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Effect of Sodium Nitrite and Sodium Chloride on the Flavor of Processed Pork Bellies

W. I. Kimoto, A. E. Wasserman and F. B. Talley

USDA-Agricultural Research Service, Eastern Regional Research Center, 600 East Mermaid Lane, Philadelphia, Pennsylvania 19118 (U.S.A.)

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Fresh pork bellies, untreated or pumped with NaCl *or* $NaNO_2$, *or both, were processed with and without smoke. Sensory evaluation of the samples indicated that most of the differences in bacon flavor were due to* NaCl, *with a lesser but significant effect due to* $NaNO_2$.

Introduction

The flavor of cured meat products can be affected by such factors as salt, sugar, spices, smoke, and nitrite. A number of investigators have reported the effect of $NaNO_2$ on the flavor of processed meat products. More cured flavor in nitrite-, compared to no-nitrite-containing meat products has been reported for pork roast (CHO and BRATZLER, ref. 1), frankfurters (WASSERMAN and TALLEY, ref. 2; SIMON *et al.,* ref. 3; SKJELKVALE *et al.,* ref. 4), hams (KEMP *et al.,* ref. 5; BROWN *et al.,* ref. 6), and smoked meat sausage and meat loaf (SKJELKVALE *et al.,* ref. 4). No significant differences in flavors of nitrite- and no-nitrite-containing meat products have been reported for all-beef frankfurters (SIMON *et al.,* ref. 3), and salami tasted at the end of the ripening period (SKJELKVALE AND TJABERG, ref. 7). These reports suggested that the effects of nitrite on flavor of cured meat products varied from pronounced to none.

Few studies have been reported on the effect of nitrite on bacon flavor. BROOKS *et al.* (8) concluded that a satisfactory bacon can be made by using only NaCl and $NaNO_2$, but no sensory data were presented. HERRING (9) reported significantly greater acceptance scores for bacon with than without nitrite. MOTTRAM and RHODES (10), with Wiltshire bacon, concluded that NaCl made a major contribution to flavor, but that flavor increased almost linearly with nitrite concentration (in brines used to pump the pork middles) from 0 to slightly above 1,000 ppm, indicating a flavor-producing reaction between meat and nitrite. These authors also stated that close to the maximum amount of flavor attainable is produced by the moderate levels of nitrite commonly used for bacon production, and reduction in these levels would result in loss of cured flavor.

We have studied the effects of sodium chloride and sodium nitrite on the flavor of processed bellies in an effort to determine the factors involved in the development of bacon flavor.

Experimental

Fresh pork bellies (rind removed), purchased from a local pork processing plant within 3 days of slaughter, were pumped to 110% of green weight with curing pickle, which consisted of 787 ml H_2O, 147 NaCl, 50 g sugar, 4–5 g sodium ascorbate, 1.6 g $NaNO_2$, and 30 g sodium tripolyphosphate. One belly from a matched pair was stitch pumped with the cure pickle and the other was pumped with a cure solution not containing nitrite. One belly from another matched pair was pumped with a cure solution containing nitrite but not NaCl, while the other was processed as is (unpumped). Pumped and unpumped bellies were stored in polyethylene bags at 34 °F (1.1 °C) for 18–24 h. Each belly was cut in half; one half was processed with smoke and the other half without smoke in an air conditioned smokehouse until the internal temperature reached 127 °F (52.8 °C). The processing conditions were: 1 h at 100 °F, (37.8 °C), 1 h at 120 °F (48.9 °C), and 3.5–4.5 h at 132 °F (55.6 °C) (50% RH) with or without heavy smoke (hardwood sawdust). Yields were 100–104%, and 95% of the green weight for pumped and unpumped bellies, respectively. Nitrite content of the lean meat, determined by the AOAC method (15) after sensory evaluation was 80–115 ppm in the bellies pumped with solutions containing $NaNO_2$ and NaCl, and 90–170 ppm in the bellies pumped with nitrite but without NaCl.

Processed bellies that were stored at 34 °F for 12–18 h after processing were placed in the freezer for 1.5–2 h to harden the tissues, sliced about 2 mm thick, and fried for 5 min (turn over every 2 min) in a preheated teflon coated fry pan calibrated at 350 °F. Samples were blotted with paper towels to remove excess fat, wrapped in aluminum foil, and immediately submitted to a panel for evaluation in well ventilated booths under green light. The panel consisted of 18 laboratory personnel experienced, but not trained, in tasting bacon. Each panelist was given 6 samples in random order per taste session. Smoked and unsmoked samples were tasted by the same panelists in the morning and afternoon of the same day.

In experiment 1, a multiple paired comparison, panelists were asked to compare samples with a standard (commercial) bacon and to score the unknown samples for bacon flavor from much more (1), the same (4), to much less (7) flavor than the standard. In experiment 2, in which bellies were processed in the same manner as those in experiment 1 except that sodium tripolyphosphate was omitted from the curing pickle, the samples were rated for bacon flavor, without comparison with a standard, using scores ranging from none (1), moderate (4), to very strong bacon flavor (6). Hidden samples of the commercial bacon used as standard were included in experiment 1. Data were treated by analysis of variance and differences were tested by Duncan's multiple range method (STEEL and TORRIE, ref. 11).

Tab. 1 Taste panel evaluation (experiment 1) of fried bellies processed with different curing solutions[a, b]

	NaCl		No NaCl		Commercial bacon (hidden standard)[d]
	No $NaNO_2$	$NaNO_2$	No $NaNO_2$[c]	$NaNO_2$	
Smoke	4.75	4.40	6.64	6.20	4.46
No smoke	4.75	4.53	6.78	6.14	4.06

Statistical Analysis

Source	df	ss	ms	F
Total	16	502.3462		
Correction factor	1	487.7472		
Days, smoke, days × smoke	3	.0755		NS
Treatment	3	14.2172	4.7391	101.48***
NaCl	1	13.4689	13.4689	288.41***
$NaNO_2$	1	.6807	.6807	14.58**
NaCl × $NaNO_2$	1	.0676	.0676	1.45[NS]
Treatment × smoke	3	.0262		NS
Error	6	.2801	.0467	

[a] Each figure is the mean of 18 tasters each in two experiments
[b] Panelists were asked to compare samples with a standard (commercial bacon) and rate for bacon flavor on a scale of 1–7 (1 = much more, 4 = same, and 7 = much less bacon flavor than the standard)
[c] Plain belly (unpumped)
[d] Scores for the commercial bacon used as the hidden standard tested with smoked and unsmoked samples, respectively
[NS] = not significant, ** significant at P = .01, *** significant at P = .001

Results and Discussion

The results and analysis of the multiple paired comparison test (experiment 1) are summarized in **Tab. 1.** Scores for the two experimental runs (days) did not differ significantly and the effect of smoke was not significant. There was a highly significant difference, however, among treatments, which was further analyzed for effects of NaCl, $NaNO_2$, and the interaction of the two. Most of the difference among treatments was due to the effect of NaCl. Bacon made with NaCl alone was rated as having only slightly less flavor than the control while in the absence of NaCl much flavor was noted. The addition of $NaNO_2$ to the cure also had a significant effect on bacon flavor; in the presence of NaCl, the expected response of enhanced flavor due to $NaNO_2$ was obtained. However, $NaNO_2$ alone could not evoke the same level of response as the control bacon. The data indicate NaCl makes a greater contribution to the bacon flavor as recognized by the panel.

In order to evaluate the significance of the unexpected panel response in the multiple paired comparison test, panelists were requested to score the samples of bacon for bacon flavor intensity based on memory alone, without reference to a standard. This response is purely subjective and although the numerical scores can not be compared with those of the first experiment, the results were similar in that bacon samples prepared with NaCl had a significantly greater amount of bacon flavor ($P < 0.01$) than bacon with no NaCl. In samples containing NaCl there was an increase in flavor rating for those also containing $NaNO_2$ but it was not significant.

Panelists readily identified the samples processed without NaCl and scored them low in bacon flavor. For bellies processed with NaCl panel scores for amount for bacon flavor were slightly, but not significantly, higher for those with $NaNO_2$ than for those without. These results differed from those of HERRING (9) and MOTTRAM and RHODES (10). Herring's studies were based on hedonic measurement of the bacon whereas our evaluation was a comparison of flavor, either with a commercial sample of bacon or with the panelist's memory of bacon flavor, and the information obtained by the two tests is not the same. MOTTRAM and RHODES (10) reported significant differences for Wiltshire bacon cured with 0 and 1,000 or 2,000 ppm (mg/1.) nitrite in brines; comparable nitrite concentration in our investigation is 1,600 ppm. However, the preparation of these two bacon products differed; the Wiltshire bacon of MOTTRAM and RHODES (10) was used green (23–27 kg pork middles were cured but not smoked or cooked), and the rashers used, consisting of the back and belly, were much leaner than our bacon samples (belly only). The cooked products also differed; the Wiltshire bacon was cooked to about medium done, leaving a product with a high fat content and a large proportion of slightly cooked lean meat (MOTTRAM, ref. 12), whereas our bacon was fried to medium-well done so that the product was crisp, but also chewy. While the flavors of these bacons would not be expected to be the same, our taste panel results underline the major contribution of NaCl to bacon flavor, and agree with the findings of MOTTRAM and RHODES (10) on Wiltshire bacon.

The panelists in this study were experienced in sensory evaluation techniques and had evaluated bacon previously, but they were not trained as bacon flavor experts or in descriptive analysis. However, in spite of the variability in bacon flavor due to differences in processing, differences between and within bellies, and differences in the ratio of lean: adipose tissues, the flavor is sufficiently characteristic that it is readily recognized. The reliability of the panel was demonstrated in the first test by their ability to match the hidden standard with the flavor of the nationally distributed, extensively purchased commercial bacon used as the given standard. In the second experiment the mild standard was accurately rated close to "moderate" for bacon flavor.

Bacon flavor is complex and the few identifiable notes are inadequate to describe it meaningfully. The use of an expert panel to explore the changes produced by NaCl is indicated for further study.

Tab. 2 Taste panel evaluation (experiment 2) of smoked processed bellies pumped with different curing pickles[a, b]

	NaCl		No NaCl	F values	
Commercial bacon	No $NaNO_2$	$NaNO_2$	$NaNO_2$	Treatment	Panelist
3.97[c]	3.39[c]	3.72[c]	1.61[d]	12.69**	0.64[NS]

[a] Each figure is the mean of 18 panelists; [b] Samples were tasted separately and rated for bacon flavor on a scale of 1–6 (1 = none, 4 = moderate, and 6 = very strong bacon flavor); [c, d] Horizontal values not bearing same superscript differ significantly ($P < .01$); ** Significant at $P < .01$; [NS] Not significant

Sodium chloride affects the physical and chemical properties of meat; solubility of proteins is increased and muscle juices are more firmly bound (CALLOW, ref. 13; HAMM, ref. 14). These changes might alter the flavor of processed bellies. The texture of fried bacon from bellies processed with and without NaCl differed. Without NaCl the fried slices were crisp, whereas with NaCl, they were more chewy. When the processed unpumped belly (no NaCl, no $NaNO_2$, **Tab. 1**), in which the proteins were partially denatured, was pumped with the curing pickle (8% of belly weight) and again processed by the bacon schedule with smoke, the characteristic pink, cure color was obtained. On frying, however, the bacon was still crisp, as opposed to the texture of normal bacon, and, although NaCl added a salty flavor, the sample did not taste like bacon. Our results indicate that products with an identifiable bacon flavor can be produced in pork bellies processed without nitrite. The stability of flavor during storage, however, was not determined. Results reported by HERRING (9) indicate that bacon flavor will be more stable in the product cured with $NaNO_2$.

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