Effect of gallic acid/chitosan coating on fresh pork quality in modified atmosphere packaging

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I. INTRODUCTION

To ensure food safety and quality, there has been an increasing interest in the development and application of edible coatings with incorporation of bioactive compounds for fresh foods [1]. Polyphenols possess both antimicrobial and antioxidant activities [2]. Using chitosan as the coating/film matrix is very attractive in the food industry, because of its non-toxic and natural properties, and its intrinsic ability to inhibit microorganism growth and lipid oxidation [1]. In addition, modified atmosphere packaging (MAP) is currently commonly used to partly inhibit aerobic and anaerobic microorganisms and extend the shelf life of meat [3]. The aim of this research was to investigate the effect of this combined technology of edible coating and MAP on the product quality of fresh pork, with the potential to develop a new hurdle technology for fresh meat preservation to ensure food safety and quality.

II. MATERIALS AND METHODS

Preparation of chitosan coating and pork samples

Chitosan coating solutions were prepared by adding 2% chitosan w/w into 1% w/v acetic acid. Gallic acid was added to the solution at different concentrations of 0% (CHI), 0.2% (w/w) (CHI/0.2G) and 0.4% (w/w) (CHI/0.4G). The fresh pork loins were dipped in the different coating solutions for 60 seconds and then air dried at room temperature for 30 minutes. Non-coated pork samples were used as control (CON). After coating, each sample was placed in an 8 cm deep plastic tray with an absorbent pad at the bottom, and flushed with 20% CO_2 and 80% O_2 gas mixture followed by sealing hermetically with oxygen impermeable film. The steaks were stored in simulated shelf life fridge with LED lighting at 4 °C for 0, 5, 10, 15, 20 days, and rotated daily between shelves to ensure all trays received a similar level of light exposure.

Meat quality measurement and data analysis

The total viable count (TVC), lipid oxidation (TBARS) value [4], protein oxidation (free thiol group value) [5] and texture (shear force) of the samples were measured. Data were expressed as mean ± standard deviation (SD) least significant difference was used to differentiate the significant difference at a level of $p<0.05$ by using SAS software.

III. RESULTS AND DISCUSSION

Total viable count (TVC)

Compared with non-coated sample (CON), chitosan coating (CHI) inhibited the microbial growth, and addition of gallic acid in the chitosan film (CHI/0.2G and CHI/0.4G) further enhanced ($p<0.05$) the antimicrobial activity (Table 1). The enhanced antimicrobial activity by gallic acid incorporation is likely from its role in decreasing negative charges and causing ruptures or pore formation in cells, which results in the death of microorganisms [6]. However, there was no antimicrobial difference ($p>0.05$) between the addition of 0.2% and 0.4% gallic acid in the present study. This suggests that 0.2% of gallic acid addition to the chitosan film could be sufficient to inhibit the microbial growth under the current experimental conditions.

Lipid oxidation

The TBARS values of non-coated pork (CON) was increased from 0.08 to 1.004 mg MDA/kg at day 20, indicating severe oxidation. On the other hand, the TBARS values of the chitosan coated samples (CHI) were increased much more slowly, and incorporating gallic acid into the chitosan coating (CHI/0.2G and CHI/0.4G) resulted in even lower TBARS values during storage (Table 1). Gallic acid is known to be an effective antioxidant that is able to scavenge free radicals and decrease the oxidation chain reaction [7]. The incorporation of gallic acid into chitosan film could increase the oxygen barrier properties of chitosan, reduce the exposure of the meat to oxygen and thus retard oxidation [8]. However, there was no additional anti-lipid oxidation activity at higher levels of gallic acid (CHI/0.4G compared to CHI/0.2G), implying that 0.2% gallic acid in chitosan film could be the optimal formula from the present study.

Protein oxidation

Table 1 shows that the protein oxidation level was significantly lower in the chitosan coated samples, especially in the 0.2% gallic acid/chitosan (CHI/0.2G) coated samples, which suggests that adding gallic acid to chitosan coating could effectively prevent protein oxidation in pork. However, the CHI/0.4G sample which contained higher concentration of gallic acid showed a significant lower free thiol on day 20 compared to CHI/0.2G. This could result from a pro-oxidant effect of higher concentrations of gallic acid, although this pro-oxidant effect was not shown in lipid oxidation in the above section. Nieto et al. [9] observed that adding higher concentration (0.4%) of oregano essential oil into the pork patties resulted in higher protein oxidation compared to the addition of a lower concentration (0.05%). These data suggested that the antioxidant level should be optimised in food processing and preservation to avoid possible undesirable pro-oxidation effects.

Table 1 Effect of gallic acid/chitosan coating on the total viable account (TVC), TBARS values, protein oxidation (free thiol group values, nmol thiol/ mg protein), and shear force (N) of pork loin under MAP storage at 4 °C

Parameter	Treatment	Storage day				
		[c] 0	5	10	15	20
TVC	[a] CON	[b]2.56 ± 0.06^{Ae}	4.41 ± 0.06^{Ad}	5.28 ± 0.14^{Ac}	6.15 ± 0.15^{Ab}	6.39 ± 0.06^{Aa}
	CHI	2.56 ± 0.06^{Ae}	4.03 ± 0.06^{Bd}	4.63 ± 0.17^{Bc}	4.97 ± 0.13^{Bb}	5.16 ± 0.14^{Ba}
	CHI/0.2G	2.56 ± 0.06^{Ac}	3.96 ± 0.04^{Bb}	4.44 ± 0.23^{Ba}	4.60 ± 0.25^{Ca}	4.60 ± 0.18^{Ca}
	CHI/0.4G	2.56 ± 0.06^{Ac}	3.95 ± 0.04^{Bb}	4.60 ± 0.12^{Ba}	4.70 ± 0.16^{Ca}	4.61 ± 0.24^{Ca}
TBARS	CON	0.081 ± 0.06^{Ae}	0.199 ± 0.06^{Ad}	0.272 ± 0.07^{Ac}	0.535 ± 0.01^{Ab}	1.004 ± 0.06^{Aa}
	CHI	0.081 ± 0.06^{Ac}	0.214 ± 0.05^{Ab}	0.285 ± 0.06^{Ab}	0.451 ± 0.09^{Ba}	0.550 ± 0.02^{Ba}
	CHI/0.2G	0.081 ± 0.06^{Ac}	0.204 ± 0.03^{Ab}	0.239 ± 0.01^{Aab}	0.250 ± 0.05^{Cab}	0.252 ± 0.02^{Ca}
	CHI/0.4G	0.081 ± 0.06^{Ac}	0.197 ± 0.06^{Ab}	0.227 ± 0.02^{Aab}	0.242 ± 0.01^{Cab}	0.279 ± 0.05^{Ca}
Protein oxidation	CON	69.17 ± 2.38^{Aa}	64.80 ± 6.28^{Aa}	58.89 ± 1.72^{Ab}	47.12 ± 1.43^{Cc}	35.69 ± 3.31^{Cd}
	CHI	69.17 ± 2.38^{Aa}	62.21 ± 1.62^{Aa}	57.48 ± 4.12^{Ab}	53.68 ± 6.35^{ABc}	45.23 ± 4.16^{Bd}
	CHI/0.2G	69.17 ± 2.38^{Aa}	66.31 ± 1.88^{Aa}	57.46 ± 1.31^{Ab}	57.95 ± 4.27^{Ab}	49.00 ± 0.65^{Ac}
	CHI/0.4G	69.17 ± 2.38^{Aa}	65.90 ± 2.00^{Aa}	55.24 ± 3.80^{Ab}	52.13 ± 3.54^{Bb}	44.49 ± 1.15^{Bc}
Shear force	CON	194.07 ± 14.48^{Ac}	243.62 ± 12.17^{Ab}	252.62 ± 30.66^{Ab}	284.95 ± 20.51^{Aa}	299.21 ± 10.36^{Aa}
	CHI	194.07 ± 14.48^{Ab}	203.52 ± 20.35^{Bb}	238.09 ± 6.69^{Aab}	243.04 ± 5.47^{Ba}	263.65 ± 15.15^{BCa}
	CHI/0.2G	194.07 ± 14.48^{Ab}	202.72 ± 21.27^{Bab}	233.28 ± 23.64^{Aa}	242.55 ± 33.16^{Ba}	252.38 ± 13.58^{Ca}
	CHI/0.4G	194.07 ± 14.48^{Ab}	209.25 ± 38.11^{Bb}	259.41 ± 16.03^{Aa}	268.28 ± 23.35^{ABa}	272.86 ± 8.53^{BCa}

[a] CON, non-coated; CHI, 2% chitosan solution coating; CHI/0.2G, 0.2% gallic acid (w/w) in 2% chitosan solution coating; CHI/0.4G, 0.4% gallic acid (w/w) in 2% chitosan solution coating.
[b] Data in the same column or row with different letters (capital and small respectively for column and row) within a parameter indicate significant difference ($p<0.05$), respectively.
[c] The initial date of experiment where pork loins were not coated and packed and therefore had the same value.

Texture analysis

The results showed that the pork shear force values were increased with the storage time (Table 1), and protein cross-linking has been suggested as the main mechanism for meat toughening during storage (Lund et al., 2007). All chitosan coated samples exhibited lower shear force value than the control from day 5 and beyond, which indicated that chitosan coating might able to delay the lipid and protein oxidation and consequently maintain the meat tenderness during MAP storage. However, unlike lipid and protein oxidation, the statistical analysis showed no significant differences among the 3 chitosan coated samples during the whole storage period, which may suggest that the meat texture change is not as quickly as lipid and protein oxidation measured in this study.

IV. CONCLUSION

In conclusion, this work suggests that incorporation of suitable levels of gallic acid (0.2%) into chitosan solution could be a promising coating formula to extend the shelf life of pork loins stored in high oxygen MAP at 4 °C.

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