(11):4997-5005.
13. Morrison TA, Pressey R, Kays SJ. Changes in α- and ß- amylase during storage of sweet potato lines with varying starch hydrolytic potential. Journal of America Society for Horticultural Science.1993;118(2): 236-242.

14. Sun JB, Severson RF, Kays SJ. Effect of heating temperature andmicrowave pretreatment on the formation of sugars and volatile in jewel sweetpotato. Journal of Food Quality.1993;17(6):447-456.
15. Panpae K, Jaturonrusmee W, Mingvanish W, Nuntiwattanawong C, Chunwiset S, Santudrob K, Triphanpitak S. Minimization of sucrose losses in sugar industry by pH and temperature optimization. The Malaysian Journal of Analytical Sciences. 2008;12(3):513-519.
16. Sininart Chongkhong, Chakrit Tongurai. Optimization of soluble sugar production from pineapple peel by microwave-assisted water pretreatment. Songklanakarin J. Sci. Technol. 2019;41(1):237-245.
17. Simkovic I, Surina I, Vrican M. Primary reactions of sucrose thermal degradation. J Anal Appl Pyrol. 2003;70:493-504.
18. Chan CF, Chiang CM, Lai CY, Huang CF, Kao SC, et al. Changes in sugar composition during baking and their effects on sensory attributes of baked sweet potatoes. J Food Sci Technol. 2012;51:4072-4077.
19. Rivera-Mirón M I, Torruco-Uco JG, Carmona-García R, Rodríguez-Miranda J. Optimization of an extrusion process for the development of a fiber-rich, ready-to-eat snack from pineapple by-products and sweet whey protein based on corn starch. Journal of Food Process Engineering. 2020;43(11):e13532. Available:https://doi.org/10.1111/jfpe.13532
20. Maria EM, Yose R, Guoyao W. Improving the nutritional quality of juice waste mixture by steam pressure for poultry diet. Pakistan Journal Nutrition. 2012;11(2):172-175.
21. Wong You Cheong Y, d'Espaignet JT, Deville PJ, Sansoucy R and Preston TR. The effect of steam treatment on cane baggase in relation to its digestibility and furfural production. Proceeding of the 15th Congress of ISSCT (South Asia); 1974.
22. Pate FM. Value of treating bagasse with steam under pressure for cattle feed. Tropical Agriculture.1982;4:293-297.
23. Leonard W, Zhang P, Ying D, Fang Z. Application of extrusion technology in plant food processing byproducts: An overview. Comprehensive Reviews in Food Science and Food Safety. 2020;19(1):218–246.
24. Huth M, Dongowski G, Gebhardt E, Flamme W. Functional properties of dietary fibre enriched extrudates from barley. Journal of Cereal Science. 2000;32(2):115-128.
25. Daou C, Zhang H. Study on functional properties of physically modified dietary fibres derived from defatted rice bran. Journal of Agricultural Science. 2012;4(9):85–97.
26. Stojceska V, Ainsworth P, Plunkett A, İbanoğlu Ş. The advantage of using extrusion processing for increasing dietary fibre level in gluten-free products. Food Chemistry. 2010;121(1):156-164.
27. Vasanthan T, Gaosong J, Yeung J, Li J. Dietary fiber profile of barley flour as affected by extrusion cooking. Food Chemistry. 2002;77(1):35-40.
28. Esposito F, Arlotti G, Maria Bonifati A, Napolitano A, Vitale D, Fogliano V. Antioxidant activity and dietary fibre in durum wheat bran by-products. Food Research International. 2005;38(10):1167-1173
29. Saraswaty V, Risdian C, Primadona I, Andriyani R, Andayani DGS, Mozef T. Pineapple peel wastes as a potential source of antioxidant compounds. IOP Conference Series: Earth and Environmental Science. 2017;60:012013
30. Ti Li, Peiyi Shen, Wei Liu, Chengmei Liu, Ruihong Liang, Na Yan, Jun Chen. Major polyphenolics in pineapple peels and their antioxidant interactions. International Journal of Food Properties. 2014;17(8)1805-1817. DOI: 10.1080/10942912.2012.732168
31. Sun J, Chu YF, Wu X, Liu RH. Antioxidant and antiproliferative activities of common fruits. Journal of Agricultural and Food Chemisty. 2002;50:7449–7454.
32. Luximon-Ramma A, Bahorun T, Crozier A, Zbarsky V, Datla KP, Dexter DT, Aruoma OI. Characterization of the antioxidant functions of flavonoids and proanthocyanidins in Mauritian black teas. Food Research International. 2005;38:357–367.
33. Saraswaty V, Risdian C, Budiwati TA, Tjandrawati M. Pros. Teknol. Untuk Mendukung Pembang. Nas. Indonesian. 2013;1:196–200.
34. Chew K, Khoo M, Ng S, Thoo Y, Aida WW, Ho C. Effect of ethanol concentration, extraction time and extraction temperature on the recovery of phenolic compounds

and antioxidant capacity of orthosiphon stamineus extracts. Int. Food Res. J. 2011;18:1427-1435.

35. Korus J, Gumul D, Czechowska K. Effect of extrusion on the phenolic composition and antioxidant activity of dry beans of Phaseolus vulgaris L. Food Technology and Biotechnology. 2007;45:139–146.
36. Ismail FA, Zahran GH. Studies on extrusion conditions of some cereals and legumes. Egypt. J. Food Sci. 2002;30:59–76.
37. Korus J, Gumul D, Achremowicz B. The influence of extrusion on chemical composition of dry seeds of bean (*Phaseolus vulgaris* L.), Electr. J. Pol. Agric. Univ. 2006;9. Available:http:// www.ejpau.media.pl/volume9/issue1/art-10.html
38. Silva JS, Ortiz DW, Garcia LGC, Asquieri ER, Becker FS, Damiani C. Effect of drying on nutritional composition, antioxidant capacity and bioactive compounds of fruits co-products. Food Sci. Technol, Campinas. 2020;40(4):810-816.
39. Chong CH, Law CL, Figiel A, Wojdylo A, Oziemblowski M. Colour, phenolic content and antioxidant capacity of some fruits dehydrated by a combination of different methods. Food Chem. 2013;141:3889–3896.
40. Shofian NM, Hamid AA, Osman A, Saari N, Anwar F, Pak Dek MS, Hairuddin MR. Effect of freeze-drying on the antioxidant compounds and antioxidant activity of selected tropical fruits. Int. J. Mol. Sci. 2011;12:4678–4692.
41. Kamiloglu S, Demirci M, Selen S, Toydemir G, Boyacioglu D, Capanoglu, E. Home processing of tomatoes (*Solanum lycopersicum*): Effects on *In vitro* bioaccessibility of total lycopene, phenolics, flavonoids, and antioxidant capacity. J. Sci. Food Agric. 2014;94:2225–2233.
42. Nicoli MC, Anese M, Parpinel M. Influence of processing on the antioxidant properties of fruit and vegetables. Trends Food Sci. Technol. 1999:10:94–100.
43. Muniz MB, Queiroz JM, Figueirêdo RMF, Duarte MEM. Caracterização termofísica de polpas de bacuri. Food Science and Technology, 2006:26(2):360-368. Available:http://dx.doi.org/10.1590/ S0101-20612006000200019
44. Almeida MMB, Sousa PHM, Arriaga AMC, Prado GM, Magalhães CEC, Maia GA, Lemos TLG. Bioactives compounds and antioxidant activity of fresh exotic fruits from northeastern Brazil. Food Research International. 2011;44(7):2155-2159. Available:http://dx.doi.org/10.1016/j.foodres.2011.03.051
45. Hafiz AR, Suleria, Colin JB, Frank RD. Screening and characterization of phenolic compounds and their antioxidant capacity in different fruit peels. Foods. 2020;9: 1206.
46. Zhang DZ, Fang YZ. Observation on antioxidative activity of some vegetables and fruits. Acta Nutr Sin. 1990;12:191–195.
47. Wang H, Cao G, Prior RL. Total antioxidant capacity of fruits. J Agric Food Chem. 1996;44:701–705
48. Van der Sluis AA, Dekker M, de Jager A, Jongen WMF. Activity and concentration of polyphenolic antioxidants in apple: effect of cultivar, harvest year, and storage conditions. J Agric Food Chem. 2001;49:3606–3613.

© 2021 Ishak et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/70841