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IMPACT OF DEHYDRATION METHODS ON THE YIELD AND QUALITY OF LIME PEELS PECTIN

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ABASTRACT: Following the extraction of juice from lime fruits, the peels are dried and utilized in the production of pectin. Different dehydration methods are used to dry lime peels. These methods have great impact on the yield and the quality of the resultant pectin. The aim of this study was to investigate the effect of drying methods (hot air oven, microwave and Instant Controlled Pressure Drop (DIC) on the chemical composition of lime peels, and the extracted pectin. The results showed that DIC dried lime peels had the highest moisture content (12.80%), ash content (4.58%) and fiber content (26.83%). The highest pectin yield (25.77%) was obtained from the DIC dehydrated lime peels. The ash content of pectin samples ranged from 2.61% to 3.0%. Pectin extracted from DIC dried peels (DP) had the highest galactuornic acid content (86.82%). Degree of esterification of extracted pectin was 69.18%, 67.90% and 68.50% for oven dried lime peels (OP), microwave dried lime peels (MP) and DIC dried lime peels (DP), respectively. Therefore, all pectin samples were classified as high ester pectin. The extracted pectin samples were used to make strawberry jam and compared to commercial pectin. The results showed also that viscosity values of jam made by extracted pectin were higher than jam made by commercial pectin. The highest value of viscosity was found in jam made with oven pectin (OP) being 480 cp, then jam with DIC pectin (DP) being 472 cp, and then jam with microwave pectin (MP) being 450 cp. Sensory evaluation of jam samples showed that jam made with (DP) had the highest score in respect to colour and texture. Strawberry jams made with OP and DP were characterized by the highest score in respect to odour, taste and over all acceptability.

Key words: Dehydration, yield and quality, lime peels, pectin.

INTRODUCTION

Citrus are acidic, exotic, delicious and nutritious fruits. It includes lime, orange, tangerine, mandarin, grapefruit and lemon amongst others. Lime fruits, like most citrus fruits, had been reported to have a high content of antioxidants and polyphenols **(Kumar *et al.,* 2005)**.

Once the juice and essential oil have been extracted from lime fruits, the remaining by-product constitutes approx. 50% of the original fruit weight. This by- product consists of peels (albedo and flavedo), seeds and fruit pulp. Usually the waste is discarded or used for animal feed. After drying the peels waste is considered one of the main raw material for pectin extraction (**Lario *et al.,* 2004**). Citrus peel, apple pomace and sugar beet pulp are reported to be good sources of pectins **(Wang and Lu, 2014)**. Pectins are widely used in the food industry because of their gel-forming properties. They are used as gelling agents and stabilizers in jams, jellies and acid milk products. **Kanmani *et al.* (2014)** reported that maximum yields of pectin were 36.71% from lime peels, 32.42 % from sweet lime peels and 29.41% from orange peels. **Kumar *et al.* (2005)** evaluated the extraction of pectin from sun dried and microwave- dried Kaffir lime peels using different acids and extraction time for 1 hour at pH 1.5. They added that pectin yields varied

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from 10.4% to 59.30% for sun dried peel while for microwave dried peels it ranged from 25.95% to 61.80%. The best extraction condition has been achieved by using citric acid at 90°C and microwave dried peels. **Georgiev *et al.* (2012)** extracted pectin from orange and lime peels using hot distilled water and hot HCl at concentration of 0.5%. They found that lime peels were richer in pectin than orange peels and acid extraction gave higher yields than water extraction. **Ghanem *et al.* (2012)** reported that whatever the citrus cultivar, the microwave power level has significant effect on drying time of citrus peel (drying time ranged from 51.5 ± 2.828 min to 79 ±0.707 min at 100 W and from 8.75 ±0.353 min to 12 ± 0.707 min at 600 W).

Dehydration is one of the oldest and most widely used methods for fruits and vegetables preservation. The main objective of dehydration is to remove water from plant tissue to reach the level at which microbial spoilage and deterioration reactions are minimized or stopped (**Kristiawan *et al.,* 2011**).

Hot air drying is the most commonly employed commercial technique for drying vegetables and fruits, in which heat is transferred from the hot air to the product by convection, and evaporated water is transported to the air also by convection. However, the major disadvantage associated with hot air dehydrating is the long drying time even at temperatures near 60°C, resulting in the degradation of product quality (**Kumar *et al.,* 2005**). **Azad *et al.* (2014)** used different extraction methods to extract pectin from lime pomace. They reported that optimum conditions were found at 100°C and 60 min. The yield of pectin were 10.33%, 10.83% and 13.13% at ripen, mature stage and premature stage, respectively.

Microwaves are electromagnetic waves consisting of an electric and a magnetic field which oscillate perpendicularly to each other at frequencies ranging from 0.3 to 300 W (**Chen *et al.,* 2004**). Microwave energy acts directly on molecules by ionic conduction and dipole rotation and thus only polar materials can be heated based on their dielectric constant **(Eskilsson and Björklund, 2000)**. **Boukroufa *et al.* (2015)** studied the effect of microwave heating on using orange peels to extract pectin. Maximal yield 24.2% was found when microwave power was 500 W in 3 min. **Yeoh *et al.* (2008)** studied microwave and Soxhelt extraction using different pH values. They reported that the greatest total amount of pectin 5.27% (on dry basis) was obtained when microwave extraction carried out for 15 min, while the same yield was obtained at 3 hours in Soxhelt extraction.

Instant Controlled Pressure Drop (DIC) is a new texturizing process. It has been developed by **Allaf and Vidal (1989)** to improve the quality of hot-air dried food. DIC is a thermos - mechanical treatment which can be applied in agro-industries including drying of fruit and vegetables, as well as improving the extraction process of valuable components such as vegetables oils, polyphenolos and essential oils. DIC is a high temperature (up to 180°C), short time (less than 60 second) treatment followed by an abrupt pressure drop (pressure drop rate > 0.5 Mpa) toward vacuum (Ca. 0.005 Mpa) which allows the products to cross the glass transition border. This leads to an auto- vaporization of small quantity of water in the product and results in porous structure, breaks the cell wall structure and eliminate the microorganisms. The authors concluded that instant cooling of treated products prevents thermal degradation of nutrients. **Mounir *et al.* (2011)** showed that the structural changes occur by the DIC treatment can be observed by open cell structure with connective porous network, and it was different from the untreated products. **Maritza *et al.* (2012)** coupled with a drying step this process provides high-quality finished products for a similar overall cost to hot-air drying alone. **Maritza *et al.* (2012)** compared the effect of various drying methods (hot air drying, freeze drying and DIC) on physical and chemical properties of strawberries. Their results showed that the (DIC) can be used as an alternative technique to dry the foodstuffs with high quality during short time decreasing the costs of the operation. The product quality attributes are drying technique dependent. **Maritza *et al.* (2012)** compared different drying processes (Hot air drying, Freeze drying and DIC) of strawberry. They reported that DIC treatment has a great impact on drying kinetics and performances compared to those of classical hot air drying. The DIC can be used as an alternative technique to dry the foodstuffs with high quality during short time decreasing the costs of the operation.

Téllez-Pérez *et al.* (2013) studied the evolution of the main bioactive compounds (flavonoids and total phenolics) and functional properties such as the antioxidant activity of processed samples in Green "Poblano" Pepper (*Capsicum annuum* L.). They reported that using DIC as intensifying process had a direct impact on active molecules and functional activity in Green "Poblano" Pepper. Results issued from DIC-assisted hot air drying, and DIC-assisted freezing allowed identifying the most important factor in terms of DIC operating parameters. Hence, the saturated steam pressure and the processing time could normally be recognized to obtain the best DIC treatment depending of the considered food operation. **Al Haddad *et al.* (2008)** used hot air, DIC technology and microwaves for drying fruits and vegetables. They reported that it's to difficult to reach low moisture content using hot air drying, unless augmenting the hot air temperature and thus causing thermal degradation of the products and spending more energy. The DIC technology by expanding the product improves its quality and increases the drying kinetics. By using microwave assisted by ambient temperature air for drying sample already expanded by DIC, they get around 5% of moisture content on dry basis with a very high final product quality within less than 5 minutes of drying instead of, at least, two hours for DIC sample and more than 8 hours for non-treated by DIC sample, both finally dried by conventional hot air (45°C). **Maritza *et al.* (2012)** compared the effects of drying methods on antioxidant activity of dried strawberry (*Fragaria* Var. Camarosa). The obtained results showed that the differences in phenol levels were no quite comparing the three drying techniques; however, great variations were reported for anthocyanin and flavonoid content, a strong correlation between the antioxidant activity and anthocyanin content was found in DIC strawberries.

The present study reports for the first time the effect of DIC dehydration technique of citrus peel (lime peel) on the yield and quality of the extracted pectin. The purpose of this search was to study the effect of different drying methods (hot oven, microwave and Instant Controlled Pressure Drop DIC) on lime peels and extracted pectin. Also, study the viscosity and sensory evaluation of strawberry jam made from extracted pectin.

MATERALS AND METHODS

Materials

Fresh lime fruit used in this study were obtained from Agriculture Research Center Farm, Cairo, Egypt. Strawberry fruits and white sugar were purchased from supermarket in Cairo, Egypt. Citric acid and commercial pectin (Degree of esterification 63-66%) were purchased from El-Nasr Chemicals Company, Cairo, Egypt. All chemical used were analytical grade.

Methods

Preparation of Lime Peels

The fruits were carefully washed with tap water, cut into two halves and juice was extracted by hand pressing. The resultant lime peels were collected and cut to small pieces then divided into two portions. The first portion was stored directly in freezer until use and designated as fresh lime peels (FLP). The second portion was soaked in water at 90°C for 5 min, filtered by cheese cloth and divided into three portions, the first portion was dehydrated at 70°C in hot oven oven dried lime peels (ODP). The second portion was dehydrated in microwave (model Daewoo KOR- 185H) using 60% of power level for 30 min microwave dried lime peels (MDP). The third portion was dehydrated by DIC technique (University of La Rochelle, La Rochelle, France), using pressure 0.45 bar for 120 sec for 4 cycles (time of cycles 30 sec.), and the sample was designated as DIC dried lime peels (DDP).

Pectin Extraction

Pectin was extracted from dried peels according to **Owens and Schultz (1952)** as shown in Fig. 1. Hundred grams of dried peel were suspended in 3000 ml distilled water (1:30 *W/V*) and the extraction was carried out at pH 1.3 (adjusted by HCL) at 90°C for 1 hour. The slurry was cooled and filtered through cheese cloth. The filtrate was suspended and precipitated by isopropanol 96% at (1:1 *V/V*). The mixture was kept at room temperature overnight. The mixture was filtered through a cheese cloth and hand pressed. The precipitate was washed with Hcl/isopropanol (70:30 *V/V*). Washing was repeated 6 times by 70% isopropanol. Finally, the precipitate was washed with 96% ethanol and allowed to dry at 30°C using dry oven.

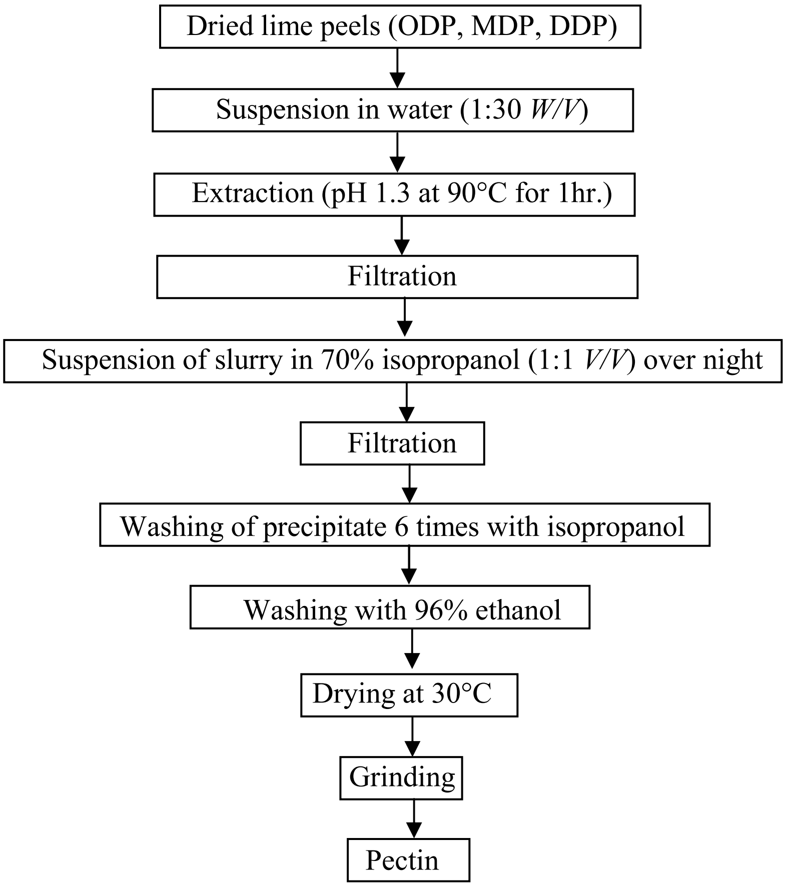

Fig. 1. Steps of extraction method of lime pectin

Jam Processing

Strawberry jam was prepared according to **Abo Samaha *et al.* (2011)** with some modifications. After removing cap of strawberries, the fruits were washed by water then they were mixed with white sugar (1:0.75 *W/W*) followed by cooking to 65% total soluble solids with continuous mixing. Pectin powder (0.4%) from the commercial and the extracted pectin was mixed with small sugar and added in final stage of cooking. Citric acid (0.3%), based on the added sugar was dissolved in water before adding to the mixture. The percentage of total soluble solids in final product of jam was 65%.

Analytical Methods of Lime Peels

Moisture, ash, fat, crude fiber, pH, and titratible acidity were determined according to **AOAC (2000)** for fresh and dried lime peels. Ascorbic acid content was determined using 2.6 dicholrophenol-indophenol was determined according to **Rangana (1977).** Chlorophyll a, Chlorophyll b and Carotenoids contents were determined for all samples according to **Holm (1954) and Wettstein (1957).**

Physico-chemicals Properties of Pectin Sample

The yield of pectin was calculated according to **Allam (1988).** Moisture and ash contents were determined according to the methods of **AOAC (2000**). Anhydrogalacturonic acid (AUA) and degree of esterification (DE) of pectin were determined according to **Allam (1988).** Equivalent weight was determined according to **Rangana (1977)**. The methoxyl content was determined according to **Gee *et al.* (1958).**

Viscosity of pectin solution (0.2%) was determined in National Research Center by Brookfield (DV-III ULTRA) Programmable Rheometer model, using spindle 03 /250 rpm.

Determination of colour value of pectin samples were measured by Hunter Lab, L optical sensor D25 (Reston, Virrginia, USA). Colour parameter L* indicates degree of lightness, a* indicates degree of redness to greenness and b* indicates degree of yellowness to blueness (**Hunter, 1958**).

Viscosity Measurement of Jam

Jam viscosity was determined in Institute of Food Technology Agriculture Research Center by Brookfield (DV-III ULTRA) Programmable Rheometer model, using spindle 03/250 rpm at 21.9°C.

Sensory Evaluation

The sensory evaluation of prepared jam samples was evaluated according to **Sulieman *et al.* (2013**), for taste, colour, odour, texture. The sensory evaluation was recorded according to a scale of 1 to 10 points under the following scale: (10-9) excellent, (8-7) good, (6-5) fair, (4-3) poor and (2-1) very poor.

RESULTS AND DISCUSSION

Chemical Composition of Dried Lime Peels

Moisture, ash, fat, pH, titritable acidity, fiber and ascorbic acid contents are shown in Table 1. Fresh lime peels showed moisture content of 70.36%. Dried lime peels had moisture content of 6.94, 10.66 and 12.80% for ODP, MDP and DDP, respectively.

Ash content was 5.48, 3.66, 3.92 and 4.58% for FLP, ODP, MDP and DDP, respectively. **Ghanem *et al.* (2012)** reported that moisture and ash contents of lemon peels were 75.041% and 4.683%, respectively.

Fat contents were 22.49, 9.88, 4.85 and 6.93% for FLP, ODP, MDP and DDP samples, respectively. **Marín *et al.* (2007)** found that fat content for lemon peels was 4.00%.

Fiber contents for FLP, ODP, MDP and DDP were 14.47, 20.84, 22.63 and 26.83, respectively. **Gorinstein *et al.* (2001)** reported that fiber content for lemon peels was 14.0% (DM).

pH values for lime peels samples were 3.53, 3.52, 3.54 and 3.88 for FLP, ODP, MDP and DDP, respectively.

Titratible acidity of FLP, ODP, MDP and DDP were 8.75, 3.18, 3.13 and 3.60 as anhydro citric acid (%), respectively.

Ascorbic acid content for FLP, ODP, MDP and DDP was 32.45, 8.51, 14.50 and 4.85 mg ascorbic/100 g, respectively.

As shown in Table 2, the amount of chlorophyll a found in FLP, ODP, MDP and DDP was 4.41, 2.81, 3.16 and 6.76 mg/100g, respectively.

Chlorophyll b content for FLP, ODP, MDP and DDP was 3.60, 1.35, 0.99 and 5.40 mg/100 g, respectively.

Carotenoids contents for FLP, ODP, MDP and DDP were 2.24, 1.17, 2.23 and 3.81 mg/100 g, respectively. It can be seen that DDP had the highest content of Chlorophyll a, Chlorophyll b and carotenoids compared to ODP and MDP. This might be due to the effect of DIC technique which allowed the release of the phytochemicals compared to oven and microwave drying methods.

Chemical and Physical Properties of Extracted Pectin

Moisture content of pectin extracted from lime peels is shown in Table 3. Moisture content of pectin is necessary to determine its specifications for commercial consideration and keeping quality of pectin. According to the specifications for identification of pectin used in food industries as mentioned by the Food Chemists Codex and FAO/WHO, the moisture content of pectin must be no more than 12%. The moisture content of pectin samples ranged from 6.90 to 7.28%. It was observed that DP had the lowest moisture content being 6.90 %, while OP and MP had higher moisture contents of 7.28% and 7.06%, respectively. Moisture content of citrus pectin in literature data ranged between 6.4 – 10% (**Rehman *et al.*, 2004**). These results are in agreement with **Kholaf (2018)** who found that moisture content of lemon and lime pectin were 7.26% and 6.50%, respectively. Pectin should have as low moisture content as possible to inhibit the growth of microorganisms and for safe storage that can affect pectin quality **(Muhamadzadeh *et al.*, 2010).**

Table 1. Chemical composition of dried lime peels (on dry wt. basis)

Lime peel	Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	pH	Titritable acidity (%)	Ascorbic acid (mg/100 g)
Fresh lime peels (FLP)	70.36 *	5.48	22.49	14.47	3.53	8.75	32.45
Oven dried lime peels (ODP)	6.94	3.66	9.88	20.84	3.52	3.18	8.51
Microwave dried lime peels (MDP)	10.66	3.92	4.85	22.63	3.54	3.13	14.50
DIC dried lime peels (DDP)	12.80	4.58	6.93	26.83	3.88	3.60	4.85

* On wet wt weight.

Table 2. Chlorophyll a, Chlorophyll b and carotenoids of dried lime peels (on dry wt. basis)

Lime peel samples	Chlorophyll a mg/100 g	Chlorophyll b mg/100 g	Carotenoids mg/100 g
Fresh lime peels(FLP)	4.41	3.60	2.24
Oven dried lime peels (ODP)	2.81	1.35	1.17
Microwave dried lime peels(MDP)	3.16	0.99	2.23
DIC dried lime peels (DDP)	6.76	5.40	3.81

Ash content of pectin samples ranged between 2.61% and 3.0% as shown in Table 3. **Azad *et al.* (2014)** reported that ash content of lime pectin varied from 2.41 to 4.06%. Obtained results are in agreement with these reported by **Kholaf (2018)** who found that ash content of pectin extracted from lemon and lime peels were 2.97 and 2.16%, respectively.

Pectin Yield

Extraction yield of pectin obtained from dried lime peels as affected by different dehydration methods is shown in Table 4. The yields of extracted pectin were 23.77%, 20.44, and 25.77% for OD, MP, and DP, respectively. The results showed that the highest yield was found in DIC dried method. The DIC treatment could be attributed to structure modification of lime peels, which was expanded during DIC thermal-mechanical treatment, allowing bioactive compounds to be more available, for extraction. **Siliha *et al.* (2015)** concluded that the mechanical effect of pressure drop occurred during DIC treatment of cactus peel resulted in structural modification of the plant tissue, being open with high expansion rate for DIC treated peels compared to the untreated. **Mounir *et al.* (2011)** also showed that more available flavonoids was observed after the DIC treatment of apples. **Téllez-Pérez *et al.* (2013)** reported that DIC treatment increased extraction of polyphenols compounds from Green "Poblano" Pepper (*Capsicum annuum* L.) The results obtained from this study are supported by **Kholaf (2018)** who found that pectin yield from lemon and lime were 30.2% and 16.8% by acid extraction and 34% and 35% by microwave extraction, respectively. **Wang *et al.* (2014)** found that the maximum yield of citrus peels pectin was 21.95% by subcritical water extraction. These results were lower than that obtained by **Kanmani *et al.* (2014)** whereas the pectin yield from lime peels was 36.71%.

Galacturonic acid contents of extracted pectin are shown in Table 5. Galacturonic acid content is very important parameter for pectin specification According to Codex Foods, galacturonic acid content must not be less than 78%. The content of galacturonic acid in pectin indicates the purity of the extracted pectin according to the food **(Chemical Codex, 1996)**. The results showed that the galacturonic acid

Table 3. Moisture and ash contents of extracted pectin from dried lime peels

Pectin sample	Moisture (%)	Ash (%)
Oven dried lime peels pectin (OP)	7.28	2.80
Microwave dried lime peels pectin (MP)	7.06	2.61
DIC dried lime peels pectin (DP)	6.90	3.00

Table 4. Effect of drying method on pectin yield extracted from lime peels

Pectin sample	Pectin yield (%)
Oven dried lime peels pectin (OP)	23.77
Microwave dried lime peels pectin (MP)	20.44
DIC dried lime peels pectin (DP)	25.77

Table 5. Galacturonic acid content, degree of esterification, equivalent weight and methoxyl content of extracted pectin from lime peels

Pectin sample	Galacturonic acid content (%)	Degree of esterification (%)	Equivalent weight	Methoxyl content (%)
Oven dried lime peels pectin (OP)	80.05	69.18	754	10.30
Microwave dried lime peels pectin (MP)	80.38	67.90	720	10.20
DIC dried lime peels pectin (DP)	86.82	68.50	700	10.11

contents were 80.05%, 80.38% and 86.82% for OP, MP and DP, respectively indicated that DP was characterized with the highest galacturonic acid content. In this study the results are in agreement with the results obtainted by **Kholaf (2018)** who reported that the pectin extracted from lemon and lime had galacturonic acid contents of 85.44% and 73.64%, respectively.

Degree of esterification of extracted pectin is shown in Table 5. Degree of esterification of extracted pectin were 69.18%, 67.90% and 68.50% for OP, MP and DP, respectively. No prounouncel difference were observed in degree of esterification among pectin samples. Pectin is divided into two groups: high ester pectin and low ester pectin. The high ester pectin has a degree of esterification higher than 50%, and the low ester pectin has degree of esterification lower than 50%. In this study all pectin samples are classified as high ester pectin. These results are similar to those stated by **Kholaf (2018)** who found that degree of esterification of lemon and lime peels were 69% and 64%, respectively. **Azad *et al.* (2014)** found that degree of esterification lime pectin was 70%.

The equivalent weight of pectin samples is shown in Table 5. The equivalent weight of pectin is an indicator of its gel-forming ability. A higher Eq.W. designates a higher gel-forming effect (**Vaclavik and Christian, 2008**). No prounouncel difference was observed in equivalent weight in all samples, it was 754, 720 and 700 for OP, MP and DP, respectively. **Rodsamran and Sothornvit (2018)** compared between characterization of pectin from lime peels extracted by microwave heating and pectin from lime peels extracted by the conventional heating method. Their results showed that equivalent weight ranged from 635.63 to 2219.39, and the highest equivalent weight was observed for the pectin using citric acid. They reported that microwave heating provided pectin with a higher equivalent weight than conventional heating for both acid types. A strong acid could lead to smaller pectin particles owing to an increase in the partial hydrolysis and partial degradation of pectin at higher temperature and with a longer extraction process (**Tang *et al.,* 2011**).

The methoxyl contents for all studied samples ranged from 10.11 % to 10.30%. Methoxyl groups of pectic play a great role in pectin solubility and gelling power properties, since its presence in high percentage decrease the polarity of pectin molecules (Table 5).

Viscosity of pectin samples is shown in Table 6. It was observed that DP was characterized by higher viscosity value (52.4 cp) than OP (35 cp) and MP (27.2 cp). The viscosity of the pectin from microwave heating was greater than that from conventional heating at the same solid concentration (**Rodsamran and Sothornvit, 2018**).

Colour value of pectin samples measured by Hunter Lab is shown in Table 7. Colour parameters (L*) were 74.02, 68.92 and 72.91 and a* values were 0.16, 0.41 and 1.31 and b* values were 9.68, 1.16 and 11.79 for OP, MP and DP, respectively. OP and DP samples were characterized by light colour while MP showed relativity darker colour. The decrease in b* values in microwave drying could be due to the destruction of the yellow and orange colour of peel. According to **Chua and Chou (2005**), during microwave drying, the bio-products are subjected to high temperatures with higher power of microwave. A similar trend was found by **Ghanem *et al.* (2012)** who reported that microwave drying decreased L* and b* for lemon peels. Therefore, the colour is adversely affected in the drying method realized at high microwave powers. The results showed that the best colour in the samples of pectin was in DP sample. This is due to the fact of DIC treatment is carried out using high temperature and high pressure for a short period of time, thus maintaining the natural colour.

Some Properties of Manufacture Strawberry Jam

Viscosity is one of the physical measurement used in this study. Table 8 shows the viscosity values of four jam samples *i.e.,* three samples made from extracted pectin (OP, MP, DP) and one made by commercial pectin as comparing sample.

The results showed that viscosity values of jam made by extracted pectin were higher than jam made by commercial pectin. The highest value of viscosity was found in jam with OP being 480 cp, then jam with DP being 472 cp, and then jam with MP being 450 cp. **Kholaf (2018)** reported that jam with pectin extracted by microwave from lime have higher viscosity values than jam with commercial pectin.

Sensory Evaluation

Sensory evaluation of jam samples is shown in Table 9. The results showed that jam with (DP) pectin had the highest score in colour and texture. Jam with OP and DP pectin had the highest score in odour, taste and over all acceptability. **Kholaf (2018**) reported that all jam samples made by pectin extracted from lime peels were accepted by the panelists. **Sulieman *et al.* (2013**) used pectin extracted from orange and lime peels in the production of jam. They reported that two samples of jam made by orange pectin and lime pectin weren't significant in overall acceptability.

Conclusion

Reported for the first time, the DIC method is considered as promising dehydration method for lime peels destined for pectin extraction industry. Pectin extracted from DIC dehydrated lime peels had the highest galacturonic acid content, highest degree of esterification, highest viscosity compared to pectins extracted from lime peels dehydrated by microwave and hot oven. The results obtained from this study showed that highest pectin yield was found in DIC dried lime peel (DP). The DIC treatment could be attributed to the new generated food matrix structure, which was expanded during

Table 6. Viscosity of extracted pectin from dried lime peels

Pectin sample	Viscosity (cp)
Oven dried lime peels pectin (OP)	35
Microwave dried lime peels pectin (MP)	27.2
DIC dried lime peels pectin (DP)	52.4

Table 7. Hunter Lab colour parameters of extracted pectin from lime peels

Pectin sample	L*	a**	b***
Oven dried lime peels pectin (OP)	74.02	0.16	9.68
Microwave dried lime peels pectin (MP)	68.92	0.41	1.16
DIC dried lime peels pectin (DP)	72.91	1.31	11.79

* Indicates degree of lightness, ** Indicates degree of redness to greenness and *** Indicates degree of yellowness to blueness.

Table 8. Viscosity of strawberry jam

Jam sample	Viscosity (poise)
Jam with commercial pectin	370
Jam with (OP)	480
Jam with (MP)	450
Jam with (DP)	472

Table 9. Sensory properties of prepared strawberry jam

Treatment	Texture	Colour	Odour	Taste	Over all acceptability
Jam with commercial pectin	8.4	8.6	8.5	8.6	8.3
Jam with (OP)	8.9	8.9	8.4	8.9	9.6
Jam with (MP)	8.6	8.4	8.4	8.5	8.6
Jam with (DP)	9.6	9.8	8.5	8.6	9.8

DIC thermal-mechanical treatment, allowing increase pectin extraction. Also, galacturonic acid content was the highest in (DP) compared with other samples. The results showed that the best colour in the samples of pectin was in (DP) sample. This is due to the fact of DIC treatment is carried out using low heat and high pressure for a short period of time, thus it maintaining the colour of pectin. The results showed that viscosity values of jam made by extracted pectin had higher viscosity than jam made by commercial pectin. The highest value of viscosity was found in jam with (OP). The results showed that Jam with (DP) has the highest score in colour and texture.

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تأثيـــــر طــــرق التجفيـــف علــــى كميـــــة وجـــــودة بكتيـــن قشـــــور الليمـــون

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يتم استغلال القشور المتخلفة عن استخلاص عصير ثمار الليمون فى إنتاج البكتين، وقد استخدمت طرق عديدة فى تجفيف قشور الليمون حيث كانت لها تأثيراً كبيراً على كمية وجودة البكتين المتحصل عليها، ولذا فإن هذا البحث يهدف الى دراسة تأثير طرق التجفيف (فرن الهواء الساخن، الميكرويف و تكنولوجيا التفريغ اللحظى) على التركيب الكيميائى لقشور الليمون والبكتين المستخلص منها، أوضحت النتائج أن قشور الليمون المعامله بتكنولوجيا التفريغ اللحظى كان لديها اعلى محتوى من الرطوبة (١٢,٨٠%)، والرماد (٤,٥٨%) والألياف (٢٦,٨٣%) مقارنة بالعينات الاخرى (قشور الليمون المجففة بفرن الهواء الساخن والميكرويف)، كما أظهرت النتائج أن قشور الليمون المجففة بتكنولوجيا التفريغ اللحظى أعطت أعلى إنتاجية من البكتين (٢٥,٧٧%)، وقد تراوح محتوى الرماد فى عينات البكتين ما بين ٢,٦١ و٣,٠٠%، ولوحظ أن أعلى محتوى من حمض الجلاكتيورنيك كان فى البكتين المستخلص من تكنولوجيا التفريغ اللحظى (٨٦,٨٢%)، وكانت درجه الاستره للبكتين المستخلص من قشور الليمون المجففة بالفرن، الميكرويف وتكنولوجيا التفريغ اللحظى هى ٦٩,١٨، ٦٧,٩٠ و٦٨,٥٠% على الترتيب، لذلك فان جميع عينات البكتين تصنف على انها بكتين مرتفع الاستره، وقد استخدمت جميع عينات البكتين فى تصنيع مربى الفراولة، حيث أظهرت النتائج أن قيم اللزوجه فى المربى المصنعه باستخدام البكتين المستخلص الناتج من طرق التجفيف المستخدمة كانت أعلى من لزوجة المربى المصنعه من البكتين التجارى، وسجل التقييم الحسى لعينات المربى أن تلك المصنعة من البكتين المستخلص من القشور المعاملة بتكنولوجيا التفريغ اللحظى كانت ذات أعلى قيم فى اللون والقوام، كما سجلت المربى المصنعه من البكتين المستخلص من القشور المعاملة بفرن الهواء الساخن و المربى المصنعة من البكتين المستخلص من القشور المعاملة بتكنولوجيا التفريغ اللحظى اعلى قيم للرائحة والطعم و القبول العام.

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