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Physicochemical and microbiological parameters of dried salted pork meat with different sodium chloride levels

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Abstract

The objective of this study was to evaluate the physicochemical and microbiological parameters of pork meat submitted to dry salting. Sodium chloride (NaCl) was added at levels of 0%, 2.5%, 5%, 7.5% or 10% by the meat weight. Dry salting technique was used, which consists of rubbing the sodium chloride manually, followed by a rest period. The data were submitted to analysis of variance using a completely randomized experimental design. The means were compared by Duncan test at 5%. The salting process reduced ($P < 0.05$) humidity and water activity, and it increased ($P < 0.05$) ash, chloride, palmitic acid, and water holding capacity levels compared to those of the control. Luminosity (L*) was lower ($P < 0.05$) in the control, and a* color was more intense in samples with 2.5% NaCl. Cooking loss was lower ($P < 0.05$) in the samples salted with 5% and 10% NaCl, and similarity was observed between the levels 0 and 7.5% salt. The treatments with levels 0% and 2.5% NaCl had higher mesophilic counts. The other microbiological parameters were within limits established by law. Therefore, salting with 5% NaCl can be used in pork meat in order to maintain the physicochemical and microbiological characteristics of the final product.

Keywords: water activity; salting; meat quality.

1 Introduction

Salting is one of the oldest methods used for the preservation of meat, resulting in a semi-dehydrated product very appreciated for its sensory properties (COSTA; SILVA, 2001). Sodium chloride (NaCl) is an essential ingredient added to meat products; it provides a number of different features and has been used as a preservative to prevent spoilage and to increase the shelf life of processed meat, in addition to providing characteristic flavor and tenderness (DESMOND, 2006). During salting, meat undergoes physicochemical and biochemical processes that influence the raw material components, sometimes associated with antimicrobial activity (GUTIÉRREZ, 2008).

Northeastern Brazil is known for its traditional production and consumption of sun-dried meat, jerked beef, and salted meat, especially beef, goat, and sheep meat, and therefore it is considered a market potential (COSTA et al., 2011). Sun-dried meat is prepared manually, without standardization, with the addition of sodium chloride at levels from 2.9 to 11.9%, resulting in a semi-dehydrated product with specific sensory characteristics. However, there is a need to standardize the processing steps in terms of drying time, sodium chloride content, and addition of preservatives in order to reduce the water activity in an attempt to provide a safer product to consumers (COSTA; SILVA, 2001) and improve the production process in terms of determining the most suitable animal species or carcass weight for the production of this sun-dried meat (COSTA et al., 2011).

Pork is usually sold in popular street markets as "sun-dried meat", but there are no studies characterizing the most the suitable product for this species. Due to the fact that the consumption of fresh pork meat is still small in some regions, studies on adding value to a product that has high regional acceptability could benefit the entire chain of pork production.

Despite the many benefits of salting, NaCl promotes lipid oxidation, accelerates the formation of metmyoglobin and consequently meat discoloration (GHEISARI; MOTAMEDI, 2010). On the other hand, sodium chloride can have technological functions difficult to be found in a single product, such as protein solubilization, flavor enhancement, preservation of food, and increased shelf life (WEISS et al., 2010). Thus, the objective of this study was to evaluate the physicochemical and microbiological characteristics of pork meat produced with different sodium chloride levels and to determine optimum sodium chloride content for food safety.

2 Materials and methods

The experiment was conducted at the Center for Humanities, Social Sciences and Agriculture (CCHSA) at Federal University of Paraiba, Campus III, Bananeiras - PB. Fifteen swine shoulders (±6.0 kg) from inspected carcasses of female commercial pigs were used with final average live weight of 76.22 kg (111 days old). After manual boning and removal of apparent fats, the meat was cut into 3-cm thick pieces, and sharp cuts were made.

Sodium chloride (NaCl) was added in five different concentrations based on the weight of the meat piece used: 0% (control), 2.5%, 5%, 7.5%, and 10%. Dry salting technique

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was used by rubbing sodium chloride manually. The meat pieces were turned every 2 hours, followed by rest periods of 4 hours. Next, the meat pieces were randomly suspended by hanging on sanitized strings and placed apart so as to allow homogeneous movement of air at room temperature (23 °C) for 10 hours. After desiccation, the meat pieces were packed in plastic film and stored under refrigeration (4 °C) for 12 hours for laboratory testing.

The meat samples were analyzed according to standards of AOAC (ASSOCIATION..., 2000). Moisture (%) was obtained by oven-drying up to a constant weight, and ash (%) was obtained by incineration at temperature of 550 °C.

The chloride content was determined by the titration method (ASSOCIATION..., 2000). Free fatty acidity was measured using the percentage of free fatty acids: oleic (C 18:1), lauric (C 12:0) and palmitic (C 16:0), according to the standards of AOAC (ASSOCIATION..., 2000).

The pH was determined with a digital pH meter (TEC – 2) in 10 g of sample homogenized with 100 mL of distilled water. The apparatus was calibrated for pH 7.0 and 4.0 and temperature of 10 °C.

Lightness (L*: 0 = black, 100 = white), red color (a*), and yellow color intensity (b*) were measured using a Minolta Chroma Meter colorimeter (model CR-10), according to Hunter (1958). After exposure of myoglobin to oxygen for 30 minutes, the measurements were taken at three different positions on the sample surface, and the average value was determined. Water activity (Aw) was determined by the direct method using a Decagon hygrometer (Aqua-Lab CX2) calibrated with distilled water at 20 °C.

The water holding capacity (WHC) was calculated by the difference between the weight of the sample (2.5 cm) before and after being submitted to a pressure of 10 kg for 10 minutes between filter papers (HAMM, 1986). Having determined the moisture values, the calculations were made according to the following formula: Free water percentage = [(mg of free water) / (mg sample x moisture percentage)]; and WHC = 100 - percentage of free water (HONIKEL, 1998).

In order to determine cooking loss, the samples were weighed, packed in plastic bags, and cooked in a water bath until the internal temperature of meat reached 75 °C. Subsequently, they were dried with paper to remove excess moisture and weighed again. The results were expressed as percentage of loss, determined by the weight difference before and after cooking.

Meat tenderness was determined based on the Shear Force (SF) in the salted pork meat using a TAX-T_2 texture meter coupled to a blade Warner Bratzler (WHEELER et al., 1997). After heat treatment and cooling to 4 °C for 12 hours, three samples from each treatment were evaluated for shear strength according to their resistance to the blades. Velocity of 5.0 mm/sec was used, and the peak force results were expressed as maximum shear strength of the sample in kg (POSTE et al., 1993).

For the microbiological analyses, 10g of each sample were aseptically weighed, homogenized, and diluted in sterile peptone water HIMEDIA®, thus obtaining dilution of 10^{-1}, followed by serial dilution process to obtain dilution of 10^{-3}. Techniques recommended by the National Laboratory of Animal Reference were used (BRASIL, 1981).

Coliforms were detected at 45 °C using the Most Probable Number technique (MPN) with three sets of three tubes inoculated with 1 mL of dilutions of 10^{-1}, 10^{-2}, and 10^{-3} in each set of tubes. The tubes contained 9 mL of Lauryl Sulfate Tryptose broth (LST) Himedia® and inverted Durham tubes. Each tube was homogenized and incubated for 24 hours at 35 °C in bacteriological incubator. Tubes showing turbidity and gas production (in inverted Durham tubes) at 45 °C were considered coliform-positive. To confirm the results, all tubes indicative of coliforms were seeded into inverted Durham tubes containing *Escherichia coli* (EC) broth Himedia®. These tubes were incubated for 24 hours at 45.5 °C in a water bath. The presence of gas was observed confirming the presence of coliforms at 45 °C (tubes with EC broth) in the samples. The results were based on the number of tubes exhibiting gas production for three successive dilutions and expressed as MPN/g sample, according to a specific table.

For the counting of mesophilic bacteria, 1 mL of each dilution was placed on sterile Petri dishes. Next, 15-20 mL of Plate count Agar (PCA) (Himedia®) was added and maintained in a water bath at 50 °C .The plates were homogenized and after solidification, they were incubated for 48 hours at 35 °C dilution.

In the search for *Staphylococcus aureus* (CFU/g), aliquots of 0.1 mL from the different dilutions were inoculated on the surface of Vogel Johnson agar Himedia® enriched with a 1% potassium tellurite solution. Seeding was done with Drigalsk loop. Petri dishes were incubated at 35-37 °C for 48 ± 2 hours, and those showing growth of typical colonies of *Staphylococcus aureus* were selected for counts using the colony counter.

In the search for *Salmonella* sp., aliquots of 25 g were added to 225 mL of Lactose Broth Himedia ® and incubated at 35 °C. After 24 hours of incubation, aliquots of 1 mL were transferred to 10 mL of Tetrathionate and Selenite-cystine enrichment broths (HIMEDIA®) and incubated for 24 hours at 42 °C and 35.5 °C, respectively. After the incubation period, grooves were made using a platinum loop on selective media Bismuth sulfite agar (BS) Himedia® and Xylose Lysine Deoxycholate Agar (XLD) Himedia®, whose plates were incubated at 35 °C for 24 hours.

The data were submitted to Analysis of Variation (ANOVA) using a completely randomized experimental design. To compare the means, the Duncan test was used with a probability of 5%. Statistical analysis was performed using the ASSISTAT® software, Version 7.5 Beta (SILVA, 2010). The microbiological analyses' data were compared to values established by standard RDC No. 12 from 01/02/2001 by the National Agency for Sanitary Surveillance for meat products such as sun-dried meat, jerked beef, and similar products (BRASIL, 2001).

3 Results and discussion

The average values of moisture, ash, chlorides and free acidity (oleic, lauric, and palmitic fatty acids) of pork meat

submitted to different sodium chloride (NaCl) levels are shown in Table 1.

The salting process reduced ($P < 0.05$) the moisture content of meat with similarities between the treatments at the levels 2.5 and 5% and between 7.5 and 10% NaCl (Table 1). On the other hand, the ash contents increased ($P < 0.05$) with the addition of NaCl compared to that of the control; the highest value (7.80 ± 0.93%) was observed with the addition of 10% NaCl. These results corroborate those obtained by Paleari et al. (2003), who varied the moisture content from 74.5% ± 1.07 to 48.2 ± 0.31%, ash from 1.1% ± 0.05 to 7.0 ± 0.07% in fresh and cured goat meat, respectively. The biochemical changes observed correspond to the reduction in water content caused by the action of salt under osmotic pressure between the muscle cells in the desiccation process.

Significant differences ($P < 0.05$) were observed for the chloride content of the samples, with similarities between the levels 2.5 and 5% NaCl and between 7.5 and 10% NaCl, which were higher than those of the control (Table 1). As expected, the chloride content of the samples increased with the addition of salt (NaCl). Purriños et al. (2011) also observed an increase in the chloride content with the addition of salt.

With regards to the free acidity, an increase ($P < 0.05$) was observed in the palmitic acid levels with the addition of 10% of NaCl compared to that of the control (Table 1). Oleic acid (C18:1) and lauric acid (C12:0) contents were not affected by the treatments tested (Table 1). These results show good control over the lipid oxidation process and may be related with the feeding of the animals during the process.

The pH values of the samples did not differ ($P > 0.05$) between the salt levels, with an average of 5.82 (Table 2), and it was considered suitable for development of cured products (GUTIÉRREZ, 2008). Assessing the influence of the addition of sodium chloride and lactic acid in raw pork and beef, combined or not, Medynsky, Pospiech and Kniat (2000) did not observe difference in the pH values. According to Costa-Corredor et al. (2010), the initial pH of meat affects the absorption of ions during the salting process, not in the post-salting process, because there is an offset in the sodium/potassium relation.

The salt levels showed no effect ($P < 0.05$) on the yellow color (b*) of meat, with an average value of 22.6 (Table 2). However, differences were observed ($P < 0.05$) for lightness (L*) and red color (a*) between the treatments (Table 2). Lightness was lower ($P < 0.05$) in samples with 5% sodium chloride and red color was more intense in the control samples (Table 2). The L* and a* values found were lower and the b* values were higher than those found in dry and cured loins (ALIÑO et al., 2009). The ratio a*/b* can be used to verify the relationship between oxymyoglobin and metmyoglobin (OLIVO et al., 2001). In the present study, it was observed a decrease in the ratio a*/b* with an increase in the sodium chloride levels in the pork meat samples, indicating the formation of metmyoglobin

Table 1. Chemical composition (mean values ± standard deviations) of pork meat submitted to different levels of sodium chloride (NaCl).

Variables	NaCl levels (%)				
	0	2.5	5	7.5	10
Moisture (%)	72.96 ± 0.48[a]	70.88 ± 1.0[b]	69.54 ± 0.96[b]	67.50 ± 1.32[c]	65.90 ± 1.11[c]
Ashes (%)	1.17 ± 0.04[d]	3.52 ± 0.43[c]	5.41 ± 2.40[b]	6.23 ± 1.41[b]	7.80 ± 0.93[a]
Chlorides (%)	3.93 ± 0.79[c]	5.50 ± 0.21[b]	6.18 ± 0.56[b]	9.68 ± 0.80[a]	10.77 ± 0.48[a]
Free Acidity (%)					
Oleic (C18:1)	2.54 ± 0.48	2.23 ± 0.14	2.20 ± 0.16	2.29 ± 0.06	2.06 ± 0.14
Lauric (C12:0)	0.73 ± 0.07	0.74 ± 0.04	0.72 ± 0.06	0.76 ± 0.02	0.76 ± 0.03
Palmitic (C16:0)	0.75 ± 0.07[b]	0.86 ± 0.11[ab]	0.83 ± 0.01[ab]	0.84 ± 0.01[ab]	0.94 ± 0.04[a]

[a]Means followed from different superscript letters in the same row differ statistically by the Duncan test at 5% of probability.

Table 2. Mean values and standard deviations of variables assessed in physical and physicochemical characterization of pork meat submitted to different levels of sodium chloride (NaCl).

Variables	NaCl levels (%)				
	0	2.5	5	7.5	10
pH	5.9 ± 0.02	5.7 ± 0.14	5.7 ± 0.20	5.9 ± 0.12	5.9 ± 0.20
Color					
L*	26.6 ± 2.40[a]	23.8 ± 0.90[ab]	21.8 ± 0.90[c]	24.7 ± 0.68[ab]	27.10 ± 0.69[a]
a*	10.2 ± 1.65[a]	6.7 ± 2.06[b]	3.9 ± 1.62[c]	1.7 ± 1.28[d]	1.7 ± 0.65[d]
b*	22.8 ± 2.00	23.3 ± 2.07	22.9 ± 0.85	22.0 ± 2.30	22.0 ± 1.04
Ratio a*/b*	0.5 ± 0.09[a]	0.3 ± 0.02[b]	0.2 ± 0.06[c]	0.1 ± 0.02[cd]	0.1 ± 0.03[d]
Aw	0.98 ± 0.004[a]	0.96 ± 0.004[b]	0.95 ± 0.001[c]	0.93 ± 0.012[c]	0.92 ± 0.004[c]
WHC (%)	68.2 ± 0.85[b]	68.4 ± 3.39[a]	73.2 ± 4.62[a]	75.2 ± 4.30[a]	75.7 ± 0.99[a]
Cooking loss (%)	12.7 ± 1.67[b]	15.3 ± 5.43[a]	9.6 ± 2.20[c]	12.4 ± 2.05[b]	7.6 ± 1.84[c]
SF (kgf/cm^2)	1.9 ± 0.13	1.9 ± 0.31	1.9 ± 0.35	2.2 ± 0.51	2.2 ± 0.29

L*: luminosity; a*: level of red; b*: level of yellow. WHC: Water Holding Capacity; SF: Shear Force. [a] Means followed from different superscript letters in the same row differ statistically by the Duncan test at 5% of probability.

Table 3. Microbiological composition of pork meat submitted to different levels of sodium chloride (NaCl).

Variables	NaCl levels (%)				
	0	2.5	5	7.5	10
Coliforms 45 °C (MPN/g)	9.3×10^1	2.3×10^1	2.3×10^1	< 3	9.3×10^1
Mesophilic Bacteria (CFU/g)	$> 1.0 \times 10^5$	1.1×10^5	3.1×10^3	1.3×10^4	3.2×10^4
Staphylococcus spp. (CFU/g)	7.0×10^2	6.8×10^3	1.4×10^3	3.0×10^2	7.5×10^1
Salmonella sp. (25 g)	Absent	Absent	Absent	Absent	Absent

and darkening of the meat pigment, which is a characteristic of salted meat products. According to Gutiérrez (2008), the salting process causes a typical soluble and unstable pink color. However, the nature and intensity of this color will depend on the myoglobin level of the raw material and on the physical state of these pigments as a result of chemical reactions during salting.

There was a significant effect ($P < 0.05$) of the salting process on the water activity (Aw), which decreased from 0.98 ± 0.004 (0%) to 0.92 ± 0.004 in fresh meat with salting at 10% NaCl (Table 2). The sodium chloride reduces the free water content of meat, which causes a decrease in moisture and Aw values. This effect was observed by Paleari et al. (2003), who studied several animals species, but especially when comparing raw and cured wild boar meat (A_w values between 0.98 and 0.90, respectively), and also by Teixeira, Pereira and Rodrigues (2011) with goat meat. Therefore, the salting process was effective in reducing the water activity of samples, showing its potential in reducing the risk of bacterial growth responsible for meat deterioration.

There was an increase ($P < 0.05$) in the water holding capacity in the salted meat compared to that of the control (Table 2). The effect of sodium chloride on the water holding capacity is associated with increased pressure in the protein matrix (ALIÑO et al., 2010). Salt acts directly on the solubility of meat myofibrillar proteins (actin and myosin), which in turn increases the water holding capacity, viscosity, and fat stability forming a stable emulsion (DESMOND, 2006), which gives gives that sensation of succulence to the palate of the consumer. These data were also confirmed by Medinski, Pospiech and Kniat (2000), and there was a reduction in drip losses and an increase in water holding capacity only when sodium chloride was added.

The cooking loss was lower ($P < 0.05$) in meat salted with 5% and 10% NaCl, with similarity between the salt levels 0 and 7.5% (Table 2). Since NaCl used in the salting of pork meat has low power to stabilize meat proteins (actin and myosin), according to the liotropic series of Hofmeister, the changes in weight loss due to cooking may have been caused by the salt used in the meat investigated.

There was no effect ($P > 0.05$) of the NaCl levels on the meat shear force (Table 2). Possibly, the NaCl levels used in the present study caused no changes in texture parameters of the salted pork meat samples. Similarly, Purriños et al. (2011) found that the salt level did not significantly affect the texture characteristics of a traditional product of Northwestern Spain made with pork forequarter.

The results obtained for the microbiological analysis as a function of salt levels are shown in Table 3. The most-probable-number method for enumerating fecal coliforms at 45 °C was within the standards established by RDC No. 12 from January 2001, which set levels of up to 10^3 MPN / g for matured meat products (BRASIL, 2001).

Treatments with lower NaCl levels (0 and 2.5%) showed higher mesophilic bacterial counts (Table 3), which may be indicative of higher contamination levels and shorter shelf life. It is possible that the higher water activity provided by these treatments have favored the development of these microorganisms. Investigating the count of mesophilic bacteria in sun-dried meat sold in different shops, Costa and Silva (2001) found levels between 1.58×10^6 and 1.58×10^7 CFU/g.

For the counting of *Staphylococcus* spp., the treatment with 2.5% NaCl appeared to be above the limit set by law (5.0×10^3 CFU/g) for food safety. All treatments showed absence of *Salmonella* sp., and therefore meet the requirements of the current legislation (Table 3). According to Desmond (2006), it is important to examine the shelf life and microbiological safety of processed meat products before the reduction or replacement of NaCl with other ingredientes.

4 Conclusions

The addition of different NaCl levels caused changes in the physicochemical and microbiological characteristics of pork meat, and the addition of 5% NaCl provided the highest quality ensuring safety standards.

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