Value Added Gummy Jelly from Palmyra Palm (*Borassus flabellifer* Linn.)

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Abstract. The palmyra palm (*Borassus flabellifer* Linn.) is a multipurpose tree. It is commonly found along the coasts of Africa, South Asia and Southeast Asia due to its strong tap root system's ability to store a large volume of water and raise the water table level in the surrounding area. Several uses of this plant include beverages, food, medicine, fiber and timber. Unfortunately, due to the short shelf-life of palmyra palm fruit, more than 60% of the annual fruit yield is lost within 10 days of harvesting, and there is limited commercial use of ripe palm fruit. As a result, the physical properties, physicochemical properties, and proximate composition of value-added gummy jelly from palmyra palm were evaluated. The results showed that up to 26% (w/w) of fruit juice (prepared by mixing the mesocarp of ripe palmyra fruit with water (at a 1:1 w/w ratio) and then removing the insoluble pulp) can be added to the gummy jelly recipe with significant effects on textural and color characteristics, as well as changes in moisture, protein, carbohydrate and energy content.

Keyword. Palmyra palm, gummy jelly, value added product

1 Introduction

The palmyra palm (*Borassus flabellifer* Linn.) is a sugar palm that is commonly grown in Africa, South Asian (including India, Bangladesh and Sri Lanka), and Southeast Asia (for example, Thailand, Myanmar, Vietnam, Cambodia, Indonesia and Malaysia) [1, 2]. This plant is also called by various names depending on different languages, such as, Talgachh and Tarkajhar in Hindi and Bangali, Lulu or Tadi in Telugu, Karimpana in Malayalam, Fan palm, Toddy palm, Tala palm and Brab tree in English [3]. This perennial plant has a maximum life span of 100 years. It can reach a height of 30 meters and bear fruit in 15 and 25 years in areas with adequate water and in arid areas, respectively [4]. Palmyra trees are typically planted near waterbodies such as lakes, rivers, and wells since their strong tap root system can penetrate up to 5 ft radially round the topsoil and 5-10 ft deep in the soil, bind the sandy soil around them, absorb moisture and store water. As a result, water resources are protected [4, 5], storm or hurricane speeds are reduced, and soil erosion is prevented [3].

Palmyra trees have nearly 800 applications, including beverages, food, medicine, fiber, and timber [6]. Palmyra products are claimed to have a variety of pharmacological properties, including anti-inflammatory, antiarthritic, cytotoxic, antibacterial, analgesic, antioxidant, antipyretic and hypoglycemic activities [7]. The pharmacological properties of each part of the palmyra palm are listed in Table 1.

Table 1. Pharmacological properties of each part of palmyra palm.

Part of the palmyra palm	Pharmacological properties	Ref.
Seed and seed coat extract	Antimicrobial activity	[3, 8]
Male inflorescence (flower)	Anti-inflammatory activity	[3]
Young roots	Diuretic agents, anthelmintic, coolant, and treatment of respiratory diseases	[9]
Palm fruit	Anti-inflammatory, anti-oxidant and hydration properties, prevention of malnutrition on children and adults	[10, 11]
Fruit pulp	Reduction of skin inflammations, treatment of nausea and vomiting	[3]
Spadix (blossom)	Treatment of heartburn and enlarged spleen and liver	[3]
Flower sap	Tonic, laxative, diuretic agents, stimulant, and amebicide	[3, 12]
Palm sugar	Treatment of liver disorder	[12]
Toddy	Ulcer treatment	[9]
Neera (palm nectar, juice)	Controlling gastric problems and ulcer treatment	[3]

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According to the palm sugar global market trajectory and analysis report [13], the palm sugar market was valued at USD 1.7 billion in 2020 and is expected to reach USD 2 billion by 2027, with a compound annual growth rate (CAGR) of 2.1% from 2020 to 2027. Aside from palm sugar, all parts of the palmyra tree provide several useful products, as presented in Table 2. The total income from one palmyra palm is approximately USD 230-256. In one acre of land, 400-500 palmyra trees can be planted [14]. An acre of land with palmyra palms could generate a total annual income of USD 92,000-128,000. As a result, this plant can provide a year-round source of income for agricultural families.

Table 2. Products from a single palmyra palm per year.

Products	Quantity	Approximately value (USD)
Neera (juice)	150 L	55
Jaggery (palm sugar)	20-25 kg	50-75
Palm candy	16 kg	120
Matured leaves	10 kg	1.38
Coir	11 kg	2.75
Leaf ribs	2.25 kg	0.96
Palm fiber	16-20 kg	0.96
Firewood	10 kg	0.69

Sources: adapted from [3, 4, 14]

The most valuable part of the palmyra palm is the fruit. Like all *Borassus* species, the palmyra palm has male and female flowers on separate plants. Fruits with a black to brown husk and a diameter of 10-18 cm develop after pollination. Each fruit contains 1-3 seeds [8], as shown in Fig. 1. The seeds (endosperm) of an unripe fruit can be eaten as a fruit [9]. The unripe fruit of the palmyra palm is extremely difficult to consume since the hard rind and fibrous portion must be removed before consumption [15]. However, when the fruit is ripe, the fibrous outer layer of the fruit can also be eaten raw, roasted, or boiled [9].

The edible pulp of the ripe palmyra palm is a soft orange-yellow mesocarp that accounts for approximately 51.07% of the total fruit (Fig. 1). This sugary part is slightly bitter and rich in vitamin C and β-carotenoids at 16.9 mg per 100 g of fruit pulp and 3 ppm per g of fruit pulp, respectively [1, 2, 16-18]. Moreover, it is considered to be a good source of pectin, iron, phosphorus, calcium, magnesium and antioxidants [19].

The pulp can be extracted manually or with a fruit pulp extractor using a pulp-to-water ratio of 1:1 or 1:2 [16, 20, 21]. It can be processed into soft beverages, toffee, cakes, jam, jelly, ice cream, sweets, cordials and other delicious food products [19, 22-24]. Unfortunately, over 60% of the annual fruit yield of the palmyra palm is lost within 10 days after harvesting due to its high moisture content, resulting in a short shelf-life [1, 2, 16] and limited commercial use of ripe palm fruit [16]. It is estimated that approximately 10,000 tons of fruit pulp are wasted each year [18].

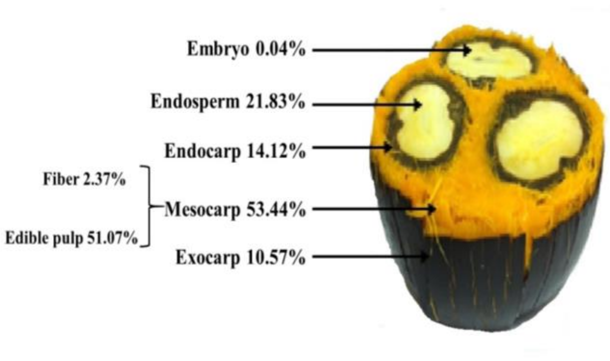

Fig. 1. Components of ripe palmyra palm fruit (adapted from [1, 25]).

The global market for jellies and gummies was valued at USD 13.9 billion in 2018, and it is expected to expand at a CAGR of 3.5% between 2019 and 2025. This market's size has grown as a result of the growing candy industry, the vegan population, and increased consumer spending. The main factors affecting consumers' purchasing decision are usually distinctive flavors, shape, textures, product design, packaging and sugar content [26].

Gummy jelly is one of the confectionery products, often containing high sugar (especially sucrose and glucose syrup) as well as one or more gelling components, flavorings, coloring and food acid [27, 28]. This product is usually produced by heating a sugar solution with gelling components, pouring it into various shapes of molds, and then removing it with powder after hardening [29]. In confectionery gels, sucrose is used as a sweetener while glucose syrup is often added more than sucrose to slow down sucrose crystallization and sucrose molecule migration [29, 30]. Moreover, glucose syrup is used to reduce water activity, which prevents microbial growth [31].

The gelling components used in confectionery gels are polysaccharides, such as thin-boiling starch, pectin, amylopectin, agar, and gum arabic [29]. Pectin, a linear chain of galacturonic acids, is usually extracted from apple pomace or citrus peel [32]. In confectionery gels, high methoxyl pectin or pectin with a degree of esterification greater than 50% is combined with sugar and food acid in order to produce a firm gel [29]. Some of the most common food acids are malic acid, citric acid, fumaric acid, adipic acid and tartaric acid. Food acids can also lower pH and improve product shelf life. In confectionery production, a 50% citric acid solution is usually added at the end of gel processing [29, 31].

Several studies have recently developed gummy jelly containing natural plant extracts and fruit juice, such as *Psidium guajava* leaf extract [33], pineapple and papaya peel powders [34], strawberry syrup [35], honey and propolis [36], *Thunbergia laurifolia* L. extract [37], rosemary (*Rosmarinus officinalis* L.) extract [38] and Babbler's Bill leaf [39]. The purpose of this study was to investigate the physical properties, proximate composition, and energy content of a value-added gummy jelly product made from palmyra palm fruit pulp.

2 Materials and methods

2.1 Preparation of palmyra palm fruit juice

Ripe palmyra palm fruits (*Borassus flabellifer* Linn.) were harvested approximately 2-3 months after pollination in Baan Lard district, Phetchaburi province in Thailand. Each fruit weighed 1-2 kg. The fruits were washed under running tap water and the exocarp (Fig.1) was peeled. The seeds were removed, and the fruit pulp (mesocarp in Fig.1) was then manually extracted into water (pulp:water ratio = 1:1) [16]. After that, the extract was sieved to remove the insoluble pulp and obtain palmyra palm fruit juice. The juice was pasteurized at 65ºC for 5 min [1, 40] and stored at -18ºC until used.

2.2. Sample preparation

The ingredients used in sample preparation were glucose syrup (Capital Glucose Co., Ltd., Nakorn Pathom, Thailand), sucrose (Baanrai Sugar Industry Co., Ltd., Uthai Thani, Thailand), high methoxyl pectin (Union Chemical 1986 Co., Ltd., Nonthaburi, Thailand), sodium citrate (Chemipan Corporation Co., Ltd., Bangkok, Thailand), fructose (Naturbiotic Co., Ltd., Nakorn Pathom, Thailand), and 50% (w/v) citric acid (Chemipan Corporation Co., Ltd., Bangkok, Thailand). According to the preliminary experiments, the formulation of gummy jelly products in this research is presented in Table 3 and the procedures of sample preparation are shown in Fig.2. The preparation processes were independently repeated on 3 separate days as replications.

2.3 Determination of pH and a_w

In order to determine pH, 5±1 g of samples were cut into thin slices and mixed with distilled water (sample:water = 1:3, w/w) [41]. The mixture was heated at 60±2 °C and constantly stirred until completely dissolved. It was cooled at 25°C before being measured with a pH meter (pH510, Eutech Instruments, Klang Selangor D.E., Malaysia), which had previously been calibrated with buffer solutions of pH = 7 and 4 [42].

The water activity of gummy jelly samples was determined at 25±2°C using a water activity meter (Aqualab, CX-2, Decagon Device, Inc., Pullman, WA, USA), which had previously been calibrated with standard solutions of a_w = 0.250 (13.4 mol/kg LiCl), a_w = 0.5 (8.57 mol/kg LiCl), and a_w = 0.984 (0.5 mol/kg KCl) [42]. 2±0.5 g of food product was placed in the sample holder of the water activity meter. All analyses were performed in triplicate.

Table 3. Formulation of gummy jelly from palmyra palm fruit juice.

Ingredients	Sample			
	No fruit juice added	**20% (w/w) fruit juice***	**23% (w/w) fruit juice***	**26% (w/w) fruit juice***
Glucose syrup (%)	42.94	42.92	41.28	39.67
Sucrose (%)	28.87	28.86	27.75	26.67
High methoxyl pectin (%)	2.25	2.25	2.17	2.08
Sodium citrate (%)	0.22	0.19	0.17	0.17
Fructose (%)	4.51	4.51	4.34	4.17
Water (%)	20.00	-	-	-
Palmyra palm fruit juice* (%)	-	20.00	23.00	26.00
50% (w/v) Citric acid (%)	1.21	1.27	1.28	1.24

*The fruit juice was prepared by mixing mesocarp the of ripe palmyra fruit with water (at a 1:1 w/w ratio) and the insoluble pulp was then removed.

Source: adapted from [34]

2.4 Texture profile analysis

Texture profile analysis (TPA) of gummy jelly was measured using a texture analyzer TA.XT2i (Stable Micro Systems Ltd., UK) as described by Amjadi *et al.* [43]. Food samples were compressed twice without being penetrated. Three replicates of the analysis were performed at 25±2°C. The following texture parameters of the samples were reported: hardness, adhesiveness, springiness, cohesiveness and chewiness [41].

2.5 Color analysis

Color values of samples were measured at room temperature using a Hunter colorimeter (Color Quest 45/0, Hunter Associates Laboratory, Inc., Reston, VA) as described by Charoen *et al.* [44]. The instrument was calibrated prior to measurement using standard white and black reflector plates [33]. Four readings per sample were conducted by changing the position of the sample. Three samples of each formulation were measured in each replicate. CIE L*a*b* color parameters (L*: lightness, a*: a positive a* represents redness and a negative a* represents greenness, and b*: a positive b* represents yellowness and a negative b* represents blueness) for 10° vision angle and D65 illuminant were measured.

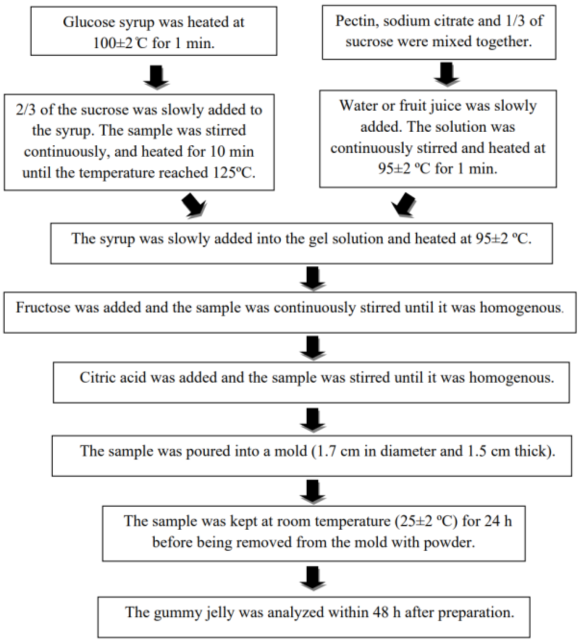

Fig. 2. Workflow for sample preparation.

2.6 Proximate analysis

Proximate analysis, including moisture, protein, lipid, ash, crude fiber and carbohydrate contents, was performed according to the Association of Official Analytical Chemists' procedures [45]. Carbohydrate (%) was calculated using equation (1) [35].

$$Carbohydrate(\%) = 100 - (moisture+ash+lipid+protein) \quad (1)$$

The energy content of each sample was calculated by multiplying the percentages of lipid, protein and carbohydrate by 9, 4 and 4, respectively, and then adding all of the multiplied products together. The energy content in calories was then multiplied by a factor of 4.185 to convert it into kJ [46].

2.7 Statistical analysis

Every analysis was carried out in triplicate, with three subsamples. Significant differences among averages were analyzed in a completely randomized design (CRD) with one-way analysis of variance (one-way ANOVA) and Duncan's multiple range test (DMRT) at a 95% confidence level using IBM SPSS Statistics 26 (IBM Corporation, Armonk, NY).

3 Results and discussion

3.1 pH and a_w

Table 4 presents the pH and a_w of gummy jelly with different concentrations of palmyra palm fruit juice. In this research, citric acid was added to every sample to obtain a pH of ≈ 2.0-3.7, which is the recommended pH range for gelation of high methoxyl pectin [47]. In acidic conditions, pectin chains have lower electrostatic repulsive forces since there is less dissociation of carboxyl groups of galacturonic acid residues [48]. Gummy jelly samples with the addition of palmyra palm fruit juice had a slightly higher pH than the sample without fruit juice ($p<0.05$). Since the pH of palmyra fruit juice was 4.52-4.87, the addition of fruit juice could lead to a slight increase in the pH of the final product. As concentrations of palmyra palm fruit juice increased, a_w of the samples tended to slightly increase since palmyra palm fruit pulp had a high moisture content of 82.13±0.42%. Some gummy jelly products supplemented with natural extracts, such as *Psidium guajava* leaf extract, Babbler's Bill leaf, and juçara and passion fruits, also have a_w of 0.7-0.8 [44, 39, 49].

Table 4. pH and a_w of gummy jelly from palmyra palm fruit juice.

Parameters	Sample			
	No fruit juice added	**20% (w/w) fruit juice***	**23% (w/w) fruit juice***	**26% (w/w) fruit juice***
pH	3.12^b ±0.01	3.22^a ±0.03	3.23^a ±0.02	3.25^a ±0.03
a_w	0.704^c ±0.003	0.685^d ±0.018	0.751^b ±0.003	0.779^a ±0.004

*The fruit juice was prepared by mixing the mesocarp of ripe palmyra fruit with water (at a 1:1 w/w ratio) and the insoluble pulp was then removed.

Data are presented as mean ± SD (n = 3).

Different superscripts within the same row indicate significant difference between the samples in the Duncan's multiple range test ($p < 0.05$).

3.2 Texture profile analysis

Texture profiles are one of the important factors affecting consumer acceptability. The texture profiles of gummy jelly with and without the addition of palmyra palm fruit juice are shown in Table 5. The texture profiles studied in this research included hardness, adhesiveness, springiness, cohesiveness and chewiness. The force required to compress a food product by a given amount is referred as its hardness [41].

Adhesiveness is defined as the energy required to overcome the attractive forces between the food surface and the surface of other materials contacting the food [50]. Springiness is elastic recovery when the compressive force is removed. Cohesiveness is the strength of the internal bonds in the food sample. Chewiness is the amount of energy required to chew a solid food product until it is ready for swallowing [41].

The samples with 23-26% (w/w) fruit juice tended to have higher hardness, springiness, cohesiveness, and chewiness as compared to the gummy jelly without the addition of fruit juice. Since there is approximately 11.6-13.3% sugar found in palmyra fruit pulp [3], the addition of fruit juice to the product can also increase the sugar concentration of the product. Sugar concentration in confectionery products can reduce the hydration of pectin molecules [51]. The hydrophobic interactions of methoxyl groups could also stabilize the gel structure [48]. Furthermore, because palmyra palm fruit is a good source of pectin [19, 52, 53], adding the fruit juice can increase pectin in the food system, resulting in a slight increase in gel strength and, as a result, increasing the hardness, springiness, cohesiveness, and chewiness of the product. A previous study on gummy candies enriched with pineapple and papaya peel powders also found that the modified candies were firmer and more elastic than the control samples [34]. Unlike other texture profiles, the adhesiveness of samples decreased as concentrations of palmyra palm fruit juice increased. In gummy jelly, adhesiveness is usually undesirable [53], since high adhesiveness indicates that the food product would stick to other non-food surfaces, such as the teeth, palate and tongue [50]. Therefore, the product with 26% (w/w) fruit juice, which provided the lowest adhesiveness, was highly recommended over the gummy jelly without fruit juice.

Table 5. Texture profiles of gummy jelly from palmyra palm fruit juice.

Texture	Sample			
	No fruit juice added	20% (w/w) fruit juice*	23% (w/w) fruit juice*	26% (w/w) fruit juice*
Hardness (g.force)	953.55^{b} ±19.88	881.51^{c} ±57.49	$1{,}067.95^{a}$ ±32.81	$1{,}088.23^{a}$ ±32.03
Adhesiveness)g.force(	221.47^{b} ±7.87	325.08^{a} ±9.22	115.42^{c} ±2.83	60.96^{d} ±7.43
Springiness (g.force.sec)	0.968^{b} ±0.003	0.964^{b} ±0.001	0.952^{c} ±0.002	0.979^{a} ±0.003
Cohesiveness	0.639^{a} ±0.006	0.602^{c} ±0.004	0.631^{b} ±0.003	0.637^{ab} ±0.003
Chewiness	563.62^{b} ±15.28	457.95^{c} ±6.06	609.01^{a} ±9.76	571.69^{b} ±19.34

*The fruit juice was prepared by mixing the mesocarp of ripe palmyra fruit with water (at a 1:1 w/w ratio) and the insoluble pulp was then removed.

Data are presented as mean ± SD (n = 3).

Different superscripts within the same row indicate significant difference between the samples in the Duncan's multiple range test ($p < 0.05$).

3.3 Color

The color parameters (L*, a*, b*) of gummy jelly with various concentrations of palmyra palm fruit juice are presented in Table 6. As concentrations of fruit juice increased, all parameters significantly increased ($p<0.05$). The products with palmyra palm fruit juice were orange-yellow (Fig.3) since the fruit pulp is bright yellow or orange (Fig.1) according to the high amount of pro-vitamin A, carotenoids [1, 18, 54]. Srithuvaragan and Anuluxshy could extract pigments from palmyra palm fruit pulp and the yield of β-carotene determined in the literature was 3 ppm per g of fruit pulp [18]. As a result, the palmyra fruit pulp can also be used as a natural food colorant.

Table 6. Color of gummy jelly from palmyra palm fruit juice.

Color	Sample			
	No fruit juice added	20% (w/w) fruit juice*	23% (w/w) fruit juice*	26% (w/w) fruit juice*
L*	20.08^{c} ±0.42	23.81^{a} ±0.32	24.21^{a} ±0.50	21.60^{b} ±0.48
a*	1.75^{d} ±0.10	4.31^{c} ±0.06	5.43^{b} ±0.08	5.79^{a} ±0.15
b*	4.46^{d} ±0.11	5.42^{c} ±0.02	9.21^{b} ±0.14	10.74^{a} ±0.46

*The fruit juice was prepared by mixing the mesocarp of ripe palmyra fruit with water (at a 1:1 w/w ratio) and the insoluble pulp was then removed.

Data are presented as mean ± SD (n = 3).

Different superscripts within the same row indicate significant difference between the samples in the Duncan's multiple range test ($p < 0.05$).

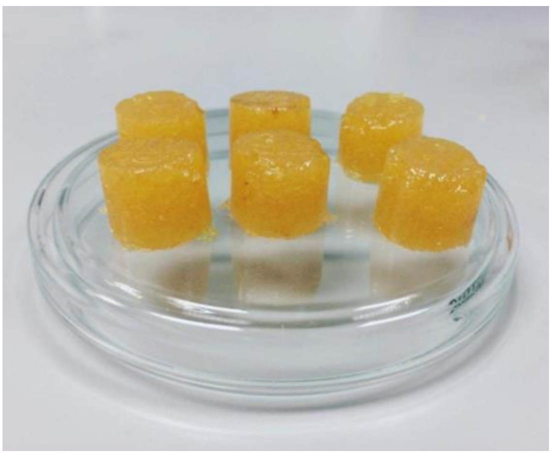

Fig. 3. Gummy jelly with 26% palmyra palm fruit juice.

3.4 Proximate composition

Table 7 presents the proximate composition of the gummy jelly with different concentrations of palmyra palm fruit juice. There was no significant difference in lipid, ash and crude fiber between samples with and without the addition of fruit juice (p≥0.05) since there were low levels of these compositions in the fruit pulp (approximately 2.03-2.06% of lipid, 1.23-1.27% of ash and 0.49-0.52% of fiber) [2]. The addition of fruit juice increased the moisture and protein content of the product while significantly reducing the carbohydrates, resulting in a lower energy content. Although the palmyra palm fruit is high in sugar and carbohydrates [2, 3], the pulp must be extracted using water [16, 20, 21], resulting in the diluted fruit juice and a reduction of carbohydrates in the final product.

Table 7. Proximate composition of gummy jelly from palmyra palm fruit juice.

Composition	Sample			
	No fruit juice added	**20% (w/w) fruit juice***	**23% (w/w) fruit juice***	**26% (w/w) fruit juice***
Moisture (%)	11.60[d] ±0.13	14.22[c] ±0.19	14.84[b] ±0.36	15.79[a] ±0.31
Protein (%)	0.26[b] ±0.03	0.43[a] ±0.04	0.46[a] ±0.02	0.47[a] ±0.01
lipid (%)[ns]	0.16[b] ±0.03	0.19[a] ±0.05	0.17[a] ±0.03	0.14[a] ±0.03
Ash (%)[ns]	0.39 ±0.09	0.45 ±0.09	0.42 ±0.07	0.48 ±0.07
Crude fiber[ns] (%)	0.21 ±0.01	0.21 ±0.01	0.20 ±0.01	0.20 ±0.01
Carbohydrate (%)	87.59[a] ±0.19	84.70[b] ±0.20	84.11[c] ±0.45	83.12[d] ±0.27
Energy content (kJ)	1,476.4[a] ±3.6	1,432.4[a] ±3.1	1,422.2[a] ±6.6	1,404.5[a] ±4.8

*The fruit juice was prepared by mixing the mesocarp of ripe palmyra fruit with water (at a 1:1 w/w ratio) and the insoluble pulp was then removed.

Data are presented as mean ± SD (n = 3).

Different superscripts within the same row indicate significant difference between the samples in the Duncan's multiple range test ($p < 0.05$).

[ns]The samples were not significantly different (p≥0.05).

4 Conclusions

Ripe palmyra fruit pulp can be used to produce gummy jelly with significant effects on the textural and color characteristics of the product, as well as a slight increase in moisture and protein content, but a decrease in carbohydrate and energy content. Furthermore, the addition of fruit juice could also reduce the undesired adhesiveness of the final product. The palmyra palm fruit juice concentration in the product is recommended to be up to 26% (w/w) of fruit juice (prepared by mixing the mesocarp of ripe palmyra fruit with water (at a 1:1 w/w ratio) and then removing the insoluble pulp). This product's production could be potentially profitable for agricultural families.

Acknowledgements

This research was funded by Faculty of Applied Science, King Mongkut's University of Technology North Bangkok (KMUTNB), Contract no. 642053.

References

1. S. Artnarong, P. Masniyom, J. Maneesri, Isolation of yeast and acetic acid bacteria from palmyra palm fruit pulp (*Borassus flabellifer* Linn.), International Food Research Journal, **23**, 3 (2016): 1308-1314
2. M.K. Golly, A.S. Amponsah, V. Mintah-Prempeh, E. Agbamakah, M.A. Akari, L. Adu-Poku, G.F. Paokuaa, V. Gandaa, B. Agodey, Development of food products from palmyra palm (*Borassus flabellifer* L.) fruit pulp for possible commercialization, STU International Journal of Technology, **1**, 4 (2017): 89-102
3. T.R. Sridevi Krishnaveni, R. Arunachalam, M. Chandrakumar, G. Parthasarathi, R. Nisha, Potential review on palmyra (*Borassus flabellifer* L.), Advances in Research, **21**, 9 (2020): 29-40
4. P. Veilmuthu, *Palmyra – nature's perennial gift in the face of climate crisis* (Climate South Asia Network, Bangalore, 2020)
5. B. Kolappan, *Still standing: how palmyra trees withstood the force of the cyclone* (The Hindu, THG Publishing Private Limited, Chennai, 2018)
6. S. Arulraj, B.J. Augustine, Underutilized palms. In: K.V. Peter (ed), *Underutilized and underexploited horticultural crops*, (New India Publishing Agency, New Delhi, 2008)
7. V.P. Gummadi, G.R. Battu, K. Diyya, K. Manda, A review on palmyra palm (*Borassus flabellifer*), International Journal of Current Pharmaceutical Research, **8**, 2 (2016): 17-20
8. H. Jana, S. Jana, Palmyra palm: Importance in Indian agriculture, Rashtriya Krishi, **12**, 2 (2017): 35-40
9. G. Shirisha, R. Sarshaik, J. Nagasowjanya, *Borassus flabellifer* fruit versatile pharmaceutical application: An overview, International Journal of Advanced Research in Medical and Pharmaceutical Sciences, **3**, 4 (2018): 12-16
10. H.J. Pramod, A.V. Yadav, V.N. Raje, M. Mohite, G. Wadkar, Antioxidant activity of *Borassus flabellifer* (Linn.) fruits, Asian Journal of Pharmacy and Technology, **3**,1 (2013): 16-19
11. A. Jerry, A Comprehensive review on the medicinal properties of *Borassus flabellifer*, Journal of

Academia and Industrial Research, **7**, 7 (2018): 93-97

12. P. Saranya, *Characterization of palmyra fruit Borassus flabellifer Linn. pulp and development of ready to serve beverage from palmyra fruit pulp* (Periyar University, Salem, 2016)
13. Global Industry Analysis, Inc., *Palm sugar global market trajectory and analysis (2020-2027)* (Global Industry Analysis, Inc., San Jose, 2021)
14. S. Karthigayini, S. Sahana, V. Sinthujan, Analyzing and recommending marketing strategies for palmyra based productions in Sri Lanka, Journal of Academic and Industrial Research, **8**, 10 (2020): 166-169
15. A. Mani, B. Krishna, P. Dutta, An array of processed and value-added products from palmyra palm, Multilogic in Science, **8**, Special Issue A (2018): 154-156
16. A.K. Chaurasiya, I. Chakraborty, J. Saha, Value addition of palmyra palm and studies on the storage life, Journal of Food Science and Technology, **51**, 14 (2014): 768-773
17. V. Kumari, P. Kiranmayi, P.C. Vengaiah, Estimation of vitamins, minerals and amino acids in palmyra palm (*Borassus flabellifer* L.) fruit pulp, International Research Journal of Pharmacy, **7**, 12 (2016): 70-73
18. R. Srithuvaragan, B. Anuluxshy, Extracting pigments from palmyrah fruit pulp (*Borassus flabellifer* L.) for the production of natural colorants for food, International Journal of Science: Basic and Applied Research, **48**, 4 (2019): 145-151
19. D.D. Ariyasena, E.R. Jansz, A.M. Abeysekera, Some studies directed at increasing the potential use of palmyrah (*Borassus flabellifer* L.) fruit pulp, Journal of the Science of Food and Agriculture, **81**, 14 (2001): 1347-1352
20. D.D. Ariyasena, E.R. Jansz, S. Jayesekera, A.M. Abeysekara, Inhibitory effect of bitter principle of palmyrah (*Borassus flabellifer* L) fruit pulp on the growth of mice: evidence using bitter and non bitter fruit pulp, Journal of the Science of Food and Agriculture, **80**, 12 (2000): 1763-1766
21. E.R. Jansz, N.T. Wickremasekara, K.A.V. Sumuduni, A review of the chemistry and biochemistry of seed shoot flour and fruit pulp of the palmyrah palm (*Borassus flabellifer* L), Journal of the National Science Foundation of Sri Lanka, **30**, 1&2 (2002): 61-87
22. B.C. Das, S.N. Das, *Cultivation of minor fruits* (Kalyani Publishers, New Delhi, 2003)
23. P.J. Rao, M. Das, S. Das, Thermophysical properties of sugarcane, palmyra palm, and date-palm granular jaggery, International Journal of Food Properties, **11**, 4 (2008): 876-886
24. I. Chakraborty, A.K. Chaurasiya, J. Saha, Quality of diversified value addition from some minor fruits, Journal of Food Science and Technology, **48**, 6 (2011): 750–754
25. T.A. Davis, D.V. Johnson, Current utilization and further development of the palmyra palm (*Borassus flabellifer* L., Arecaceae) in Tamil Nadu State, India, Economic Botany, **41**, 2 (1987): 247-266
26. Grand View Research, Inc., *Jellies & Gummies Market Size, Share & Trends Analysis Report By Flavor (Cherry, Berries), By Distribution Channel (Store Based, Non-store Based), By Region, And Segment Forecasts, 2019 - 2025* (Grand View Research, Inc., San Francisco, 2019)
27. P. Burey, B.R. Bhandari, R.P.G. Rutgers, P.J. Halley, P.J. Torley, Confectionery gels: a review on formulation, rheological and structural aspects, International Journal of Food Properties, **12**, 1: 176-210
28. P. Marfil, A. Anhe, V. Telis, Texture and microstructure of gelatin/corn starch based gummy confections, Food Biophysics, **7**, 3 (2012): 236-243
29. H.-D. Belitz, W. Grosch, P. Schieberle, *Food Chemistry (4th edition)* (Springer-Verlag, Berlin, 2009)
30. W.P. Edwards, *The Science of Sugar Confectionery (2nd edition)* (The Royal Society of Chemistry, Cambridge, 2018)
31. E.B. Jackson, *Sugar Confectionery Manufacture (2nd edition)* (Blackie Academic and Professional, London, 1995)
32. A.C. Hoefler, Hydrocolloids: Practical Guides for the Food Industry (Eagen Press, St Paul, 2004)
33. R. Charoen, W. Savedboworn, S. Phuditcharnchnakun, T. Khuntaweetap, Development of antioxidant gummy jelly candy supplemented with *Psidium guajava* leaf extract, KMUTNB International Journal of Applied Science and Technology, **8**, 2 (2015): 145-151
34. K.F. Romo-Zamarrón, L.E. Pérez-Cabrera1, A. Tecante, Physicochemical and sensory properties of gummy candies enriched with pineapple and papaya peel powders, Food and Nutrition Sciences, **10**, 11 (2019): 1300-1312
35. S. Takeungwongtrakul, P. Thavarang, S. Sai-Ut, Development of Strawberry gummy jelly with reduced sugar content from strawberry syrup, International Journal of Agricultural Technology, **16**, 5 (2020): 1267-1276
36. R. Rivero, D. Archaina, N. Sosa, G. Leiva, B. Baldi Coronel, C. Schebor, Development of healthy gummy jellies containing honey and propolis, Journal of the Science of Food and Agriculture, **100**, 3 (2020): 1030-1037.
37. T. Kitpot, Development of gummy jelly mixed with *Thunbergia laurifolia* Linn. extract for reducing breath alcohol concentration, Food and Applied Bioscience Journal, **8**, 3 (2020): 29-37.
38. C. Cedeño-Pinos, M. Martínez-Tomé, M.A. Murcia, M.J. Jordán, S. Bañón, Assessment of rosemary

(*Rosmarinus officinalis* L.) extract as antioxidant in jelly candies made with fructan fibres and stevia, Antioxidants, **9** (2020), 1289.

39. T. Suwan, W. Pradutprom, W. Ngamroop, N. Choosuk, C. Phungamngoen, Development of Babbler's Bill leaf gummy jelly, Burapha Science Journal, **22**, 1 (2017): 189-201
40. S. Artnarong, P. Masniyom, J. Maneesri, Preparation the substrate from palmyra palm fruit by *Candida stellimalicola* fermentation for acetic acid production, KKU Research Journal, **21**, 2 (2016): 397-403
41. P. Delgado, S. Bañón, Determining the minimum drying time of gummy confections based on their mechanical properties, CyTA - Journal of Food, **13**, 3 (2015): 329-335
42. Herbstreith & Fox GmbH & Co. KG, Confectionery Gum and Jelly Products (Herbstreith & Fox GmbH & Co. KG, Neuenbürg/Württ, 2004)
43. S. Amjadi, M. Ghorbani, H. Hamishehkar, L. Roufegarinejad, Improvement in the stability of betanin by liposomal nanocarriers: Its application in gummy candy as a food model, Food Chemistry, **256** (2018): 156-162
44. N. Sumonsiri, N., Kundacha, N. Pom-iam, Effect of microcrystalline cellulose on physical characteristics and sensory acceptance of chocolate flavored milk, Current Research in Nutrition and Food Science, **6**, 3 (2018): 781-788
45. AOAC. *Official Methods of Analysis of AOAC International (19th edition)* (AOAC International, Arling, 2012)
46. M.K. Golly, B. Amadotor, Nutritional composition of the seed of *Icacina senegalensis/oliviformis* (flase yam), Pakistan Journal of Nutrition, **12**, 1 (2013): 80-84
47. A.M. Stephen, G.O. Philips, P.A. Williams, *Food Polysaccharides and Their Applications (2nd edition)* (CRC Press, Boca Raton, 2006)
48. D. Gawkowska, J. Cybulska, A. Zdunek, Structure-related gelling of pectins and linking with other natural compounds: a review, Polymers, **10**, 7 (2018): 762
49. J.S. Miranda, B.V. Costa, I.V. de Oliveira, D.C.N. de Lima, E.M.F. Martins, B.R. de Castro Leite Júnior, W.C.A. do Nascimento Benevenuto, I.C. de Queiroz, R.R. da Silva, M.L. Martins, Probiotic jelly candies enriched with native Atlantic Forest fruits and *Bacillus coagulans* GBI-30 6086, LWT Food Science and Technology, **126** (2020), 109275
50. K. Nishinari, Y. Fang, A. Rosenthal, Human oral processing and texture profile analysis parameters: Bridging the gap between the sensory evaluation and the instrumental measurements, Journal of Texture Studies, **50**, 5 (2019): 369-380
51. P. Sriamornsak, Chemistry of pectin and its pharmaceutical uses: a review. Silpakorn University International Journal, **3** (2003): 206–228
52. S. Assoi, K. Konan, L.T. Walker, R. Holser, G.N. Agbo, H. Dodo, L. Wicker, Functionality and yield of pectin extracted from Palmyra palm (*Borassus aethiopum* Mart) fruit, LWT Food Science and Technology, **58** (2014):214-221
53. S. Assoi, K. Konan, G.N. Agbo, H. Dodo, R. Holser, L. Wicker, Palmyra palm (*Borassus aethiopum* Mart.) fruits: novel raw materials for the pectin industry, Journal of the Science of Food and Agriculture, **97**, 7 (2016): 2057-2067
54. M.H. Rodiah, B. Jamilah, B, S.M. Sharifah Kharidah, A.R. Russly, Physico-chemical and antioxidant properties of mesocarp and exocarp from *Borassus flabellifer*, International Food Research Journal **26**, 5 (2019): 1469-1476