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KANSAS STATE UNIVERSITY SWINE INDUSTRY DAY 2015

Influence of Carcass Fat Iodine Value and Packaging Type on Shelf-life of Bacon Slices Packaged for Hotels, Restaurants, and Institutions (HRI) [1]

A. M. Tapian, B. L. Goehring, J. A. Unruh, B. M. Gerlach, G. D. McCoy, J. M. DeRouchey, R. C. Johnson[2], S. S. Dritz[3], J. M. Gonzalez, M. J. Matney, and T. A. Houser

Summary

Pork carcasses were selected for fat iodine value (IV) using a NitFom™ sensor. Carcasses were sorted into 3 IV categories, with the target IV range defined as 58 to 63 (low), 68 to 73 (intermediate), and 78 to 83 (high). Seventy-two pork carcasses were identified and bellies collected from both the right and left sides of the carcass for a total of 144 bellies in the study, with 48 bellies (24 carcasses) in each IV category. This experiment had 3 IV treatments, with an average measured carcass IV of 66.5 g/100g (low), 72.6 g/100g (intermediate), and 77.9 g/100g (high) and 2 packaging treatments (aerobic and anaerobic). Fresh bellies were analyzed for dimensional characteristics (weight, length, width, and thickness) and belly firmness. From each belly, 10 sheets of bacon with 7 slices per divider sheet were laid out representing 10 storage dates (d 0, 28 56, 70, 84, 98, 112, 126, 140, and 154) for lipid oxidation analysis. Bacon slices were analyzed for oxidative rancidity and fat color (L* a* b*) for every shelf life storage date. After packaging, bacon slices were stored at 0 °F for the remainder of the storage period. Day 0 bacon was analyzed for fatty acid composition, pH, and proximate composition. Bacon manufactured from high IV category carcasses had a greater ($P < 0.05$) analyzed IV compared to the intermediate or low IV category, with mean IV values of 76.9, 70.9, and 67.7 g/100g respectively. Belly firmness decreased ($P < 0.05$) as the IV category increased. Bacon slices were not different in proximate composition (fat, moisture, and protein) or pH. High IV bacon samples had greater ($P < 0.05$) percentages of linoleic acid, linolenic, and total polyunsaturated fatty acids; and decreased ($P < 0.05$) percentages of myristic, palmitic, stearic, and total saturated fatty acids compared with the low IV category. Aerobic and anaerobically packaged bacon from the high IV group had lower ($P < 0.05$) L* compared with low IV group. After d 0, aerobically packaged bacon

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had lower a* values on every sample day through d 154 ($P < 0.05$). Anaerobically packaged bacon had higher a* values on every sample day after d 0 through d 154 ($P < 0.05$). Increasing storage time from d 0 to 154 increased ($P < 0.05$) b* values for both aerobic and anaerobic packaging treatments. Thiobarbituric acid reactive substances (TBARS) did not differ between IV categories. Aerobically packaged bacon had greater ($P < 0.05$) TBARS from d 0 compared to d 28. Thiobarbituric acid reactive substances values were also greater from d 28 to d 154 for aerobically packaged bacon. Thiobarbituric acid reactive substances values for anaerobically packaged bacon did not increase from d 0 to 84. Soluble collagen, insoluble collagen, and total collagen were higher ($P < 0.05$) in the high IV category than the low IV category. No differences were detected in fat cell size or the number of fat cells in bacon fat between IV categories. In conclusion, IV category had minimal impact on frozen bacon quality. However, frozen bacon stored in aerobic packaging resulted in rapid development of lipid oxidation and more pronounced changes in fat color compared with bacon stored in anaerobic packaging.

Key words: bacon, iodine value, pork

Introduction

Determining the impact of adding dried distiller grains with solubles (DDGS) to the diet and its impact of fatty acid composition on belly firmness and slice yields is a central topic of discussion. This has led researchers and industry personnel to emphasize expressing fat quality in terms of iodine value (IV). The impact of carcass fat IV has been studied most commonly by feeding DDGS at various levels (0, 20, 30, and ≥ 45%)[4,5]. While these studies detail the impacts on pork quality, there is variation in reported IV at various DDGs additions. Therefore, it would be practical to design research based on specific IV as opposed to individual diets. It is typical in literature to identify lipid oxidation as a major concern when shifting porcine fat composition to greater concentrations of unsaturated fatty acids (higher IV). However, it is unclear how large the difference between IV levels must be to notice a difference in fat quality and how severely that affects lipid oxidation. In addition, the effects of IV on aerobically packaged bulk bacon in food service are unclear. This is especially important because pork bellies are further processed with salt, which is commonly found to increase lipid oxidation. Therefore, it is essential to determine the implications of IV and how the difference in IV levels affects the shelf life of aerobic-packaged and anaerobically packaged bacon.

Procedures

Fresh pork bellies were acquired from a commercial swine harvest facility (Farmland Foods, Milan, MO) on three sampling dates. Target IV categories were defined before entering the plant as low (58 to 63 g/100g), intermediate (68 to 73 g/100g), and high (78 to 83 g/100g). Using a NitFom™ (Near-Infrared-Transmission Spectroscopy) sensor unit (Carometec A/S, Herlev, Denmark), IV was measured on the left side of

[4] Goehring, B. L., T. A. Houser, J. M. DeRouchey, M. C. Hunt, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz, J. A. Unruh, and B. M. Gerlach, 2010. Effects on bacon quality of feeding increasing glycerol and dried distillers grains with solubles to finishing pigs. Swine Day 2010 Report of Progress 1038, pp.136–143.

[5] Leick, C. M., C. L. Puls, M. Ellis, J. Killefer, T. R. Carr, S. M. Scramlin, M. B. England, A. M. Gaines, B. F. Wolter, S. N. Carr, and F. K. McKeith. 2010. Effect of distillers dried grains with soluble and ractopamine (paylean) on quality and shelf-life of fresh pork and bacon. J. Anim. Sci. 88:2751-2766.

the pork carcasses above the scapula, and two inches from the midline of the carcass as carcasses exited the kill floor going into the blast freezer. The IV of at least 200 carcasses was measured during each sampling date before selecting the sample population.

A total of 72 pork carcasses were identified, and both the right and left bellies were collected. Belly weight, dimensions (length, width, and thickness), and firmness were measured. Belly firmness was measured by centering the belly, skin side down, perpendicular to the belly length over a round metal bar. Firmness was quantified by measuring the distance between the ham and shoulder edges. A greater distance between the belly ends implies a firmer belly. After measurements were taken, bellies were shipped to a commercial processor (Farmland Foods, Denison, IA) to be processed into bacon and sliced. Bellies were sliced using a high-speed slicer set to a slice thickness of 4 mm. Line workers were instructed not to do any slice sorting so all bacon slices were in continuous order from the shoulder end to the ham end. Bacon slices were bulk boxed with just 1 belly per box, and shipped to the Kansas State University Meat Laboratory (Manhattan, KS) to be assigned to packaging treatments.

Upon arrival at the KSU Meat Laboratory, bacon from the paired bellies was randomly assigned to 1 of 2 packaging treatments. Packing treatments were aerobically packaged using either a poly-liner overwrap or an anaerobic 24-in. × 30-in. vacuum package pouch (3-mil standard barrier, Prime Source Vacuum Pouches, Bunzl Processor Division, Koch Supplies, Kansas City, MO). The bacon slices were kept in chronological order from shoulder to ham end, with the slices kept together so the overall belly profile was retained. This allowed the sliced bacon slab to be divided lengthwise into 5 zones. A measuring stick was created measuring 23.6 in. long with five 4.72-in.-long zones marked on it. This stick allowed for consistent slice sampling among bellies when it was centered along the length of sliced belly so each belly sampling zone was consistent. For each packaging treatment, 7 bacon slices were selected from each belly, laid out in a hotel, restaurant and institution (HRI) single-slice layout style on a paper divider sheet. One slice was taken out of each zone, and two random slices were laid out on a divider sheet. The two random slices were laid out to allow easy stacking of the bacon sheets for storage. Each sheet of bacon originated from a single belly, and 10 different sheets were made per belly to correspond with 10 different shelf life dates (d 0, 28 56, 70, 84, 98, 112, 126, 140, and 154). During sorting, bacon slices from zone 2 were taken for collagen and histochemical analysis.

For each sampling date, fat color was measured using a Hunter Lab Miniscan EZ spectrophotometer (Illuminant A, 1-in.-diameter aperature, 10° standard observer; Hunter Associates Laboratory, Reston, VA). After color measurement, samples were ground into a composite sample. From this composite, bacon was analyzed for proximate composition, fatty acid composition, pH, and thiobarbituric acid reactive substances (TBARS).

Results were analyzed as a completely randomized block design with a split plot using the MIXED Procedure of SAS (SAS Institute, Inc., Cary, NC) with belly as the experimental unit. Fixed effects were the packaging treatments (aerobic and anaerobic) and IV categories (low, intermediate, and high). Significance was set at $P < 0.05$, and pairwise comparisons between treatments were made if overall means were significant.

Results and Discussion

No significant differences were observed among the hot carcass weights of pork carcasses assigned to the 3 IV categories (Table 1). A difference ($P < 0.05$) was observed between the IV of the pork carcasses between each IV category.

There were no differences between belly weight, length, width, or thickness among IV categories (Table 2). Bellies were firmer ($P < 0.05$) for the low IV category compared with both the intermediate and high IV categories. The high IV category had the softest bellies of all IV categories.

Belly IV in the high IV category was greater ($P < 0.05$) than the intermediate and low IV categories (Table 3). Proximate composition (moisture, fat, and protein) and pH were not different among IV categories. The percentage of saturated fatty acids contained in the bacon slices including myristic, palmitic, stearic, and total saturated fatty acids were greater ($P < 0.05$) for the low IV category compared to the high IV category (Table 4). The percentage of unsaturated fatty acids in bacon slices including linoleic, linolenic, eicosadienoic, and total polyunsaturated fatty acids were higher ($P < 0.05$) for the high IV category compared to the low IV category.

No three-way interactions among belly IV category, packaging type, and storage duration were observed for color characteristics of bacon slices. However, an interaction between packaging type by IV category was detected ($P < 0.05$) for L*, a*, and b* values. Lightness (L*) values were higher ($P < 0.05$) for the low IV category compared with the intermediate and high IV categories for both the aerobically packaged samples and the anaerobically packaged samples (Table 5). However, the incremental increase in lightness was much more pronounced in the aerobically packaged samples as compared with the anaerobically packaged samples. Redness values (a*) were higher ($P < 0.05$) in aerobically packaged bacon from the high IV category compared with the intermediate and low IV categories (Table 6). In contrast, the low and intermediate IV categories had higher a* values compared with the high IV category. Much like a* values, yellowness values (b*) were higher ($P < 0.05$) in aerobically packaged bacon from the high IV category compared with the intermediate and low IV categories (Table 7). However, the low and intermediate IV categories had higher b* values compared with the high IV category. It should be noted that none of the aforementioned changes in L*, a*, or b* values have practical significance due to the very small changes in values.

An interaction between packaging type by storage length was observed ($P < 0.05$) for L*, a*, and b* values. Lightness (L*) values were numerically higher for aerobically packaged bacon compared to anaerobically packaged bacon (Table 8). Additionally, L* values increased ($P < 0.05$) from d 0 to 154 for aerobically packaged bacon. Bacon packaged in anaerobic packaging had minimal changes in lightness during the 154-d storage period and was more stable compared to the aerobically packaged samples. Redness (a*) values decreased ($P < 0.05$) from d 0 to 154 for the aerobically packaged bacon samples, indicating that samples became less red as storage length increased (Table 9). Anaerobically packaged samples increased ($P < 0.05$) in redness from d 0 to 28 but only changed slightly for the remainder of the storage period. Anaerobically packaged samples were much more stable in redness than aerobically packaged samples. Both aerobically packaged bacon and anaerobically packaged bacon samples became more ($P < 0.05$) yellow

(b*) in color with increased storage duration (Table 10). The anaerobically packaged treatments had a greater amount of numerical change in b* values due to storage length compared with the aerobically packaged bacon slices.

No significant three-way interactions among belly IV category, packaging type, and storage duration were observed for lipid stability of bacon slices. However, an interaction between packaging type and storage length was observed ($P < 0.05$; Table 11). Thiobarbituric acid reactive substances values increased rapidly during storage for the aerobically packaged bacon treatments. Thiobarbituric acid reactive substances values increased from 0.42 mg malonaldehyde/kg of sample on d 0 to 1.07 mg malonaldehyde/kg sample on d 28 for the aerobically packaged bacon samples. TBARS values then increased at a more gradual pace from 1.07 mg malonaldehyde/kg of sample on d 28 to 1.66 mg malonaldehyde/kg of sample on d 126 for aerobically packaged bacon. The anaerobically packaged bacon also had increased ($P < 0.05$) TBARS from d 0 to 154 but were more gradual and were not more than 1.0 mg malonaldehyde/kg of sample until d 126. In fact, no change in TBARS values occurred in the anaerobically packaged samples from d 0 to 70. No interactions were detected in TBARS values for IV and packaging type (Table 12). In addition, no differences ($P > 0.05$) were detected for TBARS values due to IV category (Table 13).

No differences were observed in the size or number of the fat cells among the 3 IV categories (Table 14). However, the soluble collagen content in the high IV category was greater ($P < 0.05$) than the collagen content in the low IV category. There was a trend for the high IV category to have more soluble collagen than the intermediate IV category ($P = 0.096$). The insoluble collagen content in the high IV category was greater ($P < 0.05$) than that of the low IV category, and there was a trend ($P = 0.097$) for the high IV category to have a greater insoluble collagen content than the intermediate IV category. Following the pattern of the soluble and insoluble collagen content, the high IV category had greater amounts of total collagen ($P = 0.008$) than the low IV, and the high IV bellies tended to have more total collagen ($P = 0.090$) than those in the intermediate category. There was no change in the percentage soluble collagen among the IV categories.

In summary, no practical differences in fat color due to differences in IV were observed. However, bacon fat under aerobic packaging was whiter (higher L*), compared to anaerobically packaged bacon as the bacon aged from 0 to 154 d. As storage time increased, regardless of packaging type, the color of bacon fat became more yellow and less red. Bacon stored aerobically rapidly reached a level of oxidation that would be considered rancid (≥ 1.00) within the first 28 d of storage, while bacon stored anaerobically did not reach rancidity levels until after d 112. Overall, the aerobic bacon contained higher levels of oxidation (1.61) at the end of the study than those observed with the anaerobic bacon (1.05). Iodine value did not affect lipid oxidation in this study. High IV bellies contained greater amounts of collagen, which corresponds with softer bellies. This study suggests there are no lipid oxidation differences between bacon slices that have an average difference of 9.2 units. Furthermore, it is possible to detect differences in belly firmness with an average IV difference of 3.2 g/100g.

Table 1. Mean hot carcass weights and iodine values from carcasses in the sample population[1, 2]

	Iodine Value Category			
Item	High	Intermediate	Low	SEM[3]
Hot carcass weight, lb	216.20	212.99	216.55	1.38
Iodine value[4], g/100g	77.9[a]	72.6[b]	66.5[c]	1.89

[1] Treatment means with different superscripts are different ($P < 0.05$).
[2] A total of 72 carcasses were selected over 3 repetitions with 24 carcasses per IV category.
[3] Standard error of the mean.
[4] Calculated using NitFom™ (Near-Infrared-Transmission Spectroscopy).

Table 2. Mean dimensional characteristics of bellies from the sample population[1,2]

	Iodine value category			
Item	High	Intermediate	Low	SEM[3]
Belly weight, lb	17.24	17.23	18.50	0.57
Belly length, in	29.45	29.61	29.72	0.48
Belly width, in	12.83	12.79	12.64	0.27
Belly thickness, in	1.36	1.40	1.44	0.05
Belly firmness, in	5.55[a]	7.95[b]	11.45[c]	0.52

[1] Treatment means within a row with different superscripts are different (P < 0.05).
[2] A total of 144 bellies were measured over 3 repetitions with 48 bellies per IV category.
[3] Standard error of the mean.

Table 3. Mean chemical characteristics of bacon samples from high, intermediate, and low iodine value categories[1,2]

	Iodine value category			
Item	High	Intermediate	Low	SEM[3]
Belly/bacon iodine value[4]	76.90[a]	70.90[b]	67.70[b]	1.54
Moisture, %	45.00	44.00	41.50	1.81
Fat, %	36.40	38.30	41.80	2.38
Protein, %	13.60	13.00	11.80	0.58
pH	6.34	6.38	6.38	0.03

[1] Treatment means within a row with different superscripts are different ($P < 0.05$).
[2] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[3] Standard error of the mean.
[4] Calculated from fatty acid analysis using AOCS (1998) protocol: (C16:1 × 0.95) + (C18:1 × 0.86) + (C18:2 × 1.732) + (C18:3 × 2.616) + (C20:1 × 0.785) + (C22:1 × 0.723) expressed as g/100g.

Table 4. Mean fatty acid percentage for bacon samples from pigs of high, intermediate, and low iodine value categories[1,2]

	Iodine value category			
Item	High[3]	Intermediate[4]	Low[5]	SEM[6]
Myristic acid (C14:0), %	1.31[b]	1.39[ab]	1.45[a]	0.03
Palmitic acid (C16:0), %	21.50[b]	23.20[a]	24.30[a]	0.45
Palmitoleic acid (C16:1), %	2.58	2.72	2.75	0.14
Margaric acid (C17:0), %	0.38	0.40	0.36	0.02
Stearic acid (C18:0), %	10.00[b]	11.40[a]	12.10[a]	0.36
Oleic acid (C18:1n9c), %	36.30	36.80	37.30	1.15
Vaccenic acid (C18:1n7), %	3.49	3.57	3.50	0.22
Linoleic acid (C18:2n6t), %	20.10[a]	16.50[b]	14.40[b]	1.20
α-Linolenic acid (C18:3n3), %	0.69[a]	0.55[b]	0.47[b]	0.07
Gondoic acid (C20:1),%	0.72	0.84	0.79	0.04
Eicosadienoic acid (C20:2), %	0.82[a]	0.74[b]	0.68[c]	0.02
Total SFA, %[7]	33.78[b]	36.82[a]	38.82[a]	0.69
Total MUFA, %[8]	43.50	44.25	44.72	1.08
Total PUFA, %[9]	22.72[a]	18.78[b]	16.46[b]	1.36

[1] Treatment means with different superscripts in a row are different ($P < 0.05$).
[2]A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[3] High iodine value average 76.9 g/100g.
[4] Intermediate iodine value average 70.9 g/100g.
[5] Low iodine value average 67.7 g/100g.
[6] Standard error of the mean.
[7] Total saturated fatty acids, expressed as percentage of total fatty acids present.
[8] Total monounsaturated fatty acids, expressed as a percentage of total fatty acids present.
[9] Total polyunsaturated fatty acids, expressed as a percentage of total fatty acid present.

Table 5. Mean lightness (L*)[1] values of frozen bacon fat samples with different iodine value categories and packaging treatments[2,3]

	Iodine value category			
Packaging type	High[4]	Intermediate[5]	Low[6]	SEM[7]
Aerobic	81.40[c]	83.20[b]	84.20[a]	0.134
Anaerobic	80.50[c]	80.90[b]	81.40[a]	0.134

[1]L*, lightness, 0 = black, 100 = white.
[2]Treatment means with different superscripts in a row are different ($P < 0.05$).
[3]A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4]High iodine value average 76.9 g/100g.
[5] Intermediate iodine value average 70.9 g/100g.
[6] Low iodine value average 67.7 g/100g.
[7] Standard error of the mean.

Table 6. Mean redness (a*)[1] values of frozen bacon fat samples with different iodine value categories and packaging treatments[2,3]

	Iodine value category			
Packaging type	High[4]	Intermediate[5]	Low[6]	SEM[7]
Aerobic	3.68[a]	3.27[b]	3.26[b]	0.061
Anaerobic	4.92[b]	5.10[a]	5.19[a]	0.061

[1] a*, redness, positive values = red, negative values = green.
[2] Treatment means with different superscripts in a row are different ($P < 0.05$).
[3] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4] High iodine value average 76.9 g/100g.
[5] Intermediate iodine value average 70.9 g/100g.
[6] Low iodine value average 67.7 g/100g.
[7] Standard error of the mean.

Table 7. Mean yellowness (b*)[1] values of frozen bacon fat samples with different iodine value categories and packaging treatments[2,3]

	Iodine value category			
Packaging type	High[4]	Intermediate[5]	Low[6]	SEM[7]
Aerobic	8.87[a]	8.49[b]	8.46[b]	0.057
Anaerobic	8.35[b]	8.66[a]	8.61[a]	0.057

[1] b*, yellowness, positive values = yellow, negative values = blue.
[2] Treatment means with different superscripts in a row are different ($P < 0.05$).
[3] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4] High iodine value average 76.9 g/100g.
[5] Intermediate iodine value average 70.9 g/100g.
[6] Low iodine value average 67.7 g/100g.
[7] Standard error of the mean.

Table 8. Mean lightness (L*)[1] values of frozen bacon fat samples with different storage lengths and packaging treatments[2,3]

	Storage duration, d										
Packaging type	0	28	56	70	84	98	112	126	140	154	SEM[4]
Aerobic	82.3^{de}	81.5^{f}	82.5^{cde}	82.9^{c}	83.0^{c}	83.0^{c}	82.8^{cd}	82.6^{cde}	84.9^{a}	83.9^{b}	0.246
Anaerobic	81.9^{a}	79.5^{g}	80.2^{f}	80.9^{cde}	80.9^{def}	81.5^{bcd}	81.1^{cde}	80.7^{ef}	81.4^{bcde}	81.1^{cde}	0.244

[1] L*, lightness, 0 = black, 100 = white.
[2] Treatment means with different superscripts in a row are different ($P < 0.05$).
[3] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4] Standard error of the mean.

Table 9. Mean redness (a*)[1] values of frozen bacon fat samples with different storage lengths and packaging treatments[2,3]

	Storage duration, d										
Packaging type	0	28	56	70	84	98	112	126	140	154	SEM[4]
Aerobic	4.41^{a}	4.01^{b}	2.98^{g}	3.47^{de}	3.29^{ef}	3.00^{fg}	3.67^{cd}	3.64^{cd}	2.81^{g}	2.78^{g}	0.112
Anaerobic	3.86^{g}	4.99^{def}	5.19^{cde}	5.15^{cde}	5.34^{abc}	4.95^{ef}	4.79^{f}	5.61^{a}	5.27^{bcd}	5.53^{ab}	0.111

[1] a*, redness, positive values = red, negative values = green.
[2] Treatment means with different superscripts in a row are different ($P < 0.05$).
[3] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4] Standard error of the mean.

Table 10. Mean yellowness (b*)[1] values of frozen bacon fat samples with different storage lengths and packaging treatments[2,3]

	Storage duration, d										
Packaging type	0	28	56	70	84	98	112	126	140	154	SEM[4]
Aerobic	7.68^{e}	8.03^{d}	8.01^{d}	8.71^{bc}	8.04^{d}	8.54^{c}	9.73^{a}	9.65^{a}	8.83^{b}	8.86^{b}	0.106
Anaerobic	6.85^{i}	7.95^{h}	8.13^{gh}	8.33^{fg}	8.61^{def}	8.75^{cde}	9.06^{b}	8.92^{bc}	9.44^{a}	9.38^{a}	0.105

[1] b*, yellowness, positive values = yellow, negative values = blue.
[2] Treatment means with different superscripts in a row are different ($P < 0.05$).
[3] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4] Standard error of the mean.

Table 11. Mean thiobarbituric acid reactive substances (TBARS) values (mg malonaldehyde[1]/kg sample) of frozen bacon samples with different storage lengths and packaging treatments[2,3]

	Storage duration, d										
Packaging Type	0	28	56	70	84	98	112	126	140	154	SEM[4]
Aerobic	0.42^{f}	1.07^{de}	1.16^{cd}	1.19^{cd}	1.13^{cd}	1.45^{b}	1.25^{c}	1.66^{a}	1.66^{a}	1.61^{ab}	0.07
Anaerobic	0.41^{d}	0.41^{d}	0.46^{d}	0.45^{d}	0.68^{c}	0.63^{c}	0.92^{b}	1.45^{a}	0.69^{c}	1.05^{b}	0.07

[1] Product of lipid oxidation.
[2] Treatment means with different superscripts in a row are different ($P < 0.05$).
[3] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4] Standard error of the mean.

Table 12. Mean thiobarbituric acid reactive substances (TBARS) values (mg malonaldehyde[1]/kg sample) for frozen bacon samples with different iodine value categories and packaging treatments[2,3]

	Iodine value category			
Packaging type	High[3]	Intermediate[4]	Low[5]	SEM[6]
Aerobic	1.30	1.20	1.30	0.033
Anaerobic	0.74	0.74	0.67	0.034

[1] Product of lipid oxidation.
[2] Treatment means with different superscripts in a row are different ($P < 0.05$).
[3] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[4] High iodine value average 76.9 g/100g.
[5] Intermediate iodine value average 70.9 g/100g.
[6] Low iodine value average 67.7 g/100g.
[7] Standard error of the mean.

Table 13. Mean thiobarbituric acid reactive substances (TBARS) values for frozen bacon samples stored up to 154 days in anaerobic and aerobic packaging[1,2]

	Iodine value category			
	High[3]	Intermediate[4]	Low[5]	SEM[6]
Malonaldehyde[7] mg/sample kg	1.0	0.99	0.97	0.023

[1] Treatment means with different superscripts in a row are different ($P < 0.05$).
[2] A total of 144 bacon samples were measured over 3 repetitions with 48 bacon samples per IV category.
[3] High iodine value average 76.9 g/100g.
[4] Intermediate iodine value average 70.9 g/100g.
[5] Low iodine value average 67.7 g/100g.
[6] Standard error of the mean.
[7] Product of lipid oxidation.

Table 14. Mean histology characteristics and mean collagen content of bacon fat from high, intermediate, and low iodine value categories[1,2]

	Iodine value category			
Characteristic	High[3]	Intermediate[4]	Low[5]	SEM[6]
Fat cell size, μm	4016.2	4222.5	4369.0	175.43
Fat cell count, mm^2	246.0	233.0	223.3	14.99
Soluble collagen, mg/g	13.40^{a}	12.20^{ab}	11.20^{b}	0.54
Insoluble collagen, mg/g	35.50^{a}	30.20^{ab}	24.90^{b}	1.92
Total collagen, mg/g	49.00^{a}	42.40^{ab}	36.20^{b}	2.31
% Soluble collagen	29.70	29.70	33.10	1.46

[1] Treatment means with different superscripts are different ($P < 0.05$).
[2] A total of 144 samples were measured over 3 repetitions with 48 samples per IV category.
[3] High iodine value average 76.9 g/100g.
[4] Intermediate iodine value average 70.9 g/100g.
[5] Low iodine value average 67.7 g/100g.
[6] Standard error of the mean.