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Effects of protected omega-3 fatty acid derived from linseed oil and vitamin E on growth performance, apparent digestibility, blood characteristics and meat quality of finishing pigs

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Abstract. This study was conducted to evaluate the effects of protected omega-3 fatty acid and vitamin E on the growth performance, nutrient digestibility, blood profiles and meat quality of finishing pigs. A total of 140 female and castrated-male finishing pigs [(Yorkshire × Landrace) × Duroc] with an average initial bodyweight of 46.5 kg were blocked and stratified based on sex and bodyweight to a 2 × 2 factorial design with the respective factors being (1) without and with 300 IU vitamin E (Vit E), and (2) without and with 0.75% protected omega-3 fatty acid (*n*-3 FA) derived from linseed oil in a 12-week trial. Each treatment consisted of seven replicate pens with five pigs (three barrows and two gilts) per pen. The supplementation of Vit E improved ($P < 0.05$) and *n*-3 FA tended to increase ($P = 0.07$) overall average daily gain. The apparent digestibility of nitrogen tended to increase ($P = 0.07$) with the addition of Vit E in the diet. The concentration of IgG significantly increased ($P < 0.05$) with the addition of Vit E in the diet whereas the concentration of cortisol was significantly reduced ($P < 0.05$) with the addition of Vit E. There was a significant ($P < 0.05$) interaction between Vit E and *n*-3 FA on cortisol levels. Surface longissimus muscle redness (a*) increased with the supplementation of Vit E. However, the score of colour darkness based on sensory evaluation and drip loss on Day 5 were significantly reduced with the addition of Vit E in the diet.

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Introduction

With recent increases in consumer concerns about food quality and food safety, there has been increased interest in pork quality improvement. Potential improvement to pork quality attributes such as muscle colour, water-holding capacity, pork palatability, back fat thickness, and carcass yield has been researched extensively. A major cause of deterioration to the quality of meat during storage is lipid oxidation. It can lead to several undesirable changes. These include the development of oxidative rancidity and associated increase in unpleasant odours. These changes can reduce the shelf-life of pork. Polyunsaturated fatty acids (FA) are essential FA that cannot be synthesised by the body but can be obtained from the diet. However, they are susceptible to oxidation. The composition of dietary fat ingested by pigs is closely related to FA composition of fat depots. Therefore, they can be readily manipulated by altering the fat source. Dietary supplementation of omega-3 FA (50 g/kg extruded linseed) can make meat suitable for fresh consumption but not suitable for long-time storage as cured pork due to oxidation (Cannata *et al*. 2010). In swine, linseed and its by-products are often used as a source of omega-3 FA because alpha-linolenic acid (ALA) is readily available in linseed. In addition, ALA is less susceptible to oxidation. Therefore, omega-3 FA of linseed and its by-products have fewer problems with quality or storage compared with fish oil FA (Van Oeckel *et al*. 1996). Furthermore, if the active ingredient of FA is protected, it might be effective in reducing the faster disappearance of active ingredients thereby allowing effective release to the appropriate site. A study by Bosi *et al*. (1999) showed that when organic acids were protected, absorption of dietary acids in the stomach were effectively retarded thereby allowing more effective delivery of the acids to the distal ileum, caecum, and colon of piglets.

A common strategy to reduce oxidation in pork and improve its shelf-life and quality is by using antioxidants such as vitamin E (Vit E). In growing-finishing pigs, National Research Council (NRC) (1998) has recommended that the amount of Vit E to prevent deficiency symptoms should be 11 IU/kg feed of DL-a-tocopherol. However, increased levels of Vit E up to 30 IU/kg or higher are also recommended (Ullrey 1981).When diets contain higher level of polyunsaturated FA, additional oxidative stability is required. In such situation, Vit E levels can be increased up to 200 IU (Buckley *et al*. 1995) and higher levels up to 550 IU has been fed to growing pigs' without any toxic effects (Bonnette *et al*. 1990). However, the uptake of Vit E is influenced by its degree of oxidation and the type of FA in the diet (Monahan *et al*. 1990; Lopez-Bote *et al*. 2003).

We hypothesised that the combination of *n*-3 FA from linseed oil and Vit E could have synergistic effects for the improvement of growth performance and meat quality of

growing-finishing pigs. The objective of this study was to evaluate the effects of dietary supplementation of 300 IU Vit E and 0.75% *n*-3 FA from linseed oil to corn-soybean meal-based diet on growth performance, nutrient digestibility, blood profile, meat quality, and carcass characteristics in finishing pigs.

Materials and methods

The experiment was conducted at the swine experimental unit of Dankook University (Anseodong, Cheonan, Choongnam, Korea). The study protocol was approved by the Animal Care and Use Committee of Dankook University.

Animal, experimental design and housing

A total of 140 mixed sex pigs [(Landrace × Yorkshire) × Duroc] with an initial average bodyweight of 46.5 kg were used in a 12-week trial. Pigs were blocked and stratified based on sex and bodyweight in a 2 × 2 factorial design with the following factors: (1) with or without 300 IU Vit E, and (2) with or without 25% replacement of tallow with linseed oil as a source of *n*-3 FA (*n*-3 FA). The level of omega-3 FA for this study was determined based on our primary test that evaluated different levels of omega-3 FA from linseed oil and the level of supplemental Vit E was set at 300 IU based on a previous study, which indicated that Vit E level up to 550 IU is not toxic (Bonnette *et al*. 1990). Each treatment consisted of seven replicate pens with five pigs (three castrated barrows and two gilts) per pen. Diets were formulated to meet or exceed NRC (2012) recommendations for all nutrients (Table 1). Throughout the experiment, all pigs were provided with *ad libitum* access to feed and water through a self-feeder and nipple drinker, respectively. Target room temperature and humidity were 25°C and 60%, respectively.

Source of omega-3 FA

The omega-3 FA used in this study was provided by a commercial company (Morningbio Co., Ltd, Cheonan, Korea). The plant based omega-3 FA produced from linseed oil was protected using spray drying method as previously described by Watanabe *et al*. (2002). Protected *n*-3 FA contains 55.75% linolenic acid as active ingredient. Besides this it also contains 15.73% linoleic acid, 18.89% oleic acid, 5.22% palmitic acid and 4.41% stearic acid.

Sampling and measurements

Bodyweight was measured initially, at Week 6, and at Week 12 of the experimental period. Feed consumption was recorded on a pen basis during the experiment to calculate average daily gain, average daily feed intake, and gain-to-feed ratio. Chromium oxide was added to the diet as an indigestible marker at 0.20% of the diet for 7 days before faecal collection at the 12th week to calculate apparent DM, nitrogen (N), and energy digestibility. Faecal samples were collected randomly from at least two pigs (one barrow and one gilt) from each pen were mixed and pooled, and a representative sample was stored in a freezer at −20°C until analysed. All feed and faecal samples were freeze-dried and finely ground to pass through a 1-mm screen. Dry matter and N digestibility were determined using methods established by Association of Official Analytical Chemists (AOAC 2000). Chromium levels were determined via UV absorption spectrophotometry (UV-1201, Shimadzu, Kyoto, Japan). Apparent total tract digestibility of DM and N were calculated using indirect methods described by Williams *et al*. (1962). Gross energy was determined by measuring the heat of combustion in the samples using a Parr 6100 oxygen bomb calorimeter (Parr instrument Co., Moline, IL, USA).

Two pigs (one barrow and one gilt) were randomly selected from each pen and bled via jugular venipuncture at the end of the experiment (14 pigs per treatment). Blood samples (5 mL) were collected into vacuum tubes (containing no additive) and tubes containing K_3EDTA (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ, USA) to obtain serum and whole blood, respectively. White blood cells and lymphocyte counts of whole blood samples were determined using an automatic blood analyser (ADVIA 120, Bayer, Tarrytown, NY, USA). Serum was separated by centrifugation for 15 min at 3000*g* at 4°C and

Table 1. Composition of experimental diets (as-fed basis) and calculated and analysed energy and nutrient contents

n-3 FA, omega-3 fatty acid; Vit E, vitamin E

Ingredients (%)	*n*-3 FA–		*n*-3 FA+	
	Vit E–	Vit E+	Vit E–	Vit E+
Corn	57.61	57.55	57.61	57.55
Wheat, hard red spring	10.00	10.00	10.00	10.00
Wheat bran	5.00	5.00	5.00	5.00
Soybean meal (44%)	19.70	19.70	19.70	19.70
Tallow	3.00	3.00	2.25	2.25
Molasses	2.50	2.50	2.50	2.50
Limestone	0.90	0.90	0.90	0.90
Dicalcium phosphate	0.70	0.70	0.70	0.70
Salt	0.30	0.30	0.30	0.30
L-lysine	0.09	0.09	0.09	0.09
Vitamin mix[A]	0.10	0.10	0.10	0.10
Mineral mix[B]	0.10	0.10	0.10	0.10
Vit E[C]	0.00	0.06	0.00	0.06
n-3 FA (linseed oil)	0.00	0.00	0.75	0.75
Calculated value (%)				
Metabolisable energy (MJ/kg)	13.8	13.8	13.8	13.8
Vitamin E (%)	0.001	0.031	0.001	0.031
Omega-3 FA (% of ether extract)	1.61	1.61	2.03	2.02
Omega-6 FA (% of ether extract)	0.21	0.21	0.30	0.30
Crude protein	16	16	16	16
Lysine	0.90	0.90	0.90	0.90
Methionine	0.29	0.29	0.29	0.29
Calcium	0.61	0.61	0.61	0.61
Total phosphorus	0.42	0.42	0.42	0.42
Analysed value				
Dry matter	88.73	88.70	88.81	88.69
Crude protein	16.2	16.2	16.3	16.2
Lysine	0.89	0.92	0.90	0.93
Methionine	0.28	0.29	0.29	0.30
Calcium	0.64	0.67	0.63	0.65
Total phosphorus	0.44	0.44	0.42	0.43

[A]Provided per kg of complete diet: vitamin A, 8000 IU; vitamin D3, 800 IU; vitamin E, 40I U (basal level); vitamin K, 2 mg; vitamin B_2, 4 mg; vitamin B_6, 3 mg; vitamin B_{12}, 20 μg; pantothenic acid, 15 mg; niacin, 20 mg; biotin, 0.02 mg.

[B]Provided per kg of complete diet: Cu, 150 mg; Fe, 150 mg; Zn, 50 mg; Mn, 40 mg; I, 0.5 mg ; Co, 0.5 mg; Se, 0.3 mg.

[C]300 IU vitamin E as a supplement to experimental diet.

stored at 4°C until determination for serum immunoglobulin G (IgG) and cortisol (Rodent Cortisol ELISA Kit, Endocrine Technologies, Minneapolis, MN, USA).

At the end of the experiment two pigs (one barrow and one gilt) per replicate pen per treatment were randomly selected and slaughtered at local commercial slaughter house. Carcasses were placed in a conventional chiller at 4°C. After a 24-h chilling period, carcasses were fabricated into primal cuts. Meat samples including lean and fat were taken via perpendicular cut loins into 2-cm-thick chop beginning from the 10th and 11th ribs region from back fat thickness of pigs were measured 5 cm from the right-hand side of the midline from three different sites (shoulder, mid-back and loin at a position directly above the point of elbow, last rib and last lumbar vertebra) using a real-time ultrasound instrument (Piglog 105, SFK Technology, Herlev, Denmark) (Kim *et al*. 2004). Back fat thickness of pigs were measured 5 cm from the right-hand side of the midline from three different sites (shoulder, mid-back and loin at a position directly above the point of elbow, last rib and last lumbar vertebra) using a real-time ultrasound instrument (Piglog 105, SFK Technology) (Kim *et al*. 2004). The meat samples were thawed at room temperature before evaluation. Sensory evaluation was conducted by six trained panellists to evaluate the colour darkness, firmness and marbling of fresh loin samples using a five-point assessment scheme according to the procedures established by the National Pork Producers Council (NPPC) (1991). Immediately after the subjective tests were conducted, meat colour of the longissimus muscle (LM) as lightness (L*), redness (a*), and yellowness (b*), was determined using a Minolta Chromameter (CR-210, Minolta, Japan) to evaluate the freshly cut surface after 30 min of blooming at 4°C. Water-holding capacity (WHC) was measured using methods of Kauffman *et al*. (1986). Briefly, a 0.2-g sample was pressed at 3000 psi for 3 min onto laboratory grade 125-mm-diameter filter paper. The areas of pressed sample and expressed moisture were delineated and determined with a digitising area-line sensor (MT-10S; M. T. Precision Co. Ltd, 123 Tokyo, Japan). A ratio of water area : meat area was calculated to give a measure of WHC, with smaller ratio indicating higher WHC and is termed as 'Expressed juice percentage'. LM area was measured by tracing the LM surface at 10th rib, which also used the above-mentioned digitising area-line sensor. Cook loss was determined as described previously by Sullivan *et al*. (2007). Briefly, 5 g of meat sample were heat-treated in plastic bags separately in a water bath (100°C) for 5 min. Samples were cooled at room temperature. Cooking loss was calculated as (sample weight before cooking-sample weight after cooking)/sample weight before cooking × 100.

Cumulative drip loss was measured using ~2 g of meat sample according to the plastic bag method, which was described by Honikel (1998). Briefly, two (2.5 × 2.5 cm) chops were weighed, placed in a drip loss tube (C. Christensen Laboratory, Hillerod, Denmark), and held at 2°C for 24 h. Then, meat samples were removed, blotted dry on paper towels, and re-weighed. Differences between sample weights were used to calculate drip loss percentage.

Statistical analyses

Data were subjected to two-way ANOVA according to the factorial design of the study using SAS (SAS Institute Inc., Cary, NC, USA). Pen was used as experimental unit. Variability in data was expressed as standard error of means (s.e.m.). A probability level of $P < 0.05$ was considered to be statistically significant. Probability level of less than 0.1 was considered tendency.

Result and discussion

Growth performance and apparent nutrient digestibility

Vitamin E significantly ($P < 0.05$) improved overall average daily gain whereas *n*-3 FA tended ($P = 0.07$) to improve overall

Table 2. Effects of dietary vitamin E and omega-3 fatty acid supplementation on the performance of finisher pigs offered feed *ad libitum* for 12 weeks
n-3 FA, omega-3 fatty acid (0.75%) derived from linseed oil; Vit E, 300 IU vitamin E

Items	*n*-3 FA–		*n*-3 FA+		s.e.[A]	*P*-value		
	Vit E–	Vit E+	Vit E–	Vit E+		Vit E	*n*-3 FA	Vit Ex *n*-3 FA
				Bodyweight (kg)				
Initial	46.5	46.5	46.5	46.5	1.14	0.995	0.995	0.999
6 weeks	77.5	78.6	78.3	78.8	1.55	0.611	0.716	0.853
12 weeks	113.7	116.0	115.7	116.2	1.63	0.411	0.491	0.573
				0–6 weeks				
Average daily gain (ADG; g)	738	764	758	771	12.45	0.135	0.280	0.587
Average daily feed intake (ADFI; g)	2227	2283	2276	2231	35.5	0.865	0.963	0.169
Gain-to-feed ratio	0.332	0.335	0.333	0.345	0.006	0.219	0.219	0.457
6–12 weeks								
ADG (g)	863	892	892	890	10.1	0.194	0.190	0.142
ADFI (g)	2651	2692	2657	2678	39.3	0.439	0.919	0.792
G/F	0.326	0.331	0.336	0.333	0.004	0.745	0.200	0.517
				Overall				
ADG (g)	800	828	825	830	7.35	0.034	0.074	0.143
ADFI (g)	2439	2488	2467	2455	29.6	0.538	0.924	0.314
Gain-to-feed ratio	0.329	0.333	0.335	0.338	0.004	0.367	0.216	0.855

[A]Standard error of means. Each mean represents seven pens with two gilts and three barrows per pen.

average daily gain (Table 2). No significant treatment effects were found for other measures of growth performance. The apparent digestibility of N tended ($P = 0.07$) to be improved by the addition of Vit E but not *n*-3 FA in the diet. No interactive effects of Vit E and omega-3 FA were observed for growth performance parameters and apparent nutrient digestibility (Table 3). Other studies have noted similar results. For example, it has been reported that dietary supplementation with linseed oil (Nguyen *et al*. 2004) or Vit E (Asghar *et al*. 1991) can improve average daily gain in swine. Abril *et al*. (2003) also reported improvement of average daily gain in pigs receiving 1250 g per pig of omega-3 FA from marine algae. In contrast Gardiner *et al*. (2008) observed linear reduction in average daily gain but no effect on feed intake and feed efficiency in growing finishing pigs with dietary supplementation of 3, 6 and 9 g of *Ascophyllum nodosum* extract rich in omega- 3 FA. The inconsistent results for average daily gain are likely associated with differences in the source and levels of *n*-3 FA and in the age of the pigs used between experiments. The lack of effect of *n*-3 FA in our study on feed intake, feed efficiency or apparent nutrient digestibility is in agreement with the results of Cho and Kim (2013) who reported that addition of 1.5% and 3% micro-encapsulated *n*-3 FA from linseed oil did not have any effect on growth performance and nutrient digestibility of finishing pigs.

Blood profile

The concentration of IgG was significantly ($P < 0.05$) increased by the addition of Vit E to the diet. The concentration of cortisol was significantly ($P < 0.05$) reduced by the addition of Vit E or tended to be reduced ($P = 0.052$) in pigs offered the diets supplemented with *n*-3 FA. However, there was a significant ($P < 0.05$) interaction between Vit E and *n*-3 FA on cortisol levels. The concentrations of white blood cells and lymphocyte were not significantly ($P > 0.05$) affected by the supplementation of Vit E or *n*-3 FA in the diet (Table 4).

Immunoglobulin G is a major immunoglobulin in blood, lymph fluid and cerebrospinal fluid and is a key factor in humoral response. Our results for Vit E on IgG are supported by Niu *et al*. (2009) who reported that dietary IgG production was increased in broilers fed diets supplemented with 200 mg/kg Vit E. The reduction in serum cortisol elicited by Vit E in our study also has implications with respect to the animal's immune system and ability to better handle disease and stress situations. In a previous study (Upadhaya *et al*. 2015) we found that *n*-3 FA but not Vit E supplementation reduced serum cortisol in lipo polysaccharide-challenged pigs. Carroll *et al*. (2003) and Gaines *et al*. (2003) also reported that the inclusion of menhaden fish oil (containing omega-3) in the diets offered immune system-activated pigs reduced serum cortisol and tumor necrosis factor-α. The changes reported here for IgG and cortisol suggest Vit E and omega-3 have the potential to improve the immune status of growing pigs.

Meat quality and carcass characteristics

Supplementary Vit E significantly improved surface LM colour (a*) and reduced drip loss measured on Day 5. Vit E supplementation also reduced LM colour score based on sensory evaluation (Table 5). There were no treatment effects on any other measures of meat quality except for a trend ($P = 0.065$) in the reduction of carcass weight in pigs offered diet supplemented with *n*-3 FA (Table 5).

Meat quality deterioration can occur due to several factors, including genetics, improper practices in handling, storage, and cooking. However, lipid oxidation is probably the most substantive factor impacting key parameters such as colour, flavour, and texture. Supplementation of Vit E plays an important

Table 3. Effects of dietary vitamin E and omega-3 fatty acid supplementation on the apparent nutrient digestibility of finisher pigs offered feed *ad libitum* for 12 weeks

n-3 FA, omega-3 fatty acid (0.75%) derived from linseed oil; Vit E, 300 IU vitamin E

Items	*n*-3 FA–		*n*-3 FA+		s.e.[A]	*P*-value		
	Vit E–	Vit E+	Vit E–	Vit E+		Vit E	*n*-3 FA	Vit Ex *n*-3 FA
Dry matter (%)	70.1	71.4	71.6	72.1	1.15	0.430	0.343	0.678
Nitrogen (%)	67.3	69.5	69.2	71.2	1.13	0.074	0.129	0.908
Energy (%)	70.8	71.6	71.5	71.6	1.4	0.757	0.818	0.825

[A]Standard error of means. Each mean represents seven pens with one gilt and one barrow per pen.

Table 4. Effects of dietary vitamin E and omega-3 fatty acid supplementation on whole blood (WBC and lymphocyte) and serum profile (IgG and cortisol) of finisher pigs offered feed *ad libitum* for 12 weeks

n-3 FA, omega-3 fatty acid (0.75%) derived from linseed oil; Vit E, 300 IU vitamin E

Items	*n*-3 FA–		*n*-3 FA+		s.e.[A]	*P*-value		
	Vit E–	Vit E+	Vit E–	Vit E+		Vit E	*n*-3 FA	Vit Ex *n*-3 FA
IgG (mg/dL)	660	704	674	709	14.03	0.014	0.522	0.741
Cortisol (μg/dL)	1.4	1.1	1.2	1.1	0.04	0.001	0.052	0.033
WBC (10^3/μL)	23.9	22.7	21.2	22.3	1.36	0.999	0.277	0.413
Lymphocyte[B]	57.8	59.2	60.1	57.5	1.58	0.705	0.846	0.233

[A]Standard error of means. Each mean represents seven pens with one gilt and one barrow per pen.
[B]Lymphocytes are expressed as a percentage of the total WBC count.

Table 5. Effects of dietary vitamin E and omega-3 fatty acid supplementation on carcass characteristics and meat quality of finisher pigs offered feed *ad libitum* for 12 weeks

n-3 FA, omega-3 fatty acid (0.75%) derived from linseed oil; Vit E, 300 IU vitamin E

Items	*n*-3 FA–		*n*-3 FA+		s.e.[A]	*P*-value		
	Vit E–	Vit E+	Vit E–	Vit E+		Vit E	*n*-3 FA	Vit Ex *n*-3 FA
Carcass weight (kg)	94	92.5	92	91	0.97	0.241	0.065	0.702
Backfat thickness (mm)	21	21.1	21	20	0.71	0.353	0.136	0.746
Meat colour								
L* (lightness)	54.19	52.59	53.96	53.78	0.77	0.276	0.547	0.396
a* (redness)	16.64	17.1	16.51	17.3	0.28	0.044	0.826	0.515
b* (yellowness)	5.34	5.41	5.51	5.29	0.14	0.734	0.865	0.318
Sensory evaluation[B]								
Colour	3.7	3.4	3.6	3.4	0.09	0.02	0.306	0.602
Firmness	3.76	3.74	3.68	3.78	0.08	0.56	0.769	0.56
Marbling	3.6	3.68	3.68	3.65	0.07	0.742	0.742	0.513
Cooking loss (%)	44.63	43.46	42.68	43.6	2.13	0.954	0.68	0.631
Cumulative drip loss (%)								
Day 1	8.64	6.56	5.88	6.48	0.79	0.365	0.104	0.116
Day 3	12.8	11.72	11.67	12.25	1.03	0.811	0.774	0.437
Day 5	19.23	16.5	17.8	15.68	0.89	0.018	0.229	0.741
Day 7	27.54	26.53	26.73	26.46	1.09	0.57	0.695	0.728
LMA[C] (cm^2)	50.7	51.3	51.43	51.05	0.93	0.869	0.729	0.481
Expressed juice[D] (%)	54.65	53.78	53.21	53.55	0.77	0.783	0.373	0.524

[A]Standard error of means. Each mean represents seven pens with one gilt and one barrow per pen for meat quality.

[B]Colour score: 1 = pale grey, to 5 = dark purplish red; marbling score: 1 = devoid to practically devoid, to 5 = moderately abundant or greater; firmness score: 1 = very soft and very watery, to 5 = very firm and dry (NPPC 1991). Sensory evaluation was conducted immediately after thawing meat samples that was obtained 24 h after chilling the carcass at 2°C.

[C]Longissimus muscle area at the 10 and 11th rib.

[D]Expressed juice was calculated based on water-holding capacity.

role in reducing meat deterioration by minimising oxidation. Furthermore, linseed and its by-products are often chosen as a source of omega-3 FA because ALA readily available in linseed is less susceptible to oxidation. Therefore, *n*-3 FA from linseed and its by-products have fewer problems associated with quality or storage than fish oil FA (Van Oeckel *et al*. 1996).

In the present study, no adverse effect in meat quality such as expressed juice percentage, LM area, back fat thickness, was observed after the addition of 300 IU of Vit E or 0.75% *n*-3 FA, which was in agreement to the findings of Nassu *et al*. (2011) who also reported no effect on beef quality with Vit E supplementation. In contrast Secrist *et al*. (1997) found that indicators of fat deposition (fat thickness, and marbling score) tended to increase with Vit E supplementation. There was a trend in carcass weight reduction with the supplementation of *n*-3 FA in the present experiment. The trend in carcass yield reduction could possibly be due to lower numbers of animal used for carcass analysis. The effect of Vit E and *n*-3 FA acid on pork colour and WHC can vary. For example, Jensen *et al*. (1997) indicated that feeding Vit E at levels of 100, 200 and 700 IU/kg in pigs had no significant effect on muscle colour or drip loss given the effect of Vit E on aspects of meat quality. The finding of improved redness of meat with Vit E supplementation in the present study is in line with Asghar *et al*. (1991) who reported that when pigs were fed 200 IU of a-tocopherol acetate per kg of feed, the surface redness of muscle (measured by Hunter a* values) was increased whereas the drip loss from frozen pork chops upon thawing was decreased. Obviously, the response to dietary Vit E supplementation will depend on the level of Vit E fed and the time of feeding as well as the response criterion used. The reduction in sensory colour score associated with Vit E supplementation was unexpected. However, sensory evaluation of meat quality is a relatively new and increasingly important aspect of food science and our findings warrant further investigation.

Conclusion

In conclusion, increasing the level of Vit E from 40 to 300 IU or including 0.75% protected linseed oil containing 55.75% linolenic acid in the diet offered to pigs for 12 weeks improved overall growth rate. The addition of Vit E alone increased IgG level and the redness of meat. The addition of Vit E or omega-3 FA reduced cortisol concentration in the serum.

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