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Quality, textural profiles, oxidative stability and bacterial content during retail display of beef patties formulated with pectin powder

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Abstract - Pectin plays an important role in the food industry as a gelling and stabilizing agent with various bioactive compounds. This study aimed to elucidate the effects of pectin powder (PP) on the quality, texture, oxidative stability and bacterial content of beef patties during retail display. The beef Longissimus thoracis (LT) was ground and divided into 3 groups: 1) control group (0% PP), 2) ground beef supplemented with 1% PP and 3) ground beef supplemented with 2% PP. Then beef patties were made, wrapped and displayed at 4°C for 0, 3, and 6 days. Regarding the product quality, it was found that PP reduced pH and cooking loss, but on the other hand, it increased L*, a* and b* color coordinates of the beef patties ($P<0.05$). Regarding textural profiles, on day 6 of display, it was found that beef supplemented with 2% PP had the lowest hardness, cohesiveness, gumminess and chewiness, but the highest adhesiveness ($P<0.05$). However, 1% and 2% PP groups had less springiness compared to the control group ($P<0.05$). As for oxidative stability, groups with PP had increased antioxidant activity ($P<0.05$), but still, there was no significant difference in lipid oxidation among all the groups after 6 days of display ($P>0.05$). In addition, PP had no effect on total bacterial count during retail display ($P>0.05$). Therefore, from the experimental results it can be concluded that supplementing beef patties with pectin powder can improve their

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quality and texture by increasing color coordinates, water holding capacity, tenderness, and antioxidant activity.

Keywords: Pectin, beef patties, texture, quality, oxidation

1. Introduction

Beef patties for beef burgers are made from minced beef (lean and fat). Mincing mechanically disrupts meat protein structures, leading to improved sensory tenderness (Honikel, 2014). However, mincing can lead to the release of tissue fluids that are rich in nutritional content for various microorganisms, and this promotes rapid microbial growth (Djordjević et al., 2018). To maintain freshness and inhibit microbial growth, minced beef should be stored at 4°C for a maximum of 3 days (Parafati et al., 2019). Prolonged storage beyond this timeframe can negatively impact quality parameters, including texture and color (Olivera et al., 2013). Besides the microbial aspects, mincing meat also increases exposure to oxygen from the atmosphere, especially facilitating the oxidation of fat and protein that are important components in meat. Oxidation is the main cause of meat product deterioration, seen in undesirable color and odor. Additionally, toxic compounds can form as byproducts of oxidation (Morrissey et al., 1998; Xiong, 2000).

Pectin is a type of structural fiber originally found in the cell walls and intracellular layers of plant cells, especially in many types of fruit like apples, oranges, and lemons (Mudgil, 2017). Currently, the main sources of commercial pectin are citrus peels and apple pomace. However, other sources have been explored, such as banana peel, passion fruit peel, pumpkin, pepper, kiwi fruit, olive pomace, soy hull, and pineapple pulp (de Moura et al., 2017). Pectin is a polysaccharide and its typical monosaccharides include galacturonic acid (dominant monosaccharide), rhamnose, galactose and arabinose. Its main chains consist of D-galacturonic acid units linked by α-1,4 glycosidic bonds (forming homogalacturonan) or alternating units of α-1,4-linked d-galacturonic acid and α-1,2-linked L-rhamnose residues (forming rhamnogalacturonan-I) (de Moura et al., 2017). Pectin polysaccharides hold significant potential for healthcare, food, and cosmetic industries due to their therapeutic effects and relatively low toxicity (Minzanova et al., 2018). In the food industry, pectin is used as gelling agent, thickener, emulsifier, texturizer, stabilizer, and fat or sugar replacer, while mainly pectin is used for gelling since it has good water and fat binding properties (Thakur et al., 1997). Moreover, pectin possesses various bioactivities, such as antibacterial, antioxidant, anti-inflammatory and anti-tumor activities (Minzanova et al., 2018). Previous study found that beef burger formulated with pectin from tomato fiber showed decrease in cooking loss, reduction in diameter of burgers was decreased and at levels of 12.5 and 25% tomato pectin for fat replacement had the highest acceptance (Namir et al., 2015). Therefore, the objective of this study was to examine the effects of commercial pectin powder supplementation on the quality, texture, oxidative stability, and total bacterial content of beef patties during retail display.

2. Materials and methods

2.1 Materials

The beef Longissimus thoracis (LT) and subcutaneous fat were purchased from a local market in Mueang Surat Thani district, Surat Thani province, Thailand. The beef muscles were trimmed of visible fat and connective tissues and stored at 4ºC with fat until use. Commercial pectin powder (food grade) was purchased from Chemipan corporation company. The commercial pectin used in this trial was extracted from apple and had a high methoxyl content.

2.2 Preparation of beef patties and experimental design

The 90% lean meat from beef LT and 10% subcutaneous fat of beef were mixed and ground. Then ground beef was divided into 3 experimental groups (5 replicates in each group) using a completely randomized design (CRD) as follows: 1) Control group (95 g ground beef + 5 ml distilled water), 2) ground beef mixed with 1% pectin powder (PP) (95 g ground beef + 1 g commercial PP mixed in 4 ml distilled water) and 3) ground beef mixed with 2% PP (95 g ground beef + 2 g commercial PP mixed in 3 ml distilled water). Then 100 g beef patties were made and a simulation of the retail display was conducted by wrapping the beef patties with oxygen permeable foil and displaying them at 4°C under fluorescent light for 24 h per day, with sampling at 0, 3, and 6 days.

2.3 pH measurement

The pH was assessed on days 0, 3, and 6 during the retail display using a penetrating electrode connected to a portable pH-meter (Mettler Toledo) for the measurements.

2.4 Color measurement

The CIE color coordinates lightness (L*), redness (a*), and yellowness (b*) were assessed on days 0, 3, and 6 during the retail display. The measurements were conducted using a Hunterlab Miniscan color meter with the following specifications: D65 light source, 10^{o} standard observer, $45^{o}/0^{o}$ geometry, 1-inch light surface, and a white standard. The measurement was replicated at three different locations on each sample.

2.5 Analysis of cooking loss

The water holding capacity of beef patties was assessed during retail display on days 0, 3, and 6 in terms of the cooking loss according to the method of Pastsart et al. (2024). To determine this, the beef patties were placed in the plastic bags and cooked in a water bath maintained at 90°C for 15 minutes. Before cooking, each sample was weighed, and the weight was recorded again after cooking. The cooking loss was then calculated as the difference between the pre-cooking and post-cooking weights and expressed as a percentage of the initial weight.

2.6 Texture profile analysis (TPA)

The textural profile of beef patties was evaluated using a texture analyzer (Brookfield model CT3) with a 10 kg

capacity on days 0, 3, and 6 of retail display. The beef patties were initially cooked in a water bath at 90°C for 15 minutes and then cut into 1x1x1 cm samples. Each type of sample was measured in triplicate. The texture profile of the beef patties was characterized in terms of hardness, cohesiveness, springiness, adhesiveness, gumminess and chewiness.

2.7 Antioxidant activity analysis

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay provides insights into the ability of beef patties to scavenge free radicals, reflecting their antioxidant potential. The antioxidant activity of beef patties was assessed on days 0, 3 and 6 of display at 4°C using a DPPH assay, following the method described by Wang et al. (2019). The DPPH assay is based on the principle that DPPH is a free radical generator. Briefly, 2.5 g of beef patties was mixed and homogenized with 7.5 ml of ethanol. The homogenates were extracted on a shaker for approximately 10 minutes at room temperature. The mixture was then centrifuged at 1,800 rpm for 10 minutes. The resulting supernatants were collected. From each sample, 0.5 ml of supernatant was added to 3.5 ml of 0.1 mM DPPH in ethanol. The mixture was thoroughly mixed and stored in the dark at room temperature for 20 minutes. The absorbance of each sample was measured at 517 nm using a spectrophotometer. Ethanol was used as a blank. DPPH scavenging activity was calculated as follows:

$$\text{DPPH Scavenging activity (\%)} = (1-As/Ac) \times 100$$

Here Ac is the absorbance of the control (DPPH in ethanol solution without sample) and As is the absorbance of the sample.

2.8 Lipid oxidation analysis

Lipid oxidation was assessed in beef patties during refrigerated storage on days 0, 3 and 6 of display. The evaluation was based on thiobarbituric acid reactive substances (TBARS), following the standard method described by Tarladgis et al. (1960). Specifically, malondialdehyde (MDA), a secondary product of lipid oxidation, was quantified at 532 nm using a spectrophotometer and expressed in micrograms (µg) of MDA per g of meat.

2.9 Determination of total bacteria

To evaluate the effect of using PP on the number of bacteria in beef patties, the total bacteria count was performed according to Hossain et al. (2015). A 1 g sample of beef patties was added to 9 ml sterilized 0.9 % NaCl (1:10), and then subsequent dilutions were prepared and assessed using cultures on nutrient agar. The populations of total bacteria were expressed as Log10 CFU/g.

2.10 Statistical analysis

The data were analyzed in SPSS Statistics program using the general linear model procedure to evaluate the influences of experimental treatments. Means were compared using Duncan's multiple range test and differences were considered significant at $P<0.05$.

3. Results and discussion

3.1 Quality of beef patties

The study investigated the effects of PP supplementation on the quality of beef patties during display (or other refrigerated storage). The results, as summarized in Table 1, revealed that on days 0 and 6 of display, the control group exhibited a higher pH compared to the other experimental groups ($P<0.05$). However, on day 3 of display, across the experimental groups there were no significant differences in pH ($P>0.05$). The pH of pectin depends on its type and properties. However, its principal chemical component is galacturonic acid, which is derived from galactose (de Moura et al., 2017; Minzanova et al., 2018). Therefore, pectin can be considered acidic due to its galacturonic acid content and its role in gelling processes. This may have decreased the pH of beef patties in the groups with PP supplementation, in the present study.

Regarding the color of beef patties (Table 1), it was observed that on day 0 of cold storage, the L* (Lightness) of the beef patties supplemented with 2% PP was the highest ($P< 0.05$), while on day 6 of cold storage, the L* of the beef supplemented with 2% pectin was higher than that of the control group ($P<0.05$). However, on day 3 of cold storage, the L* across all groups did not have significant differences ($P>0.05$). Regarding a* (Redness), during the cold storage beef patties supplemented with PP groups had higher values than the control ($P<0.05$). For b* (Yellowness), on days 0 and 6 of cold storage it was found that the beef patties supplemented with PP had higher b* than the control ($P<0.05$). However, on day 3 of cold storage, all the experimental groups had similar b* ($P>0.05$). Excessive amounts of non-meat ingredients added to meat product formulations may result in undesirable color changes. Normally, non-meat ingredients added to meat product formulations could lead to a pale color in meat products, so this study is in line with previous research from López-Vargas et al. (2014) who noted that L* increased when passion fruit albedo was supplemented in pork patties. In contrast, Selani et al. (2015) observed that there were no significant differences in the L* of beef patties when pineapple, passion fruit, or mango byproducts were added. Besides non-meat ingredients supplementation, in fresh meat itself, it was found that meat with a lower initial pH was paler (higher in L*) (Warriss & Brown, 1987). Similarly, the b* of beef patties in this study increased when PP was formulated in, and these results are consistent with those obtained by Gök et al. (2011) who reported that b* increased when ground poppy seed was added in beef patties. Conversely, López-Vargas et al. (2014) found no significant differences between b* values when passion fruit albedo was added in pork patties. The a* increased with PP supplementation in this study, which is inconsistent with results obtained by Gök et al. (2011), who found that a* was not significantly different when ground poppy seed was added in beef patties; and López-Vargas et al. (2014) reported that a* was not significantly different in pork patties when passion fruit albedo was added. Nevertheless, the highest a* should be attributed to the control group, as it consists solely of minced beef, which contains a significant amount of myoglobin, the pigment responsible for the red color in meat (Mancini & Hunt, 2005).

Table 1. Effects of pectin powder supplementation on quality of beef patties during refrigerated retail display (mean ± SD)

Items	Level of pectin powder in beef patties (%)			P-value
	0	1	2	
pH day0	5.74^{a} ± 0.01	5.61^{b} ± 0.05	5.59^{b} ± 0.05	<0.01
pH day3	5.39 ± 0.01	5.41 ± 0.03	5.43 ± 0.02	0.09
pH day6	5.43^{a} ± 0.05	5.37^{b} ± 0.02	5.34^{b} ± 0.03	0.01
*L** day0	44.88^{b} ± 3.60	44.20^{b} ± 1.28	51.10^{a} ± 0.88	<0.01
*L** day3	46.68 ± 2.74	48.93 ± 0.79	40.40 ± 18.06	0.52
*L** day6	44.30^{b} ± 1.69	46.40^{ab} ± 0.89	47.90^{a} ± 2.03	0.03
*a** day0	8.70^{b} ± 0.99	9.98^{a} ± 0.31	8.65^{b} ± 0.45	0.03
*a** day3	5.60^{b} ± 0.71	6.53^{ab}± 0.22	6.85^{a} ± 0.74	0.04
*a** day6	1.13^{c} ± 0.69	8.15^{a} ± 0.70	7.15^{b} ± 0.40	<0.01
*b** day0	10.08^{c} ± 0.32	11.85^{b} ± 0.47	13.03^{a} ± 0.51	<0.01
*b** day3	10.65 ± 1.77	11.48 ± 0.62	22.10 ± 18.01	0.28
*b** day6	7.25^{b} ± 1.30	14.48^{a} ± 1.25	13.23^{a} ± 1.22	<0.01
%Cooking loss day0	28.90^{a} ± 1.94	24.06^{b} ± 1.45	20.18^{c} ± 1.75	<0.01
%Cooking loss day3	29.70^{a} ± 2.13	20.77^{b} ± 0.58	17.00^{c} ± 2.05	<0.01
%Cooking loss day6	30.29^{a} ± 2.84	25.92^{ab} ± 8.87	19.26^{b} ± 1.03	0.05

$^{a-c}$Values with different superscripts within the same row are significantly different ($p<0.05$).

In Table 1, the water holding capacity (cooking loss) of beef patties is summarized. On days 0 and 3 of display, the control group exhibited the highest cooking loss ($P<0.05$). In this experiment, PP supplementation reduced the cooking loss from beef patties. This suggests that pectin aids in stabilizing water released from beef patties, by gel formation (Rolin, 1993). Consequently, the meat becomes juicier and more tender. This finding is in accordance with those reported previously by Namir et al. (2015), who showed that beef burgers formulated with different levels of tomato fiber pectin for fat replacement showed decrease in cooking loss.

Table 2. Effects of pectin powder supplementation on textural profiles of beef patties during refrigerated retail display (mean ± SD).

Items	Level of pectin powder in beef patties (%)			P-value
	0	1	2	
Texture (day0)				
Hardness (g)	2,270.00^{a} ± 468.60	1,516.75^{b} ± 179.11	1,137.00^{b} ± 157.05	<0.01
Cohesiveness	0.33 ± 0.02	0.31 ± 0.04	0.28 ± 0.04	0.20
Springiness (mm)	4.23^{a} ± 0.35	3.45^{b} ± 0.19	3.65^{b} ± 0.22	0.01
Adhesiveness (mJ)	2.50 ± 1.73	1.23 ± 0.50	1.25 ± 0.96	0.27
Gumminess (g)	737.00^{a} ± 134.73	487.50^{b} ± 89.60	312.00^{c} ± 55.43	<0.01
Chewiness (mJ)	308.50^{a} ± 30.65	165.25^{b} ± 35.56	114.50^{c} ± 33.81	<0.01
Texture (day3)				
Hardness (g)	2,043.50^{a} ± 420.45	1,625.75^{a} ± 316.97	938.25^{b} ± 220.81	<0.01
Cohesiveness	0.32 ± 0.03	0.30 ± 0.01	0.33 ± 0.04	0.52
Springiness (mm)	8.97 ± 8.87	3.62 ± 0.37	3.64 ± 0.31	0.29
Adhesiveness (mJ)	1.25 ± 0.96	1.75 ± 2.87	2.25 ± 2.06	0.80
Gumminess (g)	652.25^{a} ± 179.12	491.25^{ab} ± 116.94	307.00^{b} ± 75.85	0.02
Chewiness (mJ)	312.50^{a} ± 36.48	180.75^{b} ± 59.96	113.50^{b} ± 35.63	<0.01
Texture (day6)				
Hardness (g)	1,377.00^{a} ± 69.24	1,143.00^{b} ± 35.80	942.00^{c} ± 54.33	<0.01
Cohesiveness	0.33^{a} ± 0.02	0.33^{a} ± 0.01	0.28^{b} ± 0.03	<0.01
Springiness (mm)	4.67^{a} ± 0.24	3.84^{b} ± 0.21	3.56^{b} ± 0.49	<0.01
Adhesiveness (mJ)	0.25^{b} ± 0.50	0.75^{ab} ± 1.50	2.25^{a} ± 0.50	0.04
Gumminess (g)	451.00^{a} ± 16.43	382.00^{b} ± 21.37	263.50^{c} ± 29.22	<0.01
Chewiness (mJ)	210.75^{a} ± 10.31	146.25^{b} ± 13.48	94.50^{c} ± 20.66	<0.01

$^{a-b}$Values with different superscripts within the same row are significantly different ($p<0.05$).

3.2 Textural profile of beef patties

The texture measurement results of beef patties are displayed in Table 2. On day 0 of the display, it was observed that the inclusion of PP in beef patties did not affect cohesiveness or adhesiveness ($P>0.05$). However, the PP supplemented groups exhibited lesser hardness, springiness, gumminess, and chewiness compared to the control group ($P<0.05$). On day 3 of refrigerated storage, the inclusion of PP in beef had no significant effect on cohesiveness, springiness, or adhesiveness ($P>0.05$). However, the group supplemented with 2% pectin exhibited lesser hardness, gumminess, and chewiness compared to the other groups ($P<0.05$). On day 6 of display, the beef patties supplemented with 2% pectin had the least hardness, cohesiveness, gumminess, and chewiness, while having the highest adhesiveness ($P<0.05$).

From this study, pectin supplementation could reduce the hardness of beef patties, which was correlated with cooking loss. This observation suggests that pectin has the potential to draw water out of the ground beef, and hold it by gelling inside the beef patties (Rolin, 1993). Consequently, the beef patties exhibit more juiciness and tenderness. Moreover, the higher adhesiveness of beef patties supplanted with PP is attributed to adhesive properties of pectin (Gyunter et al., 2017).

3.3 Oxidative stability of beef patties

The effect of pectin supplementation on lipid oxidation measured by TBARS assay in beef patties is shown in Table 3. On day 0 of cold storage, the control group had higher lipid oxidation than 1% PP group ($P<0.05$). However, on days 3 and 6 of cold storage, lipid oxidation of beef patties did not significantly differ among the groups ($P>0.05$). From the results of the experiment, it can be seen that adding pectin to beef patties can slow down lipid oxidation of beef patties during 6 days of display compared to untreated control.

The results of the analysis of antioxidant capacity measured by DPPH assay in beef patties on days 0, 3 and 6 during refrigerated storage are shown in Table 3. The results show that on day 6 of display, PP supplementation increased antioxidant capacity of beef patties compared to a control group ($P>0.05$). This is supported by the work of Liu et al. (2016) who found that pectin extracted from the byproduct of Jerusalem artichoke (Helianthus tuberosus) exhibited DPPH radical scavenging activity. There are also reports of antioxidant properties of pectin extracted from mangosteen peel (Wathoni et al., 2019) and from various vegetables (Smirnov et al., 2017).

Table 3. Effects of pectin powder supplementation on oxidative stability of beef patties during refrigerated retail display (mean ± SD).

Items	Level of pectin powder in beef patties (%)			P-value
	0	1	2	
TBARS* day0	$0.35^{a} \pm 0.08$	$0.13^{b} \pm 0.04$	$0.22^{ab} \pm 0.13$	0.02
TBARS day3	0.72 ± 0.43	0.67 ± 0.14	0.58 ± 0.07	0.74
TBARS day6	0.84 ± 0.20	0.88 ± 0.27	0.85 ± 0.18	0.96
DPPH** day0	40.28 ± 6.92	42.26 ± 2.18	44.85 ± 2.10	0.37
DPPH day3	31.47 ± 2.23	38.12 ± 5.37	34.41 ± 10.61	0.44
DPPH day6	$34.12^{b} \pm 2.30$	$42.21^{a} \pm 1.61$	$43.83^{a} \pm 2.05$	<0.01

[a-b] Values with different superscripts within the same row are significantly different ($p<0.05$).
* Expressed in μg MDA/g meat, ** DPPH scavenging activity (%)

3.4 Total bacteria content of beef patties

Regarding the total bacteria count of beef patties, it was observed that the colony forming units of total bacteria in beef patties did not significantly differ ($P>0.05$) across the experimental groups (Table 4). This is in contrast to a previous study by Men'shikov et al. (1997) who found that

2% pectin from orange peels can inhibit pathogenic bacteria directly. The lack of significant influence of PP on total bacteria content in beef patties could be because pectin in the beef patties only indirectly inhibited bacteria. The concentration of pectin used in this experiment may have been insufficient for inhibiting bacteria.

Table 4. Effects of pectin powder supplementation on bacterial contents (Log 10 CFU/g) of beef patties during refrigerated retail display (mean ± SD).

Items	Level of pectin powder in beef patties (%)			P-value
	0	1	2	
Total bacteria day0	5.70 ± 0.27	5.80 ± 0.22	5.80 ± 0.08	0.74
Total bacteria day6	6.70 ± 0.20	6.75 ± 0.26	6.45 ± 0.17	0.16

4. Conclusion

The findings of our study suggest that pectin powder supplementation can increase CIE color coordinates and antioxidant capacity while reducing cooking loss and hardness of beef patties. This can be beneficial to quality and texture of beef patties, by increasing water holding capacity and tenderness. The increased antioxidant activity may prolong shelf-life of beef patties by hindering oxidation in the beef patties.

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