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Mango Peel Pectin by Microwave-Assisted Extraction and Its Use as Fat Replacement in Dried Chinese Sausage

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Abstract: In this research, low-fat dried Chinese sausage was formulated with mango peel pectin (MPP) extracted by microwave assisted extraction (MAE) (0%, 5%, 10% and 15% (w/w). The extractable yield of pectin attained from peel of Nam Dok Mai variety was achieved at 13.85% using 700-watt power. The extracted MPP were of high equivalent weight (1,485.78 mg/mol), degree esterification (77.19%) and methoxyl content (19.33%) with the structure of more porosity as compared to that of the conventional method. Spectrum scans by Fourier transform infrared spectrophotometer (FT-IR) advised that the extracted MPP gave the similar wave number profiles as the commercial pectin. Quality attributes of the Chinese sausages were accessed and compared with the control formula (CTRL). At higher concentrations of MPP, the product had positively increased colour intensity. The texture profile of the sausage illustrated that only the hardness value was comparable with the CTRL, while springiness, cohesiveness, gumminess and chewiness were statistically lower ($p < 0.05$). Furthermore, the sensory evaluation by experienced panellists (n=12) indicated that 5% MPP similarly represented overall acceptability with the CTRL. Consequently, MPP can be effectively applied at low level as fat replacement in Chinese sausage allowing colour improvement and product of healthier option.

Keywords: dried Chinese sausage; fat replacement; mango peel pectin; microwave-assisted extraction technique

1. Introduction

Fears for non-communicable diseases (NCDs) has influenced the awareness of naturally functional ingredients in human diet [1]. This trend, in addition, motivates the decrease in consumption of animal fats which has affected to novel formulation of products with reduced fat content [2]. However, the challenge is that the reformulations of food containing less fat than it traditional complements could adversely affect their original sensory properties certifying [3-5]. Processed meats are usually products of high fat content providing that fat could significantly improve texture, flavour, mouthfeel, and perceived juiciness of meat stuffs [6-7]. Therefore, excessive decrease in fat content can considerably alter the structural characteristics of food [8]. Chinese or Cantonese-style sausage, also called Kunchiang in Thai, is one of traditional preserved meat products. The main ingredients are meats (pork or chicken) mixed with high content of pork fat [9]. Attempts have been made in order to partly decrease or absolutely remove fat from Chinese sausage [10-11]. One option is by integrating functional ingredients such as rice starch, gum and pectin to replace the sum amount of lipid ingredient [12].

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Dietary fibre is carbohydrate polymer with more than 10 monomeric units making it is difficult to be hydrolysed by endogenous enzymes in human small intestine [13-14]. The fibre can be classified into two groups, viz., insoluble (cellulose and hemicellulose) and soluble (pectin, galactomannan, inulin, gum), depending on its solubility in aqueous solution [15]. Additionally, pectin is of commercial need for functional food industry [16]. Extractable pectin is utilised as food additive that promoted in the processes of gelling, stabilising and thickening [17]. Méndez-Zamora et al. [18] claimed that fat can be replaced with pectin and inulin in frankfurter sausages to produce healthy and functional products. The supplementation could also maintain the physical properties of meat product [19-20].

Mango peel is a potential source of dietary fibre with 5 - 11% pectin depending on the extraction methods and also of fruit varieties [21-23]. Moreover, it comprises of considerable various classes of polyphenols, carotenoids and vitamins with excellent antioxidative and functional properties [24-25], thus making the by-product of this kind a promising target for commercial valorisation [26-27].

To recover pectin from plant resources, microwave-assisted extraction (MAE) represents more effective for the extraction of satisfactory amounts of high pectin quality, compared with conventional heating techniques [28-31]. Such technique has been adopted with pectin-rich biomasses such as banana peels [32], mango peels [22,33-34], pumpkin [35], and orange peels [36]. For Thai 'Sampee' mango variety, Sommano et al. [22,34] reported the improved in recovering yield of mango peel pectin (MPP) by moderate microwave radiation with the preserve bound phenolic content and antioxidant scavenging activities. Chaiwarit et al. [37] reported that MPP from var. 'Nam Dok Mai' could be a potential biopolymer for film formulation as drug delivery systems or edible film for food packaging. There is, however, no research conducted on the functionality MPP as food additive in particular as fat replacer. With this rationale, the objectives of the present study were first to quantify the effect of MAE on functional properties of MPP of var. Nam Dok Mai and its use to formulate the reduced fat Chinese sausage.

2. Materials and Methods

2.1. Preparation of mango peel powder

Peel was removed from fully ripe mangoes var. Nam Dok Mai (L = 50.90 ± 4.34, a* = 4.82 ± 2.35, b* = 16.59 ± 3.09; peel thickness = 138.76 ± 10.55 mm; percentage of peel to fruit weight = 5.31 ± 0.38%). The peels were cut into small pieces, washed with tap water, blanched with hot water at 95 ^{o}C for 10 min, drained and cooled by spraying tap water, prior to drying at 60 ± 1 ^{o}C to obtain final moisture content of 4-6% [38]. The dried peel was ground to a fine powder in a high-speed food processor, and passed through a sieve, resulting in a final mass of particles smaller than 0.6 mm in diameter [39-40].

2.2. Extraction of mango peel pectin using microwave-assisted technique

Twenty grams of mango peel powder were suspended in 600 mL of diluted acidic solution (distilled H_2O adjusted to pH 1.5 with 2 M HCl) and soaked for 20 min at room temperature. The slurry was heated in a microwave oven with an output power of optimal condition (700 watts for 3 min) followed by re-cooling to room temperature [22]. The solution was filtered and pressed manually using a nylon cloth. The filtrates were centrifuged at 5,000 xg for 20 min to eliminate any remaining coarse particles. Pectin was precipitated from this clear supernatant by adding the same volumes of ethanol (95%); mixed and stored in a refrigerator at 4 °C for 30 min. The separation was achieved by vacuum filtration. The obtained pectin was dried in a hot air-oven at 40 °C until constant weight [41]. The yield (%) of pectin was calculated from the following equation [40];

$$\text{Yield (\%)} = \left(\frac{M_0}{M}\right) \times 100 \quad (1)$$

Where; M_0 (g) = the weight of dried pectin

M (g) = the weight of dried mango peel powder

2.3. Scanning electron microscope

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Pectin powder was attached onto a specimen stub with a double-sided tape and sputter coated with gold [42], [22] (Jiang et al., 2012a; Sommano et al., 2018b). The images were viewed at magnifications of × 100 and × 500 using SEM (JELO JSM-5910, Japan) with an accelerating voltage of 10 kV.

2.4. Fourier transform infrared spectrophotometer (FT-IR)

FT-IR analysis was implemented using an infrared spectrometer (Nicolet 6700, USA) equipped with MCT Detector (Mercury cadmium telluride). Each sample was scanned by placing the sample side down on the ATR diamond crystal and applying the pressure tower. The spectrum was verified in the transparent mode from 900 to 4,000 cm^{-1}, with a resolution of 4.0 cm^{-1} [22]. Each IR spectrum was improved for optical effects with the ATR correction algorithm (OMNIC software).

2.5. Mango peel pectin characterisations

The equivalent weight (Eq.W) was determined by the method of Ranganna [43]. Briefly, 0.5 g of dried pectin was dissolved in 100 mL of distilled water at 25 °C and stirred for 2 h until completely dissolved. One gram of sodium chloride was added and titrated with 0.1 M of sodium hydroxide (NaOH) using 5 drops of phenol red as an indicator. Eq.W was calculated using the following equation;

$$\text{Eq.W} = \frac{\text{1,000 x pectin powder (g)}}{\text{NaOH concentration (N) x NaOH volume (mL)}} \quad (2)$$

Methoxyl content (Mox) and Degree of Esterification (DE), the methods suggested in Ranganna [44] and Pinheiro et al. [45] were followed. Dried pectin (0.2 g) was stirred in CO_2-free distilled water (20 mL) until fully dissolved. One gram of NaCl was added to the solution, prior to titrating with 0.1 N NaOH in the presence of phenolphthalein. The volume was recorded as the initial titre (V_1). Then, 0.1 N NaOH solution (10 mL) was added to a neutralised polygalacturonic acid sample after the determination of the free carboxyl groups. The solution was mixed thoroughly until the colour of the solution became purple. A few drops of the indicator (0.25 N HCl) were added, and the mixture was titrated with 0.1 N NaOH until the colour turned from yellow to pink. The volume was noted as V_2. The Mox and DE were then calculated using the following equations;

$$\text{Mox} = \frac{(N)(V_2)(E)}{\text{1,000 (S)}} \quad (3)$$

$$\text{DE} = \frac{V_2 \text{ x } 100}{V_1 + V_2} \quad (4)$$

Where;

S = Mass of dried pectin (g)
N = NaOH concentration (N)
V1 = Volume of NaOH used (mL)
V2 = Volume of NaOH used (mL)
E = Equivalent weight of methoxyl = 31

The water-holding capacity (WHC), oil holding capacity (OHC) and swelling capacity (SWC) were evaluated following with some modified method of Robertson et al. [46]. Phosphate buffer (1 M, pH 6.3, 25 mL) or commercial olive oil were added to 250 mg of dry sample, stirred thoroughly and left at room temperature for 1 h. The residue was weighed after centrifugation at 3000 xg for 5 min. For SWC analysis, 0.1 g of sample was hydrated in 10 mL of distilled water in a calibrated cylinder (15 cm diameter) at room temperature. After equilibration for 18 h, the bed volume was documented. The WHC was expressed as amount of water (g) held per sample (g); the OHC was expressed oil (g) held per sample (g), while the SWC was expressed as mL/g of sample.

2.6. Development of dried Chinese sausage added mango peel pectin

2.6.1. Dried Chinese sausage formulation

Chinese sausage ingredients (CTRL) obtained from Chiang Mai Livestock Product Research and Development Centre consisted of pork, fat, sugar, sodium nitrite, sodium erythorbate and water at (%w/w) 60.0, 20.0, 12.0, 1.2, 0.1 and 6.7, respectively. Pork and fat were ground and then mixed with

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all ingredients. Pectin powder was added at a level of 5, 10 and 15% (w/w) fat replacement. It was firstly dissolved with 2 g of clean water and then mixed with the prepared ingredients for 10 min with cutter mixer (QS600, Baicheng, China). After that, the ingredients were added in dried pork sausage casing and dried in a hot air-oven at 60 ± 5 °C for 48 h. The sausages were left to cool at room temperature, packed in vacuum nylon bag and stored at 4 ±1 °C.

2.6.2. Physical quality assessments of dried Chinese sausage

- Colour

Chinese sausages added with 0, 5, 10 and 15 %(w/w) of MPP were sliced into 10-mm thickness. The colour measurement was repeated 10 times using different parts of the sausage surface using handheld colour spectrophotometer (NS800, 3nh, China). Before each set of measurements, the instrument was calibrated using a white ceramic tile. The measurement was with CIE Lab system; where L∗ denotes lightness on a 0 to 100 scale from black to white; a∗ denotes (+) red or (−) green; and b∗ denotes (+) yellow or (−) blue. To compare the overall colour changes between the MPP-supplemented Chinese sausage samples and the CTRL, the total colour differences (ΔE) between the samples (L*, a*, b*) and the CTRL (L_0*, a_0*, b_0*) were calculated as presented below [47-48];

$$\Delta E_{ab} = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (5)$$

- Texture

The sausages sliced for colour measurement were also used for Texture Profile Analysis (TPA) using a TA-TX2 texture analyser (Stable Micro Systems Ltd., Surrey, UK), attached with a 50-kg load cell. A 50-mm diameter compression cylindrical aluminium probe was used to compress a cylindrical shape of the sausage, which were compressed twice to 30% of the original height of the sausage at a compression rate of 1.0 mm/s at room temperature. The TPA settings were as follows: pre-test speed: 2.0 mm/s; test speed: 1.0 mm/s; post-test speed: 2.0 mm/s; target mode distance: 3.0 mm; trigger force: 5 g; trigger type: Auto; data acquisition rate: 200 points per sec. (pps). The delay between the first and second compression was 5 sec. The TPA analysis was carried out at ambient temperature (25 °C) and the analysis was completed within 17 sec. Six measurements were operated for each sample in the same lot. A force-time graph was generated and textural parameters, including hardness, cohesiveness, springiness, gumminess, and chewiness were calculated with software provided along with the instrument [49].

- Sensory test

Sensory evaluation of the Chinese sausage products was operated following the modified procedures by Siddaiah et al. [50] using a panel of 12 individuals from Chiang Mai Livestock Product research and Development centre, who had experience with the sensory assessment of process meat products. All the panels were assured they under-stood the definitions of appearance, juiciness, springiness, firmness, colour and overall acceptability before the panel test for Chinese sausage. Preparation of the meat products for testing occurred in a kitchen separated from the evaluation room, eliminating possible interference of fried odour. The sausage samples were sliced into 7-mm thickness and then fried with palm oil for 3 min in a low heat. Each panelist was given 2 pieces of each sample for evaluation on 9-point hedonic scale (1 = strongly dislike, 9 = strongly like).

2.7. Statistical analysis

All experiments will be operated at least triplicate samples for each test. Data was analysed using one-way analysis of variance and Duncan's test. Difference in values was considered significantly when the p value was < 0.05. All statistical analyse was performed using SPSS program (version 22.0, USA).

3. Results and discussion

3.1. Mango peel pectin extraction using microwave-assisted technique (MAE)

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3.1.1. Physical properties

- Scanning electron microscope

SEM was performed to characterise the surface of commercial citrus pectin (Figure 1a) and our MPP (Figure 1b) samples by visualising their structures and morphology. The images demonstrated that the pectin particles were of distinct shapes, Nam Dok Mai MPP presented pellets to bulky and rough particles, which differed greatly from the shape of the commercial pectin that were comparatively smooth surface. Nevertheless, the MPP particles extracted using MAE 700 watts were crumblier in shape and with more porous surfaces. Begum et al. [51] reported that the dehydrated pectin obtained from jackfruit by freeze-dried and spray-dried had high solubility due to their high porosities, smaller particle size, and higher surface area. Thus, pectin particles with more porous structures usually have a better solubility, than particles with the rigid structure and lower porosity, thereby increasing solution viscosity [52]. The porous quantity of pectin correlated with water holding capacity and affected on low hardness of low-fat frankfurter sausage property [18]. The dietary ingredients influence on high binding ability and water holding capacity of meat product [53]. According to particular characteristic of microwave, it is actually more efficient than other extraction methods due to the strong formation of vapour in polar substances created by the electromagnetic field [54]. Heat vapour modifies the cell wall matrix and leads to the severing of parenchymal cells, which rapidly and extensively opens the skin tissues, thus increasing the interaction between the extracting agent and the plant material during the extraction process [55]. Besides, the images of Nam Dok Mai MPP (Figure 1b) suggested a rough, ruptured and wrinkled surface which could be due to the sudden increase of temperature in the MAE process. Similarly, Liew et al. [56] reported that the coarse surface of the extracted pectin using MAE could be due to the rapid raise in temperature. Sources of raw materials as well as modes of extraction could largely influence morphology of the resulted pectin [28]. Regarding to commercial citrus pectin morphology, the surface showed multi-laminate structures and was fluffy with a smooth surface [57], which was considerably different from the MPP surface. The application of MAE in the extraction of pectin from the mango peel intensely increased extraction yield and also saved extraction time. From their high porosity, MPP is appropriate for fat replacer in Chinese sausage.

- FT-IR

The FT-IR analysis was generally used to evaluate the conformation of pectin bands in the standard region usually between 1,000 and 2,000 cm^{-1} for the major chemical and functional groups [58]. Figure 2 illustrated the FT-IR region ranging from 900 to 4,000 cm^{-1} of MPP. These demonstrated the similarities of the transmittance (%T) patterns in pectins extracted from different source materials. An individual peak at around 3,400 cm^{-1} was likely due to the stretching of the hydroxyl groups, whereas a small peak at around 3,000 cm^{-1} indicated C–H stretching of the CH_2 groups [59]. The strong absorption represented at 1,730–1,760 cm^{-1}, characteristic of esterified pectins, arising from the ester carbonyl stretching band, and peaks at 1,600–1,630 cm^{-1} and 1,400–1,450 cm^{-1} were due to the anti-symmetric and symmetric stretching frequencies of the ionic carboxyl groups ,[60]. The region at wavenumbers between 1,500 and 1,800 cm^{-1} was associated with the assessment of the degree of methylation ,[61]. Thus, the sharp peak at 1,730 cm^{-1} in the pectin spectra was corresponded to a higher DE value (Table 1) [62]. The region between 950 and 1,200 cm^{-1} is accordingly referred to as the 'finger print' for carbohydrates, especially sugar composition [63]. The intense peaks related to the characteristics of pectin polysaccharides (polygalacturonic acid) performed at 962, 1,024, 1,099, 1,156 and 1,223 cm^{-1}, which were assigned to C-O bending, C-C stretching, C-O stretching, C-H stretching and C-O stretching, respectively [62]. FT-IR analysis verified that the extracted constituent was pectin. Similar band patterns were detected in pectin extracted from Sam-pee mango [22], banana peel [64] and lime peel [62].

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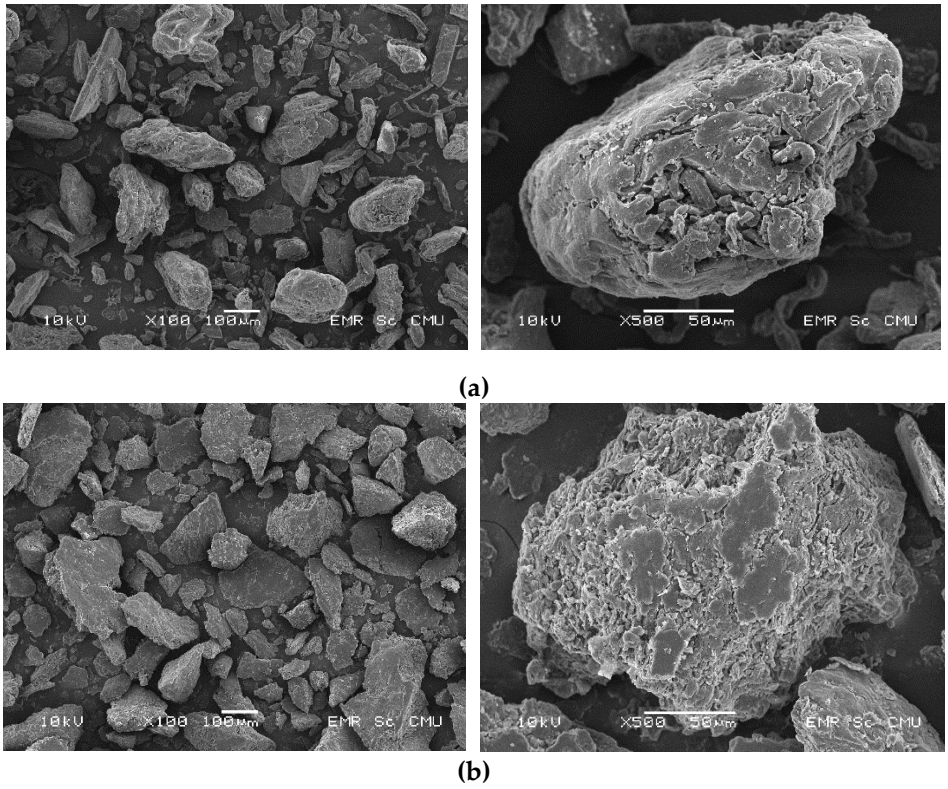

Figure 1. The SEM images of commercial pectin (citrus) **(a)** and pectin obtained using microwave-assisted extraction (MAE) from peel of Nam Dok Mai mango at 700 watts **(b)**. The images were viewed at ×100 (left) and ×500 (right).

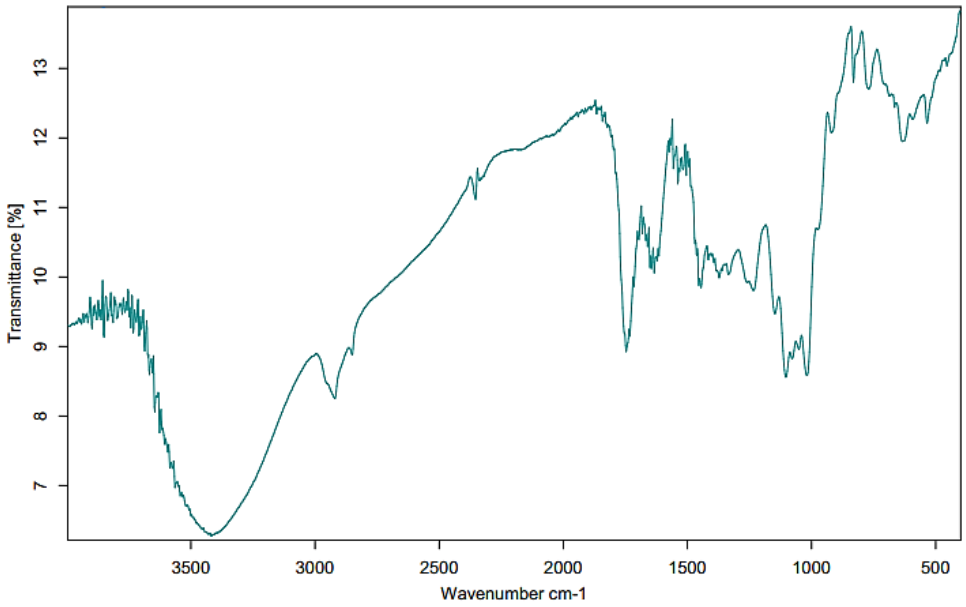

Figure 2. The FT-IR spectra of pectin extracted from Nam Dok Mai mango peel using MAE at 700 watts, from 900 to 4,000 cm^{-1} (x axis). T% is the percentage of transmittance (y axis).

3.1.2. Characterisation of mango peel pectin

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Table 1 illustrates the characterisation of Nam Dok Mai MPP extracted by conventional and MAE techniques. The average yield of MPP extraction operated by conventional heating was approximately 0.80% [22], which was dramatically low when compared to the quantity of pectin extracted by MAE at 700 watts (13.85%). Microwave extraction gave better pectin recovery when compared to conventional extraction. Similarly, MAE was reported to be applicable mode of extraction for high yield pectin recovery in grapefruit (27.81%) and navel orange peel (18.13%) [39,65]. Microwave heating is indeed more efficient than other extraction methods due to the intense formation of vapour in polar substances generated by the electromagnetic field [54]. Heat vapour modifies the cell wall matrix and leads to the severing of parenchymal cells, which rapidly and extensively break down cell membrane, thus increasing the interaction between the extracting agent and the plant material during the extraction process [55]. In addition, microwave energy also resulted in the inactivation of the pectinase [54].

Colour of pectin is an essential parameter as it influences on the appearance of the formulate gel. The colour of MPP obtained from MAE technique is shown in Table 1. Comparing the lightness (L*), our extracted MPP was slightly darker than that of commercial citrus peel pectin extracted using the same extraction method [62]. To this, pigmentation of the biomass could play important role as the pigments cannot be removed by extraction steps. Moreover, non-enzymatic browning reactions, i.e., Maillard reaction and caramelisation, are also influenced by heating and might be of great contribution to the pectin colour [66]. In addition, high pigmented pectin may be as result of bound polyphenols [67] or other water-soluble pigments. Different extraction conditions (time and temperature) could also affect pectin colour [68].

Equivalent weight (Eq.W) of pectin is an indicator of gel-forming ability. The greater Eq.W, the higher gel-forming ability achieved [69]. The Eq.W of the MPP was about 1,400 mg/mol which was 2 folds higher than that of the conventional extraction. The values are comparable with citrus pectin illustrated ranges of Eq.W between 635.63 to 2,219.39 mg/mol depending on the extracting methods [62]. Pectin recovered by MAE seems to give higher Eq.W than that of the conventional heating. The lower Eq.W could be due to higher partial degradation of pectin, thus the increase or decrease in the Eq.W value might be dependent upon the amount of free acid [70]. Consequently, it can be indicated that the heating of microwave has less damage to the pectin structure than that of the conventional method.

Methoxyl (Mox) content is an essential indicator of pectin setting time, their sensitivity to polyvalent cations and their beneficial properties in the preparation of low solid gels, films and fibres [71]. Moreover, Mox also represents the pectin distribution ability in water and gel ability [72-73]. Pectin extracted by MAE at 700 watts gave 19.33% Mox which was significantly higher than that of the conventional extraction (13.90%) [22]. Commercially, a high methoxyl pectin (generally at 8–11% Mox) can form gels at a high sugar content (> 65% sugar), while a low methoxyl pectin with less than 7% Mox can form gels at a lower sugar content [74]. In this study, MPP was classified as high methyl pectin due to the higher Mox (> 7%); therefore, it could readily disperse in water and had a higher binding capacity with sugar with ideally suitable to Chinese sausage formula with high sugar composition [62].

DE is a significant molecular index for pectin classification that defines the extent to which carboxyl groups in pectin molecules exist as the methyl ester [75]. The DE value of pectin extracted by MAE from Nam Dok Mai mango peel was 77.19% which was higher than using conventional heating method (68.90%). In the similar study, MAE of pectin from lime albedo, pulp and flavedo produced higher DE values than those of conventional extraction pectin [28]. According to the DE values, MPP extracted by MAE can be classified as high methoxyl pectin as DE > 50% [36,76]. In addition, the pectin had a rapid-set gel formation as DE > 72% [72]. Acid type and heating method were the important factors affected the DE rather than the peel-to-extractant ratio [62].

Swelling capacity (SWC), water holding capacity (WHC) and oil holding capacity (OHC) of MPP extracted using MAE 700 watts are represented in Table 1. SWC elucidates how much the fibre matrix swells when water is absorbed. The high SWC is correlated to the amount of soluble dietary fibre, especially pectin [77]. The SWC value result acquired for MPP (24.16 mL/g sample) was greater than

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those obtained for other fruit fibre, including those from passion fruit pulp, peel and seeds (7.2 mL/g sample) [78] or cocoa pod husks (5.81 mL/g sample) [79]. This value is identified the structural characteristics and chemical composition of the fibre play an important role in the kinetics of water uptake [80].

WHC is the ability of a moist material to hold water when subjected to an external centrifugal gravity force or compression. The value consists of the sum of linked water, hydrodynamic water and physically trapped water, the latter of which contributes most to this capacity [81]. WHC of MPP was 9.60 g water/g sample, while the fibres from passion fruit albedo and passion fruit seed and pulp were 13.00 and 1.80 g water/g sample, respectively [77]. Besides, Chirinang [82] reported that the WHC of cassava pulp (8.17 g water/g sample) was higher than those of onion by-products [83], malt bagasse, oat hull, rice hull and fibrous residue from banana pseudo-stems [84]. WHC value demonstrated that Nam Dok Mai pectin has potential applications in products requiring hydration, viscosity development, and freshness preservation, such as cooked meat or bakery [77].

OHC is a physical property associated with the chemical structure of plant polysaccharides and depends on surface properties, overall charge density, thickness, and the hydrophobic nature of the fibre particle [85]. Our MPP presented a considerably lower OHC (0.81 g oil/g sample) than other fruit and vegetable-derived fibres, such as passion fruit albedo, 2.03 g oil/g sample [77], pomegranate bagasse, 5.9 g oil/g sample [86], or ripe kiwi 6.00 g oil/g sample [87]. As a result of its low OHC, the extractable MPP has potential ingredients for fried products since it would not provide a greasy sensation [77].

Table 1. Qualities and functionalities of mango peel pectin extracted by conventional and MAE techniques.

Extraction techniques	Qualities of pectin							Functionalities of pectin		
	Pectin yield (%)	L*	a*	b*	Equivalent weight (mg/mol)	Methoxyl content (%)	Degree of esterification (%)	Swelling capacity (mL/ g sample)	Water holding capacity (g water/ g sample)	Oil holding capacity (g oil/ g sample)
MAE 700	13.85 ± 0.51	36.33 ± 1.11	5.25 ± 1.05	11.26 ± 2.13	1,485.78 ± 0.74	19.33 ± 0.04	77.19 ± 0.72	24.16 ± 0.22	9.60 ± 0.46	0.81 ± 0.04
Conventional*	0.80 ± 0.06	-	-	-	657.89 ± 47.33	13.90 ± 2.10	68.90 ± 3.70	-	-	-

Data are expressed as mean ± standard deviation, n = 3
MAE 700 = microwave-assisted extraction at 700 watts
*Reference method Sommano et al. [34]
- = no data

3.2. Physical quality assessments of formulated dried Chinese sausage

3.2.1. Colour

Lightness (L*), redness (a*), and yellowness (b*) are considered the most informative parameters for quality assessment of product [88]. Surface colour of the dried sausage supplemented with MPP was illustrated in Table 2. From the result, it can be described that the higher concentration of the MPP added to the sausage, the lower the value of lightness. Our result also illustrated that, the redness and yellowness of the sausage increased in all formulated product and the colour intensity was higher with the increasing concentrations of the MPP. The result is correspondent with the report of Sarıçoban et al. [89] who found that the carotenoids as food additive improved the redness in meat batters. Compared with the CTRL (0% pectin), ΔE values of the formulated products were significantly distinct from the CTRL ($p < 0.05$) ranging from 9.91- 5.55 from the highest to the lowest concentrations, respectively. For this it is possible that food additive may convincingly play to the darkening of the product. According to Almeida et al. [90], fat replacement with high amount of amorphous cellulose (75% and 100%) in emulsified cook sausage reduced the surface lightness of the product. The values were well correspondent to the appearance of the sausage as illustrated in Table 2. Regardless of the product mouth-feel, it might be a promising option to adjust the colour of sausage

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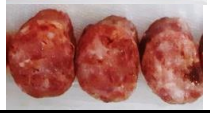
by adding differently treated MPP, which may be a good choice as a partial substitute for nitrite [91]. The others textural enhancement such as protein isolate and starch, however, affected colour of the meat product differently. Moreover, the protein isolate from pea can enhance cod sausage colour towards higher b*(yellowness) depending on ingredient mixtures and their concentrations [92]. Likewise, the addition of quinoa flour in frankfurter sausage significantly increased colour intensity of the product [93]. On the contrary, the resistance starch addition had no influenced on the sausage colour [94]. In this study, addition of MPP had considerably altered the colour of Chinese sausage due to the bioactive compounds especially carotenoid consisting in ripe mango peel [34,95-96]. This is quite beneficial for the use of the dietary fibre of this kind as functional ingredient.

Table 2. Colour of dried Chinese sausage added mango peel pectin at different levels.

Percentage of pectin	L*	a*	b*	ΔE	
0 (CTRL)	53.60 ± 7.44^{a}	6.69 ± 2.40^{c}	7.27 ± 1.32^{c}	-	
5	52.88 ± 2.87^{a}	9.36 ± 0.80^{b}	11.25 ± 0.62^{b}	5.55 ± 1.02^{a}	
10	55.42 ± 1.82^{a}	10.46 ± 0.69^{ab}	13.31 ± 0.85^{a}	7.59 ± 0.74^{b}	
15	50.37 ± 3.81^{a}	12.16 ± 1.17^{a}	14.14 ± 0.74^{a}	9.91 ± 2.12^{c}	

Data are expressed as mean ± standard deviation, n = 10
Mean values with the same lowercase superscript letter are not significantly different ($p < 0.05$) between the row.

3.2.2. Texture

The force-deformation curves of the formulated samples are represented in Figure 3. The textural behaviour of sausages with MPP concentrations of 0, 5, 10 and 15%(w/w) are shown in Table 3. The hardness is the maximum peak force (F_1) during the first compression cycle required to compress a food between the molar teeth [97]. From the result, the hardness of all formulated samples was not significantly different ($p > 0.05$), whereas springiness, cohesiveness, gumminess and chewiness were lower in treatments with the pectin fibres ($p < 0.05$). The CTRL had the highest hardness value of 15.87 N followed by adding 5, 10 and 15%(w/w) pectin powder with the values of 13.15, 12.89, and 12.70 N, respectively. Cierach et al. [98] described that the hardness in the sausages is related to their fat content. The higher MPP added to the sausage formula, the smaller slope of first peak obtained (hardness) (Figure 3). These differences in hardness profiles could be due to the binding ability and water holding capacity of fat and MPP mixture [53]. It could be obviously seen that, the texture of sausages with addition of MPP were softer. This could be in association with gel strength of pectin quantity under compression [99]. According to Campagnol et al. [100], the hardness of fermented sausages added with amorphous cellulose as fat replacement at levels of 50, 75 and 100% (w/w) was not significant different from the control.

The springiness is a textural parameter, which is correlated with elasticity of the sample. For texture profile analysis, springiness is associated with reversible ability of food after the end of first bite and the begin of the second bite. If springiness is high, it requires more mastication energy in the mouth [101]. The springiness values of four sausage samples were also represented in Table 3. There was significant difference in the springiness values of all treatments of the sausages ($p < 0.05$). The sausage added with 15%(w/w) MPP showed the lowest springiness value compared with other samples. The higher concentration of MPP added, the lower springiness value obtained. Zapata and Pava [93] reported that quinoa flour supplementation had no significantly influence on the

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springiness of frankfurter sausage. Whereas the higher MPP concentration negatively affected the springiness of Chinese sausage samples because of the gelling characteristic [12].

The cohesiveness (consistency) indicates the strength of internal bonds making up the body of food and the degree to which a food can be deformed before it ruptures (breaks) [102]. Cohesiveness is defined as the ratio of the positive force area during the second compression to that of the first compression. It also indicates the ability of the product to hold together [99]. The cohesiveness values of the sausage samples were in the ranges of 0.28 to 0.50. The highest and lowest values obtained were for 0% and 15%(w/w) of the pectin supplementation, respectively. Garcia-Santos et al. [94] revealed that the sausage with the addition of resistant starch had low value of cohesiveness (0.50-0.70). Choe et al. [103] also reported the cohesiveness values of sausages supplemented with wheat fibre for the reduction of fat ranged from 0.27 to 0.34. Troutt et al. [104] found that the addition of three-ingredient combinations of Polydextrose®, potato starch and either sugar beet, oat or pea fibre reduced cohesiveness of beef patties. While quinoa flour had no noticeably effect on the cohesiveness value of frankfurter sausage [93]. The more supplementation of MPP in the Chinese sausage, the lower value of cohesiveness ($p < 0.05$) because gelling was formed at higher concentration.

Gumminess is defined as the product of hardness and cohesiveness. It is a characteristic of semisolid foods with a low degree of hardness and high degree of cohesiveness. From Table 3, it can be seen that higher amount of MPP resulted in the lower values of gumminess, however the values of Chinese sausages supplemented with MPP were not significantly distinguished ($p > 0.05$). The higher gumminess has also ascended from the higher hardness value [101]. Regarding to Cardoso et al. [92], the gumminess value of cod frankfurter sausage remarkably increased ($p < 0.05$) with pea protein supplementation. Méndez-Zamora et al. [18] also represented the gumminess of frankfurter sausages replacing fat with inulin and pectin was lower when higher amount of pectin was added. In this research, Chinese sausage samples supplemented with MPP represented both of visco-elastic and gumminess behaviour from the pectin attribute.

Chewiness is a measure of energy required to masticate the food and is normally reported for solid foods. It is defined as the product of gumminess and springiness [99]. The chewiness value of four Chinese sausage samples varied from 2.18 to 7.94 N. There was significant difference in the value of all sausage treatments ($p < 0.05$). Similarly, higher amount of MPP powder supplemented in the sausage also effected on lower value of chewiness. Feng et al. [105] found the statistical differences of gumminess between low-fat Chinese sausages supplemented with Mesona Blumes gum or rice starch mixed gels ($p < 0.05$). Cardoso et al. [92] reported that the chewiness value of cod sausage statistically increased ($p < 0.05$) with pea protein and carrageenan integration. The results could be due to the absence of a water content adjustment, causing moisture to decrease while protein and carbohydrate contents increased. On the other hand, the chewiness value of the Chinese sausages with MPP additive noticeably descended with the higher pectin levels. Since the presence of high-water content in the sausages, it could enhance swelling and gelling properties of the pectin.

Table 3. Texture profile analysis of dried Chinese sausage added mango peel pectin at different levels.

Texture characteristics	Percentage of mango peel pectin			
	0 (CTRL)	**5**	**10**	**15**
Hardness (N)	15.87 ± 3.45^{a}	13.15 ± 0.66^{a}	12.89 ± 2.26^{a}	12.70 ± 1.48^{a}
Springiness (mm)	1.00 ± 0.01^{a}	0.84 ± 0.07^{b}	0.78 ± 0.06^{b}	0.61 ± 0.04^{c}
Cohesiveness	0.50 ± 0.01^{a}	0.39 ± 0.06^{b}	0.37 ± 0.03^{b}	0.28 ± 0.02^{c}
Gumminess (N)	7.92 ± 1.78^{a}	5.15 ± 0.99^{b}	4.78 ± 0.99^{b}	3.54 ± 0.52^{b}
Chewiness (N.mm)	7.94 ± 1.80^{a}	4.40 ± 1.15^{b}	3.78 ± 1.04^{bc}	2.18 ± 0.41^{c}

Data are expressed as mean ± standard deviation, n = 6

Mean values with the same lowercase superscript letter are not significantly different ($p < 0.05$) between the column.

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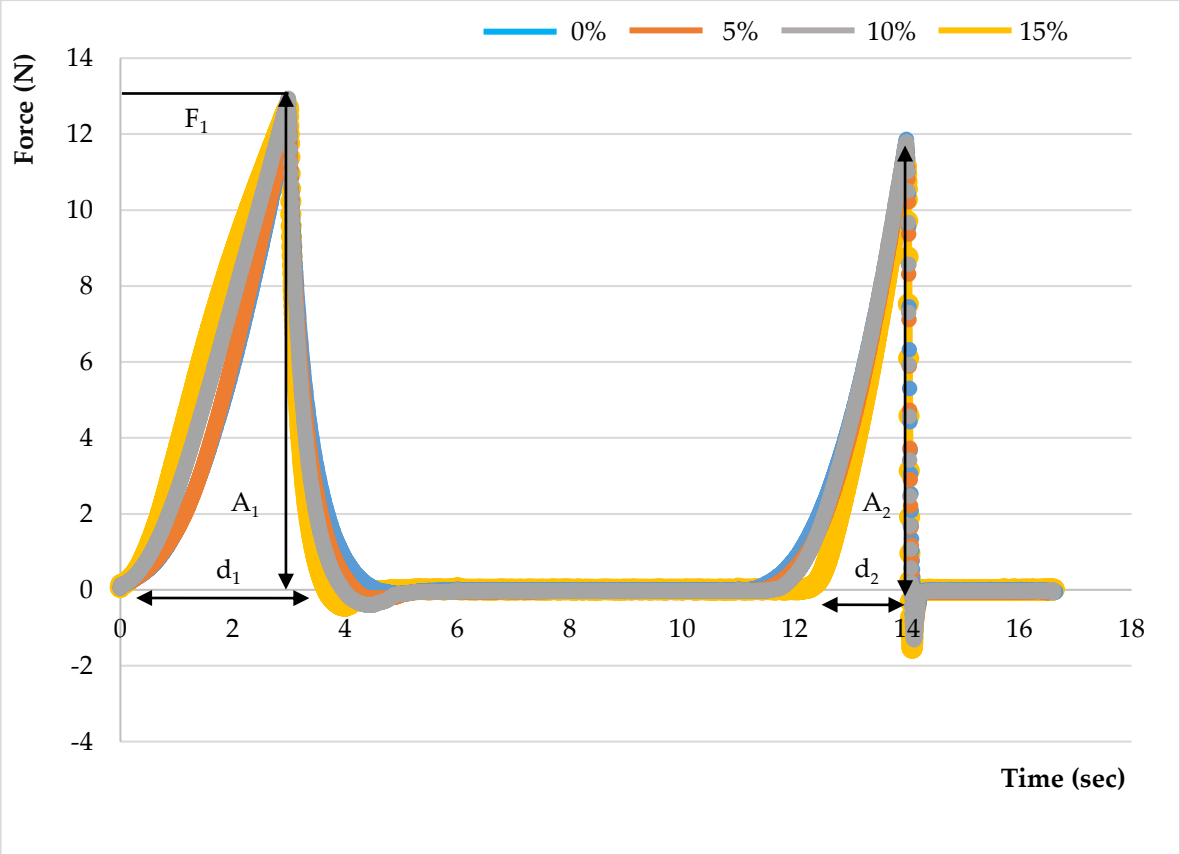

Figure 3. Texture profile of dried Chinese sausage added mango peel pectin at different levels. Where; Hardness: F_1; Cohesiveness: A_2/A_1; Springiness: d_2/d_1; Gumminess: HardnessxCohesiveness; Chewiness: GumminessxSpringiness.

Regarding to all texture results, MPP influences on texture attributes of Chinese sausage due to their functional characteristics of pectin are used as gelling and texture modified agent in meat products [12]. Consequently, Chinese sausage supplemented with low amount of the pectin is considerably similar texture properties of the conventional sausage.

3.2.3. Sensory evaluation

Sensory evaluation can assist food scientists in instructively gaining a distinct understanding of the consequences of reformulation low-fat meat processes. Table 4 represents the acceptance of the sensory attributes of Chinese sausages added with MPP. Each sample was evaluated by 12 trained panels (Sex: 6 females, 6 males; Age = 25-40 years). The addition of pectin in levels of 5 and 10%(w/w) slightly influenced ($p > 0.05$). The sensory attributes compared with the CTRL, while the maximum pectin amount (15%(w/w)) showed the least acceptance scores in all parameter. Regarding overall acceptability, five percentage of the pectin was the most favourite treatment because of its juiciness and appearance, whereas 15% was the least accepted. Similar texture attributes (Table 3), the low pectin level added in sausage was more accepted than higher levels. Méndez-Zamora et al. [18] reported that higher levels of pectin added in low-fat frankfurter sausage affected the flavour and odour. Rahman et al. [106] reported that fish sausages with higher starch content had given higher sensorial hardness. Lin and Huang [107] revealed that the konjac or gellan gum additive could improve the firmness of low-fat frankfurter sausage owing to the reduction of fat. Feng et al. [105] found the Mesona Blumes gum or rice starch mixed gels still exhibited the properties of juiciness, facilitating a better overall acceptability of the low-fat Chinese sausage. From sensory evaluation of low-fat Chinese sausage added MPP results, it can be primarily summarised that MPP at high concentrations had dramatically influenced Chinese sausage sensory attributes after sample preparative by pan frying.

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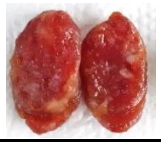
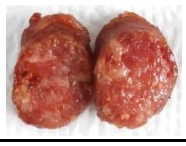
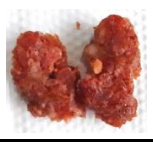
Table 4. Sensory analysis of dried Chinese sausage added mango peel pectin at different levels with 9-points hedonic scale scoring.

Parameters	Percentage of mango peel pectin (w/w)			
	0%	5%	10%	15%
Appearance	7.42 ± 2.15[a]	7.08 ± 1.08[a]	5.83 ± 1.53[ab]	4.92 ± 1.83[b]
Juiciness	8.33 ± 0.89[a]	6.92 ± 1.16[a]	6.83 ± 0.94[a]	5.42 ± 1.56[a]
Springiness	6.75 ± 1.66[a]	6.75 ± 1.82[a]	6.17 ± 1.53[ab]	4.00 ± 2.45[b]
Firmness	6.08 ± 2.02[a]	6.17 ± 1.70[a]	5.92 ± 1.56[a]	4.00 ± 2.00[b]
Colour	5.58 ± 2.23[a]	6.00 ± 2.00[b]	5.83 ± 1.70[b]	4.08 ± 2.68[c]
Overall acceptability	6.58 ± 1.68[a]	6.58 ± 1.56[a]	6.00 ± 1.41[a]	3.08 ± 1.88[b]
Prepared sausage for sensory				

Data are expressed as mean ± standard deviation, n = 12
Mean values with the same lowercase superscript letter are not significantly different ($p < 0.05$) between the column.

4. Conclusions

Microwave-assisted extraction technique evaluated in this study had successfully proven to be a complementary method for the extraction of mango pectin. Consequently, we achieved a significantly greater pectin yield from peel of Nam Dok Mai mango with the MAE 700 watts. The characterisation of the pectin processed superior in equivalent weight, methoxyl content and degree of esterification than that of the conventional method. The substitution of 5% pectin to fat content in the Chinese sausage could enhance colour and conserve the physical qualities as well as sensory attribute. In conclusion, MPP can be utilised in the low-fat Chinese sausage formula as a novel functional food product.

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