

Processing and sensory evaluation of a primal cut cured with nitrite alone or nitrite-nitrate mixture

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In 1975, the Expert Panel on Nitrosamines appointed by the Secretary of the United States Department of Agriculture proposed eliminating nitrate salts from cured meat products (USDA 1975). The traditional saltpeter used in cures for many centuries has been coupled with nitrite in recent years as information developed indicating nitrate was reduced to nitrite, which is the actual active component. Several kinds of cured meat, however, are still currently processed with nitrate only or mixtures of nitrate and nitrite. Dried beef is one of these products, cured by immersion for as long as 6 weeks in a brine containing nitrate and nitrite. Consultation with several producers of dried beef who had tested an all-nitrite cure revealed dissatisfaction with the process, including concern over the increased occurrence of uncured areas in the pieces of meat. Other users of the nitrate cure insisted that the flavour differed from that with nitrite cure.

In an effort to learn more about the process of curing meat for dried beef, and probably other primal cuts of meat cured in a similar manner, we examined the process and the product.

Materials and methods

Sirloin tips, weighing 7–9 lb (3–4 kg), and known in the trade as beef knuckles, were loaded into plastic vats to a total weight of 1500 lb (781 kg) and covered with 75 gallons (288 litre) of cure brine. The brine contained salt at a mass concentration of 242 g litre⁻¹, sugar at about 30 g litre⁻¹ and the appropriate cure ingredients. The conventional brine contained NaNO₃ 7750 mg litre⁻¹ and NaNO₂ at 1670 mg litre⁻¹; the experimental brines were prepared with NaNO₂ at 2200 mg litre⁻¹. Curing was at 5 °C and the meat was turned once every week by transferring to another vat, and covering with the same brine. Single knuckles were removed from the brines after 1, 3, 5 and 6 weeks for analysis. Samples of the brine were also taken for analysis. After 6 weeks, the cured beef knuckles were dried at 65 °C for about 3 days to achieve a yield 60–65% of the original mass of the meat.

Nitrite and nitrate analyses were by the methods of US-AOAC (1975); nitrate concentrations were also estimated with the nitrate-specific electrode. After direct extraction by the method of Fiddler et al. (in preparation), samples of meat were analysed for dimethylnitrosamine (DMN), diethylnitrosamine (DEN), methylethyl-

nitrosamine (MEN), *N*-nitrosopyrrolidine (NPyr), *N*-nitrosopiperidine (NPip), and *N*-nitrosomorpholine (Mor). Chloride was measured with the chloride-specific electrode placed on the surface of the meat.

The dried beef was assessed with groups of about 40 laboratory staff in a consumer-type panel. A paired-comparison test was used to establish difference in flavour between samples, and those panelists noticing a difference were asked to indicate a preference for one of the pair. A 9-point hedonic test was also used to evaluate consumer acceptance of the dried beef. Creamed chipped beef was prepared from a white sauce plus dried beef pieces and evaluated with the hedonic test. Statistical significance was determined by standard methods (Amerine et al. 1965).

The brines were evaluated microbiologically. Total number concentration of aerobes was estimated on regular APT agar and an APT agar with 10% NaCl. Yeasts were detected on potato dextrose agar and Rogosa SL medium was used to identify lactic acid bacteria. Micrococci were detected on mannitol salt agar. All plates were incubated at 25 °C for 4–5 days. All media were obtained from Difco Laboratories¹.

Results and discussion

Microbiologically there was little difference between brines containing NO_2^- alone and those containing NO_2^- – NO_3^- . The total number concentrations of viable cells in brine were low, beginning with 10 – 10^2 per ml and attaining 10^7 per ml in the NO_2^- – NO_3^- brine and 10^6 per ml in the NO_2^- brine in 5–6 weeks. Yeast predominated, although gram + rods and cocci, both catalase positive and negative, were present in substantial numbers. The composition of the brine did not influence composition of the developing flora.

The pH of the brines initially was 7.0 for the NO_2^- – NO_3^- brine and 6.6 for NO_2^- . After 1 week, the pH of both types had dropped to 5.5–5.6. The experimental NO_2^- brine remained at pH 5.6 through the 6-week curing period, whereas the pH of the regular brine dropped gradually to 5.2.

The content of sodium chloride in the meat was measured, beginning with samples from the third week of cure. Diffusion of salt into the meat was shown by analysing samples from the surface and from the centre of the piece. Variations occurred since different pieces of meat were used at each time interval but, as expected, the content of NaCl was greater at the surface than at the centre after three weeks (Table 1). Maximum salt content in the surface of the meat was attained after about 5 weeks of curing and then declined, possibly through changes in osmotic pressure. The highest mass fraction of salt recorded was 75–88 g/kg. On soaking the meat, salt was removed principally from the surface. The dried product contained much salt: 160–210 g/kg at the surface and about 120 g/kg at the centre.

The fate of the nitrite and nitrate in the brines and the meat is shown in Table 2. The regular brine formula contained a substantial amount of NO_3^- (7 750 mg/litre) and about 35% of it disappeared in the first week, levelling off at a residual 40%

1. Reference to brand or firm name does not constitute endorsement by the US Department of Agriculture over others of a similar nature not mentioned.

after 5 weeks. Little nitrate appeared in the experimental NO_2^- brine. The nitrite concentrations of the regular and experimental brines were 1 670 and 2 200 mg/litre, respectively. The rate of disappearance of NO_2^- from the two brines was about the same, with 52–56% disappearing in 1 week and 90% in 6 weeks. The presence of nitrate in the regular brine had little effect on the concentration of nitrite.

In the meat removed from regular brine, content of nitrate increased with a gradient from the outside of the piece to the centre, ranging from 2 300 to 1 600 mg/kg. Sodium nitrite reached about 300 mg/kg in the outer layers and increased from 0 to almost 100 mg/kg at the centre. Meat cured with nitrite only contained NaNO_3 – up to 127 mg/kg at the third week and 103 mg/kg in the dried product.

Table 1. Effect of curing with NO_3^- and NO_2^- or NO_2^- alone on content of NaCl in cured beef. t , time (of curing).

t /week	Site	NaCl content/g kg ⁻¹	
		NO_3^- & NO_2^-	NO_2^-
3	surface	53	40
	centre	36	10
5	surface	76	88
	centre	44	64
6	surface	63	64
	centre	49	54
Dried	surface	205	158
	centre	115	117

Table 2. Nitrite and nitrate in brine and beef. t , time (of curing); w , mass fraction (content); ρ , mass concentration; Reg, regular NO_3^- and NO_2^- brine; Exp, NO_2^- brine.

t /week	Brine				Beef				
	$\rho(\text{NO}_3^-)/\text{mg} \cdot \text{litre}^{-1}$		$\rho(\text{NO}_2^-)/\text{mg} \cdot \text{litre}^{-1}$		site	$w(\text{NO}_3^-)\text{mg} \cdot \text{kg}^{-1}$		$w(\text{NO}_2^-)\text{mg} \cdot \text{kg}^{-1}$	
	Reg	Exp	Reg	Exp		Reg	Exp	Reg	Exp
0	7748	5	1670	2208		---	---	---	---
1	5120	10	814	968	Surface	827	69	68	40
					Centre	152	16	0	0
3	4129	6	570	740	Surface	1813	127	300	391
					Centre	1200	104	48	46
5	3126	5	174	326	Surface	2384	58	248	408
					Centre	1303	74	77	210
6	3000	8	157	276	Surface	2278	112	258	346
					Centre	1600	98	92	190
Dried						3097	103	37	26

Content of NaNO_2 in this meat were a little greater than in the meat from the regular cure.

Contents of NaNO_2 in both products after drying, smoking and storage were about the same: 26–37 mg/kg. These low values in the final consumer package give no indication of the amounts to which the meat was exposed during immersion nor the danger of nitrosamine formation. None of the nitrosamines tested for were detected in the knuckles cured with the regular brine (Table 3). However, in the nitrite – cured samples, contents of 3–4 $\mu\text{g}/\text{kg}$ of dimethylnitrosamine were found after 3 and 5 weeks, respectively, and the final cured dried product contained 14 $\mu\text{g}/\text{kg}$.

Table 3. Dimethylnitrosamine in cured dry beef with regular cure (Reg, nitrite and nitrate) and with the experimental cure (Exp, nitrite only). w , mass fraction (content); t , time (of curing); –, not detected (dimethylnitrosamine was confirmed by mass spectrometry in all samples where it was detected).

t/week	$w(\text{dimethylnitrosamine})/\mu\text{g} \cdot \text{kg}^{-1}$	
	Reg	Exp
0	–	–
1	–	–
3	–	3
5	–	4
6	–	–
Dried beef	–	14

Table 4. Sensory evaluation of dried beef. A = beef cured in regular $\text{NO}_3^- - \text{NO}_2^-$ brine. B = beef cured in NO_2^- brine. O = dislike extremely; 5 = neither like nor dislike; 9 = like extremely. * $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$; NS, $P \leq 0.05$.

Cure	Difference		Preference of 'Yes'
	No	Yes	
Pooled A vs Pooled B	3	38***	30 – Pooled A**
7A vs 6B	11	27*	18 – 7A ^{NS}
7A vs 5B	18	22 ^{NS}	17 – 7A*
5A vs 2A	10	34***	19 – 2A ^{NS}
6A vs 7A	19	24 ^{NS}	13 – 7A ^{NS}
3B vs 4B	21	19 ^{NS}	11 – 3B ^{NS}
1B vs 2B	19	21 ^{NS}	17 – 1B**

Table 5. Hedonic test. Scores with the same index (a, b, c) are not significantly different.

	Cure	Number of panelists	Score
Dried beef	5B	44	5.72 ^c
	6B	45	5.36 ^c
	1A	28	6.93 ^d
	7A	22	6.67 ^d
Cream chipped beef	2A	43	7.02 ^e
	6B	34	6.55 ^e

No evidence of uncured areas was found in the nitrite-treated knuckles. The apparently random occurrence of these areas, and the fact that they were observed only after the dried product was sliced, made it difficult to determine the cause. Studies are being conducted on the diffusion of cure ingredients into meat in an effort to understand this cure process more fully.

Sensory evaluation of pooled dried beef samples cured in NO_3^- and NO_2^- or NO_2^- only showed that a significant number of panelists could detect a difference between them and that the number of the panelists preferring the dried beef cured in the regular brine was significant. However, there were variations in flavour between knuckles cured in the same brine which might account, in part, for the results obtained (Table 4).

In a hedonic test (Table 5), the beef cured in NO_2^- only was rated an average of 5.5 (neither like nor dislike) whereas the NO_3^- - NO_2^- cured beef scored 6.8 ('like'). The regular-cure product was thus more acceptable. However, there was a general impression that a consumer would accept the NO_2^- cured product if the regular-cure beef were not available for comparison.

Since the extreme saltiness of the dried beef could have affected the panelist responses, it was decided to evaluate the products as creamed chipped beef, which is probably the most familiar preparation of dried beef. A hedonic comparison of one sample each of the regular-cure and experimental-cure beef in this form showed that both preparations were well accepted.

Studies are continuing, not only with beef knuckles cured in NO_2^- brine but also with knuckles injected with pickle containing lower concentrations of nitrite and immersed in brines of various composition, in an effort to produce a product acceptable to the consumer with a minimum of nitrite or nitrate in the curing process.

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Nitrate-free curing

This paper has some additional points of interest in the general comparison of nitrate-free with traditional cures. In practice, the result of eliminating nitrate is that brines contain more nitrite and that nitrite concentrations in the surface of the meat are correspondingly higher immediately after cure. In the system with nitrate, the critical microbiological question is what decides whether the nitrate is reduced during storage and distribution. Anaerobic conditions favour this; otherwise the critical factors are obscure.

A later paper on methods suggests strongly that most reports of nitrate being produced from nitrite are procedural artefacts. Because of this phenomenon, it is regarded as impossible to legislate for zero nitrate and control embracing nitrate and nitrite on equal terms should be envisaged.