

DRAGON FRUIT (*HYLOCEREUS POLYRHIZUS*) PEELS: A POTENTIAL FUNCTIONAL FOOD INGREDIENT

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ABSTRACT

*The Dragon fruit (*Hylocereus* species) is a good source of vitamins, minerals, and dietary fiber, especially the red pitaya (*Hylocereus polyrhizus*) variety. It may be a potential functional ingredient in the development of healthful food products. A recent study showed that the dragon fruit peel has higher pectin content (a soluble dietary fiber and phytonutrient), than the flesh. This study looked into the potentials of the dragon fruit peel as a safe and healthful ingredient in the development of a food product. Using standard methods, the researchers examined the freeze-dried dragon fruit peel for proximate composition, dietary fiber and fermentability in vitro, phyto nutrients, and antioxidant activity. Results showed that the dragon fruit peel is an excellent source of dietary fiber (70.3g/100g) and contains significant amounts of insoluble (40.1g/100g) and soluble (30.2g/100g) fiber. The peels also produced high amounts of short chain fatty acids; acetate (68.8 ± 1.4 mg/g), propionate (53.8 ± 2.5 mg/g) and butyrate (32.3 ± 1.7 mg/g). The peels also proved to be a rich source of phytonutrients, such as polyphenols (459 ± 86 mg/100g), flavonoids (238 ± 10 mg/100g), and anthocyanidin (356 ± 5 mg/100g). Developing a jam using dragon fruit peel, the researchers noted highly acceptable ratings for its sensory evaluation and overall product assessment; the physico-chemical characteristics (TSS and pH) of the jam were also within acceptable levels. In conclusion, the dragon fruit peels, instead of being discarded as waste, may be considered a safe functional ingredient in the development of healthful food products.*

Keywords: functional ingredients, dragon fruit peels, dietary fiber, healthful food products.

INTRODUCTION

The dragon fruit is an oblong-shaped fruit with red skin, and green or yellow scales. It is known in some Asian countries as pitaya; in North, Central, and South American countries, as pitahaya (Esquievel, Stintzing, and Carle, 2007). The flesh is juicy and plump with soft black seeds (Nerd, Gutman, and Mizrahi, 1999). The pulp color ranges from purple, or red to white (Chien, Sheu, and Lin, 2006). It is the fruit of a cactus belonging to the *Hylocereus* species, under the Cactaceae family. Among the three varieties that are commercially grown, the *Hylocereus undatus*, which has red-skin and white flesh, the *Hylocereus polyrhizus*, which has red-skin with red flesh, and the *Hylocereus megalanthus* which has yellow-skin with white flesh (Arcadio, 1986; Barbeau, 1990), the red skin-red flesh pitaya is currently favored among manufacturers and consumers worldwide.

Food manufacturers utilize only the flesh, seeds, and flower parts of the dragon fruit. The flesh parts are used for jams, jellies, candies, and yogurt; the extracts are used for juice drinks, dairy products, and alcoholic beverages; the flower, for beverages; and the seeds, for oils. The flesh and seed parts are rich in Vitamin C, antioxidants, and essential fatty acids. They are also rich sources of pigments which are widely used in food product applications (Ariffin, Bakar, Tan, Rahman, Karim, Loi, 2008). But the peels are often discarded and, as waste, cause a severe problem in the community for as they gradually ferment, they release off-odors (Okonogi, Duangrat, Anuchpreeda, Tachakittirungrod, Chowwanapoonpohn, 2007). Nonetheless, it must be noted that the peel comprises 22% of the whole fruit which is discarded and turned to waste (Jamilah, Shu, Kharidah, Dzulkifly and Noranizan, 2011).

In a study by Jamilah et al. (2011), however, the peels of the red pitaya were found to contain high amounts of dietary fiber. Since fruit and vegetable diets, specifically those which are excellent sources of dietary fiber, have health benefits and great potential as pharma food, for they can lower cholesterol, reduce risk for diabetes and coronary heart disease, and fight the discomfort caused by constipation (Telrandhe et al., 2012), the fiber-rich dragon fruit peel holds great promise. This study then looks into the potential of the dragon fruit peel as a food ingredient, and utilize its nutritional benefits, thereby preventing its being simply discarded as waste.

MATERIALS AND METHODS

Materials

Dragon fruits with red skin and red flesh (*Hylocereus polyrhizus*) were obtained from a fruit farm in Cavite, Philippines. Citric acid and ascorbic acid were purchased from Alyson's Chemical Enterprise. Other chemicals used in this experiment were of analytical grade.

Freeze Drying Procedure

The dragon fruit peels were cleaned and drained before use. Approximately 600 grams of peels were cut into small pieces, and placed in sterile polyethylene bags, sealed, and then frozen prior to freeze-drying. The frozen samples were then freeze-dried with the use of a ScanVac Coolsafe Freeze dryer. For five days the peels were freeze-dried at -38.0°C. With an Osterizer, the freeze-dried samples were then pulverized and homogenized, then placed in sterile polyethylene bags.

Proximate Analyses

A complex of data was culled from various procedures: Moisture content was determined through the AOAC Method 943.06 (AOAC, 1999). Total fat was analyzed using AOAC 948.22 (AOAC, 1948). Crude protein content estimated as % nitrogen was determined through the Kjeldahl method (AOAC, 2000). Total dietary fiber as well as soluble and insoluble fiber were determined with the use of AOAC 991.43 (AOAC, 2000). Invert sugars were analyzed using the Luff Schoorl method (AOAC, 1995). Short-chain fatty acids were estimated with the use of the in-vitro fermentation of dietary fiber method by McBurney and Thompson (1987). Total carbohydrate, energy, calories and calories from fat were computed from the data of the proximate analyses.

Phytonutrient Content and Antioxidant Activity

The Total Polyphenols and Flavonoids were determined using methods developed by Chew et al. (2011) and the results were expressed as mg gallic acid equivalent (GAE)/g DW of sample and as mg catechin equivalent/g DW of sample, respectively. For estimating anthocyanidins, Zheng's method was employed (2013) and the results were expressed as mg catechin equivalent/g DW of sample. The antioxidant activity of the peels was determined with the DPPH Assay, method by Shakirin et al. (2010) but with some modification. The results were expressed as gram Trolox/100g. For the FRAP Assay, the method of Omena et al. (2012) was utilized. The results were expressed as TEACFRAP, i.e., Trolox Equivalent Antioxidant Capacities calculated with respect to the original FRAP in mmol of Trolox g⁻¹.

Production of Dragon Fruit Peel Jam

Adopting the Food and Agriculture Organization's (FAO) processing technology of fruit peel jam, the researchers processed the fruit peels into jam (1995). To determine applicability of the product, they used three types of sweeteners: cane sugar, honey, and coconut sap sugar.

Physico-Chemical Analysis and Sensory Properties of Fruit Peel Jam

Certain characteristics of the jam, such as its Total Soluble Solids (TSS) and pH, were determined to evaluate the product's properties, and to ensure that it is within the standard set for fruit preserves. The sensory properties of the product were evaluated in terms of sweetness, sourness, thickness, texture, dragon fruit flavor, color, and general acceptability. Consumer acceptability of the three products was also determined in terms of the 5-point Hedonic scale.

Statistical Analysis

The Data were expressed as the mean \pm S.E.M., and were analyzed using Friedman's t-test. Significant differences between the control and treatment groups were determined at 5% level of significance.

RESULTS AND DISCUSSION

Proximate Compositions from the Dragon Fruit Peel

Based on the results, the dragon fruit peel can be a good source of carbohydrates (74.1 grams); hence, it can provide high amounts of calories (318 calories); this implies that the peel can be a good provider of energy.

Table 1. Proximate Compositions Of Dragon Fruit Peel Per 100g Sample

PARAMETERS	CONTENT
Total Calories, cal/100g	318.0
Total Carbohydrates, g/100g	74.1
Total Dietary Fiber, g/100g	70.3
Soluble	30.2
Insoluble	40.1
Ash, % w/w	16.1
Moisture, % w/w	4.3
Protein, % w/w	5.5
Total Fat, g/100g	<0.0005
Total Sugars as Invert, % w/w	3.7

Also, it can be noted that one of the carbohydrates present is the non-starch polysaccharide, pectin, as presented in a study by Jamilah *et al.* (2011). Pectin, a soluble dietary fiber, is used as a jellifying agent (May 2000). In a study by Muhammad *et al.* (2014), dragon fruit peels were found to contain High Methoxy (HM) pectin, the type of pectin that can form gels with the presence of sugar and acids (Sriamornsak, 2003). This observation signifies the possible production of jam without the addition of any industrial pectin that is usually used in food products to form jams and jelly. The development of this product can also mean that the peels can be processed and developed into another source of pectin which, in turn, can be used as a jellifying agent and functional ingredient for other food products.

It can be noted further that the peel is an excellent source of dietary fiber (70.3 grams). According to Anderson *et al.* (2009), dietary fiber intake provides many health benefits. Individuals with high intakes of dietary fiber appear to be at significantly lower risk of developing coronary heart disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal diseases. Increasing soluble fiber improves glycemia and insulin sensitivity in non-diabetic and diabetic individuals. Fiber supplementation in obese individuals significantly enhances weight loss. Increased fiber intake benefits a number of gastrointestinal disorders including the following: gastroesophageal reflux disease, duodenal ulcer, diverticulitis, constipation, and hemorrhoids. Prebiotic fibers appear to enhance immune function too.

According to Horn (1997), the recommended ratio of Insoluble Dietary Fiber (IDF) to Soluble Dietary Fiber (SDF) is 3:1. The insoluble fiber content of the peel is 40.1 grams while the soluble fiber content is 30.2 grams; the ratio from the said values is 3:2.3 respectively. The insoluble fiber form can be composed of celluloses, hemicelluloses and lignin; on the other hand, the soluble dietary fiber can be composed of β -glucans, pectins, gums, mucilages and

some hemicelluloses (IFST, 2007). That the ratio of SDF to IDF is higher signifies that the peels can act as a good source of pectin. Moreover, according to the Dieticians of Canada (2013), the SDF is responsible for lowering blood cholesterol and Lower Density Lipoproteins (LDL) levels.

As regards percent ash content, the table shows a value of 16.1%. This is a higher value compared to the ash content of fresh foods, which is >5% (Nielsen, 2010). Further analysis such as specific mineral determination can be done to identify the micronutrients present and the mineral content in the peels. Moisture content of the dragon fruit peels is 4.3% which is low. This can be attributed to the fact that the peels were freeze-dried and thawed prior to analysis, and which may have resulted in the loss of water and lower moisture content. The protein content of the peels, based on the results, is 5.5% (w/w). This is notable because protein is needed by the body to maintain fluid balance, to repair tissues, and regulate cell growth, while also being a source of energy (Vaclavik, Christian, 2008).

Another observation to point out is that the dragon fruit peel is low in fat (<0.0005g/100g). Such results mean that the peel poses no health risks if consumed regularly because of its very low fat content. The total sugars as invert is at 3.7% (w/w), invert sugar. Invert sugar is created either by acid or enzyme hydrolysis (Vaclavik, Christian, 2008). This is done to form equal amounts of glucose and fructose which are the basic units of sucrose. The produced sugars which is more soluble, such as glucose, is less sweet and fructose is sweeter. This sugar when combined with untreated sucrose can be applied to food products that require minimal crystallization.

Table 2. Short Chain Fatty Acid Content of Dragon Fruit Peels

SAMPLE	SCFA (mg/g)		
	ACETIC ACID	PROPIONIC ACID	BUTYRIC ACID
Dragon fruit Peel	68.8 ± 1.4	53.8 ± 2.5	32.3 ± 1.7

Results in Table 2 show that the dragon fruit peel contains considerable amounts of short-chain fatty acids. Short chain fatty acids (SCFA) are "carboxylic acids with an aliphatic tail of less than 6 carbons" (IUPAC, 1997). SCFAs are produced by the anaerobic fermentation of fermentable carbohydrates in the colon (Meier, 2009). One of the types of SCFAs are: acetic acid, propionic acid and butyric acid.

According to Henningsson, Björck and Nyman (2001) acetic acid is utilized in the liver where it is converted into Acetyl-CoA, and acts as a precursor for lipogenesis but it can also stimulate the gluconeogenesis. Propionic acid functions in the odd chain fatty acid metabolism as a central metabolite (Layden et al., 2012). Also propionic acid has been shown to inhibit the activity of the enzyme HMG co-enzyme reductase, the limiting enzyme for cholesterol synthesis (Chen, Anderson, Jennings, 1984).

Butyric acid counts for 70% of the total energy demand of the colonic mucosa as it is metabolized by the cells in partiality to glucose and glutamine. Reportedly, it is important for the prevention and treatment of diseases of the colonic mucosa, like distal ulcerative colitis, and cancer (Henningsson et al., 2013). Butyric acid has been described to slow down the growth of colonic tumor cell lines (Whitehead, Young and Bhathal, 1986).

Furthermore, butyrate appears to stimulate apoptosis in tumor cell lines (Hague et al., 1995) and lessen cell differentiations (Barnard and Warwick, 1993). Almonte's study, (2013), also presents the short chain fatty acid content of the peels of several local fruits in the country. The values of the results show that the peels produced significant amounts of SCFA, with mango peels having the highest amount for acetic acid; calamansi has the highest propionic acid content but it was the only fruit that produced trace amounts of butyric acid.

In contrast, the results of the SCFA content of dragon fruit peels showed high amounts of acetic acid (68.9 ± 1.4 mg/g), propionic acid (53.8 ± 2.5 mg/g) and even high amounts of butyric acid (32.3 ± 1.7 mg/g). According to Since, pectin was established as a good source of acetic acid (Casterline, Oles and Ku, 1997), the dragon fruit peels' high amounts of pectin may explain their higher amount of acetic acid. In the study presented by Jamilah et al. (2011), the dragon fruit peels also contain substantial amounts of starch (11.07 ± 0.03), the source of butyric acid (according to Casterline et al., 1997); hence, the peels have remarkable amounts of butyric acid. However, in the same study conducted by Jamilah et al. (2011), the presence of arabinogalactan and guar gum was not determined; yet, this could account for the source of propionic acid (Casterline et al., 1997).

Phytonutrient Content and Antioxidant Activity

As can be observed from the results, the peel can be a good source of polyphenols, flavonoids and anthocyanidins. Polyphenol content is at 459 ± 86 mg gallic/100g, the highest amount of antioxidants in the peel. Polyphenols are known to have antioxidant properties and have the ability to lower the risk of heart disease and cancer (Wu, Chen, Ho and Yang, 2003). The polyphenols are responsible for the red to blue to purple color of some fruits and vegetables, including the pigment betacyanins (Wu et al., 2006), which give the red-purple color of the dragon fruit's peel and flesh. According to the study done by Wu et al. (2006), betacyanins make up the total phenolics found in the *Hylocereus* fruit, due to the presence of the phenol structure in the molecule.

The flavonoids content of the peels is 238 ± 10 mg catechin/100g, the lowest amount detected among the antioxidants. Flavonoids which are also part of the polyphenols, are mostly found in fruits, vegetables and a number of beverages (Buhler and Miranda, 2000). The flavonoids have been of interest to scientists because of their promising biological activities: antiviral, anti-allergic, anti-platelet, anti-inflammatory, anti-tumor and antioxidant activities (Buhler and Miranda, 2000). Its antioxidant activity could reduce free radical formation and scavenge free radicals (Pietta, 2000).

The results for the anthocyanidins show that the peels contain 356 ± 5 mg catechin/100g. Anthocyanidins are also part of a class of flavonoids also responsible for blue, purple, red and orange colors of fruits and vegetables. Their antioxidant effects could prevent or lower the risk of cardiovascular diseases, diabetes, arthritis, and cancer (Miguel, 2011).

Table 3. Phytonutrient Contents per 100 g Dragon Fruit Peels

PARAMETERS	RESULT (MEAN \pm SEM)
Polyphenols (mg gallic/100g sample)	459 ± 86
Flavonoids (mg catechin/100g sample)	238 ± 10
Anthocyanidin (mg catechin/100g sample)	356 ± 5
Antioxidant Activity	
DPPH (mg trolox/100g sample)	2.4 ± 0.4
FRAP (mg trolox/100g sample)	376 ± 31

For the antioxidant activity, the DPPH is lower in terms of percent inhibition, $2.4 \pm 0.4\%$ mg trolox/100 g sample. This analysis is done to determine the radical scavenging activity of antioxidants against free radicals (Tenore, Novellino and Basile, 2012). Although the DPPH activity is lower, it still has some potential because the antioxidant activity of the peels is greater compared to that of the flesh, as presented in the study by Wu et al. (2006). However, for the FRAP activity, the value is higher at 376 ± 31 mg trolox/100 g sample, meaning, it can be a good reductant. The FRAP assay is conducted to determine the antioxidant power of the food sample; reducing ferric to ferrous ion at low pH causes the formation of a blue colored ferrous-tripyridyltriazine complex (Benzie and Strain, 1996). But in the study by Tenore, Novellino and Basile (2012), the results of the DPPH and FRAP assays were in reverse, the peels have higher radical scavenging potential and lower reducing capacity. According to the authors, a reasonable explanation for this different finding may be found in the different polyphenolic profiles in the samples. As suggested by Rodriguez et al. (2002), even small structural changes can deeply affect the phytochemical biological properties of the samples (hence, the different results for the analyses).

Physico-chemical Properties of the Fruit Peel Jam

Table 4. Physico-chemical Evaluation of Dragon Fruit Peel Jam Using Different Types of Sugar

CATEGORY	TREATMENTS		
	Sugar Cane	Honey	Coco Sugar
TSS	66°B	68°B	67°B
pH	3.95	3.70	4.19

According to the Food and Agriculture Organization (FAO, 1995), the standard jam is made up of 50% pulped fruit and 50% sugar with total soluble solids of 60–70°Brix. To form a gel, the fruit must contain pectin and achieve the pH range of 3.2–3.4 required for jams. Since the dragon fruit peels already contain pectin, no commercial pectin was added to the mixtures.

The 3 types of sweeteners formed jams with TSS meeting the standard. However, all the pH values were higher than the requirement; this may be due to the fact that the dragon fruit is not a high acid fruit. Adjusting the pH to the required range may affect the sensory property of the product and may yield a very sour product.

Sensory Properties and Consumer Acceptability of the Fruit Peel Jam

The products were evaluated in terms of sweetness, sourness, thickness, texture, color, dragon fruit flavor, and general acceptability. Based on the statistical analysis, no significant difference was observed among the treatments in terms of sweetness, sourness, thickness, texture, dragon fruit flavor, and general acceptability, except for their color.

Table 5. Sensory Evaluation Results of Dragon Fruit Peel Jam Using Different Types of Sugar

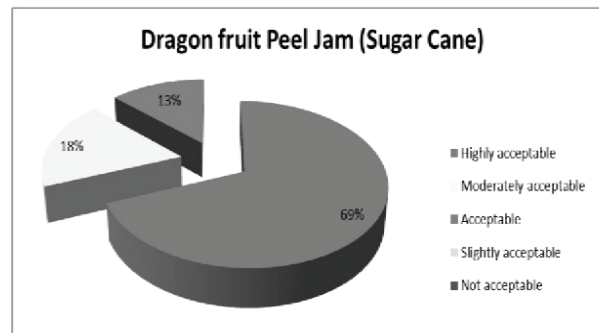
QUALITY ATTRIBUTES	Types of Sweetener		
	(Sugar cane)	(Honey)	(Coco sugar)
Sweetness	2.05	1.75	2.20
Sourness	1.90	2.28	1.83
Thickness	2.10	1.63	2.28
Texture	1.83	2.15	2.03
Color	1.43	1.83	2.75
Dragon fruit Flavor	2.10	2.18	1.73
General Acceptability	2.10	2.18	1.73

For sweetness, no significant difference was observed among the three treatments. The samples were rated as moderately sweet. The same observation was acquired for sourness; all samples were regarded as moderately sour. No significant differences were also perceived for thickness and texture. All samples were moderately thick with a soft texture. Next, the samples were evaluated for their dragon fruit flavour. While the red flesh of the red skin dragon fruit is mildly sweet, the peels are bland to the taste. The grassy nature of the peels flavor was masked by the acid taste from the ascorbic and citric acid used as preservatives; in other words, the products had a weak dragon fruit peels flavour. The jam with sugar cane tasted sweet; the product treated with honey had a fruity flavour; the jam with coconut sap sugar had a flavor similar to that of coco jam.

Differences in color were observed to be highly significant. For each treatment/sweetener produced a gradation of color from red to yellow to brown. Sugar cane gave a reddish pink shade; honey gave a golden yellow color; coconut sugar made the jam dark brown. Sixty percent (60%) of the evaluators rated the samples from the three treatments as highly acceptable. None of the consumer evaluators rated the samples as not acceptable.

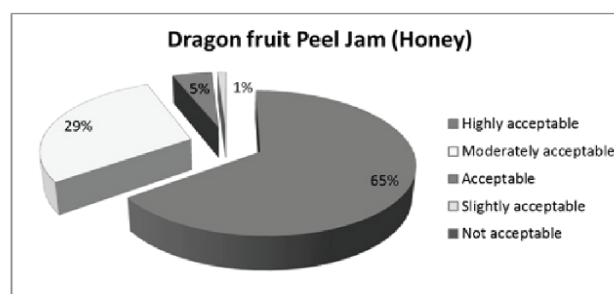
For consumer acceptability test, 69% of the respondents rated the sugar cane-treated jam as highly acceptable; 18% gave it a rating of moderately acceptable; and 13% rated the product as acceptable only (Figure 1).

Figure 1. Consumer Acceptability Result for Jam with Refined Sugar



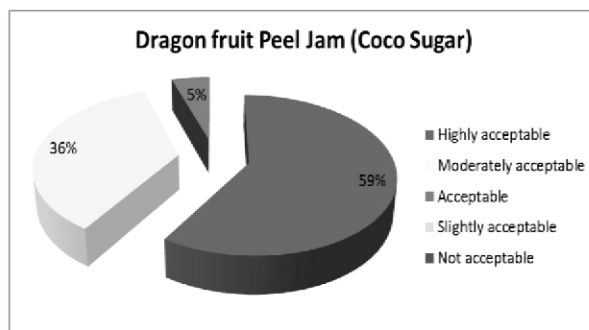
As for the jam with honey (Figure 2), 65% of the respondents assessed the product as highly acceptable; while 29% rated it as moderately acceptable; 5%, acceptable; and only 1%, slightly acceptable.

Figure 2. Consumer Acceptability Result for Jam With Honey



Lastly, for the jam with coconut sugar, 59% of the respondents evaluated the product as highly acceptable, 36% assessed it as moderately acceptable, and only 5%, acceptable (Figure 3). None of the respondents (0%) regarded any of the products as Not Acceptable.

Figure 3. Consumer Acceptability Result for Jam With Coco Sugar



CONCLUSION

The dragon fruit peel is an excellent source of dietary fiber and phytonutrients and may be considered as a safe functional, even healthful, ingredient in the development of food products.

It is recommended that the peels be analyzed for their vitamin and mineral content to determine the significance of their full nutrient composition. The use of the peels for other food products other than the jam may be done.

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