APPLICATION OF BIO-BASED POLYMERS FOR FRESH MEAT PACKAGING

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ABSTRACT

This research is focused on the application of biopolymers for fresh meat packaging, as a potential replacement to the commercial PVC film wrapped on expanded polystyrene (PS) tray system. For each experimental thesis, beef steaks were packed using an expanded polylactic acid (PLA) tray, having a biodegradable pad and either wrapped with a PVC film, or heat-sealed with three different biopolymeric films: PLA, Mater-Bi 1 and Mater-Bi 2. As control, meat samples were packed in PS trays with a polyolefinic pad wrapped with a PVC film, hence replicating a commercially available packaging system for fresh meat. All the samples were stored at 4 °C for 8 days and the meat quality was assessed throughout the whole storage period by using physical, chemical and microbiological indexes (pH, colour, lipid oxidation, weight loss, psychrophilic bacteria, *Pseudomonas spp., Brochothrix thermosphacta*). The experimental data indicated that no significant differences exist among the various packaging systems investigated.

Key words: biopolymers; fresh beef meat; packaging; Podolian cattle; shelf-life.

INTRODUCTION

Bio-based polymers or biopolymers are obtained from renewable resources, and being both compostable and biodegradable, their utilisation in food packaging may represent a good technological opportunity for reducing the amount of plastic wastes, with positive consequences on the environment (Alves *et al.*, 2006; Cutter, 2006). In particular, biopolymers for food packaging have, in general, a

relatively high permeability to O_2 and H_2O; therefore, their utilization is of interest mainly for those foodstuffs, such as meat, having few gas and water vapour barrier requirements, with a shelf-life limited to a few days of storage (Avella *et al.*, 2005).

Packaging of fresh beef meat can be realised in several ways: under vacuum, under air, in very permeable packages, usually made using expanded polystyrene (PS) trays wrapped with PVC film, allowing proper O_2 intake for right colour retention, or under an O_2 enriched atmosphere in barrier packaging materials. Interesting results have been recently also reported regarding the use of biopolymeric materials for meat packaging in combination with the use of PS trays or protective atmosphere (Cannarsi *et al.*, 2005; Cornini *et al.*, 2005).

In this work, packaging of fresh beef meat using an expanded biopolymeric tray made of polylactic acid (PLA) and heat-sealed with 3 different biopolymeric films, was investigated as a potential replacement for commercial packaging systems based on expanded PS tray over-wrapped with PVC.

MATERIALS AND METHODS

Meat was obtained from six different Podolian young bulls, all fed with the same diet, and slaughtered at 18 months of age, with a mean weight of 444 ± 21 kg. Dressed carcasses were divided into two sides and chilled for 24 h at 4°C. Afterwards, the *Longissimus lumborum* muscle was taken from the left side of each animal, and all the removed sections were vacuum-packaged and aged at 4°C until 8 days post-mortem.

The muscles were then cut and for each thesis two steaks of similar size (100 g, thickness 1 cm) were packed using an expanded PLA tray (23 cm x 14.5 cm x 3.5 cm) having a biodegradable pad (Coopbox Europe S.p.a, Italy), and either overwrapped with a PVC film, or heat-sealed with three different biopolymeric films: PLA (Treophan, Germany), Mater-Bi 1, a monolayer film, and Mater-Bi 2, a coextruded tri-layer film having better mechanical performances. Both Mater-Bi films (Novamont, Italy) were compostable and based on polyesters partially derived from renewable sources (Tab. 1). As control, meat samples were packed using PS trays with a polyolefinic pad (Coopbox Europe), wrapped with a PVC film, hence replicating a commercially available packaging system for fresh meat.

All samples were stored at 4°C for 8 days and the meat quality was assessed throughout the whole storage period by using physical, chemical and microbiological indexes. Colour was measured on the meat surface using a Minolta Chroma meter CR-300 with a D 65 illuminant, using CIELAB L*, a*, b* and Hue angle values. The oxidative deterioration of lipids was assessed according to Buege and Aust (1978) and expressed as mg malondialdehyde (MDA)/kg meat, while metmyoglobin content, expressed as percentage of total myoglobin content, was calculated according to Krzywicki (1979). Weight loss was determined gravimetrically and expressed as percentage of the original weight, while pH was measured using a pH meter equipped with a probe for solids. Microbiological quality of the samples was monitored by assessing the levels of psychrophilic bacteria, *Pseudomonas* spp. and *Brochothrix thermosphacta.* Statistical analysis of the data (ANOVA, LSD test, Correlation analysis) was performed by using the statistical package SAS (ver. 9.1., 2005).

RESULTS AND DISCUSSION

All the parameters considered for meat quality evaluation resulted influenced only by storage time (Tab. 2) and not by the packaging system of meat (Tab. 3). In particular, the pH value increased significantly over the storage period ($P < 0.001$) and according to Nychas *et al.* (1998) this trend is probably due to an increase in the production of proteases by psycrotrophic bacteria. However, in the present study no significant correlation between pH value and level of psychrophilic bacteria was recorded (Tab. 4).

Consumers relate the bright red colour of meat with freshness, and this parameter, besides depending on oxymyoglobin levels, is also affected by breed and rearing system. In particular, Podolian meat is naturally characterized by a darker colour, due to the extensive rearing system and to the utilization of pasture as the unique feeding resource (Napolitano and Girolami, 2001). In comparison with the data reported in literature for other fresh beef breeds, all the initial colour parameters of the tested samples were lower, while the metmyoglobin value resulted higher (Djenane *et al.*, 2003; Insausti *et al.*, 2001). Moreover, Hue values increased progressively during storage ($P<0.001$) and this increase showed to be negatively correlated to redness a* (Tab. 4), in agreement with Insausti *et al.* (1999). The a* value, a good indicator of colour acceptability, decreased only of 21% with respect to the initial value, reaching after 8 days a value of about 17, higher than the a* value reported as acceptable for beef steaks packaged in a CO enriched atmosphere by John *et al.* (2005). Conversely, b* (yellowness) and L* (lightness) parameters increased after 3 and 6 days, respectively, ($P<0.001$). L* changes could be affected by water loss, being these variables positively correlated, while b* increase could be related to the lipid oxidation. On the other side the a* decrease may result from the gradual formation of metmyoglobin on the meat surface, in agreement with Insausti *et al.* (2001) (Tab. 4).

Lipid oxidation increased during meat storage ($P<0.001$), even if the MDA level reached after 8 days was below the threshold value for rancidity (1-2 mg/kg meat); this could be due to the lower intramuscular fat content that characterizes the Podolian meat in comparison with other beef breeds (Djenane *et al.*, 2003; Cifuni *et al.*, 2004; Insausti *et al.*,2001).

Weight loss increased significantly to a maximum of about 3% after 8 days ($P<0.001$), a value comparable to that recorded by Cornini *et al.* (2005) for beef meat packed in protective atmosphere by using an expanded PLA tray heat sealed with a PLA film. Weight loss showed to be the only one parameter somehow influenced by the different packaging systems (Tab. 3), and the difference could be ascribed to the different WVTR properties of the PVC and Mater-Bi 2 films (Tab. 1). Several authors (Guignot *et al.*, 1994; Price and Schweigert, 1994) have highlighted a direct influence of pH on the charged groups of the myofibrils and thus on the water holding capacity, but in this study no correlation between water loss and pH was found (Tab. 4), as also reported by Insausti *et al.* (2001).

Table 1. Principal technical characteristics of packaging films.

Characteristics	Packaging film			
	PLA	Mater-Bi-1	Mater-Bi-2	PVC
Thickness (μm)	25	35	35	12
WVTR (g/m^2 24 h) (38°C; 100% R.H.)	175	408	842	34.1
OTR (cm^3/m^2 24 h) (23°C; 50% R.H.)	610	1246	2491	2940

All the microbiological in-

dices considered in this study increased constantly over the whole storage period, especially during the first 3 days of storage. Similar results were reported in a work on Podolian meat by Cannarsi *et al.* (2005), even if the initial values of psycrotrophics, *B. thermosphacta* and *Pseudomonas* spp were higher than those recorded in our meat samples.

The permissible maximum level of total bacteria in refrigerated meat ranges from 10^7 to 10^9 cfu/g; however, the correlation between bacterial numbers and sensorial spoilage is imprecise, thus making difficult to use bacterial levels as a spoilage index (Borch *et al.*, 1996). In fact Young *et al.* (1998) reported that the bacterial count at which meat could be considered spoiled (10^7 cfu/g) did not coincide with the panellists rejection of meat on the basis of colour, while Insausti *et al.* (2001) reported that meat samples with bacterial counts lower than from 10^7 cfu/g resulted unacceptable from a sensory point of view. Therefore, it is necessary, but not sufficient, to use microbiological indices for quality evaluation of meat; however, rather than the total count of bacteria, it is preferable to use as a spoilage indicator the growth of a specific spoilage bacteria, such as *Pseudomonas spp.* or *B. thermosphacta.*

CONCLUSION

Shelf-life evaluation of the fresh beef steaks stored at 4°C for 8 days highlighted that no significant differences existed among the various packaging systems, suggesting that for fresh meat packaging it could be possible to replace the PS tray/PVC film system, with a commercially viable solution, represented by an expanded PLA biopolymeric tray heat-sealed with a biopolymeric film, characterized by a negligible environmental impact in comparison with the use of synthetic plastic materials.

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ERRATA CORRIGE

In the paper "Application of Bio-based Polymers for Fresh Meat Packaging", by F. Galgano, F. Favati, M.M. Russo, P. Romano, A. Braghieri, A. Girolami, published in Special Issue of Italian Journal of Food Science (IJFS) "Proceedings of SLIM 2008 Shelf-Life International Meeting" - Ischia (Naples), June 25-27th 2008, Table 2 and 3, referring to the effect of storage time and packaging system on meat quality parameters and Table 4, referring to correlation analysis (Pearson coefficients), were erroneously not printed.

IJFS and the Italian Scientific Group for Food Packaging (GSICA) apologize for the error. The table are reported in the following:

Table 2 - Effect of storage time on meat quality parameters.

Physical-chemical and microbiological parameters	Storage time (days)				Significance
	0	3	6	8	
pH	5.68 ^{a}	5.75 ^{ab}	5.71 ^{a}	5.82 ^{b}	***
L*	36.29 ^{c}	37.13 ^{b}	37.75 ^{a}	37.83 ^{a}	***
a*	21.30 ^{a}	21.66 ^{a}	20.13 ^{b}	16.85 ^{c}	***
b*	1.94 ^{b}	4.34 ^{a}	4.47 ^{a}	4.31 ^{a}	***
Hue (arctg b*/a*)	4.81 ^{c}	12.04 ^{b}	12.76 ^{b}	14.78 ^{a}	***
Metmyoglobin (%)	35.08 ^{d}	42.12 ^{c}	54.56 ^{b}	60.52 ^{a}	***
MDA (mg/kg meat)	0.17 ^{d}	0.47 ^{c}	0.65 ^{b}	0.88 ^{a}	***
Weight loss (%)	0.00 ^{d}	0.16 ^{c}	2.19 ^{b}	2.90 ^{a}	***
Psychrophilic bacteria (log cfu/g)	4.83 ^{d}	6.86 ^{c}	7.96 ^{b}	8.71 ^{a}	***
Pseudomonas spp. (log cfu/g)	2.83 ^{d}	4.55 ^{c}	6.92 ^{b}	8.17 ^{a}	***
B. thermosphacta (log cfu/g)	2.05 ^{d}	3.99 ^{c}	5.30 ^{b}	6.48 ^{a}	***

*** Significant for P<0.001.
Data in the same row with different superscripts are significantly different (LSD test at P<0.05).

Table 3 - Effect of packaging system on meat quality parameters.

Physical-chemical and microbiological parameters	Packaging system					Significance
	A	B	C	D	E	
pH	5.75 ^{a}	5.74 ^{a}	5.73 ^{a}	5.72 ^{a}	5.75 ^{a}	n.s.
L*	37.53 ^{a}	37.23 ^{a}	37.07 ^{a}	37.09 ^{a}	37.32 ^{a}	n.s.
a*	20.32 ^{a}	19.89 ^{a}	19.86 ^{a}	19.95 ^{a}	19.89 ^{a}	n.s.
b*	4.04 ^{a}	3.86 ^{ab}	3.53 ^{ab}	3.63 ^{ab}	3.77 ^{ab}	n.s.
Hue (arctg b*/a*)	11.69 ^{a}	11.01 ^{a}	11.00 ^{a}	10.60 ^{a}	11.19 ^{a}	n.s.
Metmyoglobin (%)	51.48 ^{a}	50.08 ^{ab}	45.97 ^{bc}	47.74 ^{abc}	45.10 ^{c}	n.s.
MDA (mg/kg meat)	0.53 ^{a}	0.56 ^{a}	0.55 ^{a}	0.57 ^{a}	0.51 ^{a}	n.s.
Weight loss (%)	1.45 ^{b}	1.64 ^{ab}	1.67 ^{ab}	1.68 ^{ab}	1.88 ^{a}	n.s.
Psychrophilic bacteria (log cfu/g)	6.53 ^{a}	6.46 ^{a}	6.51 ^{a}	6.60 ^{a}	6.64 ^{a}	n.s.
Pseudomonas spp. (log cfu/g)	4.80 ^{a}	4.84 ^{a}	4.76 ^{a}	4.61 ^{a}	4.82 ^{a}	n.s.
B. thermosphacta (log cfu/g)	3.79 ^{a}	3.75 ^{a}	3.82 ^{a}	3.75 ^{a}	3.79 ^{a}	n.s.

A: control (PS tray wrapped with PVC film); B: PLA tray wrapped with PVC film; C: PLA tray heat-sealed with PLA film; D: PLA tray heat-sealed with Mater-Bi-1 film; E: PLA tray heat-sealed with Mater-Bi-2 film.
n.s. not significant.
Data in the same row with different superscripts are significantly different (LSD test at P<0.05.

Table 4 - Correlation analysis: Pearson coefficients.

	pH	MDA	L*	a*	b*	Hue	Metmyoglobin	Weight loss	Psychrophilic bacteria	*Pseudomonas* spp.	*B.thermosphacta*
pH	1.00										
MDA	-0.33***	1.00									
L*	-0.55***	0.57***	1.00								
a*	-0.18*	-0.33***	-0.22*	1.00							
b*	-0.3***	0.68 ***	0.68***	0.02	1.00						
Hue	-0.15	0.73***	0.71***	-0.46***	0.80***	1.00					
Metmyoglobin	-0.07	0.70***	0.61***	-0.31***	0.60***	0.70***	1.00				
Weight loss	0.08	0.66***	0.51***	-0.48***	0.65***	0.81***	0.73***	1.00			
Psychrophilic bacteria	-0.08	0.62***	0.43***	-0.22*	0.68***	0.77***	0.43***	0.81***	1.00		
Pseudomonas spp.	-0.12	0.61***	0.38***	-0.28**	0.61***	0.69***	0.50***	0.79***	0.88***	1.00	
B. thermosphacta	-0.25	0.55***	0.40***	-0.25*	0.59***	0.68***	0.24*	0.61***	0.85***	0.78***	1.00

*** Significant for P<0.001; ** Significant for P<0.01; * Significant for P<0.05.