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Effect of Alginate-Based Edible Coating with Oatmeal on the Quality of Nile Tilapia Fillets

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This study was realized to evaluate the effect of an alginate-based coating with oatmeal flour on lipid oxidation (quantified using the thiobarbituric acid reactive substances (TBARS) assay), color (Cielab), pH, texture, and weight loss of tilapia fillets during 15 days. Five treatments were evaluated: CON – fillets without coating, AC – fillets with alginate coating, ACO1 – fillets coated with 1% of oatmeal, ACO2– fillets coated with 2% of oatmeal, ACO3 – and fillets coated with 3% of oatmeal flour. The samples were randomly removed at 1, 5, 10 and 15 days of storage for analysis. A reduction was observed of the lipid oxidation on the coated fillets (AC, ACO1, ACO2 and ACO3) when compared to the control ($P<0.05$). Still, the coating with 3% of oatmeal was the most efficient for oxidation. The lipid oxidation increased ($P<0.05$) during the storage time. The L* values were similar among treatments, except at 5 days for color. The storage time did not affect ($P>0.05$) the L* values, a* values were negative and b* values were higher ($P<0.05$) with alginate coatings and oatmeal flour addition. Coated fillets maintained their firmness during storage, while uncovered fillets became softer ($P<0.05$). The weight loss of the fillets (Table 3) increased ($P<0.05$) during the storage period, but alginate coating and addition of oatmeal reduced ($P<0.05$) the mass loss in comparison to the CON and AC treatments. The pH did not change during the storage period for all samples ($P>0.05$). Thus, edible coatings could be used in the industry to maintain the product quality during its shelf-life.

1. Introduction

New alternatives for renewable materials have been studied in order to meet industrial needs and reduce the problems caused by the use of non-biodegradable packing materials (Vital et al, 2016; Marefati et al, 2017). Biodegradable packaging materials are usually produced from polysaccharides, proteins and lipid compounds derived from plant and animal resources, such as starch, cellulose and other biopolymers (Reddy and Rhim 2014). Among the materials used to produce food packaging, sodium alginate is one of the most exploited in the development of biodegradable food packaging films because of its good film-forming properties (Vital et al., 2016; Wang et al, 2017a). It may be used to prolong the shelf-life and preserve the quality of food, reducing oxidation, reducing contact with oxygen, increasing the water barrier and maintaining the desirable characteristics of the food (Vital, et al., 2018). Despite their high transparency, alginate films show poor water vapor barrier properties, with low flexibility like other biopolymer-based films (Liu et al, 2017). In order to improve the properties of alginate films and promote their commercial use, the films have been reinforced with natural fibers, since fibers have good mechanical properties, high availability and are ECO-friendly, recyclable and of low cost (Binoj et al, 2016). Using oats as a reinforcement material in composites is an innovative and interesting application since oats are easy to obtain and process (Oliveira et al, 2017).
Fish has high levels of moisture, free amino acids, fatty acids, and nutrient content. Moreover, fish is a perishable product due to its natural autolysis, having reduced useful life, around 6 days, when refrigerated (Cai et al, 2015, Khalafalla, et al.2015). These characteristics contribute to a short shelf life of fish, resulting in the need to develop innovative techniques for maintaining its quality attributes and extending its shelf

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life.Therefore, this study was realized to evaluate the effectiveness of alginate-based coatings reinforced with oatmeal for maintaining the quality (lipid oxidation, color preservation, texture, mass loss and pH) of refrigerated tilapia fillets for 15 days.

2. Materials and Methods

2.1. Material

Trichloroacetic acid (TCA), hydrochloric acid (HCl), and 1,1,3,3-tetramethoxypropane were acquired from Sigma-Aldrich (USA). Thiobarbituric acid (TBA) was acquired from Alfa Aesar® of the Johnson Matthey Company (USA). Calcium chloride was acquired from Anidrol (Brazil), sodium alginate from Dinâmica (Brazil), and oatmeal flour from Oetker®.

2.2. Preparation of fillets and coating

The Nile tilapia fillets (*Orechromis niloticus*) used in this study were obtained from the fish farming unit of the State University of Maringá – Codapar, located in Maringá, Paraná. The fish samples (weight ~600 g) were slaughtered, gutted, pickled, cleaned and threaded into two pieces of 100 g per piece. Then, the fillet samples were packed in polyethylene bags and conditioned in a refrigerator (2±1 °C) for 24 hours for subsequent application of the treatments.

Coating preparation followed the methodology described by Arfat et al, (2014) with modifications proposed by Vital et al., (2016). Alginate (2%) solution was prepared by dissolving glycerol (1,5%) and alginate in distilled water at 70 °C under agitation for 15 min using an Ultra-Turrax homogenizer (IKA®-T10, USA). Subsequently, the oatmeal flour was added (1%, 2% and 3%) on alginate solution and homogenized for a further 15 min, then the solution was chilled to 25 °C and used as a coating on the fillets. The fillets were rested at room temperature for 15 minutes before application of the treatments. The fillets were submerged in an alginate solution for 1 min, the excess of the coating was drained for 1 min, then submerged in calcium chloride solution (2% w/v) to complex the coating for 30 seconds, and finally, drained for another 1 min. The treatments were defined as: fillets without coating (CON), fillets with alginate coating (AC), fillets coated with 1% of oatmeal flour (ACO1), fillets coated with 2% of oatmeal flour (ACO2), and fillets coated with 3% of oatmeal flour (ACO3). Each sample, with or without oatmeal, was individually packed in plastic trays over-wrapped with a retractile film and stored refrigerated (2±1 °C) in an illuminated display under light (fluorescent lamp,1200 lux, 12h day^{-1}), simulating typical Brazilian market conditions. The treatments were performed in three replicates per treatment for each analysis. The CON, AC, ACO1, ACO2 and ACO3 samples were randomly removed at 1, 5, 10 and 15 days of storage for analysis.

2.4. Lipid Oxidation

The malonaldehyde (MDA) content in the tilapia fillets was quantified using the thiobarbituric acid reactive substances (TBARS) assay (Kempinski et al, 2017). The sample (5 g) was mixed with TCA solution (7.5 % TCA, 0.1 % EDTA and 0.1 % gallic acid) (10 mL), homogenized using an Ultra Turrax, and then centrifuged at 4 °C for 15 min and 4000 rpm (radius of the rotor 149mm). The supernatant was filtered and mixed with TBARS reagent (1 % thiobarbituric acid, 562.5 µM, HCl, 15 % TCA) (1:1 v/v). Subsequently, the mixture was boiled (100 °C) for 15 min, chilled, and then the absorbance measured at 532 nm. The results were expressed as mg MDA kg^{-1} of fillets.

2.5. Color

Color was evaluated by the CIELab system, using a portable colorimeter (Minolta CR400) with a 10 ° view angle and a D65 illuminant. Color was determined at three points, recording lightness (L*), redness (a*) and yellowness (b*).

2.6. Texture, Weight loss and pH analyses

The maximum shear force was determined following the methodology proposed by Xavier et al, (2017), using a texturometer (TAXT Plus Texture Technologies Corp., Godalming, Surrey, UK) equipped with a Warner-Bratzler blade. The instrument was set to a speed of 5.0 mm/s and the peaks expressed in N. The samples were cut into rectangular pieces of 1 cm^2.

Weight loss evaluation followed the methodology described by Honikel (1998), during the storage days. Samples were weighed and stored under refrigeration at 2 °C and after the stipulated storage period they were weighed again. The weight loss during storage is expressed as a percentage according to Eq(1).

$$\%\ \text{weight loss} = (\text{initial weight} - \text{final weight}) / \text{initial weight} * 100 \quad (1)$$

The pH was measured using a pH meter (Tradelab, Contagem, MG, Brazil), equipped with an insertion pH electrode.

2.7. Statistical analyses

All experiments were performed with the five treatments in triplicate. The effectiveness of the coatings on the tilapia fillets was assessed by analysis of variance using the general linear model (GLM) with com SPSS (v.15.0) (IBM SPSS Statistics, SPSS Inc., Chicago, USA) for Windows. Means and standard error of the mean (SEM) were calculated for each variable. The type of edible coating and the storage time were considered fixed factors. Differences between means were evaluated by the Tukey test (P<0.05).

3. Results and Discussion

3.1. Lipid Oxidation

At the first day of storage the lipid oxidation was similar (P>0.05) for all five treatments studied (Table 1).

Table 1: Effect of coating on lipid oxidation (TBARS) expressed as mg malonaldehyde kg^{-1} of fillets during storage at 2 °C.

		Treatments						
TBARS7	Days	CON[1]	AC[2]	ACO1[3]	ACO2[4]	ACO3[5]	SEM[6]	p-value
	1	0.19^{C}	0.19^{D}	0.19^{C}	0.18^{C}	0.18^{B}	0.002	0.142
	5	0.25^{aC}	0.24^{abC}	0.22^{bB}	0.21^{cB}	0.20^{cB}	0.006	0.004
	10	0.39^{aB}	0.34^{bB}	0.33^{bA}	0.31^{bA}	0.30^{bA}	0.010	0.003
	15	0.51^{aA}	0.37^{bA}	0.35^{bcA}	0.32^{cA}	0.31^{cA}	0.024	<0.001
SEM[6]		0.047	0.028	0.026	0.023	0.022		
p-value		0.001	0.001	0.001	0.001	0.001		

Means with different lowercase letters in the same line are different for treatment (P<0.05). Means with different upper case letter on the same column are different for display (P < 0.05). [1]CON – fillets without coating, [2]AC – fillets with alginate coating, [3]ACO1 – fillets coated with 1% of oatmeal, [4]ACO2 – fillets coated with 2% of oatmeal, [5]ACO3 – fillets coated with 3% of oatmeal. [6]SEM: standard error of the mean.

However, at 5, 10 and 15 days of storage, the lipid oxidation was higher for the CON and AC treatments in comparison to the ACO1, ACO2 and ACO3 treatments. Still, the lipid oxidation was the smallest and similar among treatments with 2 and 3% of oatmeal flour addition. The CON sample at 15 days of storage had higher values (0.51 MDA mg/kg) than treatments AC, ACO1, ACO2 and ACO3, with values of 0.37, 0.35, 0.32 and 0.31, MDA mg/kg, respectively. Thus, the coated samples were more effective in the control of oxidation, especially the samples with 2 and 3% of oatmeal, which may be explained by the formation of an oxygen-resistant layer on the surface of the fillets, reducing gas exchange and consequently lipid oxidation (Ojagh et al, 2010). Oxidation is the main non-microbial factor responsible for the deterioration of meat and fish and is one of the major reasons for consumer rejection and loss of quality during storage (Vital et al, 2018). Vital et al., (2016) showed that refrigerated meat had lower TBARS values when coated with a sodium alginate-based edible coating than the uncoated samples, and the coating effectively improved the quality and shelf life of the product by decreasing lipid oxidation. Thus, an edible coating incorporating an oatmeal flour may improve the shelf life of meat products by preventing lipid oxidation.

3.2. Color

The color stability during storage is important to fish processing. Color values for the fillets for the different treatments and throughout the storage period (from day 1 to 15) are presented in Table 2.

On days 1, 5 and 10, the L* values (lightness) were highest for the treatment with alginate coating and 3% of oatmeal addition (Table 2). However, on the last day of evaluation (day 15) all the values were similar. The L* values ranged from 50.5 (CON) to 57.0 (ACO3). Thus, the tilapia fillets with higher oatmeal addition were lighter. On the other hand, the storage time did not alter the L* values of the tilapia fillets (Table 2).

The a* values (redness) were negative. However, the ACO2 and ACO3 samples showed no difference during the storage period. Zhao et al, (2017) reported that negative results for the a* parameter may be related to the filleting process, if there was not enough red muscle remaining in the samples, when characterizing samples without color retention.

The b* values presented no difference during storage for ACO2, whereas for CON, AC, ACO1 and ACO3 the value increased throughout the storage period. The b* value is an important indicator of the quality and freshness of fish fillets (Mohan et al, 2016). The muscle color and color stability of tilapia fillets became more yellowish during storage. This modification may be related to the yellow pigments that resulted from the oxidation of lipids and proteins, contributing to the increase of b* values during the storage period (Wang et al, 2017b).

*Table 2: Color values (L * a * e b *) of tilapia fillets with and without coating during storage.*

		Treatments						
L*	Days	Con[1]	AC[2]	ACO1[3]	ACO2[4]	ACO3[5]	SEM[6]	p-value
	1	50.45	50.41	53.24	52.29	56.53	0.872	0.098
	5	51.82^{b}	51.32^{b}	51.06b	51.63^{b}	56.57^{a}	0.902	0.001
	10	52.92	51.54	52.95	54.80	56.97	0.686	0.051
	15	54.78	53.72	52.02	52.23	56.96	0.818	0.344
SEM		0.663	0.738	0.646	0.631	0.379		
p-value		0.061	0.541	0.735	0.339	0.636		
a*								
	1	-2.25^{dB}	-2.78^{cB}	-2.82^{cbB}	-2.85^{b}	-2.88^{a}	0.078	<0.001
	5	-2.32^{cB}	-2.80^{bB}	-2.85^{abB}	-2.88^{ab}	-2.91^{a}	0.073	<0.001
	10	-2.33^{cB}	-2.81^{bB}	-2.87^{abB}	-2.91^{ab}	-2.93^{a}	0.075	<0.001
	15	-3.26^{A}	-2.99^{A}	-3.00^{A}	-3.16	-3.20	0.051	0.394
SEM		0.158	0.032	0.025	0.053	0.061		
p-value		0.001	0.001	0.003	0.108	0.228		
b*								
	1	1.50^{dB}	1.82^{cC}	1.96^{cB}	2.60^{b}	2.89^{aB}	0.171	<0.001
	5	1.57^{dB}	1.86^{cBC}	1.98^{cB}	2.69^{b}	2.96^{aB}	0.175	<0.001
	10	1.59^{dB}	1.88^{cAB}	2.00^{cB}	2.70^{b}	2.97^{aB}	0.174	<0.001
	15	1.99^{bA}	2.29^{bA}	2.31^{bA}	2.94^{a}	3.33^{aA}	0.164	<0.001
SEM		0.073	0.072	0.056	0.057	0.067		
p-value		0.001	0.001	0.016	0.154	0.017		

Means with different lowercase letters in the same line are different for treatment (P < 0.05). Means with different upper case letter on the same column are different for display (P < 0.05). [1]CON – fillets without coating, [2]AC – fillets with alginate coating, [3]ACO1 – fillets coated with 1% of oatmeal, [4]ACO2 – fillets coated with 2% of oatmeal, [5]ACO3 – fillets coated with 3% of oatmeal. [6]SEM: standard error of the mean.

3.3. Texture, Mass Losses and pH Measurement

The texture of fillets is an important quality parameter to verify the effect of the methods of preservation on quality (Cheng et al, 2014). On the first day of evaluation, the shear force values were similar among treatments, decreasing during 15 days (Table 3).

Tilapia fillets with alginate coatings decrease the shear force of the meat during exposure. And, above all, the alginate coating added oat flour, highlighting the addition of 3%, more effectively retarded softening.

This fact may be associated with loss of water and oxidative processes during the exhibition, since softening is mainly related to enzymatic autolysis and microbial action (Yu et al, 2017). Another factor is that the coating may have a physical barrier, contributing to reducing water loss and improving texture (Vital et al., 2018).

The presence of water in the product system provides a juicier and softer product. Furthermore, lower oxygen concentrations can reduce lipid oxidation levels, and decrease the action of proteolytic enzymes (Vital et al., 2016).

On the first day of storage, the alginate coating and addition of oatmeal flour reduced the mass loss in comparison to the CON and AC treatments (Table 3). Still, the mass loss was lower during the storage period, especially in the fillets with alginate coating and addition of oatmeal flour.

The weight loss of the fillets (Table 3) increased during the storage period. Moisture during the storage of fresh or frozen meats reduces the weight of the product for sale and promotes changes in texture, taste, and color (Battisti et al, 2017). The weight loss progressively increased for all samples during storage. The coatings with oatmeal (ACO1, ACO2, and ACO3) had better barrier properties for weight loss, compared to the CON and AC. Moreover, the ACO2 and ACO3 coatings showed a better ability to inhibit the loss of fillet weight. The permeability of the coating is controlled by the diffusivity and solubility of water molecules within the film matrix, where the fibers produce a tortuous path that hinders the passage of water molecules through the matrix, decreasing the water permeability and consequently the mass loss (Liu et al, 2016).Thus, the biopolymers coating present on the surfaces of the meat acted as an additional barrier to prevent the loss of moisture.

On the first day of evaluation, the pH values were similar among treatments, ranging from 6.5 (ACO2) to 6.6 (CON) (Table 3). However, at 5, 10 and 15 days of storage the pH was lower in the fillets with addition of alginate coating compared to the pH of the CON treatment (Table 3). Also, the inclusion of oatmeal flour in the coating further reduced the pH value. Thus, the use of alginate coating and the inclusion of oatmeal in the coating prevented the pH increase.

Table 3: Shear force (N), weight loss(%) and pH of tilapia fillets during storage.

		Treatments						
Shear Force (N)	Days	Con[1]	EC[2]	ECO1[3]	ECO2[4]	ECO3[5]	SEM[6]	p-value
	1	71.06^{A}	71.94^{A}	72.24^{A}	72.65^{A}	72.88	0.254	0.123
	5	70.20^{bA}	71.09^{abB}	71.65^{abAB}	72.26^{aA}	72.32^{a}	0.278	0.010
	10	68.53^{cA}	70.10^{bC}	70.61^{bB}	71.19^{abB}	72.09^{a}	0.401	<0001
	15	63.45^{cB}	69.94^{bC}	70.28^{bB}	70.98^{abB}	71.67^{a}	0.991	<0.001
SEM		1.126	0.307	0.312	0.268	0.211		
p-value		0.001	0.001	0.019	0.001	0.239		
Weight Loss (%)								
	1	2.09^{aD}	1.46^{abD}	1.29^{abD}	1.17^{bD}	1.09^{bD}	0.129	0.030
	5	6.67^{aC}	5.78^{abC}	4.06^{bC}	3.93^{bC}	3.56^{bC}	0.428	0.015
	10	21.53^{aB}	13.56^{bB}	11.91^{bcB}	10.87^{cB}	10.05^{cB}	1.386	<0.001
	15	28.49^{aA}	19.07^{bA}	15.91^{cA}	14.35^{cdA}	13.98^{dA}	1.794	<0.001
SEM		4.055	2.576	2.223	1.997	1.937		
p-value		0.001	0.001	0.001	0.001	0.001		
pH								
	1	6.57^{D}	6.57^{D}	6.56^{C}	6.53^{D}	6.56^{C}	0.006	0.255
	5	6.73^{aC}	6.70^{aC}	6.61^{bBC}	6.59^{bC}	6.59^{bBC}	0.019	<0.001
	10	7.00^{aB}	6.79^{bB}	6.67^{cB}	6.65^{cB}	6.65^{cB}	0.045	<0.001
	15	7.36^{aA}	7.00^{bA}	6.87^{cA}	6.80^{cA}	6.87^{cA}	0.067	<0.001
SEM		0.113	0.058	0.044	0.037	0.046		
p-value		0.001	0.001	0.001	0.001	0.001		

Means with different lowercase letters in the same line are different for treatment (P<0.05). Means with different upper case letter on the same colum are different for display (P < 0.05). [1]CON – fillets without coating, [2]AC – fillets with alginate coating, [3]ACO1 – fillets coated with 1% of oatmeal, [4]ACO2 – fillets coated with 2% of oatmeal, [5]ACO3 – fillets coated with 3% of oatmeal. [6]SEM: standard error of the mean.

4. Conclusions

The edible alginate coatings with oatmeal flour reduced lipid oxidation, color losses, texture, weight loss and pH in tilapia fillets during 15 days of storage, highlighting for coating with 3% flour addition. Thus, edible coatings containing oatmeal flour have a potential application in tilapia fillets to maintain or improve their characteristics during storage.

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