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Effect of dual-functional coating of chicken fillet with pectin-curcumin-lemongrass oil emulsion on the shelf-life stability and fat uptake during frying

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ABSTRACT

This study aims to formulate the optimal pectin-curcumin-lemongrass oil emulsion (PE) for coating of chicken fillet at 50:50%, 70:30%, and 90:10%, based on microbial growth inhibition, freshness consistency, and fat absorption during frying. Throughout the 7 days of storage, chicken fillet coated with 70:30% PE showed significant ($P < 0.05$) suppressive activity against psychrophilic bacteria (8.09 ± 0.00 $\log_{10}$ CFU g^{-1}) compared to non-coated sample (8.27 ± 0.06 $\log_{10}$ CFU g^{-1}). In contrast, 90:10% PE coating inhibited the growth of yeasts or moulds on chicken fillet at 8.24 ± 0.28 $\log_{10}$ CFU g^{-1}, compared to non-coated sample (9.16 ± 0.14 $\log_{10}$ CFU g^{-1}). The 70:30% PE coating showed a better fillet's toughness (18.30 ± 1.32 N mm^{-1} s^{-1}) and firmness (1.49 ± 0.22 N mm^{-1}) when compared to fillet without coating. After 7 days of storage, coated and uncoated samples showed the same total colour difference (E value) indicating PE coating preserved the texture of fillet and colour. Both coated samples (70:30% and 90:10%) reduced fat uptake during frying by 13.70%–14.25%. The application of PE coating at 90:10% was effectively functioned as an excellent coating to preserve the quality and safety of fillet.

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1. INTRODUCTION

Natural edible coatings on chicken meat have been documented to improve oxidative stability, prevent pathogen growth, release an aromatic taste, retain colour freshness, and enhance tenderness while increasing shelf life (Adrah et al., 2021). In addition, edible coatings may capture oil droplets between network polysaccharide-based structural components (e.g., chitosan and pectin) and protein molecules (Jiménez-Saelices et al., 2021). This emulsion may control mass transfer, minimise oil and moisture diffusion, prevent oxidative gases like oxygen and carbon dioxide from penetrating food, and preserve texture, aroma, and taste (Galus and Kadzińska, 2018).

Curcumin is the main bioactive compound in turmeric, and is popular as a medicinal spice in Asian countries due to its anticancer, wound healing, antioxidant, anti-inflammatory, antimicrobial, and neurodegenerative disease prevention bioactivities (Tsuda, 2018). It also may act as a natural preservative due to its antimicrobial activity inhibiting the growth of 7 bacteria strains (*Salmonella typhi*, *Listeria monocytogenes*, *Clostridium* spp., *Staphylococcus aureus*, *Escherichia coli*, *Bacillus cereus*, and *B. subtilis*) and 4 fungi strains (*Candida albicans*, *Yersinia enterocolitica*, *Penicillium notatum*, and *Saccharomyces cerevisiae*) (Vazirian et al., 2012). Lemongrass extracts inhibit the growth of *E. coli* and *C. albicans* (Vazirian et al., 2012).

To our knowledge, no studies have been conducted on the development of a dual-functional edible coating for meat preservation. Lemongrass oil emulsions containing pectin and curcumin are seldom used in poultry products. This work aims to formulate an optimal pectin (P):curcumin lemongrass oil emulsion (E) coating for enhancing chicken fillet shelf-life and reducing fat absorption during frying.

2. MATERIALS AND METHODS

2.1. Raw materials

About 20 pieces of fresh chicken (*Gallus gallus domesticus*) breasts with average weight and size of 200 g and 15 cm, respectively, were purchased from local hypermarket in Melaka, Malaysia. The chicken breasts were brought to the laboratory in a container with ice-packs. The chicken breasts were washed and stored in a refrigerator (Panasonic, Japan) (<0 °C) until further processing.

2.2. Preparation of emulsion, coating solution, and coated chicken samples

For coating solution, 4.5% (w/v) pectin solution was mixed with the curcumin-lemongrass oil emulsion (0.1 g curcumin, 50 mL tween-80, 250 μL lemongrass essential oil, 165 mL distilled water, 75 mL glycerine) at P:E ratios of 90:10, 70:30, and 50:50. The defrosted chicken was sliced to a size of 2.54 × 2.54 × 2.54 cm pieces. The control sample was prepared through dipping the

samples into cold distilled water ($0 \pm 1\,°C$). The dipping treatment was performed for 5 min at $25\,°C$ then the fillets were drained. The samples were packed into a zipper plastic bag and stored in a chiller (Fisher and Paykel, New Zealand) at $4\,°C$. Triplicate samples from each group were withdrawn for analysis at 3 days intervals over a storage period of 7 days.

2.3. Determination of viscosity of coating formulations

The viscosity of the coating formulations was measured using a rotational viscometer (Brookfield, Canada) as described by Abdou et al. (2018).

2.4. Determination of microbial growth

Determination of microbial growth was determined according to the methods described by Abdou et al. (2018). For psychrophilic bacteria, the plate count agar (PCA) (Oxoid, England) plates were incubated in an upright position at $4 \pm 1\,°C$ for 10 days. For yeasts and moulds, potato dextrose agar (PDA) (Oxoid, England) plates were incubated in an upright position at $30\,°C$ for 5 days. Number of colony-forming unit ($\log_{10} CFU\,g^{-1}$) were calculated using the following formula:

$$\text{Number of CFU} = (\text{Number of colonies}) \times (\text{Dilution factor of the plate counted}) \times$$
$$\times \frac{1}{\text{Amount of sample in the plate}}$$

2.5. Determination of pH, texture, and colour

The pH of coated chicken samples was measured in homogenates (water in the presence of 5 mM sodium iodoacetate (Merck KGaA, Germany)) using a pH meter (Mettler Toledo, USA) according to the methods described by Abdou et al. (2018). The firmness and shear force for each sample were determined using a texture analyser (Stable Micro System, UK) as described by Bourne (2003). The colour of samples was measured using a chromameter (Konica Minolta, Japan), and the total colour difference was calculated (Choi et al., 2016).

2.6. Proximate analysis

Analysis of crude protein content was performed based on Kjedhal method following AOAC ofiicial method 970.65 (AOAC, 2005). The fat content was extracted by ethanol based on Laroche et al. (2019) using a Soxhlet extraction method. The moisture and ash contents were analysed according to Park and Bell (2004).

2.7. Determination of fat uptake during frying

The samples were fried separately at a temperature set at $160\,°C$ for 5 min. After deep-frying, the samples were drained off and fat analysis was carried out according to Laroche et al. (2019).

2.8. Statistical analysis

The means of the data between the treatment groups were compared using one-way analysis of variance (ANOVA). The statistical significance of the results was further evaluated using post

hoc-Duncan Multiple Range Test with significance set at $P < 0.05$. To determine correlations among the parameters measured, Pearson correlation was used with significance set at $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1. Effect of PE coatings on microbial growth and quality attributes

The growth of psychrophilic bacteria and yeasts/moulds was significantly ($P < 0.05$) lower in all coated samples, regardless of percentage ratio than in the uncoated group at the beginning of storage (Table 1). There was no significant ($P > 0.05$) difference in the growth of psychrophilic bacteria between coated and uncoated samples after 3 days of storage. In contrast, the 90:10 emulsion strongly inhibited the yeasts/moulds growth at $6.19 \pm 0.19 \log_{10} CFU\, g^{-1}$ as compared to an uncoated sample ($7.82 \pm 0.03 \log_{10} CFU\, g^{-1}$). After 7 days of storage, psychrophilic bacteria growth was reduced by 70:30 and 50:50 emulsions ($8.12 \pm 0.02 \log_{10} CFU\, g^{-1}$ and $8.09 \pm 0.00 \log_{10} CFU\, g^{-1}$, respectively, while the control was $8.27 \pm 0.06 \log_{10} CFU\, g^{-1}$). On the other hand, 50:50 and 90:10 emulsions reduced yeasts growth ($8.80 \pm 0.28 \log_{10} CFU\, g^{-1}$ and $8.24 \pm 0.28 \log_{10} CFU\, g^{-1}$, respectively, the control being $9.16 \pm 0.14 \log_{10} CFU\, g^{-1}$). The current findings suggest that the PE coatings act as a good inhibitor of microbial growth, which is supported by findings of Abdou et al. (2018), who discovered that pectin-curcumin nano-emulsions reduced the growth of psychrophilic bacteria in treated chicken fillet samples with cinnamon, garlic, and sunflower oils by 95.1%, 72.9%, and 42.6%, respectively. It has been shown that the essential oil of lemongrass may suppress the growth of psychrophilic bacteria. This can be attributed to the existence of bioactive compounds that have antimicrobial effects, such as turmerone, limonene, borneol, cumene, and α-phellandrene (Ibáñez and Blázquez, 2021). Antifungal activity of curcuminoids, turmeric oil, turmerol, and valeric acid is mediated by cytoplasmic granulation, cytoplasmic membrane breakdown, and inactivation against 7 different types of fungi and moulds (*Aspergillus niger*, *Penicillium digitatum*, *A. flavus*, *P. javanium*, *Curvularia oryzae*, and *Trichophyton mentagrophytes*) (Gul and Bakht, 2015).

All coated samples had similar shear and firmness values throughout 7 days of storage (Table 2), indicating that the coating formulations did not alter chicken fillet texture, hence the PE coating preserves the original texture of it. From day 0 to day 7, coated samples' pH increased from 5.64 ± 0.01 to 5.89 ± 0.03, whereas uncoated samples' pH increased from 6.04 ± 0.04 to

Table 1. Microbial count of psychrophilic bacteria and yeasts/moulds of chicken fillet coated with different percentage ratio of PE during 7 days of storage. Data are presented as mean $\pm$ S.D

Sample	Counts of psychrophilic bacteria ($\log_{10} CFU\, mL^{-1}$)			Counts of yeasts/moulds ($\log_{10} CFU\, mL^{-1}$)		
	Day 0	3 days	7 days	Day 0	3 days	7 days
Control	7.42 ± 0.17^{bA}	7.84 ± 0.01^{aB}	8.27 ± 0.06^{bC}	5.68 ± 0.11^{bA}	7.82 ± 0.03^{bB}	9.16 ± 0.14^{bC}
50:50	6.44 ± 0.00^{aA}	7.80 ± 0.12^{aB}	8.12 ± 0.02^{aC}	4.38 ± 0.18^{aA}	6.98 ± 0.78^{abB}	8.80 ± 0.28^{abC}
70:30	6.42 ± 0.00^{aA}	7.80 ± 0.05^{aB}	8.09 ± 0.00^{aC}	4.27 ± 0.02^{aA}	7.50 ± 0.04^{bB}	9.03 ± 0.04^{bC}
90:10	6.31 ± 0.01^{aA}	7.68 ± 0.03^{aB}	8.19 ± 0.07^{abC}	4.23 ± 0.02^{aA}	6.19 ± 0.10^{aB}	8.24 ± 0.28^{aC}

[a,b]: Means with different superscripts in the same column are significantly different ($P < 0.05$).
[A,B,C]: Means with different superscripts in the same row are significantly different ($P < 0.05$).

Table 2. Texture characteristics and pH changes of chicken fillet coated with different percentage ratio of PE during 7 days of storage. Data are presented as mean ± S.D

Sample	Shear/Toughness (N mm^{-1} s^{-1})			Firmness (N mm^{-1})			pH		
	Day 0	3 days	7 days	Day 0	3 days	7 days	Day 0	3 days	7 days
Control	25.26 ± 1.26[aB]	28.50 ± 1.35[aB]	14.00 ± 3.00[aA]	1.35 ± 0.15[aAB]	1.54 ± 0.11[aB]	1.03 ± 0.17[aA]	6.04 ± 0.04[cE]	6.07 ± 0.02[cE]	6.10 ± 0.07[cEF]
50:50	27.31 ± 1.28[aB]	27.40 ± 1.74[aB]	14.32 ± 0.72[aA]	1.46 ± 0.16[aAB]	1.36 ± 0.19[aAB]	1.20 ± 0.02[aAB]	5.84 ± 0.07[bCD]	5.88 ± 0.06[bD]	5.89 ± 0.03[bD]
70:30	27.12 ± 3.69[aB]	27.49 ± 1.25[aB]	18.30 ± 1.32[aA]	1.51 ± 0.43[aB]	1.32 ± 0.09[aAB]	1.49 ± 0.22[aB]	5.64 ± 0.01[aA]	5.71 ± 0.02[aAB]	5.73 ± 0.03[aB]
90:10	25.36 ± 2.38[aB]	28.53 ± 3.37[aB]	15.37 ± 4.75[aA]	1.35 ± 0.24[aAB]	1.45 ± 0.26[aAB]	1.11 ± 0.40[aAB]	5.78 ± 0.06[bBC]	6.17 ± 0.06[cF]	5.72 ± 0.03[aAB]

[a,b,c]: Means with different superscripts in the same column are significantly different ($P < 0.05$).
[A, B, C, D, E, F]: Means with different superscripts in the same row are significantly different ($P < 0.05$).

6.10 ± 0.07. This finding was supported by Zhang et al. (2021), who found that lemongrass essential oil nanoemulsion decreased total volatile basic-nitrogen (TVB-N) values directly by lowering the pH. When the value of TVB-N such as ammonia, trimethylamine, dimethylamine, and other volatile nitrogenous compounds is high, food spoils. Zhang and co-workers also found that lemongrass essential oil suppressed pH shifts, and similar results were found for other essential oil nanoemulsions (sunflower seed, cinnamon, garlic, or olive oil) (Zhang et al., 2021) that due to their nanoemulsion inhibitory effects on microbial growth, resulted in delayed and decreased TVB-N output by food spoilage bacteria.

The 50:50 sample had less moisture than the others (Table 3). Other PE coating formulations (70:30 and 90:10) exhibited somewhat higher moisture content than 50:50, but neither formulation varied substantially ($P > 0.05$) from the control, showing they are very sensitive to microbial contamination. The 90:10 sample had the lowest ash content (0.47 ± 0.04%) compared to others. All coated samples exhibited lower fat content than the control. There were no substantial ($P > 0.05$) differences in protein content between coated and control samples. Thus, PE emulsion had no effect on the chicken fillet's protein level, but it reduced the fat, making it healthier for people with high cholesterol levels and hypertension.

All coated samples, regardless of PE ratio, appeared bright yellow on day 0, whereas the control was light pink and turned to red after 3 and 7 days of storage (Table 4). The green value of a 50:50 sample (on day 0) became red after 3 days, and more intensified after 7 days. After 3 days, the light colour of 50:50 and 70:30 samples decreased. Furthermore, the 70:30 sample became red after 3 days and far less yellow after 7 days. The 90:10 sample's green value became red after 3 days, and its yellowness value increased after 7 days. Light-yellow PE coating produced higher total colour difference (E) than control on day 0. However, after 3 and 7 days of storage, coated and control samples showed the same E value. During storage, certain colour values increased and decreased, but most were not statistically ($P > 0.05$) different. PE coatings retain colour freshness by reducing lipid oxidation and hydrolysis (Viana et al., 2017). Our results were supported by Pajak et al. (2019), who discovered that the colour of emulsified films depends on the form and concentration of essential oils as well as additives (e.g., pectin to increase emulsion stability). As a result, it is recommended that perishable items such as chicken be coated with PE to maintain their freshness and stability.

Table 3. Proximate analysis (moisture, ash, fat, and protein contents) of chicken fillet coated with different percentage ratio of PE during 7 days of storage. Data was presented as mean ± S.D

Sample	Moisture (%)	Ash (%)	Fat (%)	Protein (%)
Control	77.88 ± 1.47[b]	0.69 ± 0.07[b]	17.78 ± 2.22[b]	21.78 ± 1.72[a]
50:50	74.00 ± 0.95[a]	1.04 ± 0.01[c]	8.34 ± 1.76[a]	21.23 ± 2.73[a]
70:30	76.44 ± 0.90[b]	0.90 ± 0.15[c]	6.38 ± 0.59[a]	20.09 ± 0.54[a]
90:10	77.63 ± 0.21[b]	0.47 ± 0.04[a]	6.21 ± 1.02[a]	19.57 ± 1.11[a]

[a,b]: Means with different superscripts within a column are significantly different ($P < 0.05$).
Note: Data for moisture, ash, and protein contents were log transformed to obtain normal distribution.

Table 4. Colour analysis of chicken fillet coated with different percentage ratio of PE during 7 days of storage. Data are presented as mean ± S.D

Sample	Lightness (L*)			Redness–greenness (a*)		
	Day 0	3 days	7 days	Day 0	3 days	7 days
Control	51.41 ± 1.34[aA]	54.58 ± 2.11[abA]	51.76 ± 5.94[aA]	0.26 ± 0.11[bA]	1.40 ± 0.76[bB]	1.65 ± 1.40[aB]
50:50	58.62 ± 2.43[bB]	55.56 ± 1.64[bAB]	53.37 ± 3.37[aA]	−0.77 ± 0.44[aA]	0.23 ± 1.72[aAB]	1.07 ± 1.33[aB]
70:30	56.13 ± 2.51[bA]	53.06 ± 2.66[aA]	53.36 ± 3.77[aA]	−0.40 ± 0.44[aAB]	−0.76 ± 0.31[aA]	0.44 ± 1.43[aB]
90:10	56.24 ± 4.91[bA]	58.04 ± 0.97[cA]	54.78 ± 5.80[aA]	−0.81 ± 0.47[aA]	−0.31 ± 0.18[aA]	0.84 ± 0.57[aB]

Sample	Yellowness–blueness (b*)			Total colour difference (ΔE)		
	Day 0	3 days	7 days	Day 0	3 days	7 days
Control	5.52 ± 1.07[aA]	6.16 ± 2.00[aA]	8.32 ± 1.55[aB]	-	4.33 ± 1.51[aA]	5.17 ± 3.33[aA]
50:50	9.86 ± 0.73[cA]	8.25 ± 2.22[abA]	9.07 ± 1.40[aA]	8.53 ± 3.16b[cB]	4.02 ± 2.07[aA]	5.85 ± 2.91[aAB]
70:30	7.33 ± 2.36[bA]	8.83 ± 1.10[bA]	8.47 ± 0.93[aA]	5.34 ± 1.67[aA]	5.21 ± 2.71[aA]	6.40 ± 3.50[aA]
90:10	4.78 ± 0.38[aA]	8.01 ± 1.46[abB]	8.22 ± 1.29[aB]	6.10 ± 2.48[abA]	4.94 ± 2.07[aA]	4.86 ± 3.55[aA]

[a,b,c]: Means with different superscripts in the same column are significantly different ($P < 0.05$).
[A, B]: Means with different superscripts in same row are significantly different ($P < 0.05$).

3.2. Relationships between viscosity of the coating solution and fat uptake during frying

Figure 1 shows that the viscosity of different PE coatings varied significantly ($P < 0.05$). The coating solution became thicker when pectin concentrations increased from 50% to 90%, whereas lemongrass emulsion concentrations decreased (50%–10%). The 90:10 formulation generated the most viscous coating solution (1066.67 $\pm$ 115.47 mPa s^{-1}), followed by 70:30 (503.33 $\pm$ 5.77 mPa s^{-1}) and 50:50 (20.33 $\pm$ 0.58 mPa s^{-1}). Fat absorption reduced ($P < 0.05$) in all coated chicken samples during frying, with the 50:50 absorbing the least fat (6.16 $\pm$ 2.38%) compared to the control group (33.88 $\pm$ 18.87%) (Fig. 1).

According to the findings, coating viscosity affects oil absorption. Fat uptake and viscosity were correlated ($R = 0.710$; $P < 0.05$; Table 5). This confirms the theory that coating fluid with increased viscosity may absorb more chicken fillet fat. This research used oil-in-water emulsion (O/W) consisting of 55% water and 25% glycerol. It is soluble in lipophilic antimicrobial components for plant essential oils and bioactive components (Salvia-Trujillo et al., 2017). Pectin adds consistency to the O/W emulsion and increases the emulsion's viscosity, thereby restricting oil droplet movement (McClements and Gumus, 2016). pH regulates the electric charge of droplets and is crucial for stabilising nanoemulsions; when it is sufficiently high, droplets do not aggregate owing to the electrostatic repulsion (McClements, 2004). This research found that 90%
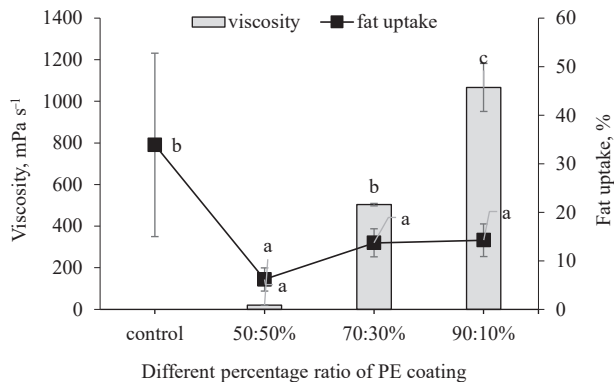

Fig. 1. The viscosity of different percentage ratio of PE and fat uptake capacity of coated chicken fillet during frying. Triplicates were done for each treatment. Different letters on the adjacent panel (bar chart or line graph) mean significantly ($P < 0.05$) differences

Table 5. Correlation among viscosity of PE coating and fat uptake capacity of chicken fillet

	Fat uptake[a]	Viscosity
Fat uptake	1	0.710* ($P = 0.032$; $N = 9$)
Viscosity	0.710* ($P = 0.032$; $N = 12$)	1

*: Pearson correlation was significant at $P < 0.05$.
[a]: Data for fat uptake was log transformed to achieve normal distribution.

of pectin-based edible coatings have the highest emulsion consistency and viscosity. This finding was consistent with results of Guerra-Rosas et al. (2016), who found that the higher the pectin content, the higher the viscosity due to the pectin's thickening properties, which are correlated with its ability to maintain large volumes of water. Free pectin molecules in an aqueous process generate gel-like structures, increasing the medium's viscosity (Hansen et al., 2001).

4. CONCLUSIONS

The 90:10 PE emulsion functions as an excellent coating to prolong shelf-life stability, inhibiting growth of yeasts, moulds, and psychrophilic bacteria. It had no effect on protein but reduced fat content. Decreased microbial growth indicated a higher acidic pH, suggesting further study is needed to determine whether acidic bioactive compounds have natural preservation properties. The 50:50 PE demonstrated the best fat absorption while frying.

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