EFFECT OF ELECTRICAL TREATMENT ON THE DIFFUSION OF NITRITE IONS INTO PORCINE MUSCLE

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Story in Brief

Thirty-six Longissimus dorsi (LD) muscles from 18 pork carcasses were obtained to test the effect of electrical treatment on the diffusion of nitrite ions into these muscles. A split-split plot design was applied to test two levels of electricity (1 and 2 amperes (amp)). The experiment was conducted in rectangular plexiglass tanks with modified curing solution. Electricity was supplied from a DC power supply. It was found that the diffusion of nitrite ions increased with increased time of exposure to electrical current, level of electricity and proximity of the muscle near the negative electrode. Position C (anterior) was placed near the negative electrode and had significantly higher nitrite diffusion ($P < 0.05$) than position A (posterior) or B (middle). This was attributed to more open microstructure in the anterior position (C) of LD or modified orientation of the phospholipid bilayer of cell membrane due to electrochemical environment.

Introduction

The process of meat preservation by curing technology is one of the most popular and ancient methods known to human civilization. Despite this long time familiarity with meat curing, two problems have persisted: lack of uniformity of color development and extensive time required to accomplish the process.

Conventional methods of applying curing ingredients to meat range from the packing of dry mixtures of the ingredients around the surface of the meat (dry cure) to the injection of various solutions into the meat (wet cure). The curing process involves a pink color formation due to a complex formed after the heme iron of myoglobin is reacted with nitric oxide to form nitrosomyoglobin during heating. Since the myoglobin moiety is present inside the muscle cells and the curing agents are applied outside the cells, each curing agent, particularly nitric oxide, must transcend several membrane barriers to reach myoglobin. For this reason a dry cure method takes about 30-40 days for a 15 pound ham. The wet curing process is much faster but it too requires a few days (2-5 days) in most commercial operations

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to accomplish the above. This "delay phase" translates into higher product cost for the consumer and less profit for the processor.

There are three approaches to solving the problem of the "delay phase": a) reduce the distance between the heme iron and curing agents by reducing the size of the cuts, b) inject the curing solution into the meat tissue using a multi-needle pump, and c) apply some form of energy or force to migrate the curing agents into the meat.

The use of electrical force to migrate ions from the curing solution into the meat tissue could lower the amount of nitrite and chloride needed to either fix the color of or preserve cured meats. Theoretically, only about 15% of the t^tal added nitrite would be required to fix color. The development of a process utilizing electro-chemical principles to diffuse curing ingredients into meat tissue could conceivably open a new dimension in cured meat processing technology and ultimately enable production of cured meats with minimal delay phase, nitrite, and salt but with maximal shelf life.

Materials and Methods

Experimental muscles were obtained from left and right loins of 18 market weight hogs. One animal was slaughtered each week to get two loins per week to run one experiment. The Longissimus Dorsi (LD) was excised from each loin (24 hours post-mortem) between the eighth thoracic vertebra and the sacro-illiac joint. All external fat was trimmed and a 15-inch long section was cut from each muscle.

Diffusion was conducted in two rectangular plexiglass tanks. Two carbon electrodes were placed on either end of the treatment tank (1 inch away from the muscle ends and 1/2 inch away from the tank ends). Nine liters of a modified curing solution containing sodium nitrite, sodium chloride, sodium tripolyphosphate, erythorbate, and sucrose were used. Two glass rods (one-fourth inch diameter) were placed under each muscle to suspend it above the base of the tank and allow maximum surface contact by the curing solution. The curing solution was chilled to about 40 F prior to use. The posterior end of the LD always faced the positive electrode. A trough was made from heavy filter paper to collect the corroded carbon particles from the positive electrode. The process of curing was allowed to take place without electricity (control) and with electricity (treated) for specified times (13, 16 or 22 hours) and current (1 or 2 amperes) under a closed hood. A Hewlett-Packard DC power supply was used to generate direct current (DC) electricity. A Fluke Voltmeter and a Simpson Multimeter were used to monitor volts and amperes, respectively.

After treatment, muscles were removed, heated to 155 F internal temperature in a convection oven and cooled to 40 F internal temperature. After cooling, each muscle was divided into 3 sections for analysis (A = posterior end, facing the positive electrode, B = middle and C = anterior end, facing the negative electrode). Each section was analyzed for sodium nitrite (1).

The experiment was conducted as a split-split plot design for two levels of electricity and three levels of time. Analyses were conducted in duplicate. Three replicates were run. Since only one power supply was available, a control was run with each treatment to account, statistically, for animal to animal variation.

Results and Discussion

In Table 1 are presented the Ø amp vs 1 amp and Ø amp vs 2 amp results. The control (Ø amp vs 1 amp) showed that on the average, position A had the most residual nitrite (48.6 ppm) followed by positon C (40.9 ppm) and B (40.6 ppm), respectively. However, these differences were not statistically significant. The residual nitrite values

Table 1. Effect of electricity and time of exposure on the diffusion of sodium nitrite (ppm) (a)

Electricity (Amperes)	Position in LD	Hours of exposure 13	16	22	Average
Ø(b)	A	44.8	42.3	58.7	48.6
	B	35.3	36.3	50.3	40.6
	C	29.4	36.6	56.8	40.9
	Average	36.5	38.4	55.3	43.4
1	A	52.8	46.1	58.7	52.6
	B	41.3	42.3	82.7	55.4
	C	56.6	89.0	129.0	91.5
	Average	50.2	59.1	90.1	66.5
Ø	A	47.3	56.0	55.9	53.1
	B	41.3	56.0	43.7	47.0
	C	36.7	54.0	46.7	45.8
	Average	41.8	55.3	48.8	48.6
2	A	50.6	63.0	37.8	50.5
	B	42.5	58.0	35.1	45.2
	C	165.6	158.0	147.8	157.1
	Average	86.2	93.0	73.6	84.3
1 & 2	Average	68.2	76.1	81.9	75.4

(a) Each figure in the table is the average of 3 observations.
(b) A separate control was run for 1 and 2 amperes.

increased with time of curing, the highest value being obtained at 22 hours at position A. Results for the 1 amp treatment indicated that position C contained the most residual nitrite (91.5 ppm) followed by position B (55.4 ppm) and A (52.6 ppm). The time-wise comparison indicated that the highest value was for 22 hours (position C, 129.0 ppm) and the lowest value was for 13 hours (position B, 41.3 ppm). The treated position C had about 1.5 times higher values than control C.

In control results of the 0 amp vs 2 amp experiment, position A had the greatest average nitrite diffusion value (53.1 ppm) followed by position B (47.0 ppm) and C (45.8 ppm), respectively. A comparison over time indicated that 16 hours showed the most diffusion (55.3 ppm) followed by 22 hours (48.8 ppm) and 13 hours (41.8 ppm). These results were quite different from those of the 0 amp Vs 1 amp control data. In 1 amp control data, the residual nitrite values increased consistently with increased time; whereas in this case (0 amp vs 2 amp) the residual nitrite values increased when the time was increased from 13 hours to 16 hours but did not increase when the time of curing was raised to 22 hours. Samples treated at 2 amp had the highest average diffusion value at positon C (157.1 ppm) followed by A (50.5 ppm) and B (45.2 ppm), respectively. The values for position A and B were similar but position C values were about three times higher than either A or B. Duncan's multiple range test suggested that position C was significantly different from either A or B ($P < 0.001$).

A comparison of the 1 amp vs 2 amp data showed that samples treated at 2 amp had lower average values for position A (52.6 vs 50.5) and B (55.4 vs 45.2) but position C was considerably higher for samples treated at 2 amp (91.5 vs 157.1) having almost a three fold higher value. There was a highly significant interaction between electricity and position ($P < 0.001$). Duncan's multiple range test indicated that position C was significantly different from either A or B. A time-wise comparison of 1 amp vs 2 amp showed an increase in diffusion values when the time for treatment was raised from 13 hours to 16 hours and from 16 hours to 22 hours, with one exeption for 2 amp where the diffusion values decreased with the increased time (from 16 to 22 hours).

Thus the diffusion of sodium nitrite ions into porcine LD muscle, in an electrochemical environment, was found to be dependent upon time of exposure to the electrical treatment, level of electricity and position in the muscle or proximity of muscle towards the negative electrode. A higher diffusion value for position C in treated sample was thought to be due to a more open microstructure of meat tissue in that section othe muscle, allowing more ions to diffuse. This could be also due to an electrochemical environmental effect on the orientation of the phospholipid bilayer of the membrane resulting in increased permeability.

Literature Cited

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