# The Effect of Brine Temperature on Smokehouse Yield, Sensory Characteristics, and Color Scores of Bacon

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## ABSTRACT

**The objective of this study was to determine if changes in brine temperatures could impact brine uptake, smokehouse yield, sensory characteristics, subjective color scores, microbial load, and residual nitrite levels of bacon. Treatments consisted of three brine temperatures -1 °C (cold), 10 °C (medium), and 21 °C (warm). There were no differences between treatments for cooked weights and chilled processed weight percentage. On d 35, the cold treatment had *(P* < 0.05) less oxidized flavor and medium and warm treatments had less color fading and a darker cured color *(P* < 0.05). Also, microbial aerobic plate counts were not changed by brine temperature *(P* > 0.05). Nitrite levels were higher *(P* < 0.05) in the cold treatment compared to the warm treatment. Brine temperatures did not change overall yield and microbial growth; however, changes in brine temperature did present difference in sensory characteristics, subjective color scores, and nitrite levels in finished product.**

**KEY WORDS:** brine temperature, sensory, shelf-life

## INTRODUCTION

The pork belly is a sub-primal comprising approximately 17.3% of a pork carcass (Aberle et al. 2001). The reason the belly is so important is because it is the cut of meat transformed into bacon. Many restaurants and stores include bacon on their

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menu or in their display case in some sort of fashion. Therefore, increased emphasis continues to shift into bacon research to enhance both yields and quality of products for meats processors, as well as marketability for swine producers. Typically, the temperature of curing brines, as well as the meat, is approximately equal to the temperature in which product is processed (Leach 2007). Previous studies assessed if varying brine temperatures injected into products affected the overall yield of the products. Three separate studies concluded brine temperature has no effect on cooking yield (Peterson et al. 2017; Keenan et al. 2015; Boles and Swan 1997). However, none of these studies used a brine temperature higher than 17 °C and two of them used varying degrees of meat temperature. A higher elevated temperature of the brine could act as a catalyst to the curing process increasing brine uptake and eventually overall smokehouse yield. Peterson et al. (2107) concluded an increase in brine uptake occurs with an increase in both brine and meat temperatures. This particular study focused on brine temperature and how changes in brine temperature can affect yield and quality aspects of bacon products. If the product yields are increased, but the consumer does not like the product, or the product has an inhibited shelf life, then the increase in yield would have a negative overall effect. If brine temperature can increase products yields while still maintaining positive quality outcomes, it would be an ideal change for bacon processors. The objective of this study was to determine if brine temperature effects brine uptake, smokehouse yield, sensory characteristics, subjective color scores, microbial load, and residual nitrite levels of bacon.

## MATERIALS AND METHODS

**Bacon Production.** Fresh bellies were obtained from a meat purveyor in the 5.44 to 6.35 kg weight range. A total of 30 bellies (USDA-IMPS #409) were used for this study (10 per treatment). Three brine temperatures were used: -1 °C (cold), 10 °C (medium), and 21 °C (warm). Bellies were randomly assigned to one of three treatments to eliminate any statistical difference in mean weight for the treatment. All bellies were tempered to 4 °C before injection. Pump percentage was maintained at 13% and contained a 1.3% salt inclusion level. Before injection, water was tempered to the respective temperatures for each treatment. Once water reached the desired temperature, brine ingredients consisting of sodium phosphate (0.5%), salt (1.2%), sugar (0.4%), sodium erythorbate (550 ppm), and sodium nitrite (120 ppm) were added, mixed, and injected at a rate of 13%. Bellies were injected using a multi-needle Gunther injector (Model PI 9-52, Gunther Maschinenbau GmbH, Dieburg, Germany). Each belly within treatment had the green weight recorded as well as pumped weight. Once injected, all bellies were heat treated in a smokehouse (Model 700 HP, Alkar, Lodi, WI) and distributed evenly among the smokehouse rack by treatment. Bellies were heat treated to an internal temperature of 50 °C. No smoke was applied while in the smokehouse to allow for more accurate cure color and sensory evaluation. Once the smokehouse cycle was complete, a product weight was recorded. Bellies were then chilled for 24 h to an internal temperature of 4 °C. After chilling, the chilled processed weight was measured. Overall yields were determined using the following formula (chilled weight/green weight*100). Once chilled, bellies were tempered to -4 °C in a freezer and then sliced. Bellies were sliced to 4 mm in thickness with a Berkel slicer (Model 909A, Berkel Company, Bonner Springs, KS) and slices were packaged using an Ultravac (Model 2100, Koch Equipment, Kansas City, MO). The sliced bacon samples, excluding the most posterior portion of the belly, were packaged using the stack pack method. The stack pack

method was utilized to allow for a more proper sampling site during the color score analysis. Additionally, the stack pack method is a form of packaging widely used within the bacon industry. Starting on the most anterior portion of the belly, bellies were sliced and packaged into 0.23 kg packages for use in the color panel, sensory panel, and nitrite analysis. Samples used in the nitrite analysis were randomly selected, 10 per treatment (n = 30), frozen, and stored until analysis.

**Sensory and Color Panels.** Trained sensory panels were conducted according to the American Meat Science Association guidelines (AMSA 1995) for testing and training. All testing involving human participants was approved by the Angelo State University Institutional Review Board (#KEL-030318). Trained sensory panels were conducted on d 0, 7, 14, 21, 28, and 35 (4 samples/treatment; 12 samples/panel; 8 panelist/panel). Samples were cooked in a convection oven for 15 minutes at 177 °C. To ensure even cooking, samples were flipped at seven and a half minutes into cooking. The samples were then cut into pieces measuring 1.27 cm and evaluated for salt flavor, oxidized flavor, and flavor intensity. Salt flavor was measured on a hedonic scale of 8 to 1 (8 = like extremely, 1 = dislike extremely), oxidized flavor was measured on a hedonic scale of 4 to 1 (4 = none, 1 = extreme oxidized flavor), and flavor intensity was measured on a hedonic scale of 8 to 1 (8 = extremely intense, 1 = none).

In addition to palatability sensory panels, panelists (8/panel) evaluated sliced bacon packages on d 0, 7, 14, 21, 28, and 35 (4 samples/treatment; 12 samples/panel) for cured color intensity, cured color characterization, cured color fading, and oxidized odor (AMSA, 2012). Cured color intensity was measured on a scale of 1 to 7 (1 = Very intense cured color, 7 = no cured color), cured color characterization was measured on a scale of 1 to 8 (1 = very dark red cured color, 8 = light pinkish cured color), cured color fading was measured on a scale of 1 to 5 (1 = no fading, 5 = extreme fading), off odor was measured on a scale of 1 to 5 (1 = no off odor, 5 = extreme off odor). Once each package had been evaluated for color, the package was opened slightly, and each panelist was allowed to smell each package to detect the presence of an off odor.

**Microbial Analysis.** Microbial test for Aerobic Plate Count (APC) was conducted on d 1, 15, and 36 of the study. Ten samples per treatment, one sample per belly, (n = 30) were tested on each respective day. Each sample was removed from its packaging, and a 10 gram sample of tissue was collected for each specific sample. Once each sample was weighed, it was placed in a filtered stomacher bag with 90 ml of buffered peptone water. The bag was then placed in a stomacher (Model 400, Seward, UK) and allowed to run for one min. Serial dilutions were performed and one mL of liquid was plated on duplicate APC Petrifilm (3M Microbiology, Maplewood, MN). Once plated, samples were allowed to sit for one min and then placed into an incubator (Model 6021-1, Caron, Marietta, OH) for 48 h at 37 °C. After incubation, plates were counted, and populations were converted to $\log_{10}$.

**Nitrite Analysis.** Bacon samples collected during slicing and utilized for nitrite analysis (AOAC 1990) was conducted on 10 samples per treatment (n = 30). To evaluate each sample, the nitrite ion was withdrawn from the tissue and mixed with the Greiss reagent (sulfanilamide + N-(1-napnhyl)-ethylenediamine) (NED). Each sample was cut and trimmed so that only lean muscle tissue was used for analysis. Lean tissue was weighed to 5 g, frozen in liquid nitrogen, and powdered. The powdered sample was placed into a 50 mL beaker and 40 mL of 80 °C deionized water was added. The solution was then

transferred to a 500 mL flask where additional 80 °C deionized water was added until the solution reached 300 mL. The flasks were then transferred to an 80 °C agitating hot water bath for 2 h. After 2 h, the contents were cooled to room temperature and diluted back to volume with deionized water and 40 mL of the contents was filtered using 15.0 cm VWR® grade 410 filter paper into a 50 mL beaker. After filtration, 2.5 mL of sulfanilamide was added to each beaker and allowed to sit for 5 min. After 5 min, the NED reagent was added and color formation was allowed to take place for 15 min. At the end of 15 min period, samples were read using a spectrophotometer (Evolution 201, Thermo Fisher Scientific, Shanghai China). A standard was prepared using deionized water and a sodium nitrite solution; 0 to 40 mL of nitrite solution was inversely added to 5 to 45 mL of deionized water, with 2.5 mL of sulfanilamide and NED being added to each to create the standard. Once the standard was read, all samples were read at a wavelength of $A_{540}$ and compared back to the standard curve.

**Statistical Analysis.** Data were analyzed using the MIXED models procedure of SAS (SAS Inst. Inc., Cary, NC). Bacon processing, as well as bacon sensory characteristics were analyzed using a completely randomized design with the fixed effect as brine temperature. The experimental unit was each individual package. Least-squares means were computed for each dependent variable, and statistically separated by a pair-wise t-test (PDIFF option of SAS) with a predetermined $\alpha = 0.05$.

## RESULTS

**Smokehouse Yield.** One of the objectives of this study was to determine if brine temperature affected overall smokehouse yield of heat treated bellies (Table 1). Three specific brine temperatures were used, -1 °C (cold), 10 °C (medium), and 21 °C (warm). Pumped percentages were similar ($P > 0.05$) across the treatments. Cooked weight percentage, which was the weight recorded directly out of the smokehouse, was also similar ($P > 0.05$) across the three treatments, as was the chilled processed weight percentage ($P > 0.05$).

Table 1. The effect of brine temperature[1] on the processing yields of bellies.

| | Treatment | | | |
|---|---|---|---|---|
| Item | Cold | Medium | Warm | SEM |
| PP[2] | 112.58 | 112.49 | 113.36 | 0.48 |
| CW%[3] | 101.97 | 101.61 | 102.14 | 0.44 |
| CPW%[4] | 100.69 | 100.37 | 101.10 | 0.40 |

[1]Cold = -1 °C; Medium =10 °C; Warm = 21 °C.
[2]PP = Pumped Percentage; Pumped percentage was calculated using (Pumped Weight-Green Weight)/Green Weight (100).
[3]CW% = Cooked Weight %; Cooked weight was calculating using (Cooked Weight/Green Weight)x100.
[4]CPW% = Chilled Processed Weight; Chilled Processed Weight was calculated using (Chilled Weight/Green Weight)x100.

**Trained Sensory and Color Panels.** Trained sensory panel results (Table 2) revealed no significant differences for salt flavor ($P > 0.05$) between treatments on d 0, d 28, and d 35. However, there were differences detected on d 7, d 14, and d 21. On d 7 and d 14, the medium (5.27; 5.55) treatment revealed significantly ($P < 0.05$) less salt flavor than the

cold (5.75; 6.00) and warm (5.75; 6.06) treatments, respectively. By d 21 the warm (5.47) treatment was rated significantly less ($P < 0.05$) for salt flavor than the cold (5.97) and medium (5.84) treatments. Oxidized flavor for d 1, 7, 14, 21, and 28 were all similar ($P > 0.05$), but by d 35 the cold (3.70) treatment had significantly ($P < 0.05$) less oxidized flavor than the medium (3.55) and warm (3.58) treatments as detected by trained panelist. Significant differences ($P < 0.05$) were found for flavor intensity between treatments on d 14 and d 21, however, results were not consistent. On d 14 the medium brine was significantly less intense ($P < 0.05$) than other treatments and on d 21 the warm brine was significantly less intense ($P < 0.05$).

Trained cured color panelist determined the medium (3.97) brine temperature to have the most intense cured color ($P < 0.05$) on d 35 (Table 3). Additionally, for cured color characterization the medium (4.53) brine temperature also revealed a much darker cured color ($P < 0.05$) as compared to the cold treatment (4.86) and was similar to the warm (4.72) treatment ($P > 0.05$) on d 35. Cured color fading also revealed differences by d 35. The warm (1.91) brine treatment had the least cured color fading, but the warm (1.91) and medium (2.05) brines had significantly ($P < 0.05$) less cured color fading than the cold (2.31) treatment. No significant differences ($P > 0.05$) were found across treatment for off odor.

**Microbial Analysis.** Results of this study indicate the investigated brine temperatures had no effect on overall bacterial growth over a 36 day period (Table 4). No significant differences ($P > 0.05$) were found between the three treatments for d 1, 15, and 36 for Aerobic Plate Counts.

**Nitrite Analysis.** The nitrite portion of this study revealed that the cold (16.86) and medium (13.60) brine treatments were similar ($P > 0.05$), and the medium and warm (12.40) brine treatments were also similar ($P > 0.05$); however, the cold treatment had a significantly higher nitrite content within the finished product ($P < 0.05$) compared to the warm treatment.

Table 2. The effect of brine temperature[1] on trained panelist sensory scores of cured bacon.

| | Salt Flavor[2] | | | | Oxidized Flavor[3] | | | | Flavor Intensity[4] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | Cold | Med | Warm | SEM | Cold | Med | Warm | SEM | Cold | Med | Warm | SEM |
| 0 | 5.38 | 5.47 | 5.64 | 0.13 | 3.89 | 3.94 | 3.95 | 0.04 | 5.50 | 5.63 | 5.64 | 0.13 |
| 7 | 5.75$^{x}$ | 5.27$^{y}$ | 5.75$^{x}$ | 0.13 | 4.00 | 4.00 | 4.00 | 0.04 | 5.73 | 5.39 | 5.73 | 0.13 |
| 14 | 6.00$^{x}$ | 5.55$^{y}$ | 6.06$^{x}$ | 0.13 | 3.98 | 3.97 | 3.97 | 0.04 | 5.92$^{x}$ | 5.50$^{y}$ | 5.86$^{x}$ | 0.13 |
| 21 | 5.97$^{x}$ | 5.84$^{x}$ | 5.47$^{y}$ | 0.13 | 3.95 | 3.89 | 3.95 | 0.04 | 5.91$^{x}$ | 5.83$^{x}$ | 5.48$^{y}$ | 0.13 |
| 28 | 5.58 | 5.53 | 5.59 | 0.13 | 3.97 | 4.00 | 3.98 | 0.04 | 5.66 | 5.56 | 5.63 | 0.13 |
| 35 | 5.67 | 5.78 | 5.95 | 0.13 | 3.70$^{x}$ | 3.55$^{y}$ | 3.58$^{y}$ | 0.04 | 5.77 | 5.81 | 5.88 | 0.13 |

$^{x,y}$Least square means within a row and attribute lacking a common superscript differ ($P < 0.05$).
[1]Cold = -1 °C; Med =10 °C; Warm = 21 °C
[2]8 = like extremely and 1 = dislike extremely
[3]4 = none and 1 = extreme oxidized flavor
[4]8 = extremely intense and 1 = none

Table 3. The effect of brine temperature[1] on objective color scores of cured bacon.

| | Cured Color Intensity[2] | | | | Cured Color Characterization[3] | | | | Cured Color Fading[4] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | Cold | Med | Warm | SEM | Cold | Med | Warm | SEM | Cold | Med | Warm | SEM |
| 0 | 3.92 | 3.94 | 3.83 | 0.12 | 4.78 | 4.81 | 4.92 | 0.12 | 1.69 | 1.48 | 1.55 | 0.09 |
| 7 | 4.17 | 4.05 | 3.98 | 0.12 | 5.05$^{x}$ | 4.67$^{y}$ | 4.78$^{xy}$ | 0.12 | 1.56 | 1.53 | 1.44 | 0.09 |
| 14 | 4.18 | 4.20 | 4.03 | 0.12 | 4.91 | 4.83 | 4.73 | 0.12 | 1.72 | 1.58 | 1.67 | 0.09 |
| 21 | 4.40$^{x}$ | 4.00$^{y}$ | 4.33$^{x}$ | 0.12 | 4.98 | 4.78 | 4.92 | 0.12 | 1.95 | 1.72 | 1.75 | 0.09 |
| 28 | 3.78$^{x}$ | 3.77$^{x}$ | 4.11$^{y}$ | 0.12 | 4.48$^{x}$ | 4.47$^{x}$ | 4.89$^{y}$ | 0.12 | 1.81 | 2.00 | 1.92 | 0.09 |
| 35 | 4.48$^{x}$ | 3.97$^{y}$ | 4.36$^{x}$ | 0.12 | 4.86$^{x}$ | 4.53$^{y}$ | 4.72$^{xy}$ | 0.12 | 2.31$^{x}$ | 2.05$^{y}$ | 1.91$^{y}$ | 0.09 |

$^{x,y}$Least square means within a row and attribute lacking a common superscript differ ($P < 0.05$).
[1]Cold = -1 °C; Med = 10 °C; Warm = 21 °C
[2]1 = very intense cured color and 7 = no cured color
[3]1 = very dark cured color and 8 = light pinkish cured color
[4]1 = no fading and 5 = extreme fading

Table 4. The effect of brine temperature[1] on Aerobic Plate Count (APC) $\log_{10}$ CFU/mL of bacon stored at retail settings.

| | Treatment | | | |
|---|---|---|---|---|
| Day | Cold | Medium | Warm | SEM |
| 1 | 2.22 | 1.99 | 2.45 | 0.25 |
| 15 | 4.93 | 5.47 | 4.93 | 0.25 |
| 36 | 6.98 | 6.60 | 6.78 | 0.25 |

[1]Cold = -1 °C; Medium = 10 °C; Warm = 21 °C

## DISCUSSION AND CONCLUSION

The purpose of this study was to determine if higher brine temperatures would affect brine uptake, smokehouse yields, retail color score, microbial load, and sensory characteristics. Overall yield was not significantly impacted by brine temperature. Three other comparable separate studies also concluded that brine temperature has no effect on cooking yield (Peterson et al. 2017; Keenan et al. 2015; Boles and Swan 1997). All sensory characteristics other than oxidized flavor were not affected by brine temperature. Three previous studies also indicated oxidized flavor rate increased over a period of time (Lowell et al. 2017; Herrick et al. 2016; Lowe et al. 2014). No significant differences ($P > 0.05$) were found for flavor intensity between treatments. This is similar to results found by (Peterson et al. 2017; Keenan et al. 2015), who found little to no differences in overall sensory/quality characteristics. Microbial analysis revealed that there was no difference in bacterial growth across treatments. This is in contrast to a previous study that found higher briner temperatures produced higher microbial counts than a conventional brine (Keenan et al. 2015). Nitrite analysis revealed the highest concentration to be within the cold brine treatment, which is in contrast to Keenan et al. (2015), who found that at elevated brine temperatures nitrite levels would increase. At brine temperatures greater than 10 °C, along with the addition of reducing agents, nitrite is rapidly reduced to nitric oxide, which can react and disappear from the brine; therefore, becoming unavailable to react with myoglobin. In conclusion, brine temperature seemed to have various effects on pork belly characteristics. There was no effect on smokehouse yields related to brine temperature. Additionally, sensory differences were seen for salt flavor, oxidized flavor, and flavor intensity; however, the differences were inconsistent between treatments and within days. Similar inferences can be drawn from the subjective color scores as the sensory scores with the exception of cured color fading. On d 35, the cold brine treatment exhibited significantly higher levels of cured color fading ($P < 0.05$) compared to both medium and warm brine treatments. Microbial analysis revealed no difference in bacterial growth across treatments.

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