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Effects of Packaging Methods and Refrigerated Storage on the Quality of Dry-cured Pork Neck

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Abstract: This study was conducted to see the effect of packaging methods and refrigerated storage on the quality of dry-cured pork neck. A dry-cured product was developed from pork neck by modifying the conventional procedure. The cured slices were stored for 90 days under Vacuum Packaging (VP), packaging with 100% N_2 (NP) and packaging with 20% CO_2+80% N_2 (MP) at 4°C. There was no significant difference of pH and shear force values between the packaging methods and due to storage up to 90 days. Moisture content and water activity reduced significantly ($p<0.05$) in all packaging methods with the increase of storage periods except between 30 and 60 days. TBARS values increased significantly with the increase of storage days and the value decreased significantly in VP sample compared to the NP and MP samples at 30 day of storage. There was no significant difference in the microbial quality (TPC, LAB, Coliforms) between the methods of packaging and due to the storage days. There was no significant difference in the sensory quality between the methods of packaging, however, the quality reduced significantly with the increase of storage days. In general, there were no significant differences between the three packaging systems on the quality of dry cured pork, therefore, we recommend vacuum packaging for this product, since it is more economic and convenient.

Key words: Dry-curing, packaging, storage, texture, sensory quality

INTRODUCTION

Cured meats are one of the important traditional meat products in the market. The quality of cured meats depends on the quality of raw meat and the process technology (Arnau *et al*., 2009). The salting time is decided according to weight and the ageing time is decided on the amount of fat. Dry curing is a traditional process where the curing ingredients are rubbed onto the surface of the meat. Dry cured products are subjected to extensive ripening or ageing wherein the typical flavor produced through biochemical reactions (Cilla *et al*., 2006). In the last decades bone in cured meat sales have decreased and substituted by sliced products. The quality of dry cured meat depends on its unique flavor. The long ripening is

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necessary for cured colour and flavor development (Arnau *et al.*, 2009). However, high production cost due to long curing makes the product less competitive in market. Dry-cured meat production is still based on tradition and there is scope for introducing new technologies to improve product quality and safety.

Modern food packaging performs beyond the conventional protection properties and serves much more functions for the product contained (Han, 2005). In order to extend shelf-life, preservation technologies such as refrigeration and Vacuum Packaging (VP) or Modified Atmosphere Packaging (MAP) are being increasingly applied for ham distribution and retail sale (Stiles, 1990).

The application of MAP to processed meat has grown greatly in recent years, but optimization of gas composition is critical to ensure both product quality and safety (Moller *et al.*, 2000). Because of its antimicrobial activity, CO_2 is the most important component in the normally applied gas mixtures (Farber, 1991) and N_2 is used as filler (Sorheim *et al.*, 1999). In case of dry-cured meat, the use of MAP is becoming extensive in meat industry, above all, it is important for exporting.

Several research have been carried out to study the effect of vacuum, different gas composition and packaging material on the preservation of dry fermented meat (Garcia-Esteban *et al.*, 2004; Cilla *et al.*, 2006; Gok *et al.*, 2008). The color, lipid oxidation, pH, microbial counts and texture profiles of dry cured meat changed differently by aerobic, vacuum and modified atmosphere packaging methods (Aksu *et al.*, 2005; Cilla *et al.*, 2006).

Normally leg and belly part of pig carcass is used for making ham and bacon, respectively and other prime meats are sold for direct consumption. However, the neck meat find less demand, hence there is need for developing a new product to add value for these meat. The aim of the present study was to develop a new product by modifying the conventional dry curing and to compare the physico-chemical, microbiological and sensory quality of dry-cured pork neck slices during refrigerated storage under different packaging conditions.

MATERIALS AND METHODS

Preparation of Dry-cured Pork

This research was conducted from 2006 to 2008. Barrow pigs purchased from local market were slaughtered in a commercial abattoir by standard procedures under the supervision of the Korean grading service for animal products. After slaughtering, carcasses were chilled conventionally at 0 for 12 h. At 24 h postmortem, carcasses were evaluated by Animal Products Grading Service (MAF, 2001). Ten carcasses of grade B were selected for manufacturing dry-cured meat. Neck muscles from both sides of the carcasses were removed 12 h postmortem and subcutaneous fat and connective tissues were removed. The raw meat was placed on shelves in a cold room for 1 month at -25°C. The frozen samples were thawed for 2 days at 10±1°C, they were rubbed with mixture of 50 g NaCl, 0.10 g $NaNO_3$, 0.05 g $NaNO_2$, 0.5 g ascorbic acid, 0.5 g sodium erythorbate, 5 g commercial seasoning (consisting of 20% Black pepper, 15% rosemary, 15% clove, 15% thyme, 15% turmeric, 10% garlic, 10% onion powder) and 1 g commercial lyophilized mixed starter culture per kg meat. The starter culture contained 4.0×10^9 cfu g^{-1} *Lactobacillus pentosus* and 6.0×10^9 cfu g^{-1} catalase-positive *Staphylococcus carnosus*. The meat samples were incubated at 0-4°C for 2 weeks with the relative humidity of 70-80%. After completion of incubation, they were brushed and washed with cold water and then dried at 30°C for 2 h and transferred to smoke room and were exposed to smoke for 30 min at 30°C. Then they were re-ripened for 3 months

at 10°C and 70% relative humidity. Finally, they were vacuum-packaged and stored for 90 days at 4°C.

Packaging of Dry-cured Pork and Storage Conditions

The dry-cured pork necks (3 kg) were divided in three groups. First group was Vacuum Packaged (VP) in bags containing 300-350 g of 0.2 cm thick sliced dry-cured pork neck. Pouches measuring 12×15×3 cm made from laminated materials with an OTR of 0.5 $cm^3/m^2/atm/24$ h were obtained from Danisco Flexible (Lyngby, Denmark). The 2nd and 3rd groups were injected with following gas mixtures: 100% N_2 (NP) and 25% CO_2+75% N_2 (MP) with a 4.5:1 gas volume to meat ratio in each pack, respectively. Gas mixtures were prepared using a PBI-Dansensor model mix 9000 gas mixer (Ringsted, Denmark). All the samples were stored at 4°C in the dark and analyzed at day 1, 30, 60 and 90 of storage using separate pack for each day.

Determination of pH and Salinity

The pH values were determined by homogenizing (T25B, IKA Sdn. Bhd., Malaysia) 10 g of a ground meat sample with 90 mL distilled water and then measuring it with a pH meter (Model 8603, Metrohm, Swiss). The salinity was determined by using a salt meter (TM-30D, Takemura, Japan).

Shear Force

The shear force of eight core samples (Ø16.50×2.00 cm) cut from each samples were determined using an Instron 3343 machine (US/MX50, A and D Co., USA) fitted with a Warner-Bratzler shear attachment, a 10 kg load cell and set to a cross head speed of 60 mm min^{-1}. Maximum peak force recorded during the test was reported as Warner-Bratzler shear force in kg cm^{-2}.

Moisture Content and Water Activity

The moisture content of ground dry-cured pork samples were analyzed using the standard analytical method (AOAC, 1995). Water activity was estimated by taking approximately 10 g ground meat samples into a holding cup and then three measurements were taken with a water activity analyzer (LKM200A, Lokas Co., Korea) and averaged.

Colour Measurement

Colour was measured instrumentally using a spectrocolorimeter (CR 400, Minolta Co., Japan) calibrated with a white plate and light trap supplied by the manufacturer. Colour was expressed using the CIE L*a*b* colour system (CIE, 1976).

Volatile Basic Nitrogen (VBN) Analysis

The VBN was determined according to the Conway micropipette diffusion method (Pearson, 1976) and was expressed as mg VBN/100 g of the sample.

Lipid Oxidation

The 2-thiobarbituric acid reactive substances (TBARS) test according to Tarladgis *et al.* (1960) was used to determine the extent of oxidative rancidity. A 5 g sample was homogenized in a 50 mL centrifuge tube with a 50 μL of BHA (7.2% in ethanol) and 15 mL of distilled water by using a homogenizer (IKA model T-25Basic, Malaysia). Two mL of the homogenate was mixed with 4 mL of a thiobarbituric acid solution (20 mM TBA in 15%

TCA), heated at 90°C in water bath, then cooled in ice and centrifuged for 15 min at 2,000 rpm (UNION 5KR; Hamil Science Industrial, Co., Ltd., Incheon, Korea). The absorbance of the supernatant was measured at 532 nm by using a spectrophotometer (Spectronic model Genesys 5, USA). The concentration of malonaldehyde (mg kg^{-1} sample) was calculated on the basis of wet weight by using a standard curve.

Microbiological Analysis

Two duplicate 25 g samples were taken aseptically from each treatment, transferred to sterile plastic pouches and homogenized for 2 min at room temperature with 225 mL sterile 1% (w/v) Ringer solution using a stomacher Lab-Blender 78860 (ST-Nom, Interscience, France). Appropriate dilutions of samples were prepared in 1% Ringer solution and plated in duplicate onto plate count agar (PCA; Difco Lab) incubated at 32°C for 48 h under aerobic conditions for total bacterial count. For Lactic acid bacteria Lactobacilli MRS Agar (Difco, Detroit, MI, USA) was used and plates were incubated anaerobically at 32°C for 2 days. Enterobacteriaceae and *E. coli* were enumerated using *E. coli/Coliform* count petrifilm plate (3 M Health care, USA) incubating at 30°C for 2 days under aerobic conditions.

Sensory Evaluation

The samples were served to 12 experienced panel members. Panelists were presented with randomly coded samples. The colour, aroma and flavour (1 = extremely undesirable, 9 = extremely desirable), juiciness (1 = extremely dry, 9 = extremely juicy), tenderness (1 = extremely tough, 9 = extremely tender) and overall acceptability (1 = extremely undesirable, 9 = extremely desirable) of the samples were evaluated using 9-point descriptive scale. Panelists were advised to cleanse their palate with water between samples.

Statistical Analysis

An analysis of variance were performed on all the variables measured using the General Linear Model (GLM) of the SAS Institute (1994). The Duncan's multiple range test was used to determine differences between treatment means.

RESULTS

pH

The pH values from dry-cured neck mixtures increased slightly during the refrigerated storage, from 5.59 to 5.63 in vacuum package samples, 5.50 to 5.67 in 100 % N_2 package samples and 5.39 to 5.56 in 25/75% CO_2/N_2 package samples, respectively (Table 1). There was no significant difference of pH values during storage between packaging methods except at day 60 of storage ($p>0.05$).

Shear Force

There was no significant difference in shear force values between packaging methods during storage up to 90 days (Table 1). The mean values for shear force ranged between 16.15 to 19.27 kg cm^{-2} during the entire storage period in all the packaging methods.

Moisture Content and Water Activity (a_w)

Moisture and a_w in all packaging methods decreased significantly ($p<0.05$) throughout refrigerated storage (Table 1). Moisture content has reduced significantly ($p<0.05$) in all packaging methods with the increase of storage periods except at 30 and 60 days. The type

Table 1: Effect of packaging methods and storage at 4°C on the physicochemical characteristics of dry-cured pork neck

		Storage (days)			
Index	Treatments*	1	30	60	90
pH	VP	5.510±0.07	5.540±0.24	5.600±0.07	5.620±0.06
	NP	5.500±0.12	5.580±0.08	5.670±0.05	5.670±0.19
	MP	5.550±0.31	5.630±0.05	5.670±0.07	5.660±0.04
Shear force (kg cm^{-2})	VP	16.560±4.44	16.630±6.62	16.570±5.75	16.890±4.88
	NP	16.710±5.96	16.150±2.76	16.090±5.84	16.710±7.03
	MP	16.590±3.45	17.790±3.54	17.010±5.68	19.270±2.73
Moisture (%)	VP	$41.350±1.00^{A}$	$30.130±0.55^{Bb}$	$30.090±0.34^{Bb}$	$25.140±0.40^{Cb}$
	NP	$40.130±1.01^{A}$	$32.500±0.23^{Ba}$	$32.530±0.30^{Ba}$	$24.990±0.50^{Cb}$
	MP	$43.130±1.00^{A}$	$29.470±0.45^{Bb}$	$29.490±0.45^{Bb}$	$28.140±0.70^{Ba}$
Water activity	VP	$0.880±0.24^{A}$	$0.875±0.35^{Aa}$	$0.877±0.70^{Aa}$	$0.860±1.15^{Ba}$
	NP	$0.880±0.85^{A}$	$0.855±0.71^{ABb}$	$0.843±1.55^{BCb}$	$0.827±1.51^{Cb}$
	MP	$0.877±0.38^{A}$	$0.830±0.14^{Bc}$	$0.817±0.72^{Cc}$	$0.807±0.57^{Cb}$
Salinity (%)	VP	$5.830±0.29^{A}$	$5.830±0.58^{A}$	$5.000±0.42^{B}$	$5.000±0.25^{Bc}$
	NP	6.330±1.53	5.170±0.29	5.330±1.76	$5.830±0.29^{b}$
	MP	5.330±1.26	6.000±1.34	5.500±0.87	$6.330±0.10^{a}$

*VP: Vacuum package; NP: 100% N_2 package; MP: 25% CO_2 + 75% N_2 package. $^{A-C}$Means with different superscripts within the same row are significantly ($p<0.05$) different. $^{a-d}$Means with different superscripts within the same column are significantly ($p<0.05$) different

Table 2: Effect of packaging methods and storage at 4°C on the surface color of dry-cured pork neck

		Storage (days)			
Index	Treatments*	1	30	60	90
CIE L*	VP	$38.33±0.39^{B}$	$38.74±0.46^{B}$	$51.25±3.56^{A}$	$49.50±4.18^{A}$
	NP	$38.96±0.89^{D}$	$39.64±2.16^{C}$	$43.36±1.62^{B}$	$48.19±1.54^{A}$
	MP	$37.10±1.13^{B}$	$39.00±2.63^{B}$	$44.18±1.78^{A}$	$48.42±2.31^{A}$
CIE a*	VP	$19.01±0.30^{A}$	$21.36±1.04^{A}$	$9.89±3.63^{C}$	$10.46±0.67^{B}$
	NP	$19.20±1.87^{A}$	$22.81±4.00^{A}$	$9.04±1.78^{C}$	$11.45±0.58^{B}$
	MP	$19.53±0.62^{A}$	$21.48±1.48^{A}$	$13.22±1.45^{B}$	$10.11±2.48^{B}$
CIE b*	VP	$5.26±0.16^{C}$	$5.94±0.41^{B}$	$5.98±0.20^{Ba}$	$6.69±0.12^{Aa}$
	NP	5.31±0.95	5.59±0.14	$5.62±0.16^{b}$	$6.43±0.38^{a}$
	MP	5.32±0.76	5.58±0.38	$5.89±0.29^{b}$	$5.85±0.33^{b}$

*VP: Vacuum package; NP: 100% N_2 package; MP: 25% CO_2 + 75% N_2 package. $^{A-D}$Means with different superscripts within the same row are significantly ($p<0.05$) different; $^{a-c}$Means with different superscripts within the same column are significantly ($p<0.05$) different

of packaging also significantly ($p<0.001$) affected a_w values. Dry-cured pork neck packed in VP had mean a_w values of 0.875, 0.877 and 0.860 at day 30, 60 and 90 of storage, respectively, which was significantly higher than those packaged in NP and MP at each day of storage.

Salinity

Salinity values in all packaging methods and storage days ranged between 5.00 to 6.33. It has decreased significantly ($p<0.05$) at 60 and 90 day of storage in vacuum packaging, however, there was no significant difference between the storage days in nitrogen packaging or modified atmosphere packaging. There was no significant difference observed between the packaging methods up to 60 day of storage, however, there was significant ($p<0.05$) difference in salinity at day 90 of storage.

Color

Storage time had a significant ($p<0.05$) effect on colour of dry cured pork (Table 2). With increased storage time, the L* values showed a tendency to increase in all the three types of packaging. The redness (a*), which is used as an indicator of color stability in meat and meat products, showed a pronounced fading within the 60 day in all packaging system.

Table 3: Effect of packaging methods and storage at 4°C on the biochemical and microbiological quality (log cfu g^{-1}) of dry-cured pork neck

		Storage (days)			
Index	Treatments*	1	30	60	90
VBN (mg/100 g)	VP	48.37±2.26^{D}	57.66±4.53^{C}	72.61±1.64^{Ba}	80.12±2.80^{Aa}
	NP	42.00±3.25^{C}	56.26±2.25^{B}	62.70±2.65^{Ab}	62.19±3.01^{Ab}
	MP	46.68±4.92^{B}	56.17±0.28^{AB}	60.65±2.77^{Ab}	59.20±1.24^{Ab}
TBARS (mg MA kg^{-1})	VP	1.47±0.31^{B}	1.16±0.30^{Bb}	6.82±0.11^{A}	6.39±0.99^{A}
	NP	2.01±0.89^{C}	3.05±0.51^{Ba}	6.85±0.26^{A}	6.37±0.11^{A}
	MP	2.43±0.26^{B}	3.33±0.34^{Ba}	7.14±0.88^{A}	6.40±0.97^{A}
Total plate counts	VP	4.47±0.38	4.95±0.40	4.97±0.33	5.04±0.28
(log cfu g^{-1})	NP	4.43±0.14	5.11±0.25	5.13±0.30	5.13±0.22
	MP	4.51±0.26	4.55±0.16	4.45±0.56	4.81±0.26
Lactic acid bacteria	VP	4.38±0.23	4.42±0.56	4.48±0.46	4.42±0.63
(log cfu g^{-1})	NP	4.14±0.12	4.68±0.39	4.57±0.40	4.57±0.54
	MP	4.36±0.29	4.09±0.33	4.19±0.36	4.20±0.72
Coliforms (log cfu g^{-1})	VP	NC	NC	0.93± 0.27	1.05±0.87
	NP	NC	NC	0.59±0.58	0.99±0.28
	MP	NC	NC	0.54±0.60	0.52±0.61

NC: Not counted; *VP: Vacuum package; NP, 100% N_2 package; MP, 25% CO_2+ 75% N_2 package. $^{A-D}$Means with different superscripts within the same row are significantly ($p<0.05$) different; $^{a-c}$ Means with different superscripts within the same column are significantly ($p<0.05$) different

There were no significant difference in the values of a* among the three different packaging systems at each day of storage. The values of b* in VP samples increased significantly ($p<0.05$) with the increase in storage time in vacuum packed samples, but no significant differences were found in NP and MP samples for yellowness during storage.

VBN Value

Significant ($p<0.05$) increase of VBN values in VP samples was found, however, there was no significant difference in NP and MP samples during storage (Table 3). No significant difference was found between the three packaging methods at 30 day of storage, however, VBN values of NP and MP samples were significantly ($p<0.05$) lower than those of VP samples at 60 and 90 day of storage. Over the storage time, VBN values increased in VP samples, with the highest increase from 48.37 mg/100 g on day 1 to 80.12 mg/100 g on day 90, NP having an intermediate increase (from 52.01 mg/100 g to 61.20 mg/100 g) and MP the lowest increase (from 56.68 mg/100 g to 59.20 mg/100 g).

TBARS Value

TBARS values increased significantly ($p<0.001$) in all packaging systems at 60 and 90 days of storage (Table 3). All the three packaging methods were efficient to avoid rancidity since, increase in lipid oxidation with storage time as indicated by TBARS data from all tested groups were below 7.14 mg MA kg^{-1}.

Microbial Quality

There was no significant difference in total bacteria, lactic acid bacteria and coliforms between packaging methods during storage (Table 3). No significant difference was found among the packaging systems between the days of storage. However, the counts of total bacteria and lactic acid bacteria in MP samples were slightly lower than those of other packaging methods after the day 30 to 90 of storage.

Sensory Quality

Results of sensory analysis are presented in Table 4. In general the sensory scores for all the parameters except color has reduced significantly ($p<0.05$) at day 60 and 90 in all the

Table 4: Effect of packaging methods and storage at 4°C on the sensory quality of dry-cured pork neck

		Storage (days)		
Items[1]	Treatments*	1	60	90
Aroma	VP	6.70±0.40	6.08±0.66	6.05±0.88
	NP	6.70±0.24^{A}	5.50±0.63^{B}	6.00±0.52^{B}
	MP	7.00±0.32^{A}	6.08±0.49^{B}	5.75±0.27^{B}
Flavor	VP	6.70±0.60^{A}	5.42±0.49^{B}	5.92±0.49^{B}
	NP	6.80±0.51^{A}	5.33±0.82^{B}	5.33±0.52^{B}
	MP	6.70±0.51^{A}	5.58±0.38^{B}	5.75±0.27^{B}
Colour	VP	6.70±0.93	5.75±0.52	5.66±0.88
	NP	6.50±0.45	5.67±0.93	6.33±1.03
	MP	6.60±1.02	5.92±0.49	6.08±0.92
Tenderness	VP	6.60±0.58^{A}	5.25±0.76^{B}	6.00±1.05^{AB}
	NP	7.10±0.37^{A}	4.92±1.28^{B}	6.00±1.14^{AB}
	MP	6.70±0.51^{A}	5.17±1.37^{B}	5.92±0.58^{AB}
Juiciness	VP	6.70±0.60^{A}	4.08±1.36^{B}	5.67±2.29^{AB}
	NP	6.70±0.51^{A}	3.83±1.47^{B}	5.75±2.36^{AB}
	MP	6.60±0.49^{A}	4.25±1.41^{B}	5.42±2.25
Overall acceptability	VP	6.70±0.60^{A}	5.58±0.38^{B}	6.30±0.57^{A}
	NP	6.70±0.24^{A}	5.67±0.75^{B}	6.40±0.74^{AB}
	MP	6.80±0.60^{A}	5.83±0.41^{B}	6.10±0.96^{B}

[1]Sensory scores were assessed on 9 point scale base on 1: Extremely bad or slight, 9: Extremely good or much. *VP: Vacuum package; NP, 100% N_2 package; MP, 25% CO_2 + 75% N_2 package. $^{A-D}$Means with different superscripts within the same row are significantly ($p<0.05$) different

three packaging methods. However, there was no significant difference in all the parameters between packaging methods in all the days. The color scores remained unaffected by the days of storage or by the packaging methods. The scores on aroma (5.5-7.0) and flavor (5.33-6.8) were in acceptable range up to 90 day of storage in all three packaging methods. In all the packaging methods the tenderness, juiciness and overall acceptability scores reduced more in day 60 than in day 90 but there was no significant differences.

DISCUSSION

Increase in pH values has been reported with storage time for dry cured beef products and the type of packaging also affected pH values (Rubioa *et al*., 2006; Gok *et al*., 2008). Similarly, Martinez *et al*. (2005) and Cilla *et al*. (2006) reported that increasing concentrations of CO_2 gave rise to lowering of pH; this effect had been related to the absorption of CO_2 by dry-cured ham, which results in the production of carbonic acid (Dixon and Kell, 1989). However, our results are not in agreement with those of Houben and Van-Dijk (2001) and Pexara *et al*. (2002), who reported decrease in pH values with increased storage time for sliced hams and for cured turkey fillets packaged with MAP, respectively.

The texture/tenderness of dry cured meat is one of the main sensory attribute. Texture mainly depends on moisture, connective tissue and fat contents. The enzymatic breakdown of myofibrillar proteins increases tenderness. Our results of shear force analysis indicated that storage period or packaging conditions has no significant effect on the tenderness or texture of the dry cured pork. These results suggest that all three packaging methods are equally useful during the storage up to 90 days for maintaining the texture.

The moisture content reduced throughout the storage period in all packaging methods which indicate the gradual evaporation loss of moisture from packets. The lower moisture content in the product justifies the lower water activity in our product which has facilitated the better storage life.

The higher a_w in VP indicates the advantages of vacuum packaging in comparison to gas flushing. However, our results are not in agreement with those of Rubioa *et al.* (2006) who reported decrease in a_w values with the increased storage time for sliced dry cured meat packed in VP and MAP, respectively. Lower moisture content in our product may have caused lower a_w value.

The increase in L* values could be due to a whitish surface (an anomaly typified by the formation of a cloak of whitish substance, normally called white film) observed in the portions of dry-cured ham (Rubioa *et al.*, 2007). Lightness was found to be more stable when samples were stored with vacuum, however, no significant differences observed between NP and MP samples and a slight whiteness was observed in the vacuum packed samples. Garcia-Esteban *et al.* (2004) and Rubio *et al.* (2007) reported that packaging system had little influence on L* and no significant differences were found between vacuum, 100% N_2 and gas packaged (20/80% CO_2/N_2) samples.

A decrease in a* values was found in cooked cured ham packed with films with oxygen transmission rate (OTR) of 10 and 32 $cm^3/m^2/atm/24$ h (Moller *et al.*, 2003), showing that color stability decreased when residual oxygen increased and they recommended a packaging film with an OTR of 0.5 $cm^3/m^2/atm/24$ h. In the present work, packaging film used had a low OTR and the oxygen analysis showed very low levels of oxygen transmission (0.1%) during the storage which might have given better color stability in these samples.

Differences in b* value along the storage period could be related to the intensity of oxidation during storage. Wang *et al.* (1995) analyzed the lipid oxidation in Chinese-style sausage stored at two temperatures (4 and 15°C) in vacuum and MP packaging found that TBARS and peroxide values were lower in MP than in vacuum conditions at both temperatures. Present results are not in agreement with those of Cilla *et al.* (2006) who reported that MAP (20% CO_2 + 80% N_2) gave rise to a more yellow colour, most probably caused by pigment oxidation. It has been demonstrated that myoglobin oxidation is favoured by increasing CO_2 concentrations (Martinez *et al.*, 2005). However, our results were in agreement with Garcia-Esteban *et al.* (2004) who found b* value increase on VP ham slices while, they did not find any increase on NP and MP slices.

TBARS data from all tested groups were below 7.14 mg MA kg^{-1} which are lower than earlier report (Rubioa *et al.*, 2006). But our TBARS values of dry cured neck was higher than that reported by Vestergaard and Parolari. (1999) and Andres *et al.* (2004) for dry cured Iberian ham stored for 220 days. These values were higher than that of Aksu *et al.* (2005) who reported that TBARS ranged from 0.16 to 2.46 mg MA kg^{-1} for pastirmas. A significantly ($p<0.05$) lower TBARS values in VP samples were found compared to the NP and MP samples at 30 day of storage, but no significant difference was found between the three packaging methods in 60 or 90 days of storage. A similar behavior of lipid oxidation was reported by Cilla *et al.* (2006) for dry-cured ham samples stored in air, VP and MAP (40:60% and 80:20% of CO_2/N_2).

The result on microbial quality is in agreement with the earlier reports (Blickstad and Molin, 1984; Ogihara *et al.*, 1993; Aksu *et al.*, 2005), which suggested that MAP having carbon dioxide and nitrogen significantly prevented lactic acid bacteria and Enterobacteriacea growth. Therefore, samples packaged by MP had the lowest Enterobacteriacea counts followed by those packaged in VP and NP (Table 4). Gram-negative bacteria are generally more sensitive to CO_2 than Gram-positive bacteria because most Gram-positive bacteria are facultative or strict anaerobes (Gill and Tan, 1980), but individual bacteria vary in sensitivity to CO_2 (Farber, 1991). It is not surprising rather supportive that MP preserves microbiological quality better than aerobic/vacuum packaging methods (McMillin, 2008).

Our results indicated that packaging methods had no influences over the sensory quality of the dry cured pork. The colour of the dry cured meat depends on the concentration of myoglobin, degree of conversion to nitrosylhaemochrome and the state of heme protein. Reduction in the scores of all the parameters at 60 and 90 days appears natural due to storage effect. Apparently the scores for tenderness, juiciness and acceptability has reduced at day 60 and again improved on day 90, though there was no significance, this minor effect might be due to some ripening effect during storage, however no similar report are available in literature.

CONCLUSION

We developed dry-cured pork from neck meat by modifying the conventional procedure for better utilization of neck meat and compared the quality during refrigerated storage with three different packaging conditions. Since, there was no significant difference in the quality between the packaging methods during storage, we recommend vacuum packaging for the cured pork neck, because it is more economic and convenient.

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