IRRADIATED BACON WITHOUT AND WITH REDUCED ADDITION OF NITRITE

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INTRODUCTION

BACON, and the use of nitrite in its cure has been a controversial subject in the United States during the last year. The study of Paul Newberne of Massachusetts Institute of Technology (Newberne, 1979), which indicates a possibility that nitrite itself is carcinogenic, received a severe criticism by the General Accounting Office and by the U.S. Congress (Anon.(a)(b), 1979). The U.S. Food and Drug Administration (FDA) contracted with the Universities Associated for Research and Education in Pathology (UAREP) to perform a full-scale pathological review of the Newberne study, the results of which should be available to the public at the time of this Congress. Even though the results of the UAREP study is not known at this time, some information is unofficially circulated among the meat specialists, consumers and the news media, that the Newberne study has some shortcomings and that the experiment has to be repeated. It means that the 12-month moratorium on any regulatory action against nitrite ended on 1 May 1980. However, it does not mean that the problem with nitrite in curing bacon and other cured meats has been ended. According to S.A. Miller of FDA (1980), the FDA's concern is not limited to questions of carcinogenesis of nitrite but includes also a number of other toxic responses which need to be considered in any safety evaluation of nitrite in addition to the nitrosamine problem (Ember, 1980). The policy of the U.S. regulatory agencies regarding the use of nitrite in bacon and other cured meats, as stated by S.J. Butler from the U.S. Department of Agriculture at the 1979 IFT Food Microbiology Division Symposium is still valid today and can be summarized as follows: (a) the nitrite issue is a real issue; (b) it is going to continue to receive public comment, since it goes to the very heart of the food safety debate; and (c) we have to take a serious approach to seeking alternatives to nitrite (Butler, 1980).

NITRITE is a unique food additive: (a) it provides protection against C. botulinum in association with other curing ingredients in cured meats (Christiansen,1980); (b) it affects the quality of the products desired by the consumers: color, flavor; and (c) it provides protection against oxidative changes. Therefore, it is a difficult problem to find a suitable alternative to nitrite in cured meats. Sofos and Busta (1980) in their recent review of the subject summarize the available information on the alternatives, which have the potential to at least partially replace nitrite: (1) Addition of high salt concentration to control C. botulinum (but the resulting products are very salty and unacceptable to the consumers and health authorities); (2) Acidification by adding organic or inorganic acids, or lactic acid starter cultures along with fermentable carbohydrates (the use of lactic acid starter cultures in bacon processing was allowed by the USDA in February 1979); and (3) the use of sorbate at 0.26% with 40 ppm sodium nitrite (disallowed by the USDA because of apparent allergic and possible mutagenic effects of sorbate).

IRRADIATION is the most promising alternative to nitrite in bacon and some other cured meats because it destroys C. botulinum and other meat spoilage microorganisms. Therefore, two applications are possible in irradiated bacon and other cured meats: (1) complete elimination of nitrite from the cures; or (2) reduction of nitrite to the low levels needed only for development of the characteristic color and flavor of the products. Examples of the feasibility of the use of irradiation for preservation of cured meats with greatly reduced nitrite and without nitrite are given by Wierbicki and Heiligman (1973), Wierbicki et al. (1974, 1975, 1976),and Wierbicki (1979)). At the 25th EMMRW, Wierbicki and Brynjolfsson (1979) presented the results on their first experiment on low-dose irradiated bacon, vacuum packed in 1-pound transparent plastic film. It was shown that the bacon without nitrite was an acceptable product which, however, after frying was different in color and flavor from what consumers are used to in nitrite-cured bacon. In this paper, confirmatory results will be presented on sensory and chemical characteristics of U.S. bacon, vacuum packed in commercial 1-pound units, using three levels of nitrite (0, 20 and 120 ppm), followed by irradiation and refrigerated storage up to 102 days.

EXPERIMENTAL

Raw Material. - The bacon was procured from an industry source using our curing formula as given in Table 1 (Bacon - Expt. 5). At the slicing time, representative slices of each lot were withdrawn for the determination of the proximate composition (Table 2). The product was vacuum packed in 1-pound units using commercial bacon

Table 1 - BACON - EXPT 5: Intended additions of curing components*

Cure	NaCl %	Sucrose %	Na-TPP %	Na-Eryth. ppm	$NaNO_2$ ppm
A	1.5	0.75	0.3	550	0
B	1.5	0.75	0.3	550	20
C	1.5	0.75	0.3	550	120

*Based on 12.5% pump and 11% pickle retention

Table 2 - BACON EXPT. 5: Proximate composition of the product 2 days after smokehouse processing

Cure	Added $NaNO_2$ ppm	Proximate Composition						
		H_2O %	Protein %	Fat %	NaCl %	Na-Eryth ppm	$NaNO_2$ ppm	pH
A	0	36.9	10.1	49.4	1.5	200	0.5	6.08
		36.7	10.3	49.3	1.4	197	0.5	6.19
B	20	35.3	10.5	50.2	1.5	223	7	6.15
		35.0	10.5	51.5	1.5	229	5	6.12
C	120	36.8	10.6	49.6	1.6	224	33	6.14
		36.8	10.7	48.6	1.5	215	37	6.08

packaging material (a transparent laminate of uncoated Nylon, polyethylene and Surlyn). After packaging, the three lots of bacon were shipped to Natick for irradiation. The item arrived at the 4th day after packaging; the product's temperature on arrival was -2°C. The product was irradiated in the 1-pound units at 4°+1°C at the 7th day after packaging, then placed into a 5°C refrigerator for storage and evaluation. The Natick 10 Mev Electron Accelerator was used for the irradiation with the doses of 2.2, 7.5 and 15 kGy at the dose rate of $5X10^8$ rads/sec.

Evaluation - The products were evaluated for: (a) Odor of irradiated and nonirradiated raw bacon samples; (b) Aerobic plate count (APC) of raw bacon (Microbiology Group, Food Science Lab., Natick); (c) Color of raw bacon; (d) Sensory testing for color, odor, flavor and texture of fried bacon by a trained panel using the 9-point quality scores (1 = extremely poor, 5 = fair, 9 = excellent; Wierbicki and Heiligman, 1973); (e) Preference tests of fried bacon by a consumer panel using the9-point hedonic scale by Peryam and Pilgrim (1957) (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely); and (f) the fat oxidation indeces - TBA, PV and FFA (Tarladgis et al., 1960; Anon. (c), 1970).

Other evaluation, to be reported separately, included: (1) Sensory evaluation of bacon irradiated with 30 kGy sterilizing dose (Anellis et al., 1965) at +5°C and -40°C; (2) Fatty acid profile of irradiated and nonirradiated bacon; (3) Thiamine retention; and (4) Radiolysis products (Angelini and Wierbicki, 1980). Nitrosamine analysis in irradiated bacon was conducted separately (Fiddler et al., 1980).

RESULTS

Destruction of Spoilage Microorganisms and Shelf Stability. Table 3 gives the APC for the bacon samples stored in a 5°C refrigerator for 102 days. Irradiation with 7.5 and 15 kGy destroyed the bacon spoilage microorganisms and resulted the product shelf stable. This confirms our previous results (Wierbicki and Brynjolfsson, 1979). The nonirradiated samples regardless of the nitrite level developed the APC above 10^6 in 64 days storage and were definitely spoiled and unacceptable for consumption. Inspection for off-odor by trained technologists lead to the following conclusions: (a) nonirradiated bacon cured without nitrite developed a putrid odor after 30 to 45 days refrigerated storage; (b) the bacon cured with 20 to 120 ppm added nitrite developed an objectionable sour-type off-odor after 45 and 60 days storage, respectively. The irradiation with only 2.2 kGy gave a protection against bacterial spoilage for only 15 to 30 days refrigerated storage. After 42 days storage an objectionable sour (but not putrid) off-odor was detectable and after 64 days storage, the samples were considered unacceptable. The APC data for the 2.2 kGy irradiated bacon indicate that the irradiation in the range of 0.3 to 2.5 kGy might be useful to destroy the putrifactive microorganisms like Pseudomonas while leaving lactic acid producing species in the product (for relative resistance of various food microorganisms to radiation, see(Ingram, 1975). It opens a great opportunity for using low doses of irradiation for selective destruction of meat spoilage microorganisms, for example, in vacuum packed boxed beef and chopped beef for hamburgers for increasing the shelflife and the microbial control of the products prepared under Good Manufacturing Practices.

Table 3 BACON EXPT. 5: Aerobic Plate Count (APC) of Raw Bacon Samples Stored at 5° + 1°C

Storage Days[1]	Cure A: 0 $NaNO_2$				Cure B: 20 ppm $NaNO_2$				Cure C: 120 ppm $NaNO_2$			
	0[2]	2.2[2]	7.5[2]	15[2]	0	2.2	7.5	15	0	2.2	7.5	15
14	$5.2x10^2$	$<10^3$	x	x	$3.8x10^2$	<10	x	x	$3.4x10^2$	<10	x	x
	$6.2x10^2$	<10			$3.0x10^2$	<10			$6.3x10^2$	<10		
42	$9.0x10^6$	$2.2x10^4$	<10	x	$1.3x10^7$	$3.3x10^4$	<10	x	$5.5x10^5$	$1.8x10^2$	<10	x
	$2.2x10^8$	$6.1x10^4$			$3.6x10^5$	$6.4x10^2$			$1.2x10^6$	<10		
64	$2.5x10^8$	$6.9x10^6$	<10	x	$2.2x10^8$	$8.6x10^6$	<10	x	$7.0x10^7$	$5.8x10^6$	10	x
	$9.3x10^7$	$7.7x10^6$			$5.4x10^7$	$4.7x10^7$			$1.4x10^8$	$3.2x10^5$		
87	xx	$2.5x10^6$	<10	<10	xx	$1.4x10^8$	<10	<10	xx	$1.2x10^8$	<10	<10
		$9.8x10^7$				$9.3x10^7$				$9.5x10^6$		
102	xx	xx	<10	<10	xx	xx	<10	<10	xx	xx	<10	<10

[1] Days after vacuum packaging of the samples at a bacon processing plant.
[2] Irradiation doses at 5°C: 0, 2.2, 7.5 and 15 kGy; the samples were irradiated 7 days after packaging.
[3] 10 = Negative at 1:10 dilution.
x APC not determined; the expected count < 10/g.
xx APC not determined; the samples were definitely spoiled.

Color of Raw Bacon. - Irradiation of vacuum packed bacon cured with 20 and 120 ppm nitrite did not cause visual changes in color. However, irradiation of the bacon cured without nitrite, changed the color from undesirable grayish-brown of uncured pork to pinkish-red, which is comparable to the color of the nitrite cured bacon. This desirable color change is increased with the increased dose of irradiation (Table 4). The color change is due to the reduction of the ferric to ferrous state of the meat pigment myoglobin (Kamerei et al., 1979). The 7.5 and 15 kGy irradiated samples of bacon cured without nitrite were placed into a display case for 56 days storage under light of 4.5°C. The product retained the color as well as the freshness, whereas the nonirradiated samples turned from grayish-brown to pinkish-yellow and had a putrid-sour odor after 56 days storage. It was also observed that the bacon samples with no-vacuum ("leakers") turned gray after irradiation, regardless

Table 4. BACON - EXPT. 5: Effect of irradiation on the color of raw bacon, cured without nitrite, after 42 days storage at 5°C. (Tech. Panel,n = 13)

Cure	Added $NaNO_2$ ppm	Irrad kGy	Color Scores M ± SD
A	0	0	2.4 ± 1.4
		2.2	4.5 ± 1.5
		7.5	5.5 ± 1.6
		15	6.3 ±0.9
C[1]	120	0	7.4 ± 0.5
LSD	(0.5)		0.44

[1] Reference nonirradiated,commercial cure, bacon sample.

Table 5. BACON EXPT. 5: Effect of irradiation on the Fat Oxidation Indeces

kGy at 5°C	TBA[1]			PV[2]			FFA[3]		
	A	B	C	A	B	C	A	B	C
0	.16	.17	.06	0	0	0	.57	.84	.85
	.09	.07	.09	0	.25	0	.55	.96	.60
2.2	.19	.13	.08	0	0	.23	.76	.77	.69
	.18	.13	.09	0	0	0	.59	.92	.64
7.5	.40	.19	.15	.18	0	0	.38	.58	.72
	.38	.26	.19	0	0	0	.94	,53	.93
15	.35	.35	.19	.21	.18	0	.72	.38	.49
	.52	.37	.25	.22	.32	0	.43	.49	.90

Cures: A - no nitrite; B - 20 ppm $NaNO_2$; C -120 ppm $NaNO_2$.

1 TBA - mg malonaldehyde/1000 g. sample

2 PV - peroxide value, meqs. 0_2/kg fat;

3 FFA - free fatty acids as % of oleic acid in fat.

Table 6 - BACON - EXPT. 5: Sensory quality of nonirradiated bacon

Cure	Added $NaNO_2$ ppm	Sensory Quality (n=11)				Pref.[1] Scores
		Color	Odor	Flavor	Texture	M±SD
A	0	5.3±2.0	7.2±1.0	6.9±0.9	6.2±1.5	6.00±1.74
B	20	8.0±0.9	7.5±0.8	7.6±1.0	7.1±1.3	6.67±1.29
C[2]	120	8.0±1.2	7.4±0.9	7.5±1.0	7.1±1.2	6.94±1.17
LSD (.05)		1.23	NSD	NSD	NSD	0.55

1 - Consumer panel, randomized block, 3 of 3, 36 subjects.

2 - Reference sample, commercial cure.

of the nitrite addition.

Fat Oxidation Indeces. - Irradiation of fatty foods without vacuum causes oxidative changes in the foods (Wierbicki et al., 1975). Table 5 gives the fat oxidation indeces (TBA, PV and FFA) for the nonirradiated and irradiated bacon cured with the three levels of nitrite after 25 days storage at 5°C following irradiation. All samples had a good vacuum. As the data indicate, irradiation within the dose range of 2.2 to 15 kGy did not cause measurable changes in PV and FFA and only minor increase in the TBA values. This area is being investigated further.

Sensory Evaluation. - Table 6 gives the sensory data for nonirradiated bacon samples cured with the 3 levels of nitrite after 22 days storage at 5°C. The mean scores of 5 or above, are indicative of products of good quality that can be expected to gain acceptance by a broad range of consumers. As the data indicate, the bacon cured without nitrite (Cure A) received highly acceptable ratings. The rating for color was significantly lower, as could be expected, since after frying,the bacon of Cure A was reddish brown rather than pink. However, this difference in the color did not greatly affect the consumer preference, even though the preference score for no-nitrite bacon was significantly lower than for the nitrite cured bacon. Similar results were obtained on the bacon from the same lots evaluated after 14 days storage. It should be emphasized that some consumers and visitors preferred no-nitrite bacon over nitrite cured bacon. It is also possible that the preference scores for no-nitrite bacon might be higher if the bacon would be served separately from other samples to the consumers. This should be investigated. The data in Table 6 further indicate that the bacon sample cured with only 20 ppm nitrite received equally high scores as the 120 ppm nitrite cured bacon, thus confirming our previous experiment (Wierbicki and Brynjolfsson, 1979). Even though, the reduction of nitrite from 120 to 20 ppm is possible under good commercial quality control practices, for practical reasons, the reduction to 40 ppm added nitrite is recommended. Based on our experiments, the bacon cured with 40 vs. 20 ppm nitrite is free from residual nitrite and nitrosamines after irradiation (Wierbicki and Brynjolfsson, 1979) and there is better assurance for elimination of undercured spots in bacon cured with reduced nitrite while using less sophisticated commercial pumping equipment. The high quality of bacon we could consistently produce in our experiments is also due to our cure composition (Table 1) which results the product of the group, classified by Cerveny (1980), as the mild cured products which are desired by the consumer.

Table 7 - BACON - EXPT. 5: Sensory quality of irradiated bacon after 25 days storage at 5°C in comparison with fresh nonirradiated reference bacon samples

Cure	Added $NaNO_2$ ppm	Irradn. kGy*	Sensory Quality (n = 9):				Preference Scores[1]
			Color	Odor	Flavor	Texture	M ± SD
A	0	7.5	3.9±1.5	6.3±1.1	5.7±1.2	5.0±1.0	5.34±1.92
		15	6.0±1.1	6.9±0.6	6.1±1.1	6.0±1.0	6.06±2.15
B	20	7.5	6.8±1.2	7.0±1.2	7.0±0.7	7.0±0.9	6.51±1.79
		15	7.4±1.1	6.9±0.9	6.0±1.9	6.6±1.5	6.37±1.49
C[2]	120	0	7.9±0.6	7.4±0.7	7.2±0.7	7.2±1.0	7.20±1.05
LSD	(<0.5)		1.08	NSD	1.13	1.04	0.56

1 Consumer panel, randomized block, 5 of 5, 35 subjects.

2 Reference, nonirradiated, commercial cure bacon sample kept frozen until the test.

Table 7 presents sensory quality data and consumer acceptance for 7.5 and 15 kGy irradiated bacon, cured without and with the reduced nitrite addition, after 25 days storage following irradiation in comparison with nonirradiated, 120 ppm nitrite cured bacon. As the data indicate, high quality irradiated bacon can be made with the reduced nitrite addition to only 20 ppm (or without nitrite at all, provided the color is acceptable to the consumer). The bacon samples of the same treatments were tested after 14 and 55 days storage and the results were similar. The slightly higher preference scores for the reference (120 ppm $NaNO_2$) bacon might be due either to the higher nitrite addition or to the fact that the reference bacon sample was "fresh" and was not subjected to the storage effect. Another taste testing arrangement has to be made to elucidate this point.

Other evaluations.

Inoculated pack study was conducted on irradiated No-nitrite and 20 ppm nitrite bacon in comparison with the nonirradiated 120 ppm nitrite bacon followed by incubation at 27°C for 60 days. Preliminary data indicate that the 15 kGy irradiation of No-nitrite and 20 ppm nitrite bacon is as safe or more safe against botulism than the commercial bacon with 120 ppm nitrite (Anon.(d)). More work in the field is anticipated.

Nitrosamines were determined on only few samples in this study and the results confirmed the previous results that No-nitrite and 20 ppm nitrite irradiated bacon is free from nitrosamines (Wierbicki and Brynjolfsson, 1979). A special, well-controlled study on nitrosamines in irradiated bacon was conducted in association with the USDA Laboratory in Philadelphia and the results of this study are presented at this Congress by Fiddler et al.(1980).

CONCLUSIONS

1. Irradiation very effectively destroys C. botulinum in bacon and other foods. This allows to produce "mild cure bacon" either without nitrite or with greatly reduced nitrite addition.

2. The bacon processed without nitrite has a characteristic color after irradiation, while in the raw state, which changes to reddish brown of uncured pork after frying. Odor, flavor, texture and consumer preference are in an acceptable range.

3. The reduction of the added nitrite from 120 ppm to 20-40 ppm in irradiated bacon is feasible. The product cured with this reduced level of nitrite has all the quality characteristics of the commercially cured (with 120 ppm nitrite) bacon in the raw state and after frying.

4. The product cured without nitrite or with only 20 to 40 ppm added nitrite contains no residual nitrite, no detectable NDMA, and no detectable or only traces (1 to 2 ppb) of nitrosopyrrolidine (NPYR).

5. The irradiation in the range of 20 to 30 kGy results in a sterile product which can be stored without refrigeration in hermetically sealed containers. The irradiation dose, lower than 20 kGy, to provide protection against botulism in raw bacon (cured without or with the reduced addition of nitrite, vacuum packed in conventional commercial packaging for refrigerated distribution) is still not definitely established.

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