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Research article

Use of pitaya (*Hylocereus* spp.) peel in jam making: Effects of peel/sugar ratio and high methoxyl pectin level on textural quality and overall acceptability of the product

Hoang Phong Nguyen, Luu Ngoc Bao Nguyen, Nu Minh Nguyet Ton*, Thi Thu Tra Tran, Van Viet Man Le

ABSTRACT

Pitaya is a tropical fruit with high nutritional value and is industrially used to make different food products. This fruit has been widely cultivated in different Asian countries. Pitaya peel is usually discarded during fruit processing as a by-product even though it is rich in different nutrients. In this study, pitaya (*Hylocereus polyzhizus* and *Hylocereu undatus*) peel is used as a material to develop a new value-added product. The protein content of red flesh pitaya peel was 1.3 times higher than that of white flesh pitaya peel. The carbohydrate and total dietary fiber contents of red flesh pitaya peel were lower than those of white flesh pitaya peel. The pectin content of red flesh fruit peel was lower than that of white flesh fruit peel. The betacyanin content of red flesh pitaya peel was 1.6 times higher than that of white flesh pitaya peel. Red flesh pitaya peel (*Hylocereus polyzhizus*) was used for the jam experiment due to high antioxidant content and activity. Effects of peel/sugar ratio and high methoxyl pectin level were evaluated for textural properties and overall acceptability. The peel/sugar ratio was varied 30/70, 40/60, 50/50, 60/40, 70/30 (w/w) and the level of high methoxyl pectin was 0 (control), 0.5, 1.0, 1.5, 2.0 and 2.5% of the puree weight. When the peel/sugar ratio increased from 30/70 to 70/30 (w/w), the jam hardness increased by 635% and the overall acceptability of jam increased from 30/70 to 50/50 (w/w). When the high methoxyl pectin level increased from 0 to 2.5%, the jam hardness increased by 120% and the overall acceptability of jam increased from 0 to 1.5%. The peel/sugar ratio 50/50 w/w and 1.5% high methoxyl pectin were appropriate due to the improvement in hardness and adhesiveness.

Key words: pitaya peel, proximate composition, jam, texture, Hylocereus polyrhizus

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INTRODUCTION

Pitaya fruits (*Hylocereus polyrhizus* and *Hylocereus undatus*) belong to *Cactaceae* family[1]. This fruit has been widely cultivated in different Asian countries. In Vietnam, both pitaya fruits with white (*Hylocereus undatus*) and red flesh (*Hylocereus polyrhizus*) are commercially available. Many products are produced from pitaya fruit such as juice, candies, jams, wine… Pitaya fruit processing technology generates various by-products, among which pitaya peel is predominant. Nowadays, pitaya peel is used in the production of animal feed and fertilizer[2]. However, the pitaya peel is rich in different nutrients, including protein, fat, pectin, vitamin B1, vitamin B2. In addition, this peel also contains various bioactive compounds such as betacyanins, and phenolics[3,4]. It can be noted that betacyanins are main pigments with high antioxidant activity from pitaya peel[5]. Recently, pitaya peel was added to the formulation of ice cream[6], noodle[7], bread[8] and cookies[9] to improve their nutritional quality.

Fruit jam is currently a well-known product in our market due to its specific flavor, convenient use, and reasonable price. Jam production is quite simple; the most important process is the mixing of fruit juice, syrup, and pectin prior to jam gelation. Fruit jam has high sugar level and low pH value; as a consequence, high methoxy pectin (HMP) is usually used for jam gelation[10]. Pitaya peel is rich in pectin[11]. Nevertheless, the use of pitaya peel in the formulation of jam product has not been considered in the literature.

In this study, the proximate composition of pitaya peel from white and red flesh was evaluated and compared. The study aimed to clarify the effects of peel/sugar ratio and high methoxyl pectin level on textural quality and overall acceptability of pitaya peel-based jam.

MATERIAL AND METHOD

Materials

Pitaya (*Hylocereus polyzhizus* and *Hylocereu undatus*) peel was obtained from fresh pitaya fruits located in Tan Nghia commune, Ham Tan district, Binh

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Thuan province. In the laboratory, fresh pitaya fruits were washed with tap water, and drained for 10 min. The peel was then separated and stored at -20^{o}C for further experimentation.

For jam preparation, high methoxy pectin was purchased from Herbstreith & Fox KG Pektin-Fabriken, Germany (Classic CS 502, 58-65% degree esterification). Sucrose (99.8% purity) was originated from TTC Bien Hoa, Vietnam. Citric acid was originated from Asia Chemical Joint Stock Company, Vietnam.

Methods

Proximate composition and antioxidant content and activity of pitaya peel from red and white flesh fruit

After defrosting, pitaya peel was cut into 1 cm in width and 5 cm in length. The peel was dried at 60^{o}C for 10 h by a laboratory convective dryer (UM400, Memmert, Germany) until the moisture was less than 13%. The peel was then ground in a mill. The obtained powder samples were used for determination of their proximate composition including moisture, crude protein, total fat, ash, total carbohydrate, starch, total dietary fiber, pectin and degree of esterification (DE) of pectin. In addition, antioxidants including total phenolics, betacyanin content, as well as antioxidant activity of pitaya peel powder samples were also determined.

Effects of peel/sugar ratio on textural properties and overall acceptability of pitaya peel-based jam

Pitaya peel was defrosted and cut into 2 × 2 × 2 cm cubes which were subsequently blanched with hot water at 85^{o}C for 3 min. After blanching, the peels were cooled with water at 2-5^{o}C for 5 min to achieve the room temperature and drained for 2 min. The obtained peels were crushed into puree; the peel/water ratio was fixed at 10% (w/w) for the crushing. The resulting puree, sugar, and citric acid were well mixed. The peel/sugar ratio was varied 30/70, 40/60, 50/50, 60/40, 70/30 (w/w) while the citric acid content was calculated so that the pH value of the mixture was about 3.5. Finally, the mixture was cooked at 80^{o}C to achieve 65% dry matter, filled in plastic bottle and placed at 10-15^{o}C for 24 h for jam gelation. The obtained pitaya peel-based jam samples were used for evaluation of textural properties and overall acceptability.

Effects of high methoxyl pectin level on textural properties and overall acceptability of pitaya peel-based jam

The preparation procedure of pitaya peel-based jam was similar to that described in section 2.2.2. High methoxyl pectin was added to hot water at 85^{o}C and the pectin/water ratio was fixed at 1:20 (w/w). The pectin solution was added to the mixture of puree, sugar, and citric acid at 85^{o}C. The resulting mix was cooked to achieve 65% dry matter. The level of high methoxyl pectin was 0 (control), 0.5, 1.0, 1.5, 2.0 and 2.5% of the puree weight. The obtained pitaya peel-based jam samples were evaluated for textural properties and overall acceptability.

Analytical methods

Proximate composition

Moisture content was determined by the drying method at 105^{o}C until constant weight using a moisture analyzer (ML-50, A&D, Japan). The protein content was evaluated by Kjeldahl - Nessler method (AOAC 984.13, 2000). Ash content was quantified by AOAC 930.30 method (2000). Total carbohydrate content was calculated by subtraction of protein, fat, and ash content from 100. Total, soluble and insoluble dietary fiber content was analyzed by AOAC 985.29; AOAC 993.19 and AOAC 991.42 methods, respectively. Starch content was estimated by AOAC 996.11 method (2007). Pectin was determined by calcium pectate method described by Campbell and Palmer [12]. Degree of esterification of pectin was determined by the method described by Pasandide et al (2017) [13].

Antioxidant content and activity

Extraction of phenolic compounds was conducted by mixing ground sample and 60% (v/v) acetone solution at room temperature for 60 min; the sample/solvent ratio was 1:10 (w/v). Total phenolic content was measured by colorimetric method with Folin – Ciocalteau reagents [14].

Betacyanin content was determined according to the procedure previously described by Priatni and Pradita (2015) [15]. Antioxidant activity was measured according to DPPH (1,1-diphenyl-2-picrylhydrazyl) assay [16].

Textural properties

Textural properties of peel-based jam samples were determined by Texture Profile Analysis (TPA) method using a Texture Analyser (TA-XT Plus C, Stable Micro System, UK) with a Windows version of Exponent Connect Lite 7.0 (Texture Technologies Co., USA).

Two cycles of compression were conducted. The jam samples were compressed by a cylinder probe with 35 mm diameter for 30% deformation; the pre-test speed, test speed and post-test speed were 1, 5 and 5 mm/s, respectively. Hardness, adhesiveness, and chewiness were then recorded[17].

Overall acceptability

The overall acceptability of pitaya peel-based jam samples was evaluated using a 9-point descriptive scale (from 1 - dislike extremely to 9 - like extremely). A 60-member untrained panel was used[17].

Statistical analysis

All experiments were carried out in triplicate. The experimental results were expressed as mean+standard deviation. Mean values were considered significantly different when $p<0.05$. Analysis of variance (ANOVA) and Tukey's comparison test were performed using the software Statgraphics Centurion 18.

RESULTS AND DISCUSSION

Proximate composition and antioxidant content and activity of pitaya peel from red and white flesh fruit

The proximate composition as well as antioxidant content and activity of red and white pitaya flesh fruit are presented in Table 1.

Proximate composition

The moisture content of both red and white flesh fruit peel was statistically similar. Similar results were also reported for red pitaya peel[4] as well as for white pitaya peel[18]. The protein content of pitaya peel with red flesh was 9.0 ± 0.8 (% dry matter), while the pitaya peel with white flesh had lower protein content (7.2 ± 0.4 % dry matter). Similar protein content was previously recorded for pitaya peel with white flesh[18]. The protein content of pitaya peel was significantly higher than that of apple peel (3.2%)[19] and passion fruit peel (3.9%)[20]. Both of dragon fruit peels (*Hylocereus polyrhizus* and *Hylocereus undatus*) had similar fat content. The fat content of pitaya peel was significantly lower than that of passion fruit peel (10.5%)[20] and apple peel (8.5%)[19] but higher than that of citrus lemon peel (4.98%)[21]. The ash content of pitaya peel with red flesh was higher than that with white flesh. Similar ash content was recorded for pitaya peel with red flesh[6]. The ash content of both red and white flesh fruit peel was higher than that of passion fruit peel (4.8%)[20] and banana peel (12.8%)[22].

Table 1 shows that the carbohydrate and total dietary fiber contents of red flesh pitaya peel were lower than those of white flesh pitaya peel. The pectin content of red flesh fruit peel was 1.2 times lower than that of white flesh fruit peel. The pectin content of pitaya peel was significantly lower than that of passion fruit peel (16.4%)[20]. Degree esterification of both red and white flesh pitaya peel was over 50%. Therefore, pectin of both red and white flesh pitaya peel belonged to high methoxyl pectin group[23]. The degree of esterification of pectin from red flesh pitaya peel in this study was 7% lower than that in the study of Muhammad et al. (2014)[24]. Difference in proximate composition of pitaya peel samples is due to different cultivars, cultivation and processing conditions.

Antioxidant content and activity

The betacyanin content of red flesh pitaya peel was 1.6 times higher than that of white flesh pitaya peel. Nevertheless, the total phenolic content of both red and white flesh fruit peel was statistically similar. Similar total phenolic content of red and white flesh fruit peels was previously recorded[25]. The total phenolic content of pitaya peel was higher than that of apple peel (1.1 mg GAE/ 100g dry matter)[19] and banana peel (161 mg GAE/ 100g dry matter)[22]. The antioxidant activity of red flesh pitaya peel was 1.2 times higher than that of white flesh pitaya peel. The antioxidant activity of both red and white flesh fruit peel was higher than that of apple peel (228 μMTE/100g dry matter)[19]. Therefore, red flesh pitaya peel was used for further experiment due to high antioxidant content and activity.

Effects of peel/sugar ratio on textural properties and overall acceptability of pitaya peel-based jam

The hardness, adhesiveness, and chewiness of peel-based jam samples with different peel/sugar ratios are indicated in Table 2.

Hardness is defined as the force necessary to attain a given formation, it is obtained as the maximum peak force during the first compression cycle[26]. When the peel/sugar ratio increased from 30/70 to 70/30 (w/w), the jam hardness increased by 7.3 times. The pitaya peel sample was rich in pectin. Increase in peel/sugar ratio enhanced the pectin content of the jam product. As a consequence, the obtained jam samples were harder. Increase in jam hardness was previously reported by Jin – Sook Kim (2013) when strawberry puree/sugar ratio was increased in the product formulation and that was due to high pectin content[27].

Table 1: Proximate composition and antioxidant content and activity of pitaya peel from red and white flesh fruit

	Hylocereus polyrhizus	Hylocereus undatus
Moisture (%)	93.4 ± 2.9^{a}	89.2 ± 0.8^{a}
Protein (% dry matter)	9.0 ± 0.8^{b}	7.2 ± 0.4^{a}
Lipid (% dry matter)	7.7 ± 0.7^{a}	6.4 ± 0.7^{a}
Ash (% dry matter)	20.3 ± 0.2^{b}	14.2 ± 0.1^{a}
Carbohydrate (% dry matter)	63.1 ± 0.7^{a}	72.2 ± 0.3^{b}
Total dietary fiber (% dry matter)	50.7 ± 0.2^{a}	59.7 ± 0.3^{b}
Soluble dietary fiber (% dry matter)	14.2 ± 0.2^{a}	19.3 ± 0.2^{b}
Insoluble dietary fiber (% dry matter)	36.5 ± 0.1^{a}	40.4 ± 0.1^{b}
Starch (% dry matter)	9.2 ± 0.2^{a}	10.3 ± 0.3^{b}
Pectin (% dry matter)	8.7 ± 0.7^{b}	10.7 ± 0.7^{a}
Degree of Esterification (%)	56.7 ± 5.8^{a}	55.6 ± 9.6^{a}
Betacyanin (mg/100g dry matter)	48.6 ± 0.1^{b}	30.1 ± 0.1^{a}
Total phenolic content (mg GAE/100g dry matter)	290 ± 9^{a}	276 ± 7^{a}
Antioxidant activity by DPPH assay (μmol TE/100g dry matter)	1172 ± 61^{b}	957 ± 82^{a}

Value with different letters within the same row are significantly different ($p < 0.05$)

Adhesiveness represents the work required to pull the compression probe away from the sample. It is calculated as the negative area under the force curve after the first compression cycle [26]. When the peel/sugar ratio increased from 30/70 to 70/30 (w/w), the jam adhesiveness decreased by 2.7 times. Increase in pectin content enhanced the number of bound water molecules in the jam sample; the gel structure was therefore stronger and less adhesive [28]. Decrease in adhesiveness of orange jam was previously recorded by Teixeira (2020) when the orange peel ratio in the product formulation was increased and that was due to higher pectin content [17].

Chewiness represents the amount of energy required to disintegrate jam product for swallowing [29]. The higher the peel/sugar ratio was, the higher the chewiness of pitaya peel-based jam was. When the peel/sugar ratio increased from 30/70 to 50/50 (w/w), the jam chewiness increased by 2.0 times. Similar result was recorrd for banana peel jelly [30].

Table 3 showed the overall acceptability of pitaya peel-based jam samples with different peel/sugar ratios. When the peel/sugar ratio increased from 30/70 to 50/50 (w/w), the overall acceptability of jam increased 1.2 times. Both samples with peel/sugar ratio of 50/50 and 60/40 (w/w) had the highest overall acceptability. However, at the peel/sugar ratio of 70/30 (w/w), the overall acceptability was 0.9 times lower than that at the peel/sugar ratio of 50/50 and 60/40 (w/w) probably due to high hardness and chewiness. Therefore, the peel/sugar ratio of 50/50 (w/w) was suitable for this experiment.

Effects of high methoxyl pectin levels on textural properties and overall acceptability of pitaya peel-based jam

The hardness, adhesiveness, and chewiness of peel-based jam samples with different high methoxyl pectin levels are demonstrated in Table 4.

The addition of high methoxyl pectin to the pitaya peel-based jam significantly improved hardness of the product. When the high methoxyl pectin level increased from 0 to 1.5%, the jam hardness increased by 1.9 times. Increase in pectin content enhanced the number of hydrogen bond in the jam sample [31]. As a result, the gel network of jam would become more rigid [32]. Increase in jam hardness was previously reported by Mohammadi-Moghaddam when the pectin content was increased in the product formulation [33]. Increase in high methoxyl pectin content in the formulation of pitaya peel-based jam reduced adhesiveness of the product. When the high methoxyl pectin

Table 2: Textural properties of peel-based jam samples with different peel/sugar ratios

Peel/sugar ratio (w/w)	30/70	40/60	50/50	60/40	70/30
Hardness (g)	69±2[a]	141±3[b]	155±2[c]	248±5[d]	507±12[e]
Adhesiveness (g.s)	-110±3[b]	-131±3[c]	-146±3[d]	-196±2[e]	-292±6[f]
Chewiness(g)	53±1[a]	73±1[b]	108±1[c]	172±1[d]	349±3[e]

Value with different letters within the same row are significantly different ($p < 0.05$)

Table 3: Overall acceptability of peel-based jam samples with different peel/sugar ratios

Peel/sugar ratio (w/w)	30/70	40/60	50/50	60/40	70/30
Overall acceptability	5.4±1[ab]	5.7±1.1[b]	6.4±1.1[c]	6.2±1.1[c]	5.7±1.1[b]

Value with different letters within the same row are significantly different ($p < 0.05$)

level increased from 0 to 1.5%, the jam adhesiveness decreased by 1.6 times. Increased high methoxyl pectin content enhanced the number of bound water molecules in the jam sample; the gel network was less adhesive [28]. Decrease in adhesiveness of apple jelly was previously recorded by Garrido (2014) when the high methoxyl level in the product formulation was increased [26].

Regarding chewiness, the higher the high methoxyl pectin level was, the higher the chewiness of the pitaya peel-based jam was. Increased pectin content resulted in harder gel structure; the jam product was more chewy. Enhanced chewiness was also mentioned for orange jam when the orange peel level increased [17].

Table 5 shows the overall acceptability of pitaya peel-based jam samples added with different high methoxyl pectin concentrations. In general, all samples were well accepted since their scores were higher than 5 points. The addition of high methoxyl pectin from 0% to 1.5% increased the overall acceptability due to the improvement in hardness and chewiness. However, the overall acceptability decreased when the high methoxyl pectin content increased from 1.5% to 2.5%. High pectin content excessively enhanced the gel strength of jam, leading to a reduced sensory acceptance [34]. Therefore, the level of high methoxyl pectin 1.5% was appropriate for pitaya peel-based jam.

CONCLUSION

Both red and white flesh pitaya peel had high protein content. The degree of esterification of pectin of both red and white flesh pitaya peel was over 50%, which was proved to be appropriate ingredient for fruit jam gelation. The pitaya fruit peel with red flesh was selected for peel-based jam making due to high antioxidant content and activity. The increase of pectin content enhanced the gel strength and the peel-based jam was harder and chewer. The peel/sugar ratio of 50/50 w/w and level of high methoxyl pectin of 1.5% were appropriate for the formulation of pitaya peel-based jam.

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LIST OF ABBREVIATIONS

HMP: High methoxyl pectin;
IDF: Insoluble Dietary Fiber;
SDF: Soluble Dietary Fiber;
TDF: Total Dietary Fiber,
TPC: Total phenolic content

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHORS' CONTRIBUTIONS

Phong Nguyen Hoang: Methodology, Investigation, Data curation, Writing-original draft.
Luu Ngoc Bao Nguyen: Investigation, Data curation.
Van Viet Man Le: Validation, Formal analysis.
Thi Thu Tra Tran: Validation, Formal analysis.
Nu Minh Nguyet Ton: Validation, Formal analysis, Writing - review and editing, Supervision.
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Table 4: Textural properties of peel-based jam samples with different high methoxyl pectin levels

Level of high methoxyl pectin (%)	0	0.5	1.0	1.5	2.0	2.5
Hardness (g)	154 ± 1^{a}	204 ± 2^{b}	233 ± 5^{b}	295 ± 6^{c}	322 ± 3^{cd}	339 ± 7^{d}
Adhesiveness (g.s)	-145 ± 3^{f}	-161 ± 4^{e}	-203 ± 3^{d}	-237 ± 4^{c}	-263 ± 6^{b}	-286 ± 6^{a}
Chewiness (g)	109 ± 2^{a}	132 ± 2^{b}	152 ± 2^{c}	171 ± 11^{d}	212 ± 11^{e}	225 ± 11^{e}

Value with different letters within the same row are significantly different ($p < 0.05$)

Table 5: Overall acceptability of peel-based jam samples with different high methoxyl pectin levels

Level of high methoxyl pectin (%)	0	0.5	1.0	1.5	2.0	2.5
Overall acceptability	6.3 ± 1.2^{a}	6.3 ± 1.1^{a}	6.8 ± 1.1^{b}	7.3 ± 0.9^{c}	6.9 ± 1.1^{b}	6.4 ± 1.0^{a}

Value with different letters within the same row are significantly different ($p < 0.05$)

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Bài nghiên cứu

Sử dụng vỏ thanh long (*Hylocereus* spp.) trong quá trình chế biến mứt đông: Ảnh hưởng tỷ lệ vỏ/đường và hàm lượng high methoxyl pectin đối với tính chất cấu trúc và mức độ chấp nhận của sản phẩm

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TÓM TẮT
Thanh long là loại trái cây nhiệt đới giàu dinh dưỡng và được dùng để sản xuất các sản phẩm thực phẩm quy mô công nghiệp. Loại trái này được trồng trọt rộng rãi tại các đất nước Châu Á. Trong quá trình chế biến, vỏ thanh long thường bị loại bỏ như một phụ phẩm mặc dù vỏ giàu giá trị dinh dưỡng. Trong nghiên cứu này, vỏ thanh long (*Hylocereus polyzhizus* và *Hylocereu undatus*) được dùng làm nguyên liệu phát triển sản phẩm mới giàu giá trị. Hàm lượng protein trong vỏ thanh long ruột đỏ cao hơn 1.3 lần so với vỏ thanh long ruột trắng. Hàm lượng carbohydrate và chất xơ thấp hơn so với vỏ thanh long ruột trắng. Hàm lượng pectin trong vỏ thanh long ruột đỏ thấp hơn so với vỏ thanh long ruột trắng. Hàm lượng betacyanin trong vỏ thanh long ruột đỏ cao hơn 1.6 lần so với vỏ thanh long ruột trắng. Vỏ thanh long ruột đỏ (*Hylocereus polyzhizus*) được sử dụng phục vụ thí nghiệm jam vì hàm lượng chất chống oxy hóa và hoạt tính kháng oxy hóa cao. Ảnh hưởng của tỷ lệ vỏ/đường và hàm lượng high methoxyl pectin được đánh giá qua tính chất cấu trúc và mức độ chấp nhận sản phẩm. Tỷ lệ vỏ/đường được khảo sát từ 30/70, 40/60, 50/50, 60/40, 70/30 (w/w) và hàm lượng high methoxyl pectin là 0 (control), 0.5, 1.0, 1.5, 2.0 và 2.5% khối lượng puree. Khi tỷ lệ vỏ/đường tăng từ 30/70 lên 70/30 w/w thì độ cứng tăng 635% và mức độ chấp nhận sản phẩm tăng dần từ 30/70 đến 50/50 w/w. Khi tăng hàm lượng high methoxyl pectin bổ sung từ 0 đến 2.5% thì độ cứng tăng 120% và mức độ chấp nhận sản phẩm tăng dần từ 0 đến 1.5%. Tỷ lệ vỏ/đường 50/50 w/w và 1.5% high methoxyl pectin được xem là phù hợp cho mẫu jam vỏ vì sự cải thiện độ cứng và độ dính.
Từ khoá: vỏ thanh long, thành phần hóa học, mứt đông, cấu trúc, Hylocereus polyrhizus

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