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Summary with Implications

Producing cured meats manufactured with natural ingredients could impact cured meat characteristics, including color. The objective of this study was to determine the effects of nitrite source (sodium nitrite or cultured celery juice powder), reducing agents (no reducing compound or sodium erythorbate/ascorbic acid), and holding times prior to cooking on cured color development in a meat model system. The addition of reducing compounds had the largest impact on cured color development and reduced residual nitrite in a cured meat model system. Treatments cured with sodium nitrite had slightly greater cured color development than treatments cured with celery juice powder. Holding times prior to cooking had limited impact on cured color development. These findings indicate that processors can produce cured meats with adequate cured meat color using celery juice powder and ascorbic acid from cherry powder without needing to extend holding time prior to cooking.

Introduction

The addition of ingredients that contain nitrite to meat allows for the development of cured meat characteristics including stable cured meat color, cured meat flavor and aroma, reduced lipid oxidation, and reduced growth of some pathogens and spoilage microorganisms. Cured meat color development occurs through the addition of nitric oxide (NO) to the heme-iron of myoglobin, the primary pigment in meat. Ultimately, the reduction of nitrite to nitric oxide occurs via reactions with endogenous compounds or added ingredients, which allow for meat curing to occur.

With the evolving consumer demand for natural and clean-label foods, common ingredients used in cured meats are being replaced with natural ingredients to provide similar functions. Sodium nitrite is often replaced with cultured celery juice powder as a natural nitrite source. Similarly, acerola cherry powder is high in ascorbic acid and can be used as an alternative to sodium erythorbate (a reducing compound) to increase the rate of meat curing reactions. The holding time between manufacturing and cooking can also impact the extent of meat curing reactions. The objective of this study was to determine the effects of nitrite source, the addition of reducing agents, and holding times prior to cooking on cured color development in a meat model system.

Procedure

This study was conducted using a 2 x 2 x 5 treatment arrangement to determine the effects of nitrite source (sodium nitrite; or celery juice powder), reducing compounds (no reducing compounds; or addition of a reducing compound), and holding time prior to cooking on cured color development and residual nitrite in a meat model system. Emulsified beef sausages were formulated to contain 156 ppm of sodium nitrite or manufactured with 0.44% celery juice powder (VegStable 504, Florida Food Products, Inc., Eustis, FL) to provide the equivalent of 100 ppm of sodium nitrite. Previous research has indicated that cultured celery juice powder is limited to this amount due to increased off flavors and reduced product acceptability when greater amounts were used. For treatments containing reducing compounds, the sodium nitrite treatment with reducing compounds had 495 ppm of sodium erythorbate added and the celery juice powder with reducing compounds treatment had 0.4% cherry powder (VegStable 515, Florida Food Products, Inc.) to provide 440 ppm of ascorbic acid. These concentrations of sodium erythorbate and ascorbic acid are molar equivalents to provide similar reducing capacity. Treatments without reducing compounds contained neither sodium erythorbate nor ascorbic acid from cherry powder. For each treatment, ground beef (1.5 lbs), 2% salt, 20% ice (meat block basis) and the treatment specific nitrite sources and reducing agents were chopped for 60 sec at 2000 rpm using a commercial food processor (Blixer 6V, Robot Coupe, Robot Coupe, Ridgeland, MS). From each treatment, the emulsions were placed into five, 100 ml glass beakers, covered in plastic film, and held at ambient room temperature for 5, 15, 30, 60 or 120 minutes prior to cooking. After the specific holding time, sausages were cooked in water baths for 30 min at 104 °F followed by 30 min at 176 °F and cooled for 30 min in an ice bath. After cooling, sausages were removed from beakers and sliced horizontally into four pieces. Samples were evaluated for objective color to measure lightness, redness, and yellowness, (CIE L*, a*, and b*, respectively), residual nitrite, cured meat pigment, and total meat pigment. Percent cured meat pigment was calculated from the results.

The experiment was conducted as a completely randomized design with factorial treatment arrangement. Three independent replications were produced. Data were analyzed using a PROC Glimmix procedure of SAS. Interactions of effects and main effects of nitrite source (sodium nitrite or celery juice powder), addition of reducing compounds (sodium erythorbate/ascorbic acid or no added reducing compound), and holding time prior to cooking (5, 15, 30, 60, and 120 min) were analyzed. When significant interactions or main effects were identified ($P \leq 0.05$), means separation was conducted using a Tukey's adjustments.

Results

The only significant ($P < 0.05$) treatment interactions were nitrite source by reducing compounds for residual nitrite, percent cured pigment, and residual nitrite. Main effects were considered for all other traits (Table 1).

Table 1. Means for main effects of nitrite sources, the addition of reducing compounds, and holding time on objective color, cured and total meat pigment, and residual nitrite in a cured meat model system

Main effects	L*	a*	b*	Cured meat pigment[1] (ppm)	Total meat pigment (ppm)	Percent cured meat pigment[1]	Residual nitrite[1] (ppm)
Nitrite source							
Sodium nitrite	62.27	13.87[a]	8.82[b]	102.77	173.42	59.3	71.12
Celery juice powder	62.44	12.58[b]	9.17[a]	88.35	168.88	52.2	45.48
SE	0.17	0.21	0.13	1.85	5.51	1.9	1.65
P–value	0.323	<0.001	0.009	<0.001	0.415	<0.001	<0.001
Reducing compounds							
None added	62.39	10.69[b]	9.15[a]	63.29	176.32	38.5	69.51
Added[2]	62.32	15.76[a]	8.83[b]	127.82	165.97	73.0	47.10
SE	0.17	0.21	0.13	1.85	3.89	1.9	1.65
P–value	0.697	<0.001	0.016	<0.001	0.068	<0.001	<0.001
Holding time (min)							
5	62.61	13.21[bc]	9.07	94.48	170.78	55.1	58.45
15	62.24	13.02[bc]	8.96	94.64	168.20	56.6	60.51
30	62.56	12.66[c]	8.84	92.25	171.62	53.7	57.74
60	62.30	13.37[ab]	9.03	96.87	174.19	55.6	58.06
120	62.04	13.88[a]	9.06	99.54	170.94	57.9	56.67
SE	0.28	0.33	0.21	2.92	8.71	3.0	2.60
P-value	0.206	0.011	0.754	0.150	0.974	0.708	0.672

[1] A significant nitrite source by reducing agent interaction was identified for these traits.
[2] Contained either 495 ppm of sodium erythorbate or 440 ppm of ascorbic acid from cherry powder.
[a-c] Means in a column and within each main effect with a common superscript are similar ($P > 0.05$).

Cured, total, and percent cured meat pigment

A significant nitrite source by reducing compound interaction was identified for amount of cured meat pigment ($P < 0.001$; Table 2). The sodium nitrite and sodium erythorbate treatment had the greatest amount of cured meat pigment value followed by celery juice powder and cherry powder treatment, sodium nitrite, and celery juice powder where each treatment was different from the others. Total meat pigment was not affected by any treatment interaction ($P \geq 0.96$) or main effects ($P \geq 0.06$). Similarly, percent cured meat pigment had a nitrite source by reducing compound interaction ($P = 0.006$). The greatest percentage was found in the sodium nitrite and sodium erythorbate treatment and celery juice powder and cherry powder treatment, sodium nitrite only was intermediate, and celery juice powder only had the least percent cured meat pigment.

Table 2. Means for the interaction of nitrite sources and the addition of reducing compounds on cured meat pigment, cured meat pigment, and residual nitrite in a cured meat model system.

Nitrite source	Reducing compounds	Cured meat pigment (ppm)	Percent cured meat pigment	Residual nitrite (ppm)
Sodium nitrite	None added	74.67[c]	44.8[b]	79.70[a]
	Added[1]	130.86[a]	73.8[a]	62.55[b]
Celery juice powder	None added	51.91[d]	32.2[c]	59.32[b]
	Added[2]	124.78[b]	72.3[a]	31.64[c]
SE		2.61	2.7	2.33
P-value		< 0.001	0.006	0.003

[1] Contained 495 ppm of sodium erythorbate
[2] Contained 440 ppm of ascorbic acid from cherry powder.
[a-c] Means within a column with a common superscript are similar ($P > 0.05$).

The sodium nitrite treatment had greater ingoing nitrite (156 ppm vs. 100 ppm) which likely explains the greater amount of cured pigment in sodium nitrite treatments than celery juice powder treatments. However, when reducing compounds are added, more cured meat pigment was formed and the differences between nitrite sources was reduced. This is further demonstrated, along with the results of percent cured meat pigment, where either nitrite source with reducing compounds were similar in producing cured meat pigment.

Objective color

Nitrite source, reducing compounds, and holding times had no impact on the L* value (lightness; $P > 0.323$). However, sodium nitrite treatments were more red (a*, $P < 0.001$) and less yellow (b*, $P = 0.009$) than celery juice powder treatments (Table 1). Similar results were identified for internal cured meat color in all-beef frankfurters (2015 Nebraska Beef Report, pp. 120–121). The greater red color is likely an indication of cured meat color development. The increased yellowness in celery juice powder sausages is likely due to the inherent color of the celery juice powder. However, the difference in yellowness may not be enough to impact consumer acceptability.

The addition of reducing compounds resulted in samples that were more red ($P < 0.001$) and less yellow ($P = 0.016$) than the treatments without a reducing compound (Table 1). The increased redness corresponds with greater cured meat pigment in samples with reducing compounds. Miller et al. reported that the internal color of beef frankfurters was less yellow in cured treatments than those that had no nitrite added (2015 Nebraska Beef Report, pp. 120–121). The increased yellowness in those without reducing compounds could also be related to less cured meat color development.

The only objective color value influenced by holding time was redness values ($P = 0.011$) where 120 minutes holding time were more red ($P \leq 0.05$) than 5, 15, and 30 minutes holding time and 60 min holding time samples were more red than 30 min holding samples (Table 1). The increased redness with longer holding times could be an indication of increased cured color but this was not reflected in measures of cured meat pigment.

Residual Nitrite

There was a significant nitrite source by reducing agent interaction for residual nitrite ($P = 0.003$; Table 2). The sodium nitrite treatment had the greatest amount of residual nitrite ($P \leq 0.05$), followed by the sodium nitrite and sodium erythorbate treatment and celery juice powder treatment, and celery juice powder and cherry powder treatment had the least residual nitrite. Holding time did not impact residual nitrite ($P = 0.672$; Table 1). It is not unexpected that treatments with sodium nitrite had greater residual nitrite than those with celery juice powder as it had greater ingoing nitrite concentration. Similarly, the addition of reducing compounds reduced the amount of residual nitrite in the products.

Conclusions

When reducing compounds are added, cured meats with similar cured color characteristics can be manufactured using sodium nitrite or natural nitrite sources. Samples manufactured with sodium nitrite were slightly more red and less yellow than those manufactured with natural nitrite sources. Holding time prior to cooking of up two hours had minimal impact on cured color characteristics.

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