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FULL PAPER

Effect of antimicrobial coating on the shelf life of smoked tilapia jerky

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Abstract

Microorganisms are the major cause of spoilage in most seafood products. The present study was conducted to evaluate the effect of antimicrobial coating on the shelf life of smoked tilapia jerky. The antimicrobial coating solution was prepared by incorporating potassium sorbate (PS) and sodium benzoate (SB) into a coating solution made from sodium alginate, whereas the plain coating solution was prepared from sodium alginate without the addition of PS and SB. Tilapia jerky was coated with antimicrobial coating solution (AC) and plain coating solution (PC) respectively and storage quality was compared to sample without coating (WC). Tilapia jerky was stored at room conditions and drawn weekly to evaluate for microbiological and physical-chemical properties. Results showed that coating could retard microbial growth and prolong the shelf life of AC and PC samples for up to 28 and 14 days respectively, compared to WC samples spoiled after 7 days of storage. The use of antimicrobial coating provides a product with higher safety and better quality.

1. Introduction

Smoking technology has been traditionally used to preserve the quality and extend the shelf life of fish products. Nowadays, smoking is more of a process of diversifying and adding value to these products. However, the storage life of smoked fish products is short due to the growth of microorganisms. Microbial contamination of food occurs mainly on the surface due to negligence during handling. This problem can be solved by using the coating method. The antimicrobial coating is a promising form of active packaging that inhibits the growth of microbial especially on the surface of food (Valdés *et al.*, 2017). In order for the packaging to possess antimicrobial properties, antimicrobial agents may be coated, incorporated, immobilised, or surface modified onto package materials (Suppakul *et al*., 2003).

In accordance with Regulations 159, Malaysia's Food Regulations 1985, no preservatives are allowed for use in smoked fish products. While referring to General Standard for Food Additives, Codex Stan 192-1995, potassium sorbate (PS) and sodium benzoate (SB) are preservatives that are allowed for use in smoked fish provided that they are used for surface treatment. Thus, coating is a way of extending the shelf life of smoked fish that meets the requirement. The use of preservatives such as PS and SB have become increasingly important in controlling the growth of microbes and extending product shelf life. These chemical preservatives have been shown to inhibit the growth of bacterial pathogens such as *Listeria monocytogenes* in media, meat (Samelis *et al.*, 2001; Islam *et al.*, 2002) and seafood (Neetoo *et al*., 2008; Neetoo *et al*., 2010; Neetoo and Mahomoodally, 2014). PS is a salt of sorbic acid and common usage levels of PS in various food products have ranged from 0.5 to 1.0% (Neetoo and Mahomoodally, 2014). Depending on the processing conditions, PS is usually applied to whole or eviscerated fish or fillets, prior to or immediately after smoking (Crozier-Dodson *et al.*, 2005). Meanwhile, the maximum limit allowed by the European Commission for SB is 0.2% (Neetoo *et al*., 2008).

Jerky is a dried meat product that is traditionally preserved by salting and drying, either with or without smoking. Numerous jerky products have been made from

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a variety of different meats with different marinating and processing techniques. Fish jerky as a healthy option to red meat jerky has been introduced to the market since the last decade (Hightower and Brown, 2011; Kong *et al*., 2012). This study was carried out to study the effect of an edible antimicrobial coating incorporating food-approved antimicrobials to inhibit the growth of microorganisms to extend shelf life and ensure the safety of smoked tilapia jerky.

2. Materials and methods

2.1 Materials

Red tilapia was obtained from the local market at Kuala Terengganu. Chemicals used were sodium alginate, potassium sorbate, sodium benzoate and glycerol with the brand name of R and M Chemicals which were supplied by local chemicals suppliers. Medias used were Plate Count Agar (PCA) (Oxoid, UK), Malt Extract Agar (MEA) (Oxoid, UK), Baird Parker Agar (BPA) (Oxoid, UK), Ringer's tablet (Oxoid, UK) and Petrifilm (3M, USA).

2.2 Preparation of coating solution

Through our early studies, the formulation and processing parameters of coating solutions were established (unpublished data). The antimicrobial coating solution was prepared by mixing sodium alginate (0.6%), potassium sorbate (PS, 0.8%), sodium benzoate (SB, 0.2%) with glycerol and filtered water. Mixed solutions were subsequently heated to 80^{o}C and bottled for future uses. Plain sodium alginate coating solution was prepared following the same method but without adding PS and SB.

2.3 Tilapia jerky preparation

Red tilapia obtained from the local market were washed and filleted. The fillets were subsequently cut into finger size (1.5×1.5×6 cm) and immersed into a 2% brine solution for 1 min to discard any remaining slime. Fifty kilograms of tilapia fingers were mixed with salt (300 g), sugar (75 g), black pepper powder (30 g), shallot powder (45 g), paprika (30 g), cumin powder (15 g), brown sugar (180 g), chilli powder (45 g) and garlic powder (30 g) in a tumbling machine for 30 mins. Marinated fingers were put on trays and smoked for 1 hr at 45^{o}C inside a smoke machine. In order to fully cook the jerky, the smoke machine temperature was set to 100^{o}C for another 30 mins. Subsequently, jerky was divided into 3 groups whereby the first group was dipped into the antimicrobial solution for 1 min (AC), the second group dipped into plain sodium alginate solution for 1 min (PC) and the last group without any dipping process served as control (WC). These three groups of samples were further dried at 55^{o}C until the moisture content of jerky was less than 50% (approximately 5 hrs). The processed jerky was then cooled and packed in a high-density polyethylene bag with 30 g each and stored at ambient conditions. Sample was withdrawn weekly for analyses.

2.4 Determination of microbiological quality

Samples were analysed weekly for Total Plate Counts, Yeast and Mould, Coliform and *Staphylococcus aureus.* The analysis of samples was based on the method by Bacteriological Analytical Manual (USFDA, 2001) with minor modifications. The mean value of microbial count (CFU/g) for samples was determined. For the preparation of homogenized samples, 10 g of samples were aseptically weighed and diluted with 90 mL Ringer's solution. Samples were homogenized for 120 seconds in a stomacher (Seward, UK) and serial dilutions 10^{-1} to 10^{-5} were prepared in sterile Ringer's solution. The method from Bacteriological Analytical Manual (USFDA, 2001) was used with the following parameter; Total Plate Counts on Plate Count Agar (PCA), incubation at 37^{o}C for 48±2 hrs; Yeast and Mould Counts on Malt Extract Agar (MEA), incubation at 32^{o}C for 72±2 hrs; Coliform on Petrifilm (3M, USA), incubation at 37^{o}C for 24 - 48±2 hrs and *Staphylococcus aureus* using Baird Parker Agar (BPA), incubation at 37^{o}C for 48 hrs±2 hrs.

2.5 Determination of physical-chemical properties

The moisture content of the tilapia jerky was determined using an oven drying method (AOAC, 2000). Five grams of samples were weighted in triplicate in pre-dried and pre-weighted glass dishes and allowed to dry for 16-18 hrs at 105^{o}C in an oven (Memmert, Germany). Following drying, samples were removed to place in a desiccator and weighed. The analysis was performed in triplicate. Moisture content was calculated using the formula:

Moisture content (%) = (initial weight – final weight) / initial weight × 100.

The water activity of tilapia jerky was determined using LabMaster-aw Novasina (Switzerland) according to the manufacturer's instructions. Blended samples were placed into three individual containers to the level marked at the container and subsequently put into the machine. Readings were taken after constant values were obtained. Analyses were performed in triplicate.

The colour values were measured from the surface of jerky samples using a Chroma Meter CR10 (Minolta Camera Co. Ltd., Osaka Japan) based on the CIE L*a*b* system, where L* describes lightness (ranging from

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black to white), a* and b* describe the chromatic coordinates (-a for greenness, +a for redness, -b for blueness and +b for yellowness). A mean value of 10 measurements was reported for each colour attribute.

2.6 Statistical analysis

Data are presented as mean±SD for at least three replications for each treatment. Experimental data were analysed by Two-way Analysis of Variance (ANOVA) and the significant differences among means were determined by Duncan Multiple Range Test (DMRT) at $p<0.05$ using the Statistical Analysis System (SAS, 2011) computing program.

3. Results and discussion

3.1 Microbiological quality of tilapia jerky

Tables 1 to 4 show the results for total plate counts, yeast and mould, Coliform and *Staphylococcus aureus* of tilapia jerky during storage. Total plate counts, yeast and mould load for all samples increased during storage, whereas Coliform and *S. aureus* remained very low throughout the whole storage duration. The WC sample showed visible mould after 14 days of storage compared to the PC sample at 28 days and AC sample at 42 days respectively. However, after taking into consideration of the maximum limit level of total plate count not exceeding 10^4 CFU/g sample, AC lasted for 28 days, compared to 14 days for PC and 7 days for WC. The coating solution covering the outer layer of food dried and form a layer of thin-film to protect the food from spoilage for a period of time. Meanwhile, antimicrobial agents from the coating material slowly absorb onto the food surface and allow these agents to inhibit the growth of microorganisms to enhance the product's shelf-life while upholding its quality and safety (Chawla *et al.*, 2021). The results obtained in this study showed a similar trend with the finding by Neetoo and Mahomoodally (2014). They found the growth of *Listeria monocytogenes* declined significantly in cold-

Table 1. Total plate count (CFU/g) of smoked tilapia jerky during storage.

Storage Time (Day)	Sample		
	Without Coating (WC)	Plain Coating (PC)	Antimicrobial Coating (AC)
0	1.7×10^3	1.9×10^3	1.6×10^3
7	4.7×10^4	2.2×10^4	6.4×10^3
14	3.2×10^8 (visible mould)	4.5×10^4	2.5×10^4
21	-	5.6×10^5	3.4×10^4
28	-	7.8×10^7 (visible mould)	4.8×10^4
35	-	-	6.6×10^5
42	-	-	5.0×10^8 (visible mould)

-, not tested.

Table 2. Yeast and mould count (CFU/g) of smoked tilapia jerky during storage.

Storage Time (Day)	Sample		
	Without Coating (WC)	Plain Coating (PC)	Antimicrobial Coating (AC)
0	$<1\times10^2$	$<1\times10^2$	$<1\times10^2$
7	6.3×10^2	$<1\times10^2$	$<1\times10^2$
14	4.6×10^3 (visible mould)	2.1×10^2	$<1\times10^2$
21	-	2.8×10^3	3.4×10^2
28	-	5.4×10^3 (visible mould)	6.7×10^2
35	-	-	2.6×10^3
42	-	-	6.0×10^3 (visible mould)

-, not tested.

Table 3. Coliform count (CFU/g) of smoked tilapia jerky during storage.

Storage Time (Day)	Sample		
	Without Coating (WC)	Plain Coating (PC)	Antimicrobial Coating (AC)
0	$<1\times10^2$	$<1\times10^2$	$<1\times10^2$
7	$<1\times10^2$	$<1\times10^2$	$<1\times10^2$
14	$<1\times10^2$ (visible mould)	$<1\times10^2$	$<1\times10^2$
21	-	$<1\times10^2$	$<1\times10^2$
28	-	$<1\times10^2$ (visible mould)	$<1\times10^2$
35	-	-	$<1\times10^2$
42	-	-	$<1\times10^2$ (visible

Note: *Escherichia coli* was not detected in all samples. -, not tested.

Table 4. *Staphylococcus aureus* count (CFU/g) of smoked tilapia jerky during storage.

Storage Time (Day)	Sample		
	Without Coating (WC)	Plain Coating (PC)	Antimicrobial Coating (AC)
0	$<1\times10$	$<1\times10$	$<1\times10$
7	$<1\times10$	$<1\times10$	$<1\times10$
14	$<1\times10$ (visible mould)	$<1\times10$	$<1\times10$
21	-	$<1\times10$	$<1\times10$
28	-	$<1\times10$ (visible mould)	$<1\times10$
35	-	-	$<1\times10$
42	-	-	$<1\times10$ (visible mould)

-, not tested.

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smoked salmon coated with cellulose films containing potassium sorbate, sodium benzoate and nisin. Results from other researchers also revealed that antimicrobial coatings and films allow the controlled diffusion and gradual release of embedded antimicrobials onto the food surface and eventually increase the shelf life and safety of the product (Min and Krochta, 2005).

3.1 Physical-chemical properties of tilapia jerky

Tables 5 and 6 show the results for moisture content and water activity of the tilapia jerky during the storage study. There were significant differences ($p<0.05$) in the moisture content of samples without coating and samples with coating. Jerky without coating (WC) had an initial moisture content of 38.80% compared to 42.97% for PC and 42.54% for AC. Coating solution dried and form a layer of film on the surface of jerky acted as a protective layer to slower moisture loss during the smoking process and this explained the reason for the coated samples had higher moisture content. However, moisture content for WC and PC were not influenced ($p > 0.05$) by the storage time. Throughout the storage period of 14 days and 28 days for WC and PC respectively, moisture content did not show any significant changes. Whereas the moisture content of AC showed significantly increased ($p<0.05$) from 42.54% at the initial to 43.66% at the end of 42 days storage.

There were no significant differences in the water activity of WC, PC and AC tilapia jerky right from the beginning towards the end of storage duration (ranging from 0.66 to 0.68). Smoked tilapia jerky in our current study had low water activity (<0.70) and remained insignificant changes ($p>0.05$) during storage duration. It has been suggested that jerky products should be dried to a water activity level of ≤0.85 to ensure safety and control pathogens (Ingham *et al.*, 2006). USDA guidelines require that jerky products have an aw value of ≤0.80 to be considered shelf-stable (USDA-FSIS, 2014). Brining process and addition of salt and sugar in the marination process may contribute to the achievement of low water activity value. Salting caused most bacteria, fungi and other potentially pathogenic organisms cannot survive due to the osmotic pressure that salt creates. Any living cell in an environment with high concentrations of salt will become dehydrated through osmosis and die or become inactivated (Sampels, 2015). This extraction of water from the product means a decrease the water activity (aw). Decreased aw results in a decreased activity of bacteria and enzymes (Oliveira *et al.,* 2012).

Figures 1(a), (b) and (c) show results for colour L*a*b* of smoked tilapia jerky during the storage study. Both coated samples PC and AC had significant ($p<0.05$) higher L* values compared to the uncoated WC sample. At the initial storage study, PC had L* of 56.04, AC of 56.92 and WC had a lower reading of 54.38. A similar observation was also obtained for a* values where coated samples had higher readings compared to the uncoated sample. Whereas there was no significant difference ($p>0.05$) for b* among all samples at the initial storage duration. All colour values L*, a* and b* of the smoked tilapia jerky were influenced ($p < 0.05$) by storage time. Compared to fresh jerky, lightness L* of all samples decreased significantly during storage. Bright brown of smoked jerky turned into dark brown colour at the end of storage period. This could be due to the oxidation process that occurred along with the storage. Both a* and b* readings were increased significantly ($p<0.05$) during the storage period. Readings for a* were ranging from 12.48 to 16.94, whereas b* ranges from 22.54 to 26.96.

Table 5. Moisture content of smoked tilapia jerky during storage.

Storage Time (Day)	Sample		
	Without Coating (WC)	Plain Coating (PC)	Antimicrobial Coating (AC)
0	38.80 ± 0.13^{aB}	42.97 ± 0.11^{aA}	42.54 ± 0.55^{bA}
7	38.78 ± 0.50^{aB}	42.66 ± 0.66^{aA}	43.07 ± 0.58^{abA}
14	38.81 ± 0.57^{aB}	42.69 ± 0.71^{aA}	43.29 ± 0.44^{abA}
21	-	43.33 ± 0.34^{aA}	43.23 ± 0.29^{abA}
28	-	42.70 ± 0.19^{aA}	43.36 ± 0.38^{abA}
35	-	-	43.35 ± 0.60^{ab}
42	-	-	43.66 ± 0.11^{a}

Values are presented as mean±SD. Values with different lowercase superscripts within the same column are statistically significantly different ($p<0.05$) while values with different uppercase superscripts within the same row are statistically significantly different ($p<0.05$).

Table 6. Water activity of smoked tilapia jerky during storage.

Storage Time (Day)	Sample		
	Without Coating (WC)	Plain Coating (PC)	Antimicrobial Coating (AC)
0	0.67 ± 0.01^{aA}	0.68 ± 0.02^{aA}	0.66 ± 0.00^{aA}
7	0.67 ± 0.00^{aA}	0.68 ± 0.00^{aA}	0.67 ± 0.01^{aA}
14	0.68 ± 0.01^{aA}	0.68 ± 0.01^{aA}	0.68 ± 0.00^{aA}
21	-	0.68 ± 0.01^{aA}	0.68 ± 0.01^{aA}
28	-	0.68 ± 0.01^{aA}	0.68 ± 0.01^{aA}
35	-	-	0.68 ± 0.01^{a}
42	-	-	0.68 ± 0.01^{a}

Values are presented as mean±SD. Values with different lowercase superscripts within the same column are statistically significantly different ($p<0.05$) while values with different uppercase superscripts within the same row are statistically significantly different ($p<0.05$).

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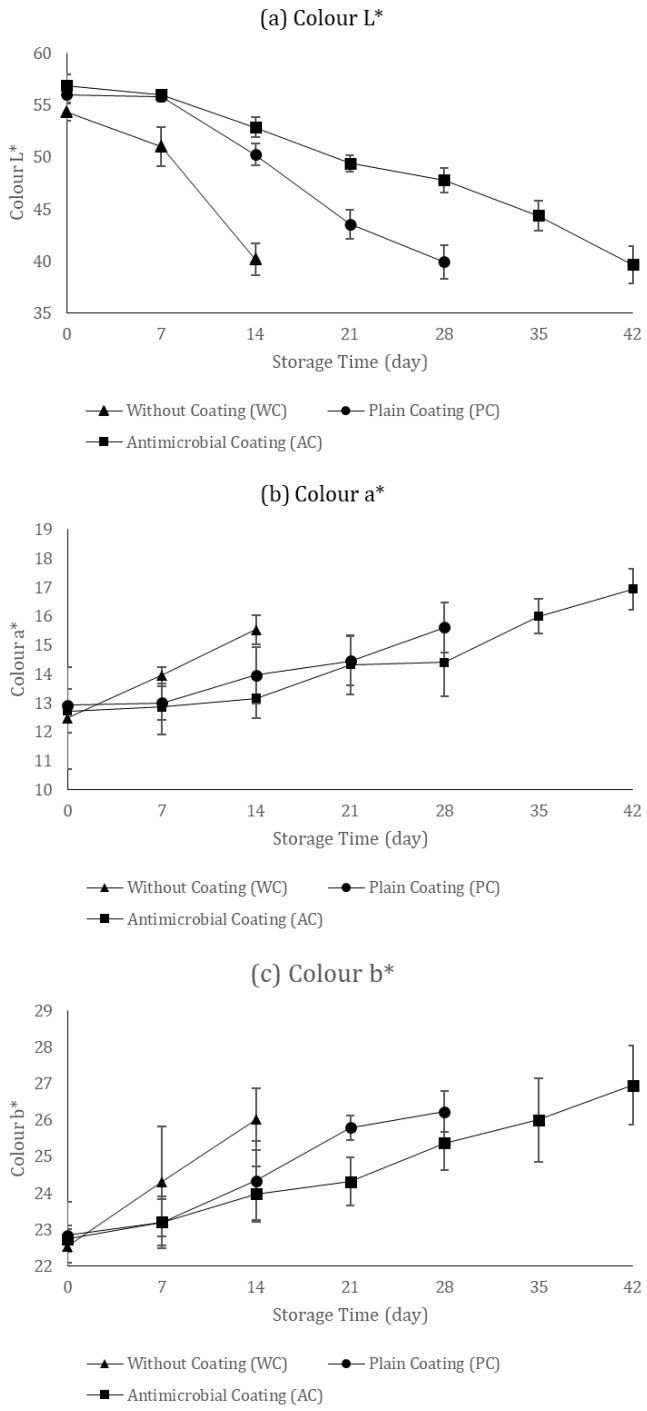

Figure 1. (a) Colour L*, lightness, (b) a*, redness and (c) b*, yellowness of smoked tilapia jerky during storage.

4. Conclusion

From our current study, the shelf life of smoked tilapia jerky using antimicrobial coating could be extended for up to 4 times longer (from 7 days to 28 days), thus the product can be stored longer and made possible to distribute the product to a wide market. This antimicrobial coating can be introduced for the use of smoked fish entrepreneurs because of its effectiveness in extending the shelf life of smoke tilapia jerky.

Conflict of interest

The authors declare no conflict of interest.

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