Effects of Soybean Hull Utilization as a Feedstuff for Fattening Pigs on Meat Quality and Blood Characteristics

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Abstract: The present study aimed to examine the utility of soybean hull as a feedstuff for fattening pigs. The data of physical characteristics of loin and blood lipid from three pigs fed formula feed as a control group and three pigs fed soybean hull as an experiment group were compared in this study. The experiment group feed was prepared by mixing of soybean hull and formula feed in a ratio of 1 : 9. There was no significant difference between the control and experiment groups in meat quality. In the fatty acid composition of inner and outer layers of back fat, the ratio of C18 : 0 significantly (P < 0.05) increased, and the ratio of C18 : 2 in both layers significantly (P < 0.05) decreased in the experiment group while the ratio of C18 : 3 also significantly (P < 0.05) decreased in inner layer. There was no significant difference in the results of blood lipid analysis. The present results revealed that feeding fattening pigs with soybean hull had no negative effect on the character of the products. Soybean hull can therefore be used as feedstuff for fattening pigs.

Key words: soybean hull, fattening pigs, feedstuff, meat quality

Introduction

Recently, various studies evaluating the by-products of less utilized organic sources in pig production have been carried out to increase the feed self-sufficiency ratio. In Japan, a large amount of soybean is imported from abroad, and used in oil and various other processed foods. Soybean hull is removed in the processing of soybean, therefore it is possible to use pure soybean hull. The chemical composition, digestibility, and total digestible nutrient values of soybean hull for pigs are shown in Standard tables of feed composition in Japan (2009) by NARO. Soybean hull includes high non-starch polysaccharides (NSP) as fibrous ingredients, therefore it seems to be poorly digested by non-ruminant animals and less utilized in pig production in Japan.

Quadros et al. (2008) evaluated the effect of soybean hull supplementation at five levels (0, 4, 8, 12, and 16%) on the growth performance of growing-finishing pigs. They reported that 16% soybean hull supplementation does not change growth performance and leaner carcass production. Wang et al. (2009) reported that slurry ammonia (NH₃) emission significantly (P < 0.05) decreased with the addition of soybean hull in the feed. Ani et al. (2013) also reported that the 10% soybean hull inclusion level reduced the feed cost per kg weight gain and the 20% inclusion level showed normal growth performance. The authors (2016) suggested that a 10% replacement of soybean hull for formula feed had no negative effect on growth performance and ammonia gas emission.

This present study aimed to evaluate the effects
of a 10% inclusion level of soybean hull in the feed on the carcass characteristics, chemical composition and physiological characteristics of loin, and level of blood lipids. A digestibility experiment was conducted to acquire background data for utilization of soybean hull as a feedstuff.

Materials and Methods

This present study was approved according to the guidelines of the Animal Welfare Act of Tokyo University of Agriculture (Accepted No. 270009).

1. Animal and experimental feed

A total of 6 crossbred (Meishan×Yorkshire×Berkshire) barrows with an average initial body weight of 53.5±2.7 kg were housed in individual metabolic cages. A daily 12hr light/dark cycle was maintained under natural ambient temperature. After adjusting to the feed and environment, the feeding experiment during a period in which the mean body weight of pigs was between 71 to 105 kg was conducted from September to November in 2014. The two dietary treatments were the control (no soybean hull replacement) group and the 10% soybean hull replacement group. It was estimated that the 10% soybean hull replacement for the formula feed of pigs (mixing ratio was follows ; soybean hull : formula feed = 1 : 9) showed no effect on the nutritional quality of basal feed. The chemical composition of experimental feed and soybean hull is shown in Table 1. The basal feed was a commercial formula one (Megumi Nikubuta 78 : Feed-One Holdings Co. Ltd., Yokohama) and the nutrient composition was also adapted to the requirements for growth stage in the experimental group, which included soybean hull replacement. Three pigs each were assigned to two dietary treatments as the control and soybean hull replacement group. The appropriate volume of feed was supplied twice a day. Drinking water was supplied ad libitum.

2. Sample collection for determination of digestibility, meat, and blood characteristics determination

Feed intake amount was determined every day and body weight was determined every week. All feces were collected for 5 days prior to finish of experimental feeding to determine digestibility of crude protein, ether extract, crude fiber, acid detergent fiber, nitrogen free extracts, and energy, while digestible crude protein (DCP), total digestible nutrients (TDN) and digestible energy (DE) intake were calculated from them. Feces were stored in a freezer (−40°C) until analysis. Blood samples were collected from the cervical vein into clot activator and un-activator vacuum tubes (Terumo Co. Ltd., Tokyo) to determine the total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides as serum lipids, and plasma TAS (total antioxidant status) values during the preliminary period and on finishing day of experimental feeding. After the preparation of plasma and serum by mild centrifugation, they were stored in a freezer (−40°C) until analysis.

At a mean final weight of 105 kg, the pigs were slaughtered at the Kanagawa Meat Center, Co. Ltd., and the cold carcass weight, carcass length, back and loin length (I, II), carcass width, back fat thickness of shoulder, back and chest, and loin area

| Table 1. Chemical composition (%) of experimental feed and soybean hull |
|---------------------------------|-----------------|-----------------|
| Moisture                        | Control*        | Experiment      | Soybean hull |
| Crude protein                   | 14.0            | 13.4            | 8.0          |
| Ether extract                   | 14.7            | 14.5            | 12.7         |
| Crude fiber                     | 4.6             | 4.7             | 5.6          |
| Acid detergent fiber            | 2.7             | 5.7             | 32.7         |
| Crude ash                       | 4.9             | 8.8             | 43.9         |
| Nitrogen free extracts          | 3.9             | 4.0             | 4.9          |
| Gross energy (kcal/g)           | 60.1            | 57.7            | 36.1         |

*: Grains : 70%, oil seed meals : 15%, brans : 9%, others : 6%, soybean hulls : not included.
of the 14th rib were determined and carcass ratio was calculated. After the above-mentioned determination, the meat and fat samples were collected from each animal and stored in a freezer (−40°C) until analysis.

3. Analysis

All fecal samples were thawed and dried at 60°C for 24 h and subsequently ground with a portable high-speed grounder (LM-PLUS, Osaka Chemical Co. Ltd., Osaka) to pass through a 1 mm mesh screen. All feed samples were also ground in the same manner. They were analyzed for all chemical composition according to the AOAC procedures (AOAC, 1995), and energy contents were determined with an automatic calorie meter (CA-4AJ, Shimadzu Co. Ltd., Kyoto).

Serum lipids, total and HDL cholesterols, and triglycerides were analyzed by UV absorption spectrophotometry (UV-1800, Shimadzu Co. Ltd., Kyoto) according to each method of a commercial analysis kit (Wako Chemical Co. Ltd., Tokyo). Plasma TAS value was also determined with a commercial analysis kit (Randox Laboratories Co. Ltd., USA).

Meat and back fat were excised from between the 4th and the 14th rib of the carcass. The sampled meat was divided into five blocks for analysis of physiological characteristics and chemical composition. The drip loss was measured in accordance with Kosaka (1983) and cooking loss was evaluated according to the NLBC (2010) method. Meat for the chemical composition analysis was ground triplicate with a 3 mm diameter and was analyzed with the methods proposed by Mitsu moto (2001). Back fat was divided into two pieces as inner layer and outer layer. The following parameters were analyzed in both samples: the melting point was evaluated according to the method described by Irie (2002). The fatty acids in the fat sources were converted to methyl esters by trans esterification with boron fluoride/methanol reagent (Morrison and Smith, 1964). The fatty acid composition was determined by gas chromatography (GC-17A, Shimadzu Co. Ltd., Kyoto) under the following conditions: 2.0 m×3.2 mm glass packed column with 5% Shinchrom E71 Shinwasorb-U 60/80, column temperature of 180°C, injection temperature of 250°C, carrier gas of N2, flow rate of 25/40 mL/min and FID detector of 250°C.

Statistical analyses

All the experimental data were analyzed by one way analysis of variance (P<0.05). Least Significant Difference Method was used in separating the significant means.

Results

1. Pig performance and nutrient digestibility

All experimental data were summarized in Fig. 1 and Table 2. There were no significant differences between pigs fed the control feed and those fed the soybean hull replacement feed. In the crude fiber and acid detergent fiber digestibility, the pigs fed the soybean hull replacement feed significantly (P<0.05) increased those values in comparison with those of the pigs fed the basal feed.

2. Carcass quality and chemical composition, and physical characteristics of loin

Soybean hull intake had no effect on the parameters of carcass quality as shown in Table 3. Furthermore, there were no significant differences...
between the control group and experimental group in the following loin parameters: moisture, crude protein and ether extract as chemical composition and water holding capacity, pH, cooking loss, and shear value.

3. Fatty acid composition and melting point of back fat
All analysis values obtained from the inner and outer layers of back fat are shown in Table 4. In the composition of fatty acids of the inner and outer

Table 2. Nutrient digestibility (%) of experimental feed

|                      | Control      | Experiment   |
|----------------------|--------------|--------------|
| Crude protein        | 86.7±2.0     | 83.4±1.2     |
| Ether extract        | 84.8±2.6     | 80.3±1.7     |
| Crude fiber          | 54.5±5.6b    | 76.5±3.6a    |
| Acid detergent fiber | 59.7±4.6b    | 73.2±2.9a    |
| Nitrogen free extracts | 86.8±1.7  | 85.9±0.9     |
| Energy               | 91.5±0.9     | 91.4±0.8     |
| DCP                  | 12.7±0.3     | 12.1±0.2     |
| TDN                  | 77.9±1.3     | 77.7±0.7     |
| DE (kcal/g)          | 3.47±0.07    | 3.43±0.04    |

Mean±SE, Control : n=3, Experiment : n=3.
Significant difference is recognized between the different superscript : at P<0.05.

Table 3. Effect of soybean hull supplementation on carcass quality, chemical composition and physical character of loin

|                              | Control     | Experiment  |
|------------------------------|-------------|-------------|
| Finished body weight         | 110.7±1.5   | 109.3±1.3   |
| Parameter of carcass quality |             |             |
| Carcass weight (kg)          | 72.7±0.7    | 69.1±1.0    |
| Carcass ratio (%)            | 65.7±1.5    | 63.3±0.7    |
| Carcass length (cm)          | 98.0±2.3    | 98.1±2.6    |
| Back and loin length (I) (cm)| 80.5±2.2    | 81.4±2.0    |
| Back and loin length (II) (cm)| 69.8±1.3   | 71.8±1.4    |
| Carcass width (cm)           | 35.8±1.0    | 35.4±0.3    |
| Back fat thickness (cm)      |             |             |
| Shoulder                     | 5.5±0.1     | 5.2±0.3     |
| Back                         | 2.1±0.2     | 2.5±0.4     |
| Chest                        | 4.4±0.2     | 5.1±0.6     |
| Loin eye area (cm²)          | 26.1±0.6    | 26.4±1.3    |
| Chemical composition         |             |             |
| Moisture (%)                 | 72.3±0.1    | 71.6±1.2    |
| Crude protein (%)            | 21.4±0.2    | 21.7±0.4    |
| Ether extract (%)            | 5.6±0.7     | 6.3±1.6     |
| Physical character           |             |             |
| Water holding capacity (%)   | 31.5±0.7    | 30.6±2.3    |
| pH                           | 6.0±0.2     | 5.7±0.0     |
| Cooking loss (%)             | 15.4±0.7    | 15.9±1.0    |
| Shear value (N)              | 26.6±1.9    | 28.9±2.1    |

Mean±SE, Control : n=3, Experiment : n=3.
The ratio of C18 : 0 in the experiment group increased significantly (P < 0.05) in comparison with that of the control group. Adversely, the ratios of C18 : 2 in both layers and C18 : 3 in the inner layer of the experimental group significantly decreased in accordance with the C18 : 0 increase, and also C18 : 1 decreased in both layers but not significantly. Total of poly-unsaturated fatty acids (PUFA) decreased in both layers and a significant decrease (P < 0.05) was shown in the outer layer. Furthermore, melting point of the inner layer of back fat decreased with soybean hull intake (P < 0.05), but this did not correlate with the total proportions of saturated fatty acids and unsaturated fatty acids. There was no significant difference in the data of outer layer of back fat.

4. Serum lipids and plasma TAS values

Total, HDL, LDL cholesterol, triglycerides in serum, and plasma TAS values are shown in Table 5.

Table 4. Effect of dietary soybean hull supplementation on fatty acid composition (%) and melting point (℃) of back fat

|                | Inner layer | Outer layer |
|----------------|-------------|-------------|
|                | Control     | Experiment  | Control     | Experiment  |
| C14 : 0        | 0.7±0.0     | 0.8±0.1     | 0.6±0.1     | 0.8±0.0     |
| C16 : 0        | 30.6±0.4    | 30.3±0.8    | 29.8±1.0    | 30.4±0.3    |
| C18 : 0        | 15.2±0.3b   | 20.2±2.1a   | 13.2±0.7b   | 18.5±1.6a   |
| Total of SFA   | 46.5±0.2    | 51.3±1.0    | 43.6±0.6    | 49.7±0.5    |
| C18 : 1 (MUFA) | 44.9±0.3    | 41.9±1.2    | 47.5±1.1    | 44.2±1.2    |
| C16 : 2        | 1.9±0.0     | 1.1±0.3     | 1.9±0.3     | 1.5±0.4     |
| C18 : 2        | 6.4±0.2a    | 4.6±0.6b    | 6.7±0.3a    | 4.5±0.2b    |
| C18 : 3        | 0.2±0.0a    | 0.1±0.0b    | 0.2±0.0    | ND          |
| Total of PUFA  | 8.5±0.1     | 5.8±0.3     | 8.6±0.2a    | 6.0±0.2b    |
| Total of UFA   | 53.4±0.1a   | 47.7±0.5b   | 56.1±0.5    | 50.2±0.6    |
| Melting point (℃) | 42.5±0.5a | 40.9±0.2b   | 39.6±0.3    | 39.7±0.4    |

Mean±SE, Control : n=3, Experiment : n=3.
Significant difference is recognized between the different superscript : at P<0.05.
ND : not detected.
The data of C18 : 3 were not included in the calculation of total of PUFA and UFA of outer layer.

Table 5. Effect of dietary soybean hull supplementation on serum lipid content and plasma total anti-oxidative status

|                | Control     | Experiment  |
|----------------|-------------|-------------|
| Serum          |             |             |
| Total cholesterol (mg/dL) | 109.0±2.3 | 107.4±4.8  |
| HDL cholesterol (mg/dL)    | 58.4±1.2  | 56.2±1.3   |
| LDL cholesterol (mg/dL)    | 31.4±1.8  | 29.3±3.4   |
| Triglycerides (mg/dL)      | 95.9±9.7  | 109.1±5.0  |
| Plasma           |             |             |
| TAS* values (mol/L)       | 0.90±0.09  | 0.90±0.04  |

Mean±SE, Control : n=3, Experiment : n=3.
* : Total anti-oxidative status
5. There is no significant difference, therefore the effects of soybean hull intake on those characteristics were not recognized in this current study.

**Discussion**

The present study aimed to evaluate the effects of soybean hull intake on the carcass and meat characteristics and serum lipid values, a follow-up to the previous study relating growth performance and ammonia gas emission from excreta (2016).

KORNEGAY (1981) reported that soybean hulls may be used in swine diets at least up to 15% without adverse effects. Any significant difference was not recognized in this study, in which soybean hull was supplemented to 10%, in agreement with KORNEGAY’s results. In the chemical composition of feed, though the 10% replacement of soybean hull for formula feed increased the ratio of crude fiber to twice the values in the basal feed (Table 1), the its digestibility increased as shown in Table 2. The digestion coefficient of soybean hull fiber was evaluated at 92.8% in our trial. This may be caused by soybean hull fiber which is composed of NSP and which plays a useful role for microorganisms in the digestive tract as a pre-biotic.

STEWART et al. (2013) evaluated the effect of 30% soybean hull feed intake on the growth and carcass quality of growing-finishing pigs, and they proposed that the carcass ratio significantly decreased with soybean hull intake, while weight gain was almost equal. Furthermore, they suggested that the inclusion of 30% soybean hull is unsuitable for pig feed, because negative damage was recognized in the growth performance and nutrients deposition of growing pigs, while there was only minor damage in finishing pigs. QUADROS et al. (2008) evaluated the effect of graded soybean hull inclusion levels as follows: 0, 4, 8, 12 and 16% on growth performance and carcass characteristics of growing-finishing pigs. They proposed that the inclusion of up to 16% of soybean hull on growing-finishing pigs feed does not change the growth performance and leaner carcass production. In this current study, the inclusion level of soybean hull was 10% for fattening pigs, and this level is the maximum without decreasing the calculated CP and TDN values in published data in Standard tables of feed composition in Japan (2009) by NARO and in nutrient requirement of Japanese feeding standard of swine (2013) by NARO for the simple replacement of soybean hull and commercial formula feed. The present results are in agreement with the previous reports.

There are no reports describing the effect of soybean hull intake on the fatty acid composition of body fat in the present findings. The current results show that soybean hull intake significantly (P < 0.05) increased the C18:0 (stearic acid) rate and decreased the C18:2 (linoleic acid) and C18:3 (linolenic acid) in the inner layer of back fat. The latter decreases affect the decrease of total ratio of PUFA. Similar variation of fatty acid level was recognized in the outer layer of back fat with C18:0, C18:2, and the total of UFA. An increase of C18:0 affected the relative decrease of the other fatty acid composition ratio, especially significant decrease (P < 0.05) was recognized in the ratio of C18:2 and 18:3 and there was no special decrease of C18:1 compared to the increase of C18:0. Increase of C18:0 seemed to be due to its de novo synthesis from the endogenous organic acid produced by microorganisms in the digestive tract with NSP composing the soybean hull fiber.

For the results of the melting point of back fat, the soybean hull intake group showed lower values than that of the control group, while the total proportion of saturated fatty acids is higher than that of unsaturated fatty acids in the inner layer of back fat. The total proportion of saturated fatty acids is lower than that of unsaturated fatty acids in the outer layer of back fat of the control pigs, while their total proportions were equal in the soybean hull intake group. There was no difference in melting point. The current results suggested that soybean hull intake tended to increase the total proportion of saturated fatty acids, but it seldom affected the melting point.

ANI et al. (2013) reported that soybean hull can be included in the diet of weaned pigs at 20% level without adverse effects on the growth performance and the following hematological values: packed cell...
volume, hemoglobin concentration, red blood cell and total white blood cell counts, with the feed containing graded levels of 0, 10, 15 and 20% soybean hull for 56 days. Plasma lipid level was determined in this current study, and triglyceride level increased with soybean hull intake. Increase of triglyceride level might be caused by the acceleration of fatty acid synthesis from endogenous fermentation in the digestive tract of the pigs fed soybean hull, but this could not be verified in this study.

There was no obvious merit in the utilization of soybean hull for pig feed, but there was also no demerit - the same as in previous reports. Ani et al. (2013) proposed that if farmers purchased soybean hull for their pig feedstuff, feed cost per kg weight gain might be reduced by its utilization. When we purchased it, it was about ¥74/kg in non-bulk small packages style and the formula feed in bulk style was ¥67-68/kg, as a reference. Therefore the utilization of bulk style soybean hull as a feedstuff will probably contribute to the cost reduction of feed for fattening pig.

We concluded that soybean hull can be included at 10% level in the feed for growing-fattening pigs without adverse effects on the growth performance.

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肥育豚用飼料への大豆皮の利用が肉質および血液性状に及ぼす影響

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要約　本試験は肥育豚飼料原料としての大豆皮の有用性を検討した。対照区として配合飼料を給与した3頭の豚と試験区として大豆皮を給与した3頭の豚の肉質と血液性状を比較した。試験区飼料は大豆皮と配合飼料を1:9で混合して調製した。肉質において対照区と試験区の間に有意差は認められなかった。背脂肪内層と外層のいずれの脂肪酸組成においても、試験区でC18:0割合が有意（P<0.05）に高くなり、C18:2は内層と外層のいずれでも有意（P<0.05）に低くなり、C18:3は内層で有意（P<0.05）に低くなった。血中脂質には有意な差は認められなかった。本試験の結果は、肥育豚飼料への大豆皮は生産物に対して負の影響を与えないことを示した。よって、大豆皮は肥育豚の飼料原料として積極的に利用することが可能である。

キーワード：大豆皮，肥育豚，飼料原料，肉質