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The Physicochemical Analysis and Anthocyanin Level of Malaysian Purple Sweet Potato Cracker

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Abstract

Purple Sweet Potato (PSP) in Malaysia is an abandoned crop. Even though it has various health benefits and nutritional values, consumers, especially Malaysians, still lack purple sweet potato consumption. It has a high dietary fibre content, a low glycemic index, and contains proteins, minerals, polyphenols, and anthocyanin. The National Health Morbidity Survey (Malaysia) in 2019 reported that 94% of Malaysian adults lack fiber consumption in their dietary patterns. As a result, it may become an alternative crop for individuals who consume less nutrients and fibre as a result of dietary choices and health issues. This one-of-a-kind crop also contains anti-oxidative, hepatoprotective, anti-inflammatory, anti-tumor, anti-diabetic, anti-microbial, anti-obesity, and anti-aging qualities. Due to the lack of a commercial food product based on this crop, it has become an unpopular crop among Malaysians. Purple sweet potato makes only a few Malaysian sweets and traditional snacks. Nonetheless, Malaysian customers continue to ignore it. Thus, Purple Sweet Potato Cracker was made, and a proximate analysis was conducted to examine its physicochemical content. It was found that the newly developed PSP crackers were high in fiber, vitamins, and minerals, as well as in calcium (1332.08 mg/kg) and contained anthocyanins of 6.68 mg/L. Besides that, this special cracker is free from food preservatives without coloring agents and additives. The processing of Purple Sweet Potato Cracker carries important features for small-medium entrepreneurs, which will contribute to the Malaysian economy perspectives, as it has a good potential to be marketed in domestic and international commercial food outlets.

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Introduction

Sweet potatoes are widely grown for their nutritive and health-promoting properties.[1,2] It also has a large influence on food security. The FAO[3] also recommends sweet potato as a nutritious food because beneficial metabolites such as β-carotene, anthocyanins, vitamins (B1, B2, C, and E), and minerals are present (Ca, Mg, K, and Zn).[4,5]

Sweet potato has recently become a research focus due to its unique nutritional and physiological properties. Aside from that, it contains anthocyanins, bioactive carbohydrates, proteins, lipids, conjugated phenolic acids, and minerals.[6] As a consequence, increasing the nutritious value of sweet potatoes in food formulation and production may be feasible. Sweet potato root or tuber contains a lot of starch and has processing properties similar to cereals.[7,8] Fresh sweet potato root may also be processed to enhance its uses and shelf life, particularly for the obese population, since research has shown that it is an anti-obesity meal.[6] The root also contains a high level of α-amylase.[7,9]

Sweet potato roots come in a variety of distinct colours. Orange-fleshed sweet potato, yellow-fleshed sweet potato, and purple-fleshed sweet potato are three of the most common. Purple-fleshed sweet potato roots are particularly appealing due to their high anthocyanin and other polyphenol content.[10] The anthocyanins are generally quantified as 3-sophoroside-5-glucoside peonidin or cyanidin and their acylated derivatives10. The root also includes mono- and dicaffeoylquinic acids, as well as caffeoyl-hexosides, in addition to anthocyanins. These polyphenols contribute to the antioxidant and other biological characteristics of the root. The sweet potato root contains both soluble and insoluble dietary fibres.[6] Dietary fibre and polyphenol levels may lead to impaired starch digestion.[11,8] As a result, sweet potato is the primary focus of this research.

Various individuals in many nations dislike purple sweet potato. The potato produces only a few products, thus resulting in the purple sweet potato's unfamiliarity to the community, especially the young generation. Even though it has various health benefits and functional properties, all the information regarding the benefits of the purple sweet potato is still unknown to many people. It is seen as not well exposed to them. As a result, it is essential to emphasise the advantages and nutritional characteristics of the purple sweet potato and its products. This potato's value-added culinary items might boost and encourage its consumption among people.

Purple sweet potato contains high energy content, various vitamins, minerals, and anthocyanins. Anthocyanins have been associated to a lower risk of premature ageing, cognitive decline, polyps, gout, stomach acid, coronary heart disease, and cancer. In addition, it also acts as an anti-inflammatory, anti-diabetic, and anti-obesity. It shows that PSP is good for daily consumption and could be part of the local crop that can benefit human health. Crackers are popular snack foods among people, including Malaysians. Manufacturers use many plant sources to produce crackers. Despite this, there has been minimal attempt to employ purple sweet potato as the principal component in cracker manufacture. As a result, the main focus of this study was purple sweet potato crackers.Therefore, it is important to analyze the cracker's nutritional contents and anthocyanins level.

Materials and Methods

The Universiti Teknologi MARA (UiTM) and the UiTM Faculty of Health Sciences approved this experimental project (approved number REC/12/2020 (MR/456). The research was carried out at Universiti Teknologi MARA (UiTM) Puncak Alam, Selangor.

Preparation of Purple Sweet Potato Cracker

The cracker was prepared with modifications[12] by the researcher. The purple sweet potato was purchased at Seksyen38 Shah Alam, Selangor, Malaysia. The purple sweet potatoes were first scrubbed before being peeled and boiled till tender. The fleshes were mashed with the masher and their weight was calculated using the conventional procedure.[12] All of the ingredients were mixed, and the dough was chilled for 10 minutes. To make the cracker, the dough was flattened using a dough sheeter and cut into a rectangular form (4 cm long and 4 cm wide). The crackers were then cooked in a preheated oven for 15 minutes at 170 °C. The crackers were allowed to cool for 30 minutes after cooking before being packaged in plastic bags and stored at room temperature in an airtight container.

Physicochemical Characteristics of Purple Sweet Potato Cracker

The sweet potato cracker was tested for its physicochemical properties to determine the moisture content, carbohydrate, protein, ash, water activity,crude fiber, crude fat, andenergy according to the method of AOAC (1995). All experiments were conducted three times (N=3).

Physical Properties of Purple Sweet Potato Cracker

Water Activity

Water actıvıty has extraordinary significance on nourishment as it controls the beginning and seriousness of mold action.[14] A RotronicHygro Lab water action estimating gadget has beenutilizedto investigate water activity. A water activity examination of the purple sweet potato cracker sample has been conducted. The cracker sample was set into three separate cups and executed after the samples in the plastic cups were measured three times. The water analysis has been performed in the same vein.

Color Analysis

A Hunter colorimeter Konica Minolta Chroma Meter CR-410 machine based on the CIE scale was utilised in triplicate in the colour evaluation, including L *, a *, and b *colour space analyses. The L* value represents brightness (0)/white (100), the a* value represents green (-)/red (+), and the b* value represents blue (-)/yellow (+) (CIE, 2019). Three samples were obtained from cracker samples for this study. Each of these samples was evaluated and subjected to a colour assessment in triplicate (N=3), and the findings were recorded.

pH

A microprocessor pH meter (pH 211, Hanna Instrument, USA) was used to measure pH changes. It has a combination glass electrode that has already been calibrated at pH 4.0 and 7.0. The pH values of the newly developed PSP cracker have been determined using 5 grams of samples that were once homogenized with 5 ml of distilled water (T-18 Homogenizer, Miccra) at 3000 rpm for 2 minutes. By placing the probe into the centre of the fluid, the pH was calculated. All tests were carried out in triplicate (N=3).

Texture Analysis

The texture properties of purple sweet potato crackers were evaluated using a TA. XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) (Stable Micro Systems Ltd.) (DAD). TPA was used to measure texture on a TA-25 MUF1/P36R probe and a TA-90 platform, with a pretest speed of 5 mm/s, a test speed of 1 mm/s, a post-test speed of 2 mm/s, and a distance of 10 mm. Hardness, which measures the peak force (g) during the first compression cycle, is one of the textural characteristics discovered by force and area measurements. Textural properties were analysed by the newly built PSP cracker (HPLC DAD). All of the studies were carried out in triplicate (N=3).

Anthocyanins Biomarker Analysis in Purple Sweet Potato Cracker

The analysis of anthocyanin determination, identification, and quantification was done using HPLC-MS.[12]

Statistical Analysis

All experiments were done in triplicate, and the data were given as the mean and standard deviation. The Statistical Package for the Social Sciences (SPSS Statistics, Version 21.0, Chicago, IL) was used to analyse the data, and p0.05 was considered statistically significant. The data is displayed as the mean± standard deviation.

Results and Discussion

Proximate Analysis of Newly Developed PSP Cracker

This section describes the proximate analysis and results obtained for the newly developed PSP cracker. Table 1 displays the findings of the cracker's proximate analysis. The proximate analysis results of the cracker were carried out to obtain the percentage of moisture content, ash, crude fiber, protein, total fat, carbohydrate, energy, dietary fiber, and pH in the cracker.

Moisture Content

The processing procedure is critical in the preparation of any crackers since it affects the moisture content of the finished products. The higher the moisture level, the fewer the dry components in the cracker. The cracker with high moisture content will easily

allow the presence of organisms that result in the cracker's taste and odor changes. It can cause deterioration and mold growth in the cracker. This could affect the shelf life of the cracker.[16] The moisture content of the newly developed PSP cracker was 4.7 g/100g (dry basis), in corroboration with other researchers.[17]

Table 1: Proximate Result of the Newly Developed PSP Cracker

Proximate analysis	Newly Developed PSP Cracker
Moisture Content g/100g	4.7± 0.05[a]
Ash g/100g	2.7±0.03[a]
Crude Fiber g/100g	60.3 ±0.13[a]
Protein g/100g	8.7±0.05[a]
Total Fat g/100g	15.0±0.04[a]
Carbohydrate g/100g	68.9± 0.54[a]
Energy kcal/100g	445 (1869kJ) ±0.63[a]
Dietary Fiber g/100g	11.4± 0.43[a]
pH	5.51± 0.16[a]

All analyses are the standard deviations of measurements taken in triplicate. Differences that are statistically significant ($p<0.05$) are denoted by values denoted by comparable superscript characters.

However, the newly designed PSP cracker's moisture content did not surpass the 6.0% standard specified by the US Department of Agriculture for crackers.The lower moisture content of food products, especially crackers, will ensure good quality[18] and convenience in the packaging. Besides that, the air circulation in the oven during the baking process and oven temperature also influence the moisture content of crackers.[19] The controlled oven temperature was the main concern when baking the newly developed PSP cracker to ensure a good circulation of hot air in the oven,resulting in the PSP cracker's good quality.

Furthermore, the thickness of the cracker also determines the moisture content. The standardization of size and thickness of the newly developed PSP cracker was carefully focused on the production stage in this study as it will also influence the cracker's moisture content and shelf life. Many previous studies used cookies for their sample research compared to the cracker. According to a study on the nutritional properties of cookies prepared from orange-fleshed sweet potato cookies supplemented with sclerotium of edible fungus, the moisture content ranged from 12.04 to 15.33 g/100 g.[20] which was higher than the newly created PSP cracker. Besides, cookies made from wheat-hog plum bagasse composite show a moisture content of 8.81g18 which also had high moisture content compared to the newly developed PSP cracker. The moisture content of the PSP cracker indicates that it was suitable for storage and packaging purposes.

Ash

The newly designed PSP cracker has an ash level of 2.7g/100g. Higher ash concentration indicates that the cracker has a considerable quantity of minerals. Sweet potatoes, for example, are high in calcium, zinc, and iron.[21] Furthermore, P, Na, K, Mg, and Cu were also minerals in sweet potatoes.[22] The ash content of PSP crackers was similar with previous studies[24,25] and the common ash content in sweet potato food products ranged from 1.1–4.9/100 g.

However, a study has reported that 3.31 % of ash was found in a cracker from a combination of sweet potato and cassava flours using moringa oleifera and sweet potato leaves.[83] The amount of ash was higher than the PSP cracker in this study as it might be due to the usage of leaves for the flour, while the PSP cracker is made from sweet potato roots. Other researchers that used sweet potato flour in their product formulation observed that biscuits with 40% to 50% sweet potato flour had significantly higher ash, fibre, and total flavonoid content.[26]

Crude Fiber

The purple sweet potato flesh has a lot of fibre. In newly developed PSP crackers, the crude fibre content was 60.3 g/100g.The US Departments of Health and Human Services and Agriculture suggest 30 grammes of dietary fibre per day to be considered a healthy diet. As a result, the dietary fibre content of the newly created PSP cracker exceeded the prescribed level. This discovery is consistent with previous research revealing that vegetables and fruits are abundant in fibre, which may help food products perform better.[27,28] The newly designed PSP cracker was expected to have a high nutritious fibre content due to the

intake of purple sweet potato roots. As a result, this PSP cracker might become one of the people's everyday snack foods.

The crude fibre level of crackers prepared from composite flour of modified sukun, sweet powder purple, mocaf, and saga seeds ranged from 3.13% to 6.68% when compared to recently released PSP crackers.[29] When compared to fresh or cooked veggies, the fibre content of modified flour is reduced owing to the flour process. This study relates to cooked purple sweet potato flesh used to make the cracker, which explains why the crude fibre content of the PSP cracker in this study was high. Furthermore, crude fibre levels in orange-fleshed sweet potato cookies enriched with edible fungus sclerotium were observed to be rather low, ranging from 1.01 to 3.68%.[30]

Food can be labelled as a "source of fibre" if it includes at least 3 g of fibre per 100 g of product, and "rich in fibre" if it has at least 6 g of fibre. As a result, this PSP cracker might be classified as a high-fiber cracker. It might also be a nice commercial add-on as part of a healthy food option. It is also consistent with the Malaysia Food Act and Regulations, which provide that food can be claimed as (1) high fiber when the overall TDF content is greater than 6% and (2) a source of fiber when it contains more than 3% TDF. As a result, in this study, PSP crackers containing 53% boiling purple sweet potato flesh were certified as a high-fiber snack. Orange sweet potato puree was utilised in the brownies, which also have a high fibre level of 75%.[31]

Protein

The protein content of the newly developed PSP cracker is 8.7 g/100 gram. According to the US Department of Agriculture National Nutrient Database, sweet potato has 1.57g of protein. This study found that wheat flour, chia seeds, cream, and milk all contributed to the high protein content of PSP crackers. All of the substances utilised included protein. Even though various flours, for example, have varied protein amounts, it is vital to understand the intended use of flour.[16] There are flours with a low protein level and flours with a high protein content, which may affect the final food product. Crackers are frequently high in protein, but cookies and cakes are low in protein. Despite its high protein level, wheat flour contributes to the texture and suppleness of the cracker.[32]

Furthermore, gluten protein in wheat flour has been demonstrated to improve the baking performance of any dough, including cookies.[33] Protein levels in crackers prepared from composite flours of modified sukun, sweet powder purple, mocaf, and saga seeds ranged from 1.65% to 12.64%, according to a recent research.[29] The protein level of the newly created PSP cracker in this study is considered high because boiling purple sweet potato flesh was used without any extra composite flour components. When compared to the newly formed PSP cracker, a recent study on the impact of guar gum on the qualities of gluten-free crispy waffles manufactured from sweet purple potato flour discovered a lower protein content of 7.67 g/100g.[34]

Crude Fat

Based on Table 3, the crude fat content of the newly developed PSP cracker was 15g/100g. The higher fat content in the PSP cracker could be attributed to the composition of the ingredients used, such as unsalted butter, cream, and milk.Many previous studies focused on developing cookies and other pastry products such as bread and brownies and little on crackers. The fat contents of purple sweet potato starch were 0.06%.35 Nevertheless, the cracker's fat content was in line with the findings of the previous study ranged from 9.58% to 15.22% in their cracker.[29]

As the Ministry of Health recommends,the daily calorie intake for Malaysians is 1,500 calories for women and 2,000 for men.[36] Nevertheless, according to a study bythe United Nations, 2910 calories / per day was the average amount of calories consumed by Malaysians. Adults' DRI for fat is 20 to 35% of total calories received from fat.[37,38] Chia seeds are a good source of poly unsaturated fatty acid[39] and contain the essential fatty acid called linolenic and linoleic acid.[40] Therefore, the consumption of chia seeds in PSP crackers could substitute for the high fat in other food products and benefit people with its advantages.

Carbohydrate

Carbohydrates are crucial for human growth because they give energy. WHO (1990, 2003)

recommends that total carbohydrate consumption range between 55% and 75% of total energy. It is based on protein energy percentages ranging from 10 to 15% and fat energy percentages ranging from 15 to 30%.It has also been reported that adults require approximately 110 to 140 g of glucose per day. The newly developed PSP cracker had a carbohydrate value of 68.9 g/100g.

The formulation of 70% purple sweet potato and 30% soybean included 38.06% carbs, according to a study on the physical and nutritional quality profiles of purple sweet potato and soy-based snack bars for pregnant women.[43] The snack bars' decreased carbohydrate content may be owing to the absence of wheat flour intake in this trial compared to PSP crackers, as wheat flour was coupled with purple sweet potato flesh. Furthermore, egg rolls made from wheat and purple flesh sweet potato composite flour contain 65.54% carbohydrates (40% wheat flour and 60% purple sweet potato flour).[44] The amount of carbs discovered was nearly identical to the carbohydrate content of the PSP cracker. Furthermore, a prior study revealed that the innovative cookies prepared from orange-fleshed sweet potato biscuits enhanced with edible mushroom sclerotium contained 62.34 to 67.22% carbs.[30]

Despite this, the carbohydrate amount of PSP crackers was comparable to the previous trial, at 68.92 g/100g of the carbohydrate content of the gluten-free crispy waffle prepared from sweet purple potato flour.[34] PSP cracker carbohydrate content ranged from 62.20 to 68.43%, which was equivalent to biscuits prepared from orange sweet potato puree and wheat flour mixes.[45]

Table 2: Total sugar content of the Newly Developed PSP Cracker

Total sugar	g/100g
Fructose	6.59 ± 0.05[a]
Glucose	0.40± 0.03[a]
Sucrose	0.20 ±0.13[a]
Maltose	5.99 ± 0.05[a]

All analyses are the standard deviations of measurements taken in triplicate. Differences that are statistically significant ($p<0.05$)are denoted by values denoted by comparable superscript characters.

Sugar Content

The boiled PSP flesh has been used in the newly developed PSP cracker instead of flour. The sweetness of the boiled flesh could increase the cracker's taste as only a little granulated sugar has been added to the formulation. It also contributed to the natural sweetness of the cracker. The granulated sugar also influenced the crunchiness of the cracker, although in a small amount. Table 2 shows the overall sugar content of the newly designed PSP cracker.

Fructose was the most abundant sugar (6.59g/100g) in the newly developed PSP cracker. On the other hand, glucose and sucrose were present in relatively low quantities, which were 0.40g/100g and 0.2g/100g. Fructose is the simplest type of monosaccharide in carbohydrates. This finding contradicts previous studies that reported sucrose was the highest content in yellow sweet potato 'amala', a thick Nigerian paste.[46] It would be due to the differences in the process whereby the newly developed PSP cracker used boiling and baking techniques. In contrast, the 'amala' only used the stirring technique to combine the yellow sweet potato flour with hot water.

Other researchers reported that the steaming process of PSP increased the sugar content of PSP snack bars with soybeans by 15.08% in 100g.[30] They also discovered that purple sweet potato and soybean did not significantly increase blood glucose because they have a very low glycemic index and are thus suitable for pregnant women suffering from gestational diabetes mellitus.

Furthermore, the maltose content of the newly developed PSP cracker was 5.99g/100g.In cracker production, sugar is important as it adds volume, gives colors, and influences the cracker's texture. Similar to this newly developed PSP cracker, even though strong flour has been used in the formulation, little sugar consumption increases the crunchiness of the cracker texture as it weakens the gluten structure.[32] Sugar is one of the important ingredients for baking products because it enhances the color quality of cookies besides providing energy.[30]

Energy

The energy content of the newly developed PSP cracker was 445 kcal/100g or 1869 kJ, as shown in Table 1. Cookies made with sprouted sorghum,

pigeon pea, and orange-fleshed sweet potato flour blends had an energy content ranging from 440.69 to 460.83 kcal.[47] Another study on purple sweet potato flour in waffles showed a higher energy value of 481.77 Kcal/100g.[34]

Furthermore, the energy level found in the newly developed PSP cracker seems to be consistent with other researchers, which found the energy content cookies made with sprouted sorghum flour, pigeon pea flour, and orange-fleshed sweet potato flour were 440.69- 460.83 kcal which is still considered to have lower energy value.[47] The lower calorie levels are appropriate for health-promoting foods that need less energy.[48] Thus, the newly developed PSP cracker could be part of the alternative snack for health-promoting purposes.

Physical Properties of the Newly Developed Purple Sweet Potato Cracker

Color of the Newly Developed PSP Cracker

As the original purple sweet potato is in purple, the purple dough was also produced during the production of the PSP cracker. The actual color of its flesh influenced the final product of the cracker. It can be seen from the initial production stage until the baking process is completed. However, slight color changes can be significantly observed before and after baking. The comparison of the PSP cracker color during the production stage. Table 3 displays the colour outcomes of Hunter L, a, and b values of PSP crackers.

The colour parameter contains L, a*, and b* values. The L value indicated the brightness level of the sample; the higher the L value, the brighter the sample (a* value indicated red-green chromatic). The cracker colour is red when it is positive; green when it is negative (b* value indicated blue-yellow chromatic).Figure 1 showed the changes in color before and after the baking process. During the initial stage, the color of the boiled PSP flesh in the crumbled form was darker than the cracker dough. This was due to the addition of wheat flour, milk, cream, and unsalted, which changed the dough color to a lighter look. After the baking process, the cracker was slightly darker than the unbaked cracker. Maillard's reaction occurred during the baking process and involved the cracker's protein content, particularly amino acids, as well as heat circulation in the oven, allowing the newly developed PSP cracker to darken. It is also due to the color fading in food processing.[49]

The changes in the cookie's color were influenced by the differences in purple sweet potato flour color and Maillard reaction scaramelization during the baking process.[50,29] The interaction of carbonyl compounds resulting from the breakdown of carbohydrates or lipids with amino compounds in the substances employed resulted in Maillard tanning. Then, continued the caramelization process once the cookies were heated at a high temperature in the oven. They also claimed that anthocyanins were related to the quality of redness of their sweet potato cookies. Table 3 displays the findings of the present study's colour analysis.

Table 3: The color value of the newly developed PSP cracker

PSP Cracker	L*	a*	b*
	47.08±0.03^{a}	11.87±0.02^{a}	1.61±0.03^{a}

Newton, (L*) = lightness, (A*) = redness and (B*) = yellowness of hunter color analysis; All analyses are the mean of triplicate measurements ± standard deviations. Statistically significant differences ($p<0.05$) are denoted by values denoted by comparable superscript characters.

The newly developed PSP cracker's L value (lightness) was 47.08. This indicated that the PSP cracker had a medium brightness. The cracker's Hunter's value (redness) was 11.87, a high score due to the use of 53% boiling purple sweet potato flesh in the recipe. This is because of the purple sweet potato's purplish tint. The cracker's Hunter b value (yellowness) was 1.61. As the amount of purple sweet potato used in this trial was half of the total components, it was natural for the cracker to become deeper and reddish.

The more purple sweet potato flour added, the lighter the result becomes.[44,29] A deeper sweet bun crumb was developed by combining wheat and purple sweet potato flour. Purple sweet potato decreased the L* and b* of Chinese steamed bread crumb and crust while raising the a* and whiteness index.[51] They claimed that the anthocyanin content of purple

sweet potato Chinese steam bread was to blame for the changes. They also emphasised that colour variations in steam bread are not always a bad thing in terms of customer acceptability.

Another study on purple sweet potato and soy-based snack bars discovered that the purple colour was created by the main component, sweet potato.[42] The amount of purple sweet potato flour used had a significant influence on the colour of the food items[43,52] and the greater the anthocyanin level, the more purple sweet potato flour used. When different percentages of purple sweet potato flour were employed, the colour of the instant noodles changed. These data suggest that eating boiling purple sweet potato flesh altered the colour of the cracker, especially on the top. The texturing results of the newly built PSP cracker are discussed in the next section.

Texture of the Newly Developed PSP Cracker

Texture properties are the most influential factors of baked products on customers' acceptability and mouth feel, especially for biscuits and crackers. In this study, hardness and fractur ability reflected the crunchiness of the newly developed PSP cracker. One of the physical features of crackers is hardness. Itis correlated with breaking force, as this study used a Texture analyzer to determine the hardness of PSP crackers. Besides that, breaking force is the pressure to break the product. The harder the product was, the greater the breaking-force value. The results of force values are expressed as grams. Hardness is determined by determining the maximum force required to cut through the sample until it reaches its base. Besides that, hardness also refers to the full force required for a probe to penetrate the product.[53]

Table 4: The Force value of the newly developed PSP cracker

PSP Cracker	Force (g)	Distance (mm)
	6.1±0.11[a]	3.807±0.05[a]

All analyses are the mean of triplicate measurements ± standard deviations. Statistically significant differences ($p<0.05$) are denoted by values denoted by comparable superscript characters.

The force value for the hardness was used in this study to measure the crunchiness of the newly developed PSP cracker. Table 4 summarises the force value result for the newly developed PSP cracker.

The newly developed PSP cracker had a force value of 6.1 g and a distance of 3.807 mm. A study by by Wang, Zhang, Mujumdar (2012) showed that the hardness value for the peeled orange sweet potato flour composite cookies ranged from 10.142 g to unpeeled orange sweet potato flour-based cookies at 8.879g. The fracturability of cookies inversely correlates with their crispness.[55] The lower the fracturability (less fracture force), the higher the crispness, and the higher the fracturability (high fracture force), the lower the crispness. The greater the force, the lower the crispness.[56]

Therefore, the results of the force value for the newly developed PSP cracker were considered slightly low as it was 6.0 g compared to previous study,[57] thus giving high fracturability and crispness of the cracker. This finding is very important as part of the cracker characteristics because textural properties are very important factors in cracker and biscuits development as they influence consumers eating quality and overall acceptability. It was also important in the packaging design and transportation of food products.[5]

Physical Properties Measurements of the Newly Developed PSP Cracker

The width of the newly created PSP cracker was measured using a ruler by arranging two crackers edge to edge to obtain an average value in millimetres. The thickness was determined by stacking two crackers on top of each other and calculating the average value in millimetres. Divide the breadth by the thickness to get the spread factor. The weight of the cracker was determined using a computerised weighing scale (in grams). The volume of the cracker was calculated by multiplying the area by the thickness. The weight ratio of volume was used to calculate density after determining volume. Measurement was repeated three times.[58] The cracker area (diameter) was 16 mm, thus, the volume of the newly developed cracker was 8 mm.[2] The width of the newly developed PSP cracker was 16 mm and 4 grams in weight. The thickness value

of the cracker was 2.0 mm. It could be considered a lower thickness value. The higher the thickness value, the crispness is lower and vice versa. The width of a cracker was also 16 mm, and the spread ratio was 80% (16mm / 2 mm x 10).

The spread ratio of the biscuit prepared from bambara nut, and cowpea-substituted wheat flour was 76%.[59] An increase in the spread ratio might be due to substantially higher oil content in the biscuit mixture. This could improve the attribute and add value to the products by preventing the biscuit from breaking during transportation, selling and marketing purposes. The ingredients used in the PSP cracker formulation also contained higher oil content as it consumed milk, cream and unsalted butter. This influenced the spread ratio of PSP crackers, which is approximately like the Bambara nut and cowpea biscuits. However, because it is tough to break for eating, it increases the worth of the crackers.

pH and Water Activity

pH is significant in food-processed items because it can alter flavour, consistency, and shelf-life. It also works as an indicator of either acidity or alkalinity of food products. This current study's pH for the novelty PSP cracker was 5.51, as tabulated in Table 5 below.

Table 5: pH value and water activity of the newly developed PSPcracker

PSP Cracker	pH	Aw
	5.51±0.08[a]	0.54±0.03[a]

All analyses are the standard deviations of measurements taken in triplicate. Differences that are statistically significant ($p<0.05$)are denoted by values denoted by comparable superscript characters.

The pH values from 5.90 to 6.20 were considered low acid to near neutral.[60] Therefore, the crackers in this study have low acidity. At low pH, within pH 1 – 3, the anthocyanins content was very stable and highly colored.[61] Nevertheless, the anthocyanins pigment was unstable at high pH values because the chemical structure of anthocyanins will change when pH is raised. At this stage, it may exhibit a variety of distinct hues depending on the pH. Examples include red (pH 1), purple (pH 7), blue (pH 10), green (pH 11), and yellow (pH 13).The yellow tint, on the other hand, indicates the development of chalcones as a result of anthocyanin degradation.[62] Because it is close to pH 7, the purple sweet potato crackers have a purple tint.

On the other hand, orange sweet potato products called panettones have pH values ranging from 4.21 to 4.28.[63] The panettones have more acidic[64] and the organic acids in the foods influenced the product's odor, flavor, color, quality, and stability.[65] For the panettones, they further stated that with the increasing pH of the products, a greater sweetness had been detected.[64]

Water activity, also known as Aw, is critical in food products because it regulates the onset and severity of mould activity. High water content means high water activity and vice versa. Food with high water content may have fast deterioration due to the changes in biological and chemical aspects of the food. Water activity is crucial for quality properties and shelf life in baked products, especially crackers, biscuits and cookies. It will influence also influence the storage and packaging type for the products. Therefore, it is important to conduct water activity analysis on any food products. In this study, water activity analysis has been conducted on the newly developed PSP cracker.

The Aw should be low in water content, less than 0.6% on baked products, especially crackers and cookies.[66] They also stated that the related food products were normally thin in size. It is in line with the newly developed PSP cracker, which also had a thin size. The air in biscuits or crackers is also water in the component materials.[67] Therefore, before producing the newly developed PSP crackers, the aspects of shaping the form and size and the baking process are crucial to avoid air in the baked crackers.

Table 5 showed the water activity value for newly developed PSP cracker in this study. The Aw was 0.54, and previous study suggested that the value should be less than 0.6.[66] Less water activity value shows that the newly developed PSP cracker has low water activity and might have a longer shelf life. This is also due to the baking process, reducing the water content in the crackers.

A study on orange sweet potato cookies found higher Aw,ranging from 0.23 to 0.33, as they incorporated orange sweet potato flour in the formulation.[68] The lower aw values measured normally related to the high fiber content of the ingredients.[69] The fiber absorbs some water and reduces the aw in food products. In this study, the newly developed PSP cracker was produced from 53% of the cooked purple sweet potato flesh from the total ingredient list. Thus, it could contribute to the high-water activity in the crackers.

Furthermore, the water activity of a given sample decreases or increases depending on the type of ingredient used, demonstrating that the use of dairy products such as milk and butter causes a high-water activity (Aw) level.[70] Previous research on rice flour with a water activity of 0.92 0.01 and quinoa flour with a water activity of 0.894 0.001 to manufacture gluten-free cakes revealed this.[71,72] Because of the material used, both studies had a high-water activity. Nevertheless, the value of the Aw in the newly developed PSP crackers is considered acceptable as the value is still within the recommended rate, which was less than 6.0.

Besides that, based on the recommended Aw point for crackers and biscuits, there are no microbial organisms below the 0.60 threshold,[73] as a higher water activity value of >0.8 facilitates the growth of microbial organisms. Furthermore, pathogenic bacteria cannot grow in water with a water activity of 0.85-0.86.74.

Anthocyanins Biomarker Content

Many researches have concentrated on the anthocyanin content of purple sweet potato to examine its importance in human health. The purple sweet potato is considered a healthy food additive to the high anthocyanins level.[75] The purple colorthat contains anthocyanins pigment in the roots makes this potato high value-added. The human diet's suggested daily intake of anthocyanins is approximately 180-215mg/day in the United States of America.[76] This level was nine times higher than the other flavonoids, including genistein, quercetin, and apigenin. Each content was suggested to be around 20-25mg/day. In contrast, the suggested consumption of anthocyanins in food sources was between 250–400mg/d.[77] The suggested anthocyanins daily intake doubles as compared to other study.[76] As this anthocyanin has been found beneficial for human health, 250-400mg/day is considered the best daily intake.

Furthermore, researchers have done many types of research and found various significant advantages of anthocyanins from purple sweet potatoes. For example, anthocyanins can reduce the rate of free radical cell death caused by smoking, air pollution, and other pollutants.[78] Anthocyanins can also help you avoid ageing, memory loss, polyps, gout, stomach acid, coronary heart disease, cancer, and degenerative illnesses including atherosclerosis.[78] Anthocyanins also aid in the prevention of aging, memory loss, polyps, gout, stomach acid, coronary heart disease, cancer, and degenerative diseases such as atherosclerosis. According to research,[79] anthocyanins can also be antimutagenic and anticarcinogenic against mutagens and carcinogens contained in food and processed foods, avoiding liver function disruptions, antihyper tension, and blood sugar levels. Almost all of the nutrients found in purple sweet potatoes aid in the prevention of coronary heart disease.

Since this present study employed purple sweet potato as the major ingredient for the cracker, the anthocyanin concentration in the newly designed PSP cracker was also assessed. Table 6 summarises the anthocyanins level results.

Table 6: The Anthocyanins level of the newly developed PSP cracker

PSP Cracker	Anthocyanins (mg/g)	Total Polyphenol (mg/g)
	6.68±0.04	30.83±0.01

All analyses are the mean of triplicate measurements ± standard deviations.
Statistically significant differences (p0.05) are denoted by values denoted by similar superscript letters.

The newly improved PSP cracker contained 6.68 mg/g anthocyanins. A piece of the cracker was approximately 4 grams, thus, the total anthocyanins in a piece of PSP cracker were 26.72 mg. The value of anthocyanins in PSP crackers was higher than the purple wheat crackers, which

was 21.6 mg/100g.80As suggested, normal anthocyanins daily intake is up to 250-400mg/day. The recommended consumption of newly developed PSP crackers was 9 to 14 pieces per day.

Based on the previous research,[51] there are six types of anthocyanidins. The anthocyanins were mostly measured in purple sweet potatoes were called 3-sophoroside-5-glucoside of peonidin or cyanidin and its acylated derivatives.[10] This current study found anthocyanidins (Cy), known as cyanidin-3-galactoside, in this cracker. Furthermore, the total polyphenol content of the newly developed PSP cracker was 30.83 mg/g.It is slightly lower than the polyphenol content in purple sweet potato cookies, which was 34.65 mg.[58] It might be due to the temperature differences during the baking process, as cookies only took shorter times than crackers.

Nevertheless, the anthocyanins content in newly developed PSP crackers was higher compared to a cracker from PSP flour produced by Sittisak *et al.*, (2019). 1.82 mg/100g was found in their cracker. This could vary due to the different geographical locations of the purple sweet potato.

Due to its properties and nutritional properties, many scholars, recommended that purple sweet potatoes are a good local crop for the source of stable anthocyanins, which could be an alternative for natural colorant and biologically active food material.[82] Besides that, purple sweet potato contains anthocyanin, a natural anti-aging nutritional supplement that is also the safest and most powerful free radical scavenger ever discovered.[83] As a consequence, transforming the purple sweet potato into the newly produced purple sweet potato cracker may become one of the people's everyday snacks.

Conclusion

PSP crackers, which have recently been invented, include a variety of nutrients that can help persons or consumers. In this study, the newly created PSP crackers had a high dietary fibre content (60.3 g/100 g), high protein (8.7 g/100 g), 68.9 g/100g of carbohydrates, 445 kcal/100g or 1869 kJ of energy content, and 6.68 mg/g of anthocyanins level, this cracker would be a type of snack for Malaysians in the future, as proved by many researchers. It also has high mineral contents and fiber crackers, and convenient for consumers for traveling as its size is small and easier to bring everywhere. The anthocyanins and other nutrients in the newly developed PSP cracker suggest the potential for purple sweet potato products to contribute beneficially to healthy eating. Therefore, the new PSP crackers produced from Malaysia's local crop may become alternative snacks for consumers.

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Conflict of Interest

The authors do not have any conflict of interest.

References

1. FAO (Food and Agriculture Organization of the United Nations). 2012.
2. Lee, W.S., Chen, I.C., Chang, C.H., &. Yang, S.S. Bioethanol production from sweet potato by co-immobilisation of saccharolytic molds and *Saccharomyces cerevisiae. Renewable Energy* 2012; 39, 216-222
3. Jang, H.H., Kim, H.W., Kim, S.Y., Kim, S.M., Kim, J.B., & Lee, Y.M. In vitro and in vivo hypoglycemic effects of cyanidin 3-caffeoyl-p-hydroxybenzoylsophoroside-5-glucoside, an anthocyanin isolated from purple-fleshed sweet potato. *Food Chemistry.* 2019; 272:688-693
4. Liu, Y., Sun, Y., Xie, A., Yu, H., Yin, Y., Li, X., & Duan, X. Potential of Hyperspectral Imaging for Rapid Prediction of Anthocyanin Content of Purple-Fleshed Sweet Potato Slices During Drying Process. *Food Analytical Methods.* 2017;(10):3836–3846.

5. Kim, H.W., Kim, J.B., Cho, S.M., Chung, M.N., Lee, Y.M., Chu, S.M., Che, J.H., Kim, S.N., Kim, S.Y., Cho, Y.S., Kim, J.H., Park, H.J., Lee, D.J. Anthocyanin changes in the Korean purple-fleshed sweet potato, Shinzami, as affected by steaming and baking. *Food Chemistry.*2012; 130(4):966-972. https://doi.org/10.1016/j.foodchem.2011.08.031
6. Wang, S., Nie, S., &Zhu, F. Chemical constituents and health effects of sweet potato. *Food Research International.* 2016; 89(1): 90-1.
7. Cui, R.B., & Zhu, F. Physicochemical properties and bioactive compounds of different varieties of sweetpotato flour treated with high hydrostatic pressure. *Food Chemistry,* 2019; 299(30):125-129
8. Zhu, F., &Wang, S. Physicochemical properties, molecular structure, and uses of sweet potato starch. *Trends in Food Science & Technology.* 2014; 36(2):68-78. https://doi.org/10.1016/j.tifs.2014.01.008
9. Collado, L.S., Mabesa, R.C., &Corke, H. Genetic Variation in the Physical Properties of Sweet Potato Starch. *Journal of Agricultural and Food Chemistry,* 1999; 47(10): 4195–4201. https://doi.org/10.1021/jf990110t
10. Zhu, F., Cai, Y.Z., Yang, X., &Ke, J., &Corke, H. Anthocyanins, Hydroxycinnamic Acid Derivatives, and Antioxidant Activity in Roots of Different Chinese Purple-Fleshed Sweet potato Genotypes. *Journal of Agricultural and Food Chemistry.* 2010; 58(13):7588–7596. https://doi.org/10.1021/jf101867t
11. Singh, J., Dartois, A., &Kaur. L. Starch digestibility in food matrix: a review. *Trends in Food Science & Technology,* 2020; 21(4): 168-180
12. Gisslen. W. *Professional Baking.* 2004
13. AOAC.*Official methods of analysis*, 16th edition. Association of Official Analytical Chemists, Washington, DC. 1995
14. Park, C.M., Hung, Y.C., Doyle, M.P., Ezeike, G.O.I. and Kim, C.Pathogen reduction and quality of lettuce treated with electrolyzed oxidizing and acidified chlorinated water. *Journal of Food Science,* 2001; 66(9): 1368-1372.
15. Diaconeasa, Z., Leopold, L., Rugină, D., Ayvaz, H., &Socaciu, C. Antiproliferative and Antioxidant Properties of Anthocyanin Rich Extracts from Blueberry and Blackcurrant Juice. *International Journal of Molecular Science*. 2015; 16(2): 2352-2365; https://doi.org/10.3390/ijms16022352
16. NDSU. Flour Analysis -North Dakota State Univerity (NDSU) Wheat Quality & *Carbohydrate Research.* 2018.
17. SonalS.Karkhanis, S.S., Stark, N.M., Sabo, R.C., &Matuana, L.M. Potential of extrusion-blown poly(lactic acid)/cellulose nanocrystals nanocomposite films for improving the shelf-life of a dry food product. *Food Packaging and Shelf Life*. 2021; 29: 100689
18. Oladunjoye, A.O., Eziama, S.C., &Aderibigbe, O.R. Proximate composition, physical, sensory and microbial properties of wheat-hog plum bagasse composite cookies, LWT, *Food Science and Technology,* 2021; 141:111038. https://doi.org/10.1016/j.lwt.2021.111038.
19. Adeyi, A.J., Adeyi, O., Oke, Adeyi, E.O., Oke, E.O., Okonkwo, C,E., &Ogunsola, A.D.Effective moisture diffusivity of Sierrathris saleonensis cracker: optimisation, sensitivity and uncertainty analyses. *Scientific African*. 2021; e00807
20. Kolawole, F. L., Akinwande, B. A., &Ade-Omowaye, B. I.Chemical composition, color, functional and pasting properties of orange-fleshed sweet potato, Pleurotustuberregium sclerotium and their flour blends. *Annals Food Science and Technology,* 2018; 19(3):423-432
21. Giri, N., &Sakhale, B.K. (2019). Development of sweet potato flour based high protein and low calorie gluten free cookies. *Current Research in Nutrition and Food Science.* 2019; 7(2):427-435
22. Ishida, H., Suzuno, H., Sugiyama, N., Innami, S., Tadokoro, T., & Maekawa, A.Nutritive evaluation on chemical components of leaves, stalks and stems of sweet potatoes *(Ipomoea batataspoir). Food Chemistry,* 2000; 68(3):359-367
23. Mei, X., Mu, T.H., & Han, J.J. Composition and Physicochemical Properties of Dietary Fiber Extracted from Residues of 10 Varieties of Sweet Potato by a Sieving Method. *Journal of Agricultural and Food Chemistry,* 2010; 58(12):7305-7310. https://doi.org/10.1021/jf101021s

24. Dincer, C., Karaoglan, M., Erden, F., Tetik, N., Topuz, A., &Ozdemir, F. Effects of Baking and Boiling on the Nutritional and Antioxidant Properties of Sweet Potato [Ipomoea batatas (L.) Lam.] Cultivars. *Plant Foods for Human Nutrition,* 2011; 66:341-347.
25. Toan, N.V., &Anh, N.V.Q. Preparation and Improved Quality Production of Flour and the Made Biscuits from Purple Sweet Potato. *Journal of Food Nutrition,* 2018; 4:1-14.
26. Cheok, C.Y., Adzahan, N.M., Rahman, R.A., Abedin, N.H.Z., Hussain, N., Sulaiman, R., & Chong, G.H. Current trends of tropical fruit waste utilisation, *Critical Reviews in Food Science and Nutrition,* 2018; 58(3):335-361 DOI: 10.1080/10408398.2016.1176009
27. Garcia-Amezquita, L.E., Eduardo, L., Ortigoz, V.T., Saldivar, S.O.S, &Chanes, J.W.Dietary Fiber Concentrates from Fruit and Vegetable By-products: Processing, Modification, and Application as Functional Ingredients. *Food and Bioprocess Technology*, 2018; 11:1439-1463.
28. Khairatika, I., Nurminah, M., &Lubis, Z. Physicochemical characteristics of crackers from composite flour (modified sukun, sweet powder purple, mocaf, and saga seeds). 713, 012036. IOP Conference Series: Earth and Environmental Science, The 2nd International Conference on Natural Resources and Technology, Medan, North Sumatra, Indonesia. 2021
29. Kolawole, F.L., Akinwande, B.A., &Ade-Omowaye, B.I.O. Physicochemical properties of novel cookies produced from orange-fleshed sweet potato cookies enriched with sclerotium of edible mushroom (Pleurotustuberregium). *Journal of the Saudi Society of Agricultural Sciences*. 2020; 19(2):174-178
30. Selvakumaran, L., Shukri, R., Ramli, N. S., Pak Dek, M. S., & Ibadullah, W. Z. W. Orange sweet potato (Ipomoea batatas) puree improved physicochemical properties and sensory acceptance of brownies. *Journal of the Saudi Society of Agricultural Sciences,* 2019; 18(3):332–336. https://doi.org/10.1016/j.jssas.2017.09.006
31. McWilliams, M. *Foods: Experimental Perspectives,* 7th Edition. California State Universit, Los Angeles:Pearson. 2014
32. Vijerathna, M. P. G., Wijesekara, L., Perera, R., Maralanda, S. M. T. A., Jayasinghe, M. & Wickrama singhe, I. Physico-chemical characterisation of cookies supplemented with sugarcane bagasse fibers. *Vidyodaya Journal of Science*, 2019; 22(1): 29-39
33. Sungin. The Effect of Gur Gum on the Qualities of Gluten Free Crispy Waffle from Sweet Purple Potato Flour, *Dusit Thani College Journal,* 13. 2019
34. Ding, Y., Shen, M., Wei, D., Xu, L., Sui, T., Cao, C., & Zhou, Y. Study on compatible characteristics of wheat and purple sweet potato starches. *Food Hydrocolloids.* 2020; 107: 10961. https://doi.org/10.1016/j.foodhyd.2020.105961.
35. IndraBalaratnam. Eat Well : Are you overeating?. 2018 | New Straits Times | Malaysia General Business Sports and Lifestyle News. Retrieved November 20, 2020, from https://www.nst.com.my/lifestyle/heal/2018/10/423827/eat-well-are-you-overeating
36. Clevelan Clinic. Healthy Fat Intake. 2019 | Cleveland Clinic. Retrieved November 19, 2021, from https://my.clevelandclinic.org/health/articles/11208-fat-what-you-need-to-know
37. Zeratsky, K. Fat grams: How to track fat in your diet. 2019- Mayo Clinic. Retrieved November 20, 2020, from https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/expert-answers/fat-grams/faq-20058496
38. Menga, V., Amato, M., Phillips, T.D., Angelino, D., Morreale, F., & Fares, C. Gluten-free pasta incorporating chia (Salvia hispanica L.) as thickening agent: An approach to naturally improve the nutritional profile and the in vitro carbohydrate digestibility, *Food Chemistry,* 2017; 221:1954-1961. https://doi.org/10.1016/j.foodchem.2016.11.151.
39. da Silva Marineli, R., Moraes, É.A., Lenquiste, S.A., Godoy, A.T., Eberlin, M.N. and Maróstica Jr, M.R., 2014. Chemical characterization and antioxidant potential of Chilean chia seeds and oil (Salvia hispanica L.). *LWT-Food Science and Technology,* 2014: 59(2):1304-1310.
40. World Health Organization, 2004. Global strategy on diet, physical activity and health.

41. Puska, P., Nishida, C., Porter, D. and *World Health Organization.* Obesity and overweight. World Health Organization, 2003. pp.1-2.
42. Rahmi, Y., Kurniawati, A.D., Widyanto, R.M., & Ariestiningsih, A.D. The sensory, physical and nutritional quality profiles of purple sweet potato and soy-based snack bars for pregnant women. *Journal of Public Health Research*, 2021; 10(2): 2241.
43. Aritonang, A., Julianti, E. and Nurminah, M., 2020, February. Physicochemical and sensory characteristics of sweet bun produced from wheat and purple sweet potato flour. In *IOP Conference Series: Earth and Environmental Science.* 2020; 454(1): 012113.
44. Samuel, F.O., Akomolafe, A.A., &Eyinla, T.E. Nutritional Evaluation And Consumer Acceptability Of Biscuits Made From Blends Of Orange Sweet Potato (Osp) Puree And Wheat Flour. *Ife Journal of Agriculture*, 2021; 33(1):1-12
45. Fetuga, G., Tomlins, K., Henshaw, F., & Idowu, M. Effect of variety and processing method on functional properties of traditional sweet potato flour ("elubo") and sensory acceptability of cooked paste ("amala"). *Food Science and Nutrition*, 2014; 2(6):682-691
46. Bello, F. A., Akpan, E. E. &Ntukidem, V. E. Development and quality characteristics of cookies from sprouted sorghum, pigeon pea and orange fleshed sweet potato flour blends. *European Journal of Nutrition & Food Safety,* 2020; 12(2):11-21.
47. Sharma, S.K., Bansal, S., Mangal, M., Dixit, A.K., Gupta, R.K., & Mangal, A.K. (2016). Utilisation of Food Processing By-products as Dietary, Functional, and Novel Fiber: A Review, *Critical Reviews in Food Science and Nutrition,* 2016; 56(10):1647-1661, DOI: 10.1080/10408398.2013.794327
48. Cai, D., Li, X., Chen, J., Jiang, X., Ma, X., Sun, J., Tian, L., Vidyarthi, S.K., Xu, J., Pan, J., & Bai, W. (2022). A comprehensive review on innovative and advanced stabilisation approaches of anthocyanin by modifying structure and controlling environmental factors. *Food Chemistry,* 2022;366:130611 https://doi.org/10.1016/j.foodchem.2021.130611.
49. Ulfa, Z., Julianti, E. and Nurminah, M. Effect of Pre-treatment in the production of purple-fleshed sweet potato flour on cookies quality. In IOP Conference Series: *Earth and Environmental Science.* 2019; 260(1): 012095)
50. Zhu, F. and Sun, J. Physicochemical and sensory properties of steamed bread fortified with purple sweet potato flour. *Food Bioscience,* 2019; 30:100411. https://doi.org/10.1016/j.fbio.2019.04.012
51. Rostiati, R., Rahim, A., &Pratiwi, P. Physical, Chemical, And Sensory Characteristics Of Instant Noodles With Purple Sweet Potato Flour (Ipomoea Batatas L. Poir) Substitution At Various Concentrations. *The Agricultural Sciences Journal* (e-Journal), 2020; 7(2):133 - 143. https://doi.org/10.22487/agroland.v7i2.633.
52. Ding, Q.B.,Ainsworth, P., Plunkett, A., Tucker, G., & Marson, H. The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. *Journal of Food Engineering,* 2006; 73(2):42-148. https://doi.org/10.1016/j.jfoodeng.2005.01.013.
53. Wang, Y., Zhang, M., & Mujumdar, A.S. Influence of green banana flour substitution for cassava starch on the nutrition, color, texture and sensory quality in two types of snacks, *LWT - Food Science and Technology,* 2012; 47(1):175-182. https://doi.org/10.1016/j.lwt.2011.12.011.
54. Aslam, H.K. W., Raheem, M.I.U., Ramzan, R., Shakeel, A., Shoaib, M., &Sakandar, H.A. Utilisation Of Mango Waste Material (Peel, Kernel) To Enhance Dietary Fiber Content and Antioxidant Properties Of Biscuit. *Journal Global Innovation Agricultural and Social Science.*2014; 2(2):76-81.
55. Jakubczyk, E., Gondek, E., &Tryzno, E. Application of novel acoustic measurement techniques for texture analysis of co-extruded snacks. LWT, *Food Science and Technology,* 2017; 75:582-589.https://doi.org/10.1016/j.lwt.2016.10.013.
56. Wang, Y.T., Liu, F.X, Fang, X.C., Hu, C.X.S. Liao, X.J. Comparison of high hydrostatic pressure and high temperature short time processing on quality of purple sweet potato nectar. *Innovative Food Science & Emerging Technologies*, 2012; 16:326-334

57. Chung, H.J. Influence of Purple Sweet Potato Powder Addition on the Quality Characteristics and Oxidative Stability of Cookies. *Journal of Food Science and Nutrition,* 2009; 14:60-65. DOI: 10.3746/jfn.2009.14.1.060
58. Durojaiye, A.W.I., Abubakar, L. G., Nwachukwu, N. G., Mohammed, A., & Ibrahim, A.S. Production and Quality of Biscuits from Composite Flours . *Journal of Food Science and Engineering,* 2018; 8:241-247 doi: 10.17265/2159-5828/2018.06.003
59. Ukom, A.N. Adiegwu, E.C., Ojimelukwe, P.C., Okwunodulu, N. Quality and sensory acceptability of yellow maiseogi porridge enriched with orange-fleshed sweet potato and African yam bean seed flours for infants. *Scientific African,* 2019; e00194
60. Anderson, Ø.M. &Jordheim, M. (2006) The Anthocyanins. In: Ø.M. Anderson and K.R. Markham (Eds.). *Flavonoids: Chemistry, Biochemistry and Applications*. CRC/Taylor & Francis, Boca Raton. 2006; 471–551
61. Chen, C.C., Lin, C., Chen, M.H., & Chiang, P.Y. Stability and Quality of Anthocyanin in Purple Sweet Potato Extracts. Foods, 2019; 8(9):393. Doi:10.3390/foods8090393 www.mdpi.com/journal/foods
62. Bet, C.D., Oliveira, C.S.D., Colman, T.A.D., Marinho, M.T., Lacerda, L.G., Ramos,A.P., & Schnitzler, E. Organic amaranth starch: A study of its technological properties after heat-moisture treatment. *Food Chemistry,* 2018; 264:435-442, ISSN 0308-8146, https://doi.org/10orange-fleshedem.2018.05.021.
63. Clerici, M.T.P.S., Schmiele, M., Júnior, L.C.G., Nojima, M.A., Steel, C.J., Chang, Y.K., Pastore, G.M., &Nabeshima, E.H. Orange-fleshed sweet potato flour as a precursor of aroma and color of sourdough panettones. LWT- *Food Science and Technology,* 2019; 101:145-151.https://doi.org/10.1016/j.lwt.2018.10.091.
64. Komlenić, D.K., Slačanac, V. and Jukić, M. Influence of acidification on dough rheological properties. Rheology, Dr. Juan De Vicente (Ed.), 2012; 265-292.
65. Cauvain, S. and Young, L. Ingredients and their influences. Baked Products. Science, Technology and Practice. Oxford: *Blackwell Publishing,* 2006; 72-98.
66. Insiah, H., Pulungan, M.H., &Rahmah, N.L. Ice Cream Cone Product Development Based On Purple Sweet Potato (Ipomoea batatas L.) (Study Substituted Purple Sweet Potato Flour and Baking Time). *Journal of Food and Life Sciences,* 2020; 4(1):1-11
67. Korese, J.K., Chikpah, S.K., Hensel, O., Pawelzik, E., & Sturm, B. Effect of orange feshed sweet potato four particle size and degree of wheat four substitution on physical, nutritional, textural and sensory properties of cookies. *European Food Research and Technology,* 2021; 247:889–905. https://doi.org/10.1007/s00217-020-03672-z
68. Chikpah, S.K, Korese, J.K., Hensel, O., & Sturm, B. Effect of sieve particle size and blend proportion on the quality properties of peeled and unpeeled orange fleshed sweet potato composite fours. *Foods*.2020; 9:1–22
69. Simatos, D., Roudaut, G., & Champion, D. Water in Dairy Products | Analysis and Measurement of Water Activity. *Encyclopedia of Dairy Sciences,* 2011; 715-726, 9780123744074. (10.1016/B978-0-12-374407-4.00493-3).
70. Singh, S., Riar, C.S., &Saxena, D.C. Effect of incorporating sweet potato four to wheat four on the quality characteristics of cookies. *African Journal of Food Science,* 2008; 2:65–72
71. Bozdogan, N., Kumcuoglu, S. &Tavman, S. Investigation of the effects of using quinoa flour on gluten-free cake batters and cake properties. *Journal of Food Science and Technology,* 2019; 56: 683–694. https://doi.org/10.1007/s13197-018-3523-1
72. Dhankhar, P. and Tech, M. A study on development of coconut based gluten free cookies. *International Journal of Engineering Science Invention,* 2013; 2(12):10-19.
73. Rahma, M.S. Handbook of Food Preservation. Taylor and Francis Group, 2nd Ed. London: New York. 2007.
74. Montilla, E.C., Hillebrand, S., &Winterhalter, P.Anthocyanin composition of black carrot (Daucus carota ssp. sativus var. atrorubensAlef.) cultivars Antonina, Beta Sweet, Deep Purple, and Purple Haze. Fruit, *vegetable and cereal science and biotechnology,* 2011; 5(2):19-24

75. Teow, C.C., Truong, V.D., McFeeters, R.F, Thompson, R.L., Pecota, K.V., &Yencho, G.C.Antioxidant activities, phenolic and β-carotene contents of sweet potato genotypes with varying flesh colors. *Food Chemistry,* 2007; 103(3):829-838.
76. Peluso, I. Palmery flavonoids at the pharma-nutrition interface: is a therapeutic index in demand?.*Biomedicine & Pharmacotherapy*,2015; 71:102–107.
77. Zhuang, J., Lu, J. Wang, X., Wang, X., Hu, W., Hong, F., Zhao, X., &Zheng, Y. Purple sweet potato color protects against high-fat diet-induced cognitive deficits through AMPK-mediated autophagy in mouse hippocampus. *The Journal of Nutritional Biochemistry,*2019; 65:35-45. https://doi.org/10.1016/j.jnutbio.2018.10.015
78. Hasyim, A., & Yusuf, M.Perluasan Butir Ubi Jalar Sebagai Pengganti Gizi Beras. Inkuiri Agrariadan Peningkatan Organisasi, Malang. 2012
79. Gamel, T.H., Wright, A.J., Tucker, A.J., Pickard, M., Rabalski, I., Podgorski, M., Ilio, N.D., O'Brien, C., & Abdel-Aal, E.S.M. Absorption and metabolites of anthocyanins and phenolic acids after consumption of purple wheat crackers and bars by healthy adults. J*ournal of Cereal Science,* 2019; 86:60-68. https://doi.org/10.1016/j.jcs.2018.11.017.
80. Sittisak, A., Fuengkajornfung, N., Sanprom, T., &Weenuttranon, J. The Quality Of Cracker From Purple Sweet Potato Flour Substituted For Wheat Flour. 2019; (145-150). International Academic Multidisciplinary Research Conference In Amsterdam 2019.
81. Zhang ZF, Fan SH, Zheng YL, Lu J, Wu DM, Shan Q, & Hu, B. Purple sweet potato color attenuates oxidative stress and inflammatory response induced by D-galactose in mouse liver. *Food Chemistry and Toxicology* 2008; 47:496-501.
82. Salawu, S.O., Udi, E., Akindahunsi, A.A., Boligon, A.A., &Athayde, M.L. Antioxidant potential, phenolic profile and nutrient composition of flesh and peels from Nigerian white and purple skinned sweet potato (Ipomea batatas L.). *Asian Journal of Plant Science and Research,* 2015; 5(5):14-23
83. Owusu, D, Oduro, I & Ellis, W.O. Development of crackers from cassava and sweetpotato flours using Moringa oleifera and Ipomoea batatas leaves as fortificant. *American Journal Of Food And Nutrition,* 2011, 1(3): 114-122