Dietary kapok seed meal supplementation improved meat quality without adverse effect on growth performance in finishing pigs

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ABSTRACT

Ninety-six crossbred [(Landrace × Yorkshire) × Duroc] finishing pigs with an average initial body weight of 67.02 ± 1.46 kg were used in this 10-week feeding trial to evaluate effect of dietary kapok seed meal (KSM) supplementation in finishing pigs. Pigs were randomly allotted into three dietary treatments (eight replicates/treatment and four pigs/pen). The dietary treatments were: (1) Control (CON), basal diet; (2) K1.5, CON + 1.5% KSM; and (3) K3.0, CON + 3.0% KSM. Overall, average daily feed intake linearly decreased (P < .05) with the increase in the level of dietary KSM supplementation. KSM groups elevated concentration of low-density lipoprotein in blood at the 10th week (P < .05). Moreover, meat colour in sensory evaluation linearly increased (P < .05) as dietary KSM concentration increased. Myristic acid, palmitic acid, stearic acid, linolenic acid, saturated fatty acids (SFAs) and SFAs/polyunsaturated fatty acids ratio linearly increased (P < .05) as dietary KSM concentration increased, except for palmitoleic acid and oleic acid where the ratio linearly decreased (P < .05). The present study results indicated that finishing pigs supplemented with 3% KSM could improve meat quality and enhance the content of fatty acids of carcass fats and muscle without any adverse effect on growth performance.

1. Introduction

Meat plays a very important role in the diet by contributing quality protein, essential minerals, trace elements, and a range of B vitamins. Moreover, it is considered essential for optimal growth and development of human, previously (Higgs 2000). Despite these important and highly acceptable properties, meat consumption has come under close scrutiny in the recent years. Particularly, saturated fatty acid (SFA) has been implicated in diseases in developed countries, including various cancers and coronary heart disease (Astrup et al. 2011). In the UK, the department of health recommended that fat intake be reduced to 30% of total energy intake (from about 40%) and that no more than 10% of energy intake should come from SFAs (from 15%) (HMSO, UK 1994). At the same time, the recommended ratio of polyunsaturated fatty acid (PUFA) to SFA (P:S) ratio should be increased to more than 0.4. However, the majority of meat naturally has a low P:S ratio of around 0.1. Consequently, an increasing awareness of the need for a higher level of SFAs and a lower level of PFUAs has focused the importance of meat as a natural supplier of these to the diet (Wood et al. 2004).

Kapok containing cyclopropenoid fatty acids, which have the effect of hardening porcine fat, is fed to swine to prevent soft fat in Japan. Pande and Mead (1970) postulated that cyclopropenoid fatty acids affect the desaturase systems in adipose tissue, but greater amounts (8.7–14.4%) have been found in kapok (Ceiba pentandra) seed oils (Bianchini et al. 1981; Gaydou et al. 1983). However, kapok seed should be regarded as a livestock feed resource; as well few experiments have been conducted to evaluate the effect of kapok seed meal (KSM) on carcass fat and muscle in finishing pigs. Therefore, the objective of this study was to assess the influence of KSM on growth performance, blood profiles, fat characteristics, and meat quality in pigs.

2. Materials and methods

The experimental protocols describing the management and care of animals were reviewed and approved by the Animal Care and Use Committee of Dankook University.

2.1. Experimental design, animals, and diets

A total of 96 crossbred [(Landrace × Yorkshire) × Duroc] pigs with an average initial body weight (BW) of 67.02 ± 1.46 kg were randomly allotted into one of the three dietary treatments, including (1) Control (CON), basal diet; (2) K1.5, CON + 1.5% kapok; and (3) K3.0, CON + 3.0%. There were four pigs per pen, and each treatment comprised eight replications. All pigs were housed in pens (1.8 m × 1.8 m) with a self-feeder and nipple drinker to allow as libitum access to enough feed and water throughout the experimental period. Temperature was maintained at 24°C. Dietary metabolic energy approximate concentrations among all treatment diets were kept by altering the ratio of corn and soybean. All experimental diets were...
Table 1. Diet composition in finishing pigs.

| Items (%)                     | CON  | K1.5 | K3.0  | Kapok seeds |
|-------------------------------|------|------|-------|-------------|
| Corn                          | 64.20| 64.20| 64.20 |             |
| Soy bean meal                 | 14.00| 12.50| 11.00 |             |
| Rapeseed meal                 | 3.00 | 3.00 | 3.00  |             |
| Kapok seed meal               | –    | 1.50 | 1.50  |             |
| Wheat, bran                   | 3.00 | 3.00 | 3.00  |             |
| Soy hulls                     | 3.00 | 3.00 | 3.00  |             |
| Rice bran                     | 3.00 | 3.00 | 3.00  |             |
| Tailow                        | 4.00 | 4.00 | 4.00  |             |
| Molasses                      | 3.50 | 3.50 | 3.50  |             |
| Dicalcium phosphate           | 0.47 | 0.47 | 0.47  |             |
| Limestone                     | 0.96 | 0.96 | 0.96  |             |
| Salt                          | 0.30 | 0.30 | 0.30  |             |
| Lysine                        | 0.27 | 0.27 | 0.27  |             |
| Vitamin and mineral premix*   | 0.30 | 0.30 | 0.30  |             |
| Total                         | 100.00| 100.00| 100.00|             |

*The vitamin and mineral premix supplied per 1 kg of the diet: 4000 IU of vitamin A, 800 IU of vitamin D₃, 15 IU of vitamin E, 4 mg of riboflavin, 15 µg of vitamin B₁₂, 10 mg of pantothenic acid, 20 mg of niacin, 15 mg of Cu from CuSO₄·5H₂O, 90 mg of Fe from FeSO₄·7H₂O, 40 mg of Mn from MnO₂, 40 mg of Zn from ZnSO₄·7H₂O, 0.2 mg of Se from Na₂SeO₃·5H₂O, 0.5 mg of Co from CoSO₄·7H₂O.

Table 2. Fatty acid composition in basal diet.

| Fatty acid (%) | CON   | K1.5   | K3.0   | Kapok seeds |
|----------------|-------|--------|--------|-------------|
| C14:0 (myristic acid) | 0.58  | 0.64   | 0.69   | 0.79        |
| C16:0 (palmitic acid)  | 19.14 | 20.42  | 21.01  | 21.21       |
| C16:1 (palmitoleic acid) | 1.09  | 0.91   | 0.83   | 0.76        |
| C18:0 (stearic acid)   | 3.89  | 4.10   | 4.35   | 4.96        |
| C18:1n9c (oleic acid)  | 25.1  | 23.6   | 22.8   | 21.72       |
| C18:2n6c (linoleic acid) | 11.13 | 20.6   | 29.4   | 50.23       |
| C18:3n3 (linolenic acid) | 0.96  | 1.05   | 1.23   | 2.39        |

Notes: CON, basal diet; K1.5, CON + 1.5% KSM; K3, CON + 3% KSM.

2.2. Sampling and measurements

Individual BW and feed consumption of each pen were measured at the end of 5 weeks and 10 weeks of experiment to monitor the average daily gain (ADG), average daily feed intake (ADFI), and gain/feed ratio (G/F).

At the end of the experiment, the pigs were transported to the abattoir for slaughter. The carcasses were placed in a conventional chiller at 4°C. After 24 h chill period, carcasses were fabricated into primal cuts. Meat samples, which included lean and fat, were taken via perpendicular cut loins into 2-cm-thick chop beginning from the 10th and 11th ribs region. Backfat thickness was determined by measuring midline fat thickness. The pH of longissimus muscle (LM) was measured in 24 h post-mortem with an insertion glass electrode (Radiometer, Lyon, France) connected to a pH-meter (NWKbinar pH, K-21, Landsberg, Germany). The electrode was calibrated at 20°C in buffers at pH value of 4.00 and 7.00. Surface LM colour (Minolta L*, a*, b*) was measured in triplicate on a freshly cut surface with a Minolta Chromameter (Minolta CR 301, Tokyo, Japan). The water-holding capacity (WHC) was measured according to the methods of Kauffman et al. (1986). In brief, 0.2 g sample was pressed at 3000 psi for 3 min on 125-mm-diameter filter paper. The areas of the pressed sample and expressed moisture were delineated and then determined with a digitizing area-line sensor (MT-10S; M.T. Precision Co. Ltd., 123Tokyo, Japan). A ratio of water:meat areas was calculated, giving a measure of WHC (the smaller ratio indicate the higher the WHC). The proportion of LM acceptable for Pork Composition and Quality Assessment Procedures (NPPC 2000) was determined via the selection of LM with acceptable colour, firmness, and marbling (all measures 3 or above, based on a scale of 1–5). Drip loss was measured using approximately 2 g of meat sample according to the plastic bag method, which was described by Honikel (1998).

At the beginning of the experiment, two pigs were randomly selected from each pen, and blood samples were taken by jugular venipuncture. The same pigs were again bled at weeks 5 and 10. The concentrations of red blood cell (RBC) counts, white blood cell (WBC) counts, and relative lymphocyte counts (% of total WBC counts) in the whole blood were evaluated. All the blood parameters (RBC, WBC, and lymphocyte) were evaluated utilizing an automatic blood analyser (ADVIA 120, Bayer, USA). Plasma total lipoprotein cholesterol concentrations were determined by enzymatic analysis using commercial kits. Low-density lipoprotein (LDL) and high-density lipoprotein (HDL) were separated by sequential ultracentrifugation in an L8-M ultracentrifuge (Beckman Instruments, Palo Alto, CA) at 125,000×g at 15°C for 19 h in a Ti-50 rotor. Separations used the following density fractionations: from 1.019 to 1.09 g/ml for LDL and 1.09 to 1.21 g/ml for HDL.

Lipid from the feed, KSM, and fat and loin muscle of carcass was extracted with hexane/isopropanol (3:2 v/v). Fatty acids were converted into methyl esters. Briefly, 0.5 ml of toluene and 2 ml of 5% KOH-MeOH were added to the lipid, and the samples were vortex-mixed and heated at 70°C for 8 min. and then cooled in cold water, 2 ml of 14% BF₃-MeOH was added to the sample, and heated at 70°C for another 8 min. The sample was cooled, and then 3 ml of 5% NaCl was added to the sample and mixed. Five milliliters of distilled water and 0.5 ml of hexane were added to extract the fatty acid methyl esters (FAME). The mixture was vortexed and centrifuged at 3000xg for 5 min, and then the upper phase was collected and dried with sodium sulphate. Samples were analysed for total fatty acids using an HP5890 gas chromatograph with a flame ionization detector (Hewlett Packard 5890 Series II, USA). The FAME were separated using a Supelcowax-10 fused silica capillary column (100 m 0.32 mm i.d., 0.25 µm film thickness; Supelco, Inc., Bellefonte, PA, USA) with a 1.2 ml/min of...
3. Results

3.1. Growth performance

The growth performance of pigs is presented in Table 3. No significant difference \((P > .05)\) was observed in ADG and G/F ratio among treatment throughout the experimental period. Overall, ADFI linearly decreased \((P < .05)\) with the increasing level of KSM supplementation.

3.2. Blood profiles and meat quality

Table 4 presents the effect of dietary kapok seed on blood characteristics of pigs. Kapok seeds diet could elevate the concentration of LDL in blood at the 10th week \((P < .05)\). As it is shown in Table 5, supplementation with KSM did not affect redness \((P > .05)\) but decreased yellowness \((P < .05)\) linearly. Moreover, colour in sensory evaluation linearly increased \((P < .05)\).

3.3. Fatty acid of carcass fat and muscle

As it is shown in Table 6, in fat, myristic acid (C14:0) was higher \((P < .05)\) in K3.0 treatment than that in CON and K1.5 treatments; palmitoleic acid (C16:1) and oleic acid (C18:1n9c) were higher \((P < .05)\) in CON treatment than that in K3.0 and K1.5 treatments. Stearic acid (C18:0) and linolenic acid (C18:3n3c) were higher \((P < .05)\) in K3.0 and K1.5 treatments than that in CON treatment; SFAs were higher \((P < .05)\) in K3.0 treatment than that in CON treatment. Moreover, myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0), linolenic acid (C18:3n3c), SFA, and SFA/PFUA ratio linearly increased \((P < .05)\) with the increased level of KSM supplementation, while palmitoleic acid (C16:1)
Table 6. Effect of kapok seed meal supplementation on fatty acid of fat and muscle in finishing pigs.

| Items (%)          | CON   | K1.5  | K3.0  | SEM  | Linear Quadratic |
|--------------------|-------|-------|-------|------|------------------|
| **Fat**            |       |       |       |      |                  |
| C14:0 (myristic acid) | 1.59<sup>b</sup> | 1.76<sup>b</sup> | 2.22<sup>a</sup> | 0.28<sup>0.01</sup> | <.05 | .54 |
| C16:0 (palmitic acid) | 24.98 | 25.00 | 25.18 | 1.37 | .05 | .73 |
| C18:1 (palmitoleic acid) | 2.35<sup>b</sup> | 1.60<sup>b</sup> | 1.49<sup>b</sup> | 0.26 | <.01 | .56 |
| C18:0 (stearic acid) | 13.24<sup>b</sup> | 21.63<sup>a</sup> | 24.67<sup>b</sup> | 1.94 | 0.01 | .32 |
| C18:1n9c (oleic acid) | 46.68<sup>b</sup> | 38.57<sup>b</sup> | 34.47<sup>b</sup> | 1.38 | .003 | .37 |
| C18:2n6c (linoleic acid) | 15.86 | 16.26 | 15.01 | 2.75 | .73 | .09 |
| C18:3n3 (linolenic acid) | 1.63<sup>b</sup> | 1.89<sup>a</sup> | 1.96<sup>b</sup> | 0.07 | <.001 | .40 |
| SFA                | 38.01<sup>b</sup> | 45.23<sup>b</sup> | 57.37<sup>b</sup> | 3.12 | <.001 | .57 |
| PUFA               | 65.98 | 61.78 | 62.63 | 3.27 | .48 | .28 |
| SFA/PUFA           | 0.58 | 0.73 | 0.92 | 0.26 | .04 | .79 |
| **Muscle**         |       |       |       |      |                  |
| C14:0 (myristic acid) | 0.37  | 0.41  | 0.43  | 0.21 | .01 | .86 |
| C16:0 (palmitic acid) | 26.98 | 27.20 | 28.68 | 1.21 | .01 | .70 |
| C18:1 (palmitoleic acid) | 2.15<sup>a</sup> | 1.93<sup>b</sup> | 1.69<sup>b</sup> | 0.26 | <.001 | .93 |
| C18:0 (stearic acid) | 14.23<sup>b</sup> | 16.63<sup>b</sup> | 22.34<sup>a</sup> | 1.53 | <.001 | .43 |
| C18:1n9c (oleic acid) | 43.61<sup>b</sup> | 37.38<sup>b</sup> | 37.00<sup>b</sup> | 1.09 | .05 | .18 |
| C18:2n6c (linoleic acid) | 9.64  | 9.09  | 9.12  | 0.78 | .43 | .29 |
| C18:3n3 (linolenic acid) | 0.43  | 0.46  | 0.49  | 0.05 | .02 | .73 |
| SFA                | 37.81 | 44.23 | 46.73 | 1.62 | .07 | .86 |
| PUFA               | 53.65 | 52.48 | 50.60 | 2.17 | .15 | .47 |
| SFA/PUFA           | 0.70 | 0.84 | 0.92 | 0.08 | .02 | .69 |

Notes: Means in the same row with different superscripts differ (< .05). CON, basal diet; K1.5, CON + 1.5% Kapok seed meal supplementation; K3, CON + 3% Kapok seed meal supplementation; SEM, standard error means.

and oleic acid (C18:1n9c) linearly decreased (P < .05) with the increased level of KSM supplementation.

In muscle, palmitoleic acid (C16:1) was higher (P < .05) in CON treatment than that in K3.0 treatment. Stearic acid (C18:0) was higher (P < .05) in K3.0 treatment than that in CON treatment; oleic acid (C18:1n9c) was higher (P < .05) in CON treatment than that in K1.5 and K3.0 treatments. Moreover, myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0), linolenic acid (C18:3n3c), SFA, and SFA/PUFA ratio linearly increased (P < .05) with the increased level of KSM supplementation, while palmitoleic acid (C16:1) and oleic acid (C18:1n9c) linearly decreased (P < .05) with the increased level of KSM supplementation.

4. Discussion
There are few reports of dietary KSM supplementation in pigs, but a number of studies were evaluated in chicken, previously. In 1986, Kapok was assessed as a kind of poultry feed by Kadirvel et al. (1986), who reported the feeding value of oil-extracted kapok cake containing 28.6% crude protein and 8.59% ether extract in a chick mash. Birds on the basal diet gained 265.9 g at 4 weeks of age, but inclusion of 10% kapok cake in the chick mash reduced weight gain to 187.4 g. Apparently, birds often developed an upset stomach by kapok meal. Hence, they only consumed small quantities of KSM (Kumar 1962). In disagreement with the results above, Narahari and Rajini (2003) found no significant differences in BW gain, feed consumption, or feed conversion for KSM levels of 0, 30, 60, and 90 g/kg. Similarly, Mtenga and Laswai (1994) found no effect when pigs were fed a 3% kapok meal. Besides, our study showed a similar result. The inconsistent findings may have been caused by gossypol, that there is apparently little gossypol in kapok (Griffing & Alsberg 1931). Gossypol changes energy metabolism by uncoupling mitochondrial oxidative phosphorylation (Reyes et al. 1986). Consequently, some new methods have been utilized in the feed industry to develop KSM containing a low level of gossypol. Moreover, crude fibre is another factor that may cause different results of studies. Dietary KSM supplementation may help to reduce nitrogen loss and improve pig intestinal health (Bindelle et al. 2008). Whereas numerous factors, which included different place of plant production and processing method, could affect the fibre content in KSM.

Meat colour is influenced by different factors such as post-mortem glycolysis, intramuscular fat (IMF) content, pigment level, and pigment oxidative status (Van Oeckel et al. 1999; Lindahl et al. 2001). As mentioned above, gossypol in kapok alters energy metabolism. An increased proportion of glycolytic fibre is associated with decreased myoglobin content, which can result in paler meat, whereas enhanced oxidative metabolism leads to redder meat and to reduced muscle colour stability (Henczel et al. 1997; Lefaucheur 2004), which was probably the reason that the KSM increased the redness value. Several studies have suggested a favourable relationship between IMF content and juiciness and tenderness of pork (Hodgson et al. 1991; Fernandez et al. 1999a). According to Fernandez et al. (1999b), an increase in IMF content up to 3.5% enhances pork consumer acceptability. In our study, we discovered that KSM elevated the marbling score, which could be associated with many kinds of fatty acids in kapok seeds. Moreover, kapok could upset stomach activity, causing an absence of synthetic amino acids and leading to a higher IMF content (Sundrum et al. 2000; Millet & Toussaint 2004). We found that KSM increased blood LDL. LDL has a capacity to transfer cholesterol from blood vessel to peripheral tissues, which probably was related to the increased IMF.

The pig is a monogastric species and is amenable to changes in fatty acid composition of adipose tissue and muscle using diets containing different oils (Wood et al. 2008). Lee et al. (2007) illustrated that a 1% cottonwood sawdust supplement increases total PUFA amount. The Malaysian Kapok (C. pentandra) seeds were found to contain about 28% oil. The oil from both raw and roasted seeds produced a positive Halphen test for cyclopropenoid fatty acids. Acid value, fatty acid composition by gas–liquid chromatography, iodine value, refractive index, saponification number, and unsaponifiables of the oil were also determined. The values (area percent) for fatty acids as methyl esters were C14:0 (0.25%), C16:0 (24.31%), C16:1 (0.4%), C18:0 (2.65%), C18:1 (21.88%), C18:2 (38.92%), C20:0 plus C18:3 (1%), malvalic acid (7.18%), C22:0 (0.44%), and sterculic acid (2.96%). Malvalic and sterculic acids were also determined. The values (area percent) for cyclopropenoid fatty acids. Acid value, fatty acid composition by gas–liquid chromatography, iodine value, refractive index, saponification number, and unsaponifiables of the oil were also determined. The values (area percent) for fatty acids as methyl esters were C14:0 (0.25%), C16:0 (24.31%), C16:1 (0.4%), C18:0 (2.65%), C18:1 (21.88%), C18:2 (38.92%), C20:0 plus C18:3 (1%), malvalic acid (7.18%), C22:0 (0.44%), and sterculic acid (2.96%). Malvalic and sterculic acids were determined as AgNO3·CH30H derivatives of their methyl esters (Berry 1979).

Our results showed that KSM increased myristic acid and stearic acid content, but decreased palmitoleic acid, oleic acid, and linolenic acid content. This result agreed with that of Mtenga and Laswai (1994), who indicated that 3% kapok meal increased SFA content and decreased PUFA content, indicating that KSM hardens lipids. We also found similar results that a higher firmness occurred in the control group. Kapok containing cyclopropenoid fatty acids, which have the effect of hardening porcine fat, is fed to swine to prevent soft fat in Japan. Moreover,
the market needs have been shifting towards a preference for dissolvable fat in mouth (Irie et al. 1984). Fat that is too hard is caused by feeding high amount of kapok meal, which contains high content of SFA. Previous study also found that supplementing pig diets containing a high level of PUFA with kapok meal increased fat hardness due to an increase of SFA and PUFA ratio (Irie 1988), which may explain that the same high fat firmness level in meat quality of our present study.

Pande and Mead (1970) postulated that cyclopropenoid fatty acids affect the desaturase systems in adipose tissue. It is generally believed that lipid oxidation in muscle foods is initiated in the highly unsaturated phospholipid fraction of subcellular membranes (Gray and Pearson 1987). Therefore, more SFAs indicate higher antioxidant ability. Additionally, modern trends towards convenience foods have resulted in an increase in the production of precooked and restructured meat products. The ratio of $n$–6:n–3 PUFAs is also a risk factor in cancers and coronary heart disease, particularly the formation of blood clots leading to a heart attack (Enser 2001). The ratio of $n$–6:n–3 PUFAs was particularly beneficial (low) in meats.

In conclusion, 3% of dietary KSM supplementation could improve meat quality and enhance fatty acid content in carcass fat and muscle without causing any adverse effect on growth performance in finishing pigs.

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