academicJournals

Vol. 9(34), pp. 856-860, 15 September, 2015
DOI: 10.5897/AJPP2015. 4382
Article Number: 631B14A55309
ISSN 1996-0816

http://www.academicjournals.org/AJPP

African Journal of Pharmacy and Pharmacology

Full Length Research Paper

Nitrite, oxidation and color during shelf life of jerked beef

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Received 11 June, 2015, Accepted 25 August, 2015

The present study aims to characterize the shelf life time effect on residual levels of nitrite, lipid oxidation and color of commercial jerked beef. Twelve samples from four different manufacturers, were collected in three shelf time slots (0 to 60, 61 to 120 and 121 to 180 days) and their nitrite concentration, lipid oxidation (TBARS) and color parameters (colorimeter and preference by ranking test) were assessed. The jerked beef (JB) samples contained up to 23.56 ppm of residual nitrite which meets the legal limits. Mean concentrations of this salt was not influenced by length of shelf life, however, a wide content variation among brands was found. Lipid oxidation means did not differ between products from different manufacturers but showed reductions after 120 days. Luminosity (L*) and redness (a*) were distinct among brands and lowered after 120 days, thus indicating discoloration and darkening. The yellowness (b*) was not influenced by manufacturer or shelf life time. The product with highest visual sensory acceptance had also more intense redness as well as lower rancidity and residual nitrite levels. Shelf life time proved to be a limiting factor to quality of jerked beef due to development of oxidation, darkening and impaired red color. The residual nitrite concentration was mainly influenced by variation between brands while evolution of shelf life promoted higher oxidation levels, loss of luminosity and red color. The most preferred sample had more redness and lower lipid oxidation, hence showing importance of nitrite to maintain quality during storage of JB.

Key words: Antioxidant, curing, intermediate moisture, rancidity, salting.

INTRODUCTION

Dry-cured meats are produced and consumed in several countries, for example *Biltong* in South Africa or *Jerky* in North America (Burnham et al., 2008). In Brazil, Charqui meat (CM) and Jerked beef (JB) are intermediate moisture products obtained by salting (4 to 5 days) and sun-drying (2 to 3 days) beef samples, resulting in foods with 45% moisture and water activity between 0.70 to 0.75; values that make them stable at room temperature (Rocha Garcia et al., 2013). JB distinguish from charqui meat due to the presence of curing salts and vacuum packaging (Shimokomaki et al., 2003).

Color is an important aspect taken into account by consumers to evaluate meat products quality as it is an indicator of freshness and safety (Mancini and Hunt,

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2005). Although sodium chloride (NaCl) is responsible for JB preservation; it is also a potent lipid oxidation catalyst (Rocha Garcia et al., 2013), affecting color and flavor, thus reducing purchase intent of consumers. Oxidative rancidity is also associated with development of toxic products, such as cholesterol oxides, acrolein and malonaldehyde (Del Rio et al., 2005).

Nitrate and nitrite, known as curing salts, are usually added to processed meat products to retard development of rancidity and improve red color found in cured meats (Shimokomaki et al., 2003). But nitrite can react with amines and amino-acids in meat to produce carcinogenic compounds (Honikel, 2008). Hence, the current study aims to characterize commercial JB samples according to their shelf life time effect on residual nitrite, oxidation levels and color characteristics.

MATERIALS AND METHODS

Samples of JB from 3 lots of four different brands (J1, J2, J3 and J4) were acquired in triplicate in a retail market in Curitiba, Paraná State, Brazil, in sum of 36 units. The samples were grouped accordingly to time elapsed (days) since the production date to the moment of analysis, resulting into 3 shelf life slots: T1 (0 to 60 days); T2 (61 to 120 days) and T3 (121 to 180 days).

Residual nitrite analysis

JB samples, in triplicate, were homogenized, weighed (10 g ± 0.001) and treated with 5 ml of sodium tetraborate (500 g L^{-1}), potassium ferrocyanide (150 g L^{-1}) and zinc acetate (300 g L^{-1}). After filtration, an aliquot of 10 ml was added to 3 ml alpha-naphthylethylenediamine (5 g L^{-1}) and 5 ml of sulfanilamide (5 g L^{-1}) and the absorbance was measured at 540 nm on a spectrophotometer (Shimadzu UV1800). The nitrite concentrations were plotted on a previously established standard curve (IAL, 2008).

Lipid oxidation

Lipid oxidation was determined in triplicate using 10 g (± 0.001) of sample homogenized and distilled in the presence of hydrochloric acid (2 ml, 4 mol L^{-1}). Aliquots of 5 ml of the distillate were transferred to test tubes containing 5 ml of 2-thiobarbituric acid (0.02 mol L^{-1}), heated in water bath (35 min/100°C) and evaluated on a spectrophotometer (Shimadzu UV1800) at 532nm. The results were expressed in mg of TBARS kg^{-1} of product (Torres et al., 1989).

Color measurement

The color was determined, in triplicate, by means of 12 measurements distributed among the internal and external surface sections of JB, using a colorimeter (Miniscan XE Plus Hunterlab®, USA). CIELAB, *L** (lightness), *a** (redness) and *b** (yellowness), values were obtained with D65 illuminant and angle of 45/0 (Youssef et al., 2003).

Sensory evaluation

Samples of each brand with shortest shelf time (T1) were cut into 2 × 3 × 3 cm cubes and subjected to preference ranking test. A 48-member untrained panel evaluated the samples according to their preference, choosing between grades 1 (least preferred) to 4 (most preferred). The sum of the instructions was analyzed at 5% significance level using the Newell and MacFarlane table (IAL, 2008).

Statistical analyses

Analysis of variance (ANOVA) was conducted with Statistica 8.0 (Statsoft, 2007) for differences among shelf life times, and the variations between brands means analyzed using Tukey multiple comparison test. Statistical significance was established at 5%.

RESULTS AND DISCUSSION

The shelf life time of commercial JB products collected ranged between 6 and 176 days. The individual concentrations of residual nitrite in the samples varied from traces (J4/T2 and J4/T3) to 23.56 ppm (J2/T3) (Table 1), thus demonstrating that all samples were within the maximum limit of 150 ppm set by international food agencies (Directive 95/2/EC, 1995). Regulatory agencies, concerned about the nitrite toxicity, have determined management and reduction of this food additive concentration in meat products over the years (Honikel, 2008). Regarding average residual nitrite levels, there was a 20-fold difference among manufacturers (traces/J4 compared to 21.18 ppm/J1) (Table 1). On the other hand, shelf life had a lower effect on nitrite levels in comparison to the influence of brands. No significant differences were found between averages of shelf life intervals (TI, T2 or T3), due to wide variation within samples. In this work, all brands described the presence of nitrate and nitrite in their formulations. Nitrate is used as a nitrite precursor by reduction reactions during processing and storage of meat products (Sebranek and Bacus, 2007). Nonetheless, the differences in residual nitrite content may result from the initial concentration of nitrate or nitrite added and also from the extent of their conversion into nitric oxide, which reacts with the iron ion located in myoglobin of the meat matrix (Honikel, 2008).

A study evaluating 7 commercial JB samples identified nitrite concentrations below 10 ppm, and 4 of them contained levels below the detectable threshold by the spectrophotometric method (Youssef et al., 2011). A nitrite level reduction from 200 to 13.90 ppm was observed during JB processing in experimental products (Youssef et al., 2003). The individual levels of TBARS/kg ranged over 400% between individual samples, oscillating from 1.25 mg (J1/T2) to 5.16 mg (J3/T3). No significant differences were observed ($p > 0.05$) among mean rancidity levels by the brands. Nevertheless, mean TBARS values increased after 120 days (T3) of storage (Table 2).

Oxidative rancidity development is an undesirable characteristic in meat products even if stored under refrigeration or a modified atmosphere (Gatellier et al.,

Table 1. Residual nitrite levels during shelf life of commercial jerked beef presentations (ppm).

Presentations	Shelf life (days)			Mean (brands)
	T1 (0-60)	T2 (61-120)	T3 (121-180)	
(J1)	22.22^{aA}±0.79	23.09^{aA}±0.75	18.22^{aA}±4.02	21.18^{A}±3.06
(J2)	0.32^{bA}±0.30	1.30^{bA}±0.77	23.56^{aB}±0.58	8.39^{B}±11.39
(J3)	0.072^{bA}±0.12	6.59^{bcB}±4.59	0.47^{bAB}±0.29	1.85^{B}±3.41
(J4)	0.03^{bA}±0.05	0.00^{cA}±0.00	0.00^{cA}±0.00	0.00^{C}
Mean (time)	5.66^{a}±9.99	7.85^{a}±10.18	19.56^{a}±11.10	-

n=36. Mean ± SD. $^{(A.B.C)}$Within the same columns, means having different superscripts are significantly different ($p<0.05$). $^{(a.b.c)}$Within the same row having different superscripts are significantly different ($p<0.05$)

Table 2. Lipid oxidation of distinct jerked beef brands by shelf life intervals (mg TBARS/kg).

Presentations	Shelf life (days)			Mean (brand)
	T1 (0-60)	T2 (61-120)	T3 (121-180)	
J1	2.13^{aA}±0.03	1.25^{aB}±0.03	4.93^{aC}±0.12	2.77^{A}
J2	2.21^{abA}±0.15	2.11^{bA}±0.09	2.19^{bA}±0.18	2.17^{A}
J3	2.48^{bA}±0.16	1.56^{cA}±0.13	5.16^{acB}±1.46	3.07^{A}
J4	1.65^{cA}±0.10	1.70^{cA}±0.06	3.09^{cB}±0.14	2.15^{A}
Mean (time)	2.11^{a}	1.79^{b}	3.48^{c}	-

n=36. Mean ± SD. $^{(A.B.C)}$Within the same columns. means having different superscripts are significantly different ($p<0.05$). $^{(a.b.c)}$Within the same row. having different superscripts are significantly different ($p<0.05$).

2007; Lund et al., 2007). The antioxidant capability of nitrite resides on the ability of this additive to chelate metals, like iron from myoglobin proteins, which acts as a catalyst in lipid oxidation (Arendt et al., 1997). Such behavior was evidenced in the analysis by Youssef et al. (2011) who had found TBARS levels between 1.03 and 1.78 mg/kg of JB. In addition, the same authors observed that these levels corresponded to half of that measured in similar products without nitrites. Considering mean lightness (L*) values, J1 presented smaller overall ($p < 0.05$) L* (38.40) during storage which contrasted with other brands that showed similar means ($p > 0.05$) (Table 3). Shelf life period evaluation showed that lightness was stable in the first 120 days between 39.39 (T1) and 40.98 (T2). However, reduction in L* values to 37.95 ($p < 0.05$) was observed in T3, which indicates brownish color of the samples. Such results followed the development of lipid oxidation (Table 2).

The evaluation of a* parameter (redness) once more showed wide variations among samples, and had values between 5.89 (J1/T3) and 10.76 (J4/T1). The redness means by shelf life intervals were reduced from 9.36 (T1) to 7.76 (T3) ($p < 0.05$), during storage. Regarding the means provided by the brands, it was found that J4 stood out ($p < 0.05$) and had higher a* (9.94) (Table 3). Yellowness (b*) values ranged from 4.81 (J4/T3) to 7.08 (J2/T3). However, after evaluating the averages observed in the shelf time intervals, there were no differences observed during storage (T1 to T3) or among manufacturers. Sensory analysis of preference by ranking for JB color was performed using samples from the range with the shortest shelf time (T1). The preference for the color of the J4 product exceeded J2, J3 and J1 by 50, 132 and 250%, respectively (Figure 1). J4 also presented greater redness ($p < 0.05$) at T1 (Table 3), the lowest ($p < 0.05$) oxidation (Table 2) and residual nitrite level (Table 1) in comparison to other brands.

Early works have shown significant association between preference for the typical red color in meat products and purchase intent; it indicates that visual evaluations are good tools to estimate perceptions from consumers (Mancini and Hunt, 2005). The use of NaCl promotes iron oxidation to its ferric form Fe^{3+}, thus favoring the formation of brown color. However, nitric oxide, originated from nitrite reduction, reacts with myoglobin, maintaining its iron ion in reduced state (Fe^{+2}), thus resulting in nitrosylmyoglobin pigment, with a bright red color (Shimokomaki et al., 2003).

Nitric oxide also stabilizes ferric ion by reducing its reactivity and preventing lipid oxidation catalysis (Parthasarathy and Bryan, 2012). It is estimated that between 2 and 14 ppm nitrite are necessary to obtain the

Table 3. Color parameters (L*. a* and b*) of commercial jerked beef presentations during shelf life.

Presentations	Shelf life (days)											
	T1 (0-60)			T2 (61-120)			T3 (121-180)			Mean (brand)		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
J1	40.13±3.77^{abA}	9.39±1.30^{aA}	6.41±0.96$^{a.bA}$	37.48±5.08^{aA}	8.63±1.27^{aA}	5.08±1.43^{aB}	37.49±3.44^{aA}	5.89±1.16^{aB}	5.92±1.90^{aAB}	38.40^{A}	7.99^{A}	5.80^{A}
J2	40.05±3.14^{abA}	8.62±1.74^{aA}	5.70±1.23^{aA}	41.48±3.52^{bA}	7.04±1.95^{bB}	6.45±1.14^{bAB}	40.89±5.39^{bA}	9.40±1.69^{bA}	7.08±1.26^{aB}	40.74^{B}	8.49^{A}	6.35^{A}
J3	41.77±3.95^{bA}	7.54±1.85^{bA}	6.69±1.63$^{a.bA}$	41.72±5.15^{bA}	9.68±1.17^{cB}	5.99±1.50$^{a.bA}$	38.09±4.10$^{a.bA}$	7.87±1.23^{cA}	6.27±1.05^{aA}	40.41^{B}	8.44^{A}	6.30^{A}
J4	38.05±5.79^{aA}	10.76±1.70^{cA}	6.69±1.29^{bA}	43.18±3.67^{bB}	10.11±1.35^{cA}	6.85±1.26^{bA}	38.69±3.69^{abA}	8.99±1.33^{bB}	4.81±1.01^{bB}	40.23^{B}	9.94^{B}	6.05^{A}
Mean (time)	39.69^{a}	9.36^{a}	6.39^{a}	40.98^{a}	8.85^{a}	6.31^{a}	37.95^{b}	7.76^{b}	6.03^{a}	-	-	-

n=36. Mean ± SD. $^{(A.B.C)}$Within the same columns. means having different superscripts are significantly different (p<0.05). $^{(a.b.c)}$Within the same row having different superscripts are significantly different (p < 0.05).

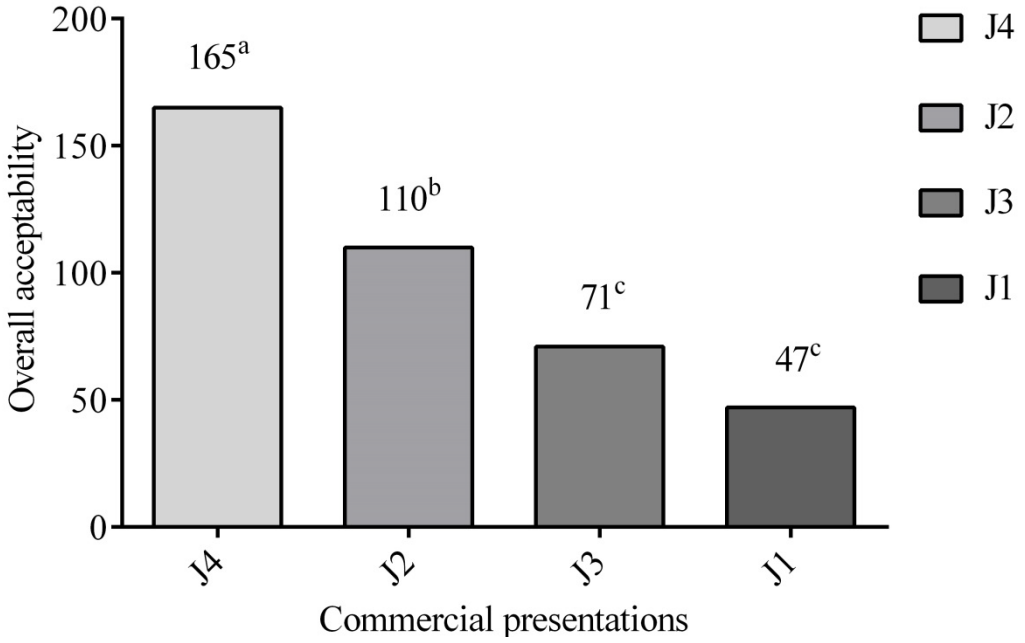

Figure 1. Colour preference ranking test from commercial presentations of jerked beef. n = 48. (a, b, c)Means in the same colum with different subscripts differ significantly (p < 0.05).

characteristic color of the cured products (Sindelar and Milkowski, 2011). Nevertheless, minimal concentrations between 10 and 15 ppm are

required to keep uniformity during the shelf life of meat (Houser et al., 2005).

Conclusion

Shelf life proved to be a limiting factor for the quality of JB as it is followed by the development of oxidation, browning and impaired red color. The residual nitrite concentration was mainly influenced by variation between brands while evolution of shelf life promoted higher oxidation levels, loss of luminosity and red color. The most preferred sample had more redness and lower lipid oxidation, hence showing importance of nitrite to maintain quality during storage of JB.

ACKNOWLEDGEMENT

The authors thank the Brazilian funding agencies CAPES, CNPq for funding this project.

Conflict of interest

The authors declare that they have no conflict of interests.

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