Eating Quality of Smoked Bacon from Swine Fed with Fish Oil

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ABSTRACT

The aim of this research was to evaluate eating quality of smoked bacon by feeding fish oil during fattening period in pigs. The 96 crossbred pigs were randomly selected from 480 pigs for more in-depth study on the efficiency to enrich tissue with n-3 fatty acids and the expression of adverse side-effects on eating quality of smoked bacon. This study was assigned to a control (0% of fish oil: CO) and 2% of fish oil (FO) in diet fed from 60 kg of body weight until 90, 100 and 110 kg of body weight, respectively. The result showed that feeding fish oil had no effect on sensory evaluation (P > 0.05) but FO had less triglyceride (P < 0.01), tended to have lower cholesterol (P > 0.05) and higher TBA value than CO (P < 0.001). Furthermore, FO had higher EPA and DHA than CO. The n-6:n-3 fatty acid ratio of FO was lower than CO (P < 0.001). In terms of sex, there was not significant difference between groups in sensory evaluation (P > 0.05). Not only bacon from gilts had more cholesterol and TBA value but also less MUFA and PUFA than barrows. Slaughter weight at 90 kg had the highest TBA value but the lowest in total n-3 fatty acid level (P < 0.05). In conclusion, supplement 2% fish oil, selected barrow and slaughter at 110 kg of body weight were suitable to produce smoked bacon.

Key words: Eating quality, Bacon, Fish oil, Fatty acid

INTRODUCTION

In present, people are going to face with obesity which consequence involved on many disease e.g. diabetes, high blood pressure and cardiovascular disease (Malik et al., 1999). Fish oil remains the main dietary source of long chain polyunsaturated fatty acids omega-3, which desirably impact on human health. Increase of omega-3 fatty acids intake is currently recommended. Up to now, there have many studies revealed that consumption of fish oil, is enriched with omega-3 fatty acid, might be prevented the risk of many diseases (Kaushik et al., 2009; McEwen et al., 2010). Therefore, the food manufacturer should be considered to produce the healthy food products which containing highly omega-3 fatty acid. Fish oil is the main dietary source of long chain omega-3 polyunsaturated fatty acids. Omega-3 PUFA family consists of: alpha-linolenic acid (ALA C18:3) and its longer-chain metabolites: eicosapentaenoic acid (EPA C20:5) and docosahexaenoic acid (DHA C22:6). Moreover, beneficial health effects of omega-3 are demonstrated mainly in prevent heart disease, atherosclerosis, cardiovascular disease cancer and rheumatoid arthritis. However, high level of unsaturated fatty acids in meat product is involved on shelf life and rancidity. One way to increase the intake of n-3 PUFA without changing the nutritional behavior of the consumers would be to fortify traditional food items such as meat and meat products with n-3 PUFA (e.g., feeding

pigs diets containing fish oil). There have the studies focused to increase n-3 PUFA by supplement the other sources of n-3 PUFA in diet on pork product such as dry-cured ham, in dry-fermented sausages (Hoz et al., 2004; Musella et al., 2009). However, the numbers of studies focusing by fish oil supplement as a source of n-3 PUFA are limited according to the fishy odor and rancidity problems.

The aim of this study was to enrichment of meat product with polyunsaturated fatty acids by feeding fish oil addition in different level. This study would be the advantages of food enrichment with fish oil as well as characteristics of market of such products were presented.

MATERIALS AND METHODS

Animals and experiment treatments

The animals in this study were used three-way crossbred (Large White x Landrace x Duroc) finishing pigs in total 480 pigs. The animals were assigned to 2 dietary treatment groups in a completely randomized design and balanced for sex. The pigs were fattened with supplement fish oil on diet from 60 to 90, 100 and 110 kg of body weight (BW). Treatments consisted of control diets without fish oil (0% of fish oil: CO) and diet with 2% of fish oil (FO). Unrefined fish oil (T.C. Union Agrotech Co. Ltd., Bangkok, Thailand), a relatively inexpensive tuna cannery by-product, was chosen for the present experiment because this product is economically viable for pork production. The animals were fed at a level that ensured complete feed intake but also guaranteed satiety and had free access to fresh water. The animals were randomly selected into 4 pigs/ pen/ treatment (in total 96 pigs) for further producing smoked bacon.

The method for preparation of the smoked bacon was described according to the preparation method of the Department of Livestock Development (1999), Thailand. The brine composition used for curing of the uncooked bacon. The ingredients of the brine were (g kg^{-1} aqueous solution): ice water, 893.3, nitrite cure salt (mixture of NaCl and $NaNO_2$, 0.96:0.04 w/w), 40.7; sugar, 27.7; phosphate, 27.7; monosodium glutamate, 5.8; sodium erythorbate, 2.3; milk protein, 1.1; smoke powder, 1.3. Bellies were thawed at 4°C, skinned and trimmed without removal of the subcutaneous fat to sizes of 20 cm × 30 cm. The cold brine (2°C) was injected into the bellies at a level equivalent to proportionately 0.3 of the meat weight. After injection, bellies were allowed to equilibrate for 24 h at 4°C. This was followed by careful washing with water and hanging to let the remaining water drip off. Subsequently, the cured bacons were dried without smoking in the smoking chamber for 30 min at 70°C, and then smoked for another 3 h at the same temperature. The bacons were then stored at –20°C until being frozen and directly cut into 3-mm thick slices.

The bacon was also subjected to sensory evaluation as outlined by Wiriyajaree (1992) after 1 month of storage at –20°C in a vacuum-packaged form. A panel of 9 trained persons was used for grading color, texture, flavor, and overall acceptability applying a scale from 1 to 9. This was done with grilled smoked bacon of each individual group. Per session, 12 different meat samples were served to the panelists. Panelists also were invited to note the occurrence of off-flavors or fishy flavor.

Additionally, cholesterol and triglyceride contents were measured by a method adapted from Jung et al. (1975) and Biggs et al. (1975). The thiobarbituric acid (TBA) number was analyzed according to Rossell (1994) in smoked bacon samples cut into 4 pieces and stored separately at 4°C in closed plastic bags for 0, 3, 6, and 9 days.

Fatty acid methyl esters (FAME) were prepared as outlined by Morrison and Smith (1964) in lipids extracted from diet and LM samples by chloroform/methanol (2:1 vol/vol) (Folch et al., 1957). Subsequently, FAME were analyzed on a gas chromatograph (GC 14B, Shimadzu, Tokyo, Japan) equipped with a FID detector at injection and detector temperatures of 240°C. The temperature program was carried out with an initial temperature of 160°C held for 2 min. The final temperature was 240°C held for 20 min. In between, a temperature gradient was applied with 2°C/min from 160 to 180°C and with 4°C/min from 180 to 240°C. The flow rate of the carrier gas, helium, was 1 mL/min. A mixed FAME standard (Supelco 37 component, Bellefonte, PA) was used for the

identification of FA. Because the standard FA mixture used did not include docosapentaenoic acid (DPA, C22:5n-3), this FA was not included. Individual FA were related to total FAME in calculating FA profile, whereas amounts of individual FA in meat and fat tissue were calculated based on proportions of FA times total fat content (ether extract).

Statistical analysis

Data were subjected to ANOVA applying the GLM procedure (SAS Inst. Inc., Cary, NC). Dietary treatment, sex, slaughter weight and dietary treatment × sex × slaughter weight were considered as effects. Multiple comparisons among means were carried out with Tukeyís procedure.

RESULTS AND DISCUSSION

Sensory evaluation

Feeding with fish oil had no effect on color, texture, flavor and overall acceptability (Table 1) ($P > 0.05$). The previous study showed that the panelists were not found to have any different sensory evaluation of bacon between non-supplemented linseed and supplemented linseed groups (Sheard et al., 2000). There have been previous studies reported that supplements 2 and 4% of fish oil in feed did not increased fishy odor in frankfurters (Jeun-Horng et al., 2002) and feeding with 0.4% fish oil had no effect on sensory evaluation score (Bryhni et al., 2002). There is no influence of sex on sensory evaluation ($P > 0.05$). This result was the same trend as previous study, overall acceptability and flavor score of bacon from barrows were not significantly different with bacon from gilts (Jaturasitha et al., 2002). In terms of slaughter weight revealed that bacon produced from 90 kg of slaughter weight was higher flavor (6.23, 5.62 and 5.50 respectively; $P < 0.05$) and overall acceptability scores (5.54, 5.54 and 6.31 respectively; $P < 0.01$) than bacon produced from slaughter weight of pigs at 100 and 110 kg, respectively. According to the results, it could be assumed that produced bacon from pigs in heavy weight were given more abnormal flavor than pigs in light weight (Simm et al., 2004).

Cholesterol and Triglyceride levels

In present study revealed that fish oil in diet was unaffected on cholesterol level ($P > 0.05$) (Table 1). However, there was significant difference on triglyceride level between bacon from pigs fed with FO and CO groups ($P < 0.01$). Bacon from pigs fed with FO had trend to less cholesterol level (137.30 and 140.38 mg/100g; $P > 0.05$) and triglyceride level less than bacon from pigs fed with CO (50.85 and 54.33 g/100g; $P < 0.01$). There were previous studies reported that triglyceride level in lard was tended to decrease when increased fish oil level in diet (Jaturasitha et al., 2007, 2008). In terms of sex effect, bacon from gilts had more triglyceride level than barrows (56.49 and 48.70 g/100g; $P < 0.001$). The previous study reported that cholesterol level in *Longissimus dorsi* was not different between sex, meanwhile, barrows had less triglyceride level than gilts (Jaturasitha et al., 2008). Sex was involved on fat composition of bacon due to barrows have fat composition more than gilts and almost fat from barrows including triglyceride which consequently involved on phospholipids and cholesterol level (Leszczynski et al., 1992). For slaughter weight was found to be affected on cholesterol and triglyceride levels. Bacon from slaughter weight of pigs at 90 kg had the highest cholesterol level (174.90 mg/100g; $P < 0.001$). Additionally, bacon from slaughter weight of pigs at 110 kg had the highest triglyceride level (56.43 g/100g; $P < 0.001$).

Table 1. Effect of feed, sex and slaughter weight of finishing swine on cholesterol triglyceride level and TBA values of smoked bacon.

Criteria	Feed		Sex		Slaughter weight			SEM	*P*-value			
	Control	Fish oil	Barrow	Gilt	90	100	110		Feed	Sex	Slaughter wt.	Interaction
Cholesterol (mg/100g) and triglyceride (g/100g)												
Cholesterol	140.38	137.30	141.44	136.24	174.79^{e}	128.50^{f}	113.23^{g}	14.79	0.30	0.08	<0.001	1***,2***,3**,4***
Triglyceride	54.33^{a}	50.85^{b}	48.70^{d}	56.49^{c}	49.59^{f}	51.76^{f}	56.43^{e}	2.43	<0.01	<0.001	<0.001	2***,3**,4***
Storage (day) TBA number mg of malondialdehyde/kg												
Day 0	0.24^{b}	0.35^{a}	0.26^{d}	0.33^{c}	0.42^{e}	0.25^{f}	0.22^{g}	0.00	<0.001	<0.001	<0.001	1***,2***,3***,4**
Day 3	0.42^{b}	0.63^{a}	0.56^{c}	0.53^{d}	0.82^{e}	0.56^{f}	0.26^{g}	0.00	<0.001	<0.001	<0.001	1***,2***,3***,4***
Day 6	0.32^{b}	0.51^{a}	0.37^{d}	0.46^{c}	0.60^{e}	0.38^{f}	0.27^{g}	0.00	<0.001	<0.001	<0.001	1***,2***,3***,4***
Day 9	0.39^{b}	0.61^{a}	0.44^{d}	0.56^{c}	0.59^{e}	0.51^{f}	0.40^{g}	0.00	<0.001	<0.001	<0.001	1***,2***,3***,4***
Sensory evaluation												
Color	5.62	5.80	5.76	5.67	5.81	5.58	5.75	0.15	0.42	0.66	0.69	NS
Texture	5.57	5.47	5.42	5.62	5.67	5.69	5.21	0.13	0.64	0.31	0.10	NS
Flavor	5.96	5.61	5.82	5.75	6.23^{e}	5.50^{f}	5.62^{ef}	0.14	0.10	0.74	<0.05	NS
Overall acceptability	5.85	5.75	5.82	5.78	6.31^{e}	5.54^{f}	5.54^{f}	0.15	0.66	0.85	<0.0	NS

$^{a\text{-}b}$superscripts within row are significantly different by feed effect. $^{c\text{-}d}$sex effect. $^{e\text{-}g}$slaughter weight effect. 1,2,3 and 4 = interaction between feed×sex, feed×slaughter weight, sex×slaughter weight and feed×sex×slaughter weight respectively. *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$

Thiobabituric acid (TBA) value

Bacon from pigs fed with FO group was showed higher TBA value in day 0, 3, 6 and 9 than bacon from pigs fed with CO group ($P < 0.001$) (Table 1). The previous study reported that the oxidation can be observed from TBA value. In case of high polyunsaturated fatty acid meat, TBA value can be a good index (Ponnampalam et al., 2001). Although, an increased fish oil level in diet increased polyunsaturated fatty acid in meat and consequently involved on high oxidation and rancidity in meat (Bryhni et al., 2002). It is well-know that in a dose-dependent manner, fish oil adversely affects on shelf life, flavor (creating fishy off-flavor) and, with that, overall acceptability of pork from fed with fish oil (Sheard et al., 2000). In the pigs supplemented with 4 and 6% of sardine fish in diet had higher iodine number than control group (0% of sardine fish) (Irie and Sakimoto, 1992). In our study, we were found that bacon from barrows had lower TBA value than gilts in day 0, 6 and 9 ($P < 0.001$) except in day 3 ($P > 0.05$). The influence of sex on objective fatness parameters has been widely documented, the findings being that females display higher values than males for all measurements (Tejeda et al., 2008). Meanwhile, bacon from slaughter weight of pigs at 90 kg had the highest TBA value ($P < 0.001$). Correa et al. (2008) reported that belly fat from gilts and slow growing pigs is more unsaturated and is therefore more prone to rancidity during storage, leading to a potentially reduced bacon shelf-life.

Fatty acid composition

The present study found that diet with fish oil has involved on fatty acid in meat. Bacon from pigs fed with FO had greater total n-3 fatty acid (1.71 and 0.79; $P < 0.001$) and lower the ratio of n-6:n-3 fatty acid (11.03 and 24.03; $P < 0.001$) than bacon from pigs fed with CO (Table 2). The previous study reported that the fatty acid composition of pork and a pork product supplemented diet with 1% fish oil plus 2% rapeseed oil were increased omega-3 fatty acid in tissue (Leskanich et al., 1997). The fatty acid profile of both adipose tissue and muscle was altered as a result of the consumption of fish oil. The feeding of n–3 PUFA to animals with the purpose of improving the meat quality for human nutrition also increases the susceptibility of the meat to oxidation, may consequently manifest as off-odours and flavours (Hoffman et al., 2005). Moreover, total n-6 fatty acid tended to decrease (18.61 and 19.06; $P > 0.05$) in bacon from pigs fed with FO when compared bacon from pigs fed with CO. According to the increasing of n-3 polyunsaturated fatty acid and decreasing of n-6 polyunsaturated fatty acid can be led to the ratio of n-6:n-3 fatty acid decreased in swine fed with linseed (Nuernberg et al., 2005). In terms of sex influence in this study revealed that bacon from barrows had greater MUFA and PUFA than bacon from gilts (39.91 vs 36.66; $P < 0.01$, 21.59 vs 19.75; $P < 0.001$, respectively). It might have many factor involvement on fatty acid on muscle tissue such as sex, breed and species (Raes et al., 2004). There have previous studies revealed that the average of intramuscular fat in barrows were approximately 0.6 % which higher than gilts. Moreover, barrows had higher SFA than gilts (Van Oeckel et al., 1996; Nilzen et al., 2001). Tejeda et al. (2008) pronounced that total PUFA in meat was greater in females than in males. Slaughter weight in present study was not affected on SFA, MUFA and PUFA ($P > 0.05$). In contrast, slaughter weight at 90 kg had the lowest on total n-3 fatty acid ($P < 0.05$). An increase in slaughter weight had no significant affected on fatty acid composition, except for a tendency (P=0.06) of the PUFA level (Correa et al., 2008). Virgili et al. (2003) reported that swine at 10 months of age has higher palmatic acid and oleic acid, meanwhile, lower linoleic acid and linolenic acid than swine at 8 months of age.

Table 2. Effect of feed, sex and slaughter weight of finishing swine on fatty acid of smoked bacon (Percentage of total fatty acids).

Criteria	Feed		Sex		Slaughter weight			SEM	P-value			
	Control	Fish oil	Barrow	Gilt	90	100	110		Feed	Sex	Slaughter wt.	Interaction
C 14:0	1.29^{b}	1.39^{a}	1.37	1.31	1.44^{e}	1.31^{ef}	1.27^{f}	0.02	<0.05	0.19	<0.05	NS
C 16:0	22.57	23.2	23.39^{c}	22.34^{d}	23.2	22.72	22.6	0.24	0.21	<0.05	0.51	NS
C 16:1	1.26^{b}	1.81^{a}	1.58^{c}	1.49^{d}	1.73^{e}	1.51^{f}	1.38^{g}	0.00	<0.001	<0.05	<0.001	3**,4*
C 17:0	0.18^{b}	0.26^{a}	0.25	0.20	0.18	0.25	0.24	0.00	<0.05	0.12	0.22	NS
C 17:1	0.01^{b}	0.04^{a}	0.04	0.01	0.02	0.01	0.05	0.00	<0.05	0.09	0.13	2*
C 18:0	11.29	11.2	11.52^{c}	11.01^{d}	10.89^{f}	11.22^{ef}	11.67^{e}	0.06	0.83	<0.05	0.06	2***,3**,4**
C 18:1n9	35.32	35.95	36.71^{c}	34.57^{d}	34.40^{f}	36.01^{ef}	36.52^{e}	0.51	0.35	<0.01	<0.05	2*
C 18:2n6	18.83	18.37	19.39^{c}	17.81^{d}	18.59	18.69	18.51	0.12	0.17	<0.001	0.89	NS
C 18:3n3	0.79^{b}	0.82^{a}	0.85^{c}	0.77^{d}	0.81	0.81	0.81	0.00	<0.05	<0.001	0.10	3*
C 20:0	0.21	0.16	0.19	0.18	0.12^{f}	0.19^{ef}	0.24^{e}	0.00	0.12	0.61	<0.05	NS
C 20:1	0.58	0.58	0.58	0.58	0.51^{f}	0.57^{f}	0.66^{e}	0.00	0.95	0.85	<0.01	2**
C 20:2	0.60^{a}	0.55^{b}	0.59	0.57	0.54^{f}	0.56^{ef}	0.63^{e}	0.00	<0.05	0.30	<0.05	2**
C 20:3n6	0.16^{a}	0.10^{b}	0.13^{c}	0.12^{d}	0.00^{g}	0.19^{f}	0.20^{e}	0.00	<0.001	<0.01	<0.001	2***,3***,4***
C 20:4n6	0.07^{b}	0.14^{a}	0.14^{c}	0.06^{d}	0.18^{e}	0.08^{f}	0.06^{f}	0.00	<0.01	<0.01	<0.01	2**,3***,4***
C 20:5n3	0.00^{b}	0.12^{a}	0.09^{c}	0.03^{d}	0.02^{f}	0.06^{ef}	0.10^{e}	0.00	<0.001	<0.01	<0.01	1**,2**
C 23:0	0.11	0.08	0.09	0.11	0.07^{f}	0.23^{e}	0.00	0.00	0.44	0.60	<0.001	NS
C 24:0	0.00^{b}	0.22^{a}	0.12	0.10	0.04	0.14	0.16	0.00	<0.001	0.42	<0.01	2**
C 22:6n3	0.00^{b}	0.77^{a}	0.38	0.39	0.31^{f}	0.43^{e}	0.41^{ef}	0.00	<0.001	0.79	<0.05	2*
SFA	35.66	36.53	36.93^{c}	35.25^{d}	35.98	36.07	36.22	0.42	0.16	<0.05	0.95	2*,4*
MUFA	37.18	38.39	39.91^{c}	36.66^{d}	36.66	38.09	38.61	0.56	0.10	<0.01	0.09	2*
PUFA	20.46	20.87	21.58^{c}	19.75^{d}	20.46	20.82	20.72	0.16	0.28	<0.001	0.71	2*
P:S	0.57	0.57	0.58^{c}	0.56^{d}	0.57	0.58	0.57	0.00	0.82	<0.01	0.48	3**,4***
Total n6	19.06	18.61	19.67^{c}	17.99^{d}	18.77	18.96	18.77	0.13	0.19	<0.001	0.87	NS
Total n3	0.79^{b}	1.71^{a}	1.32c	1.89^{d}	1.14	1.29	1.32	0.00	<0.001	<0.05	<0.05	2*
n6:n3	24.03^{a}	11.03^{b}	17.41	17.66	18.32^{e}	17.39^{ef}	16.88^{f}	0.18	<0.001	0.52	0.03	NS

$^{a\text{-}b}$superscripts within row are significantly different by feed effect. $^{c\text{-}d}$sex effect. $^{e\text{-}g}$slaughter weight effect. 1,2,3 and 4 = interaction between feed×sex, feed×slaughter weight, sex×slaughter weight and feed×sex×slaughter weight respectively. *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$

CONCLUSIOIN

Bacon from swine fed with fish oil not only decreases cholesterol and triglyceride levels, but also increases total n-3 fatty acid especially DHA and EPA. However, bacon from swine fed with fish oil has also high rancidity.

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