Effect of cooking method and storage time on lipid oxidation and sensory attributes of bacon

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Abstract – This work aimed to study the effect of different cooking methods and storage times on the extent of lipid oxidation and sensory perception of sliced bacon. Pork bellies from varying populations were produced into bacon and subjected to two storage times (2 and 28 days) and two cooking methods (microwave and grilling). Grilled bacon exhibited higher increase in both free and total malondialdehyde compared to raw bacon. Microwave heating also increased MDA levels in cooked bacon but to a lower level than grilling. Storage time before cooking however had no significant effect on lipid oxidation. In terms of sensory attributes, grilled bacon strips were crispier, saltier, and less chewy and at the same time showed a trend for less off-flavor compared to their microwaved counterpart regardless of their higher content of lipid oxidation products.

Key Words – malondialdehyde, microwave, grilling, pork, belly

I. INTRODUCTION

The advent of lipid peroxidation during storage or cooking of meat products is unwanted, not only because it is a form of quality deterioration that leads to undesirable odors, rancidity, texture modification and loss of essential fatty acids but also because some of its secondary products have been implicated in several human pathologies including atherosclerosis, cancer and ageing [1, 2]. Although most international and national health agencies have recommended reduced saturated fatty acids (SFA) and increased mono- and polyunsaturated (MUFA and PUFA) in dietary fats stating health reasons [2-4], this trend may however predisposes food matrix to rapid lipid oxidation due to higher susceptibility of PUFA to oxidation and as such, may deny the purpose of their inclusion in human diets.

The impact of cooking or heat treatment on lipid oxidation has been previously evaluated in meat system [1, 5]. However, not much data is available regarding bacon. Bacon is a widely consumed meat product in Europe and North America and its consumption trend has been sustained regardless of constant increase in price [4]. Considering the importance of this meat product, the present study hence observed the effect of two common cooking methods for this product (microwave and grilling) and storage time on level of lipid oxidation and sensory perception.

II. MATERIALS AND METHODS

The right side of the bellies excised from 48 pigs from two genetic types (Landrace*Large White sows × Lacombe [Peak Swine Genetics, Leduc, AB, Canada] and Iberian [Semen Cardona, Cardona, Spain] boars), two genders (barrows and gilts) and fed two different diets (commercial and 10% LinPro [co-extruded 50% flaxseed:50% field peas; O&T Farms, Regina, SK, Canada]) were used to produce bacon (brine composition of 9.1% nitrite salt and 1% sugar) in a commercial processing plant in Edmonton (AB, Canada). This population was chosen to represent a wide range of compositional variability in commercial bacon. Fatty acid analysis was carried out on fat and lean layers of raw bellies [6]. Bacon was sliced (2.45 mm) and vacuum packaged. The storage times were 0, 2 and 28 days at 4^{o}C, after which bacon was cooked either by microwave on a baconwave^{TM} tray (5 min, Amana Radarange, Model CRSW459P, 1500 Watts) or grilling (250^{o}C, 5 min one side, turned and cooked for another 2.5 min on the other side and later turned again to cook for another 1 min). Traditional thiobarbituric acid method (TBA) [7] and a new free-malondialdehyde method (MDA) [8] were employed to assess the level of lipid oxidation in bacon prior and after the completion of the storage duration and cooking treatment. Sensory analysis was also carried out by a 7-member trained panel. A nine point scale was employed with 9 meaning “extremely intense” and 1 refers to “none” for all observations except off-flavor intensity which was in reverse order. PROC MIXED procedure in SAS version 9.4 was used to analyze the data and significant difference was declared at P<0.05.

III. RESULTS AND DISCUSSION

Table 1 gives an overview of the wide variation in the composition of the pork bellies used in this study. The iodine value (IV), PUFA, MUFA and SFA vary widely and this varying composition may affect its oxidative stability to different levels.

Table 1: Description of pork bellies used for bacon

(%)	Sub fat		Inter fat		Lean	
	Mean	SD	Mean	SD	Mean	SD
IV	64.3	2.32	59.0	2.47	58.3	1.58
MUFA	50.9	1.54	47.6	2.04	50.8	1.49
PUFA	12.1	1.35	10.5	1.58	10.0	1.57
SFA	37.0	1.61	41.9	1.75	39.1	1.19
n-6	10.0	0.93	8.52	0.95	8.38	1.29
n-3	2.09	0.76	1.97	0.89	1.48	0.55
n-6/n-3	5.45	1.97	5.23	2.21	6.48	2.38
MC*	37.3	7.18				
T fat*	51.2	9.26				

*MC; Moisture content and T fat; total fat are mean values of all three layers. Sub fat; subcutaneous fat, Inter fat; intermuscular fat and lean; *Latissimus dorsi.*

The effects of cooking methods and storage times on moisture, fat and total cooking loss in bacon are shown in Table 2. Contrary to previous studies, where moisture loss constituted the major part of cooking loss [9], in bacon however, fat loss represents the bulk of cooking loss due to the fatty nature of the product. In the literature, higher cooking loss has been observed in microwaved than in grilled meat samples [1, 10]. Nevertheless, no cooking method effect was observed (P>0.05) in the present study. Since bacon is sliced very thin (2.54 mm) before cooking, most of the moisture and fat content is easily drained off during cooking due to rapid heat transfer, leaving no observable difference between cooking methods.

Results in Table 3 show the increase in lipid oxidation due to each of the treatments compared

Table 2: Cook loss for bacon with different cooking methods and storage times

Cook Loss	Micro	Grill	P value	2 d	28 d	P value
Fat (%)	40.7	47.0	0.180	42.6	45.2	0.570
Water (%)	35.6	32.2	0.263	34.5	33.3	0.682
Total (%)	77.6	76.9	0.203	77.3	77.2	0.910

to levels in raw bacon (day 0). Using the TBARS method, grilled bacon experienced a significant increase in the level of MDA up to about 0.74 mg MDA/kg muscle (P<0.001) (Table 3). Compared to an average of about 0.163 mg MDA/kg quantified in raw bacon, microwaved samples had an average of 0.693 mg MDA/kg while the grilled samples contained an average of about 0.93 mg MDA/kg. There exists a wide range (0.33 - 1.5 mg MDA/kg) of MDA level in the bacon samples employed in the present study. On the other hand, storage time before cooking had no effect (P>0.05) on lipid oxidation (results not shown). Similar results were observed when free-MDA method was employed to assess the extent of lipid oxidation [8]. Grilling resulted in higher change in free MDA in raw bacon compared to microwave cooked bacon. The values with free-MDA were much lower compared to those reported in TBARS. This is not unexpected as TBARS derivatization process has been reported to be more rigorous and harsh (pH $\leq$3 and T^o, 100^{o}C) and as such, both bound and free MDA, as well as other artefacts, are quantified [8], making the TBARS procedure of low specificity.

Table 3: Change in lipid oxidation of raw bacon with cooking methods

Lipid Oxidation	Treatments		SEM	P value
	Micro	Grill		
Δ TBARS (mg MD/kg)	0.507^a	0.744^b	0.022	<0.001
Δ Free-MDA (μg MD/kg)	3.256^a	7.512^b	0.427	<0.001

$^{a\text{-}b}$Different letters in each row indicate significant difference at P<0.01

In the case of free MDA method, however, derivatization is more mild at room temperature and pH around 4-5. Compared to our study, similar levels of MDA have been reported in various meat samples in previous studies [1, 5]. However, microwave has often been reported to produce higher levels of MDA than grill. This discrepancy could be due to the differences in grilling parameters/procedure employed as well as nature of the meat samples. In our case, thin sliced bacon was cooked much longer and at higher temperature compared to other studies where steaks (8-20 mm thick) were grilled at 130-190^{o}C for 2-5 min [1, 5].

Table 4 shows the effects of cooking method on bacon sensory traits. Storage time, again, did not influence ($P>0.05$) sensory perception of any properties examined (results not shown). Grilled bacon was crispier than microwaved bacon ($P<0.05$). The crispy nature of grilled bacon could be due to the crust forming nature of this cooking method whereas microwave cooking has been reported to form no crust during the cooking process [1]. Furthermore, microwaved bacon appeared to have higher chewiness ($P<0.05$) compared to grilled bacon which can also be related to its lack of crispiness. The only interaction observed between cooking methods and storage time was for initial crispiness of bacon ($P=0.0046$) (Figure 1). Initial crispiness was lower for microwaved bacon compared to grilled bacon at 2 days but this difference in crispiness disappeared after storage for 28 days. Grilled bacon was significantly saltier than microwaved bacon ($P=0.008$). The higher saltiness in grilled bacon may be due to its slightly higher water/brine retention (Table 2) compared to well dehydrated microwaved bacon. It however stands to be proven if microwave cooking induces higher protein modification/oxidation which may affect its water holding capacity due to structure loss. This modification may as well contribute to the higher chewiness observed in microwaved bacon which may be due to protein polymerization.

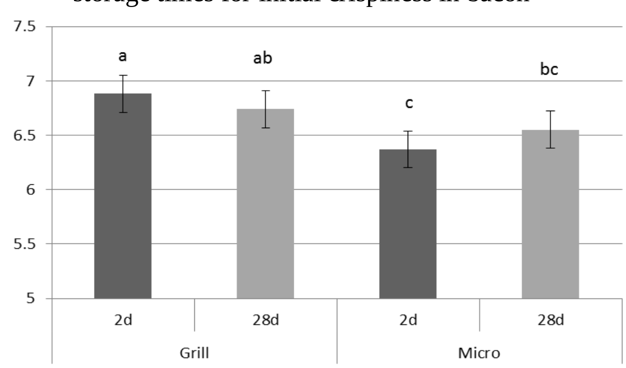
Although not significant, a trend in off-flavor intensity ($P=0.077$) was observed for microwaved bacon. This difference may not be due to the level of MDA in the bacon samples as on the average, our bacon samples contained less than 1 mg MDA/kg muscle which has been reported as the threshold for off-flavor development in meat [10]. This trend may hence be implicated on the protein modification which may as well be related to the overall crispiness and chewiness nature of micro-waved bacon.

Table 4: Effect of cooking methods on sensory perception of bacon

	Grill	Micro		P value
	Mean	Mean	SEM	
Initial Crispiness	6.81^{a}	6.46^{b}	0.16	0.019
Overall Crispiness	6.72^{a}	6.28^{b}	0.15	0.003
Salt intensity	5.70^{a}	5.42^{b}	0.18	0.008
Smoke flavour	5.41	5.66	0.20	0.077
Bacon flavour	5.97	5.93	0.19	0.548
Chewiness	5.23^{b}	5.50^{a}	0.23	0.014
Mouth Coating	3.71	3.57	0.29	0.187
Off-flavor Intensity	8.33	7.92	0.23	0.077

$^{a-b}$Different letters in each row indicate significant difference at $P<0.05$. A 9-point scale was used with 9=extremely intense and 1=none for all observations except off-flavor intensity in reverse order.

Figure 1: Interaction between cooking methods and storage times for initial crispiness in bacon



$^{a-c}$Different letters in each row indicate significant difference at $P<0.05$.

Since the lipid oxidation observed in this study could not only be due to the cooking methods but other inherent properties of the pork bellies (Table 1), parameters that may contribute to MDA development were studied in a multiple regression analysis (Table 5). These included MUFA, SFA, iodine value (IV), n-6, n-3, ratio of n-6/n-3 and ratio of PUFA/SFA all from three belly layers (lean, subcutaneous and intermuscular fat layers) and total fat. A significant model ($P=<0.001$) was developed with R^2=0.859 with nine selected parameters as shown in Table 5.

Table 5: Multi-regression analysis of TBARS contributing parameters.

Variable	Parameter Estimate	Standard Error	Pr > |t|
Intercept	15.298	2.439	<0.001
MUFA lean	-0.169	0.026	<0.001
SFA lean	-0.137	0.025	<0.001
n-3 lean	-0.756	0.118	<0.001
n-6/n-3 lean	-0.220	0.042	<0.001
n-6/n-3 EX	0.169	0.038	<0.001
IV IN	0.161	0.032	<0.001
MUFA IN	-0.116	0.026	<0.001
n-6 IN	-0.489	0.085	<0.001
Total fat	0.013	0.003	0.001

IN: intermuscular fat, EX: subcutaneous fat, Lean: *Latissimus dorsi* muscle

IV. CONCLUSIONS

As much as the inherent composition of pork belly may contribute to bacon's lipid oxidative status, the choice of cooking method also plays a great role. Although MDA increase with household cooking may not prompt any organoleptic defect, its biological role may be an area to focus. The contribution of protein modification to meat organoleptic properties also demands further study. The effect of extended storage time on bacon lipid oxidation stability will also be worth exploring.

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