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Effects of Dietary Canola Oil on Growth, Feed Efficiency, and Fatty Acid Profile of Bacon in Finishing Pigs and of Longissimus Muscle in Fattening Horses*

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Studies were carried out to determine the effect of feeding diet containing 5% canola oil on growth, feed efficiency, and fatty acid profile of bacon in finishing pigs and of longissimus muscle in horses fattening for meat production. In experiment 1, twenty cross-bred barrows and twenty cross-bred gilts (average weight, 80 kg) were blocked by sex and weight, and five barrows or five gilts were allotted to one of eight pens (6.25 m^2/pen), respectively. Four pens (two with barrows and two with gilts) randomly selected were assigned to a control diet containing 5% tallow and the remaining four pens to a diet containing 5% canola oil. The average daily weight gain, daily feed intake and feed efficiency over a 6-wk feeding period were not different ($p>0.05$) between the two diets, nor was backfat thickness. Fatty acid profile in bacon fat showed that the n-3 fatty acid (α-linolenic acid) content in pigs fed diet containing 5% canola oil was approximately three times ($P<0.01$) as much as in pigs fed tallow. In experiment 2, thirty-two Jeju horses (average weight±SE, 244±5 kg) were blocked by sex and weight, and two horses of the same sex and similar body weight were allotted to one (15 m^2/pen) of eight pens. Eight pens (four with males and four with females) selected randomly were assigned to a control diet containing 5% tallow and the remaining eight pens to a diet containing 5% canola oil. The average daily weight gain, daily feed intake and feed efficiency for concentrates without roughages over a 5-month feeding period were not different ($P>0.05$) between the two diet groups. Fatty acid profile in the muscle fat showed that the n-3 fatty acid (α-linolenic acid) content in horses fed diet containing 5% canola oil was approximately two times ($P<0.01$) that in horses fed tallow. The increased ($P<0.01$) n-3 fatty acid content in pigs and horses fed canola oil decreased the ratio of n-6 to n-3 fatty acids compared to the control, indicating a significant improvement in pork and horsemeat fatty acid profile for health benefit. Our study demonstrated that feeding diet containing 5% canola oil may help produce pork and horsemeat with more health benefit, increasing their α-linolenic acid content without deleterious effects on growth of pigs and horses.

Key words: Pigs, Horses, Canola oil, Fatty acid profile, α-linolenic acid

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INTRODUCTION

Cardiovascular disease is the primary cause of death in developed countries and also a leading cause of death worldwide. The relationships between diet and cardiovascular disease have been widely studied for the last century. In 1908, Ignatowski reported that feeding rabbits diets containing a high level of saturated fatty acids or cholesterol resulted in artherosclerosis.[1)] In the early 1950's, studies also found that serum cholesterol level was increased by dietary saturated fatty acids and to a less extent by dietary cholesterol in humans.[2)] In the meantime, epidemiological studies showed that cardiovascular disease increases proportionately with increasing serum cholesterol levels.

These findings led to a traditional diet-heart hypothesis, speculating the primary role of dietary saturated fatty acids and cholesterol in the cause of atherosclerosis and cardiovascular disease. Understanding of nutrients and diets that improve health has increased for the last few decades through: 1) studies on the mechanism of atherosclerosis at a molecular level and metabolic effects of various nutrients and diets, 2) large-scale group studies, and 3) dietary experiments. Among these nutrients or dietary components, n-3 (or ω-3) fatty acids are classified as essential fatty acids because they are not synthesized in animal's body and thus must be provided through diet. Canola, perilla,

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soybean and linseed are good sources of n-3 fatty acid.

Many health-conscious consumers tend to avoid red meat because of the public perception of the adverse effects of saturated fatty acids that are linked to coronary heart disease. Therefore, it is desirable to modify animal products so that they have a higher ratio of polyunsaturated to saturated fatty acids.[3] As a consequence many studies have been done to increase n-3 fatty acids in pork.[4,5] Different from beef, meats of nonruminants including pork, horsemeat and chicken high in unsaturated fatty acids can be produced by feeding diets high in unsaturated fatty acids such as those in vegetable oils. Canola oil contains high levels of the n-3 fatty acid α-linolenic acid and is ideal for human consumption compared with other vegetable oils because the ratio of α-linolenic acid to linoleic acid is 1:2.[6]

Health benefit is known to be an important factor in the selection of food items by consumers,[7] and thus it is important to develop diets that can effectively prevent or alleviate diet-related diseases, such as cardiovascular disease and cancer. Animal industry is interested in developing products that are supposed to be good for consumers' health and production of meat rich in unsaturated fatty acids is one of its concerns.[8] There are several extensive reviews of the biological effects of n-3 fatty acids and their roles in reducing coronary heart disease.[9-12] The popularity of horsemeat has recently been increasing due to its low fat content and delicacy, especially in Jeju where most inherent horses have been raised for meat as well as for draft and riding for a long time. We studied the effect of feeding a diet containing 5% canola oil on growth, feed efficiency and fatty aid profile of bacon in late finishing pigs and of longissimus muscle in fattening Jeju horses.

MATERIALS AND METHODS

1. Animals and Diets

In experiment 1, twenty cross-bred barrows and twenty cross-bred gilts (Yorkshire×Landrace×Duroc, average weight 80 kg) were blocked by sex and weight, and five barrows or five gilts were allotted to one of eight pens (experimental units, 6.25 m^2/pen covered with sawdust), respectively. Four pens (two with five barrows each and two with five gilts each) randomly selected were assigned to a control diet containing 5% tallow and the remaining four pens to a diet containing 5% canola oil. The diet containing 5% canola oil also contained 5% canola meal substituting for 3.7% soybean meal (on an isonitrogenous basis) and approximately mimicked a diet containing 10% canola seed. Additional 100 mg α-tocopheryl acetate per kg of diet (for both control and canola oil) was provided to increase oxidative stability of pork,[13] especially in pigs fed canola oil. Pigs were allowed to have free access to diets (Table 1) and water during the 6-wk feeding period and were fasted for 12 hours before slaughter (average weight, 116 kg). Backfat thickness was determined manually at the last rib, and about 500 g bacon samples were taken from 10 pigs randomly selected from each treatment, frozen in liquid nitrogen and stored at -20 ℃ for later analysis.

Table 1. Composition of diets used in experiment 1

(% as-fed basis)

Ingredient	Control	Canola
Corn	76.97	75.67
Soybean meal, 44% CP	15.8	12.1
Canola meal, 38% CP	-	5.0
Tallow[1)]	5.0	-
Canola oill	-	5.0
Lysine	0.1	0.1
Limestone	0.6	0.6
Dicalcium-phosphate	1.0	1.0
Premix[2)]	0.15	0.15
Salt	0.35	0.35
Alpha-tocopheryl acetate	0.011	0.011
Barox[3)]	0.02	0.02

1) Fatty acid profile of beef tallow and canola oil as weight percentages of total fatty acids was C14:0, 1.6 and 0.09; C16:0, 20.24 and 4.93; C16:1, 2.28 and 0.17; C18:0, 19.18 and 2.84; C18:1, 48.09 and 60.39; C18:2, 7.84 and 23.36; and C18:3, 0.77 and 8.22; respectively.

2) Provided the following per kg of diet: Fe, 120 mg; Cu, 9 mg; Mn, 30 mg; Zn, 48 mg; I, 0.3 mg; Se, 0.15 mg; vitamin A, 7,500 IU; vitamin D3, 1,500 IU; vitamin E, 37.5 IU; vitamin K3, 22.5 mg; vitamin B1, 1.5 mg; vitamin B2, 3.0 mg; vitamin B6, 1.5 mg; vitamin B12, 0.015 mg; pantothenic acid, 7.5 mg; niacin, 30 mg; biotin, 0.075 mg; folic acid, 1.5 mg.

3) BHA, 2%; BHT, 10%; ethoxyquin, 20%; lecithin, 10%; and vegetable oil, 58% (CTC Bio, Ltd, Seoul Korea).

In Experiment 2, thirty-two Jeju horses (average weight± SE, 244±5 kg) were blocked by sex and weight, and two horses were allotted to one of eight pens (experimental units, 15 m^2/pen covered with sawdust). Eight pens (four with two males each and four with two females each) were randomly selected and assigned to a control diet (Table 2) containing 5% tallow and the remaining eight pens to a diet containing 5% canola oil. The amounts of concentrates supplied during the 5-month feeding trial were 1.0 (1st one month of experimental period), 1.3 (2nd), 1.5 (3rd), 1.7 (4th) and 1.7% (5th) of their average body weight of each pen. Horses had free access to hay (Italian ryegrass) and water during the 5-month feeding period. After the feeding trial, horses were slaughtered at a commercial slaughter house after overnight fasting and about 500 g longissimus muscle samples were taken from each horse and stored at -20 ℃ for later analysis.

Table 2. Composition of concentrates used in experiment 2 (% as-fed basis)

Ingredient	Control	Canola
Corn	71.5	71.5
Soybean meal	18.1	18.1
Tallow[1)]	5.0	-
Canola oil1	-	5.0
Molasses	3.0	3.0
Calcium phosphate	1.2	1.2
Limestone	0.6	0.6
Salt	0.45	0.45
Premix (vit & min)[2)]	0.15	0.15

1) The fatty acid profiles are the same as those in Table1.
2) Provided the following per kg of diet: Fe, 120 mg; Cu, 9 mg; Mn, 30 mg; Zn, 48 mg; I, 0.3 mg; Se, 0.15 mg; vitamin A, 7,500 IU; vitamin D3, 1,500 IU; vitamin E, 37.5 IU; vitamin K3, 22.5 mg; vitamin B1, 1.5 mg; vitamin B2, 3.0 mg; vitamin B6, 1.5 mg; vitamin B12, 0.015 mg; pantothenic acid, 7.5 mg; niacin, 30 mg; biotin, 0.075 mg; folic acid, 1.5 mg.

Table 3. Effects of dietary canola oil on daily weight gain, daily eed intake and feed efficiency in finishing pigs[1)]

Item	Control	Canola	p[2)]
Daily weight gain (g/day)			
0~3wk	0.96± 0.05	1.01± 0.06	0.2290
3~6wk	0.75± 0.04	0.79± 0.09	0.4969
0~6wk	0.85± 0.03	0.90± 0.05	0.3301
Daily feed intake (g/day)			
0~3wk	3.0 ± 0.05	3.1 ± 0.05	0.4860
3~6wk	3.7 ± 0.08	3.5 ± 0.03	0.0689
0~6wk	3.3 ± 0.06	3.3 ± 0.03	0.1304
Weight gain/feed intake (g/g)			
0~3wk	0.321±0.017	0.325±0.021	0.1936
3~6wk	0.204±0.009	0.226±0.026	0.1362
0~6wk	0.259±0.009	0.273±0.014	0.4837

1) Values are means±SE of 4 groups of 5 pigs each.
2) p-values are based on the student t-test.

2. Determination of Fatty Acid Profile

In experiment 1, about 2 g of frozen bacon samples was homogenized in a mixture of chloroform:methanol:water (1:2:8) using a polytron and lipid layer was extracted and dried under flowing nitrogen.[14)] Extracted lipid was esterized using the AOCS standard procedure[15)] and methyl ester was extracted into hexane and dried. Fatty acid profile was determined using a gas chromatography (Varian 3800, Varian, Inc., Walnutcreek, CA) equipped with flame ionization detector and Supelcowax 10 fused-silica capillary column (30 m×0.32 mm, i.d.) (Supelco, Bellefonte, PA). Temperature of oven, injection port and detector was 190 ℃, 240 ℃ and 260 ℃, respectively, and helium flow rate was 20 mL/min. Fatty acid profile was expressed as percentages of individual fatty acids detected.

In experiment 2, about 10 g of frozen longissimus muscle samples of horses was homogenized and treated for lipid layer extraction as described above. The procedure used for fatty acid profile was similar to that used in experiment 1

3. Statistical Analysis

Data were analyzed by the Student's unpaired t-test using SAS-PC software (The SAS System for Windows ver. 8.02). All data were presented as the mean±SE and statistical significance was considered at $p<0.05$.

RESULTS AND DISCUSSION

In the pig feeding trial, the average daily weight gain, daily feed intake and feed efficiency over the 6-wk feeding period were not different between the two diets (Table 3). Nor was backfat thickness (control, 25.7±1.3 mm vs canola oil, 27.9±1.1 mm, data not shown). These data indicate that substitution of canola oil for tallow does not adversely influence growth or backfat thickness in finishing pigs. Canola oil may be supplied with canola seed more economically than with refined oil because the canola oil diet also containing 5% canola meal did not adversely affect growth or feed efficiency compared to the control. In addition to canola oil, canola meal could have also contributed to the n-3 fatty acid content in pork although the amount might be insignificant because the fat content in canola meal is less than 5% (indicating fat supplied by canola meal is less than 0.25% of the diet).

Table 4. Effect of dietary canola oil on fatty acid profile of bacon fat in pigs[1)]

Fatty acid	Control	Canola	p[2)]
$C_{14:0}$	0.99±0.02	0.96±0.02	0.2831
$C_{16:0}$	19.76±0.21	18.70±0.22	0.0032
$C_{16:1}$	2.07±0.05	1.74±0.07	0.0016
$C_{18:0}$	13.12±0.31	12.02±0.34	0.0316
$C_{18:1}$	49.60±0.30	49.70±0.38	0.8770
$C_{18:2}$	13.75±0.53	15.03±0.30	0.0526
$C_{18:3}$	0.65±0.03	1.82±0.05	0.0001

1) Values are means±SE of 10 pigs and expressed as percentages of total fatty acids determined.
2) p-values are based on the student t-test.

Busboom *et al.* reported that a diet containing 20% canola seed did not show any deleterious effect on growth or carcass compared with a control containing no canola seed in finishing pigs.[16)] Feeding pigs diets containing 5 or 10% canola oil increased growth rate and the concentration of linoleic and α-linolenic acids while decreasing that of arachidonic and docosadienoic acids in liver compared to a diet without added fat.[17)] However, reduced fat firmness has been reported in pigs fed diets containing high levels of canola oil.[5,18,19)]

Fatty acid profile in bacon (Table 4) showed that the n-3 fatty acid, α-linolenic acid in pigs fed diet containing 5% canola oil was approximately three times ($P<0.01$) as much as that in pigs fed tallow. This decreased the ratio of n-6:n-3 fatty acids in pigs fed canola oil compared to the control (8 vs 21), indicating a significant improvement in pork fatty acid composition for health benefit. Most ideal ratio of these fatty acids have been known to be 4:1[20] or 2:1 - 1:1[21,22], but common American diets have 16.7 for the ratio.[22]

Dietary intake of n-3 fatty acid has been known to help reduce the prevalence rate of cardiovascular disease through preventing arrhythmia, reducing serum triacylglycerol level and thrombosis, and improving epithelial tissue of blood vessels.[23] Deterioration of pork quality (flavor, color, texture, and nutritive value) has been a concern when pigs are fed diets containing high levels of canola oil or unsaturated fatty acids. But supplementing diets with high levels of vitamin E improved oxidative stability of pork counteracting the effect of increased polyunsaturated fatty acid contents in the pork.[24-27] Our pig diet contained 100 mg vitamin E/kg in addition to that (37.5 mg/kg) in the basal premix.

In the horse feeding trial, the average daily weight gain, daily feed intake, and feed efficiency for concentrates excluding hay over the 5-month feeding period were not different ($P>0.05$) between the two diet groups (Table 5). Fatty acid profile in the longissimus muscle fat showed that the n-3 fatty acid, α-linolenic acid in horses fed diet containing 5% canola oil was approximately twice ($P<0.01$) as much as that in horses fed tallow (Table 6). This decreased the ratio of n-6:n-3 fatty acids in horses fed canola oil compared to the control (3 vs 6), indicating improvement in meat fatty acid profile for health benefit. Interestingly, the percentage of n-3 fatty acid (α-linolenic acid) is much higher in horse fat than in pig fat (1.94 vs 0.65 for the controls and 4.09 vs 1.82 for those fed 5% canola oil diets). This species difference in n-3 fatty acid content suggests that meat from hay-fed horses is a significant source of n-3 fatty acid compared to pork from grain-fed pigs. Grasses have been known to be a good source of n-3 fatty acids, while seeds (e.g., cereal grains) contain mainly the n-6 fatty acid linoleic acid.[3]

In conclusion, our study demonstrated that feeding diet containing 5% canola oil may help produce pork or horsemeat with more health benefit, increasing its α-linolenic acid content without deleterious effects on growth of animals.

Table 5. Effect of dietary canola oil on daily weight gain and feed efficiency during a 5-month feeding period in fattening horses[1)]

Item	Control	Canola	p[2)]
Daily weight gain (kg)	0.59± 0.04	0.54± 0.04	0.3059
Daily feed intake (kg)			
Concentrate	4.05± 0.12	4.14± 0.10	0.5647
Hay	5.34± 0.25	6.15± 0.37	0.0810
Weight gain/feed intake (kg/kg)			
Concentrate	0.138±0.010	0.121±0.009	0.1887
Hay	0.107±0.005	0.083±0.006	0.0100

1) Values are mean±SE of 16 horses. Initial and final body weight of control animals and animals fed canola was 241±8.4, 329.3±9.6, 248.2±6.6, and 327.9±8.7 g, respectively

2) p-values are based on the student t-test.

Table 6. Effect of dietary canola oil on fatty acid profile of longissimus muscle fat in horses[1)]

Fatty acid	Control	Canola	p[2)]
$C_{14:0}$	4.18±0.09	4.15±0.18	0.8884
$C_{16:0}$	31.18±0.43	31.13±0.39	0.9298
$C_{16:1}$	7.39±0.29	7.01±0.28	0.3615
$C_{18:0}$	4.44±0.16	4.65±0.18	0.3828
$C_{18:1}$	38.56±0.43	36.13±0.51	0.0010
$C_{18:2}$	12.31±0.60	12.84±0.65	0.5518
$C_{18:3}$	1.94±0.28	4.09±0.37	<0.0001

1) Values are mean±SE of 16 horses.

2) p-values are based on the student t-test.

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