Veterinary and Animal Science 11 (2021) 100166

Contents lists available at ScienceDirect

Veterinary and Animal Science

journal homepage: www.elsevier.com/locate/vas

Effects of soybean curd residue and rice bran on lamb performance, health, and meat quality

Yu Yoshihara [*], Shun Yokoyama

Graduate School of Bioresources, Mie University, Kurimachoyacho 1577, Tsu, Mie, Japan

ARTICLE INFO

Keywords:
Blood profile
Body weight
Meat quality

ABSTRACT

Recycling food by-products as animal feed could decrease livestock production costs. We investigated how replacing conventional corn and wheat bran feed (control) with rice bran and soybean curd residue (RBSR) would influence lamb performance and meat quality. Eleven lambs were divided into the control and the RBSR-fed groups. The amount of feed consumed by the lambs, as well as their body weight, nutrient properties (total protein, non-esterified fatty acid, total cholesterol, glucose concentrations) in blood samples, and fecal condition were evaluated. Meat quality (water holding capacity, cooking loss, fat content, and shear force) of their carcasses were also evaluated. Results shows daily body weight gain per lamb in the RBSR-fed group was approximately 2.2-fold than that in the control group. The mean total blood protein and glucose concentrations exhibited increasing trends after feeding with RBSR. In addition, the shear force of the meat was significantly lower and crude fat content was significantly higher in RBSR-fed lambs than in lamb fed the control feed. The study concluded that, RBSR could replace conventional feed for Japanese sheep and can be used to not only reduce feed and disposal costs but also increase animal production and meat quality.

1. Introduction

There are increasing calls for the recycling of food by-products or food waste as animal feed to foster sustainability in society while reducing animal feed costs and disposal costs globally. In Japan, such animal feeds prepared from food by-products and surplus food are called eco-feed and they are expected to reduce pork production costs in Japan considerably (Sugiura, Yamatani, Watahara & Onodera, 2009).

Rice bran and soybean curd residue (RBSR) are traditional Japanese food by-products. They are not only rich in CP, fat, and energy but also have good palatability and digestibility characteristics; therefore, they are potential replacements for imported grain feed in Japan (Cao, Takahashi & Horiguchi, 2009). However, there are concerns over feed quality and nutrition stability, in addition to animal health and meat quality when eco-feed is used in livestock production. Generally, eco-feed contains a lot of water, which makes feed quality and nutrients deteriorate more easily. In addition, dietary kapok oil supplementation makes firm fat which prevents the development of soft fat, and therefore produces pork with inferior grades. Kapok oil decreases pork palatability as its supplementation reduce mono-unsaturated fatty acids (Maeda et al. 2017). However, the effect of eco-feed on lamb performance and meat quality has not been investigated. In the present study, we investigated the potential effects of replacing imported grain feed (corn and wheat bran) with RBSR on lamb performance and meat quality.

2. Materials and methods

2.1. Animal management

The experiments were carried out at a farm in Miyagi Prefecture, in northern Japan. We used 11 5–6 month-old male lambs (Suffolk) that had been maintained in the same barn for 3 weeks from the end of August 2018. Each lamb was individually moved to 2 pens (10 m^2) in turn to separate at feeding time. Six male lambs (mean body weight: 31.6 kg) were fed 125 DM g of conventional corn and 125 DM g of wheat bran (control) in the morning and in the evening with 500 g feeding of timothy and wild grass, and the other five male lambs (mean body weight is 28.1 kg) were fed with 125 g of rice bran and 125 g of soybean curd residue daily as a corn and wheat bran replacement. When the lambs were fed, the feed remaining in the troughs after 30 min was removed and weighed. The lambs fed on RBSR were habituated to the new feed by the addition of small amounts of RBSR into their feed for 5

* Corresponding author: Tel: +81-059-231-9506.
E-mail address: yoshihara@bio.mie-u.ac.jp (Y. Yoshihara).

https://doi.org/10.1016/j.vas.2021.100166
Received 29 September 2020; Received in revised form 13 January 2021; Accepted 19 January 2021
Available online 20 January 2021

days before the beginning of the feeding experiments and assessments. The RBSR was dried in a forced-air oven at 60 °C for 48 h before the feeding. The chemical composition of the feeds based on standard tables of feed composition in Japan (NARO 2010) are presented in Table 1.

Lambs were fed for 4 months, and this duration included a 7-day adaptation period. Initial and final body weights of the lambs were recorded by a digital flat scale. Daily gain was calculated based on the initial and final body weights.

2.2. Blood and fecal analysis

Blood samples were obtained from the lambs supplied with RBSR and collected in evacuated EDTA tubes on the initial and final dates of the experiment at similar period. Total protein, total cholesterol, non-esterified fatty acids (NEFA), and glucose in the plasma were measured using commercially available kits on a Hitachi 7180 Auto-analyzer (Hitachi Ltd., Tokyo, Japan).

We examined fecal samples from all the lambs in the course of the experiments and the clinical severity of any diarrhea was scored (Yoshihara et al., 2016). Scores were Level 1: healthy feces (fully formed); Level 2, loss of shape of less than half of the feces; Level 3, loss of shape of more than half of the feces; and Level 4, loss of shape of all of the feces, with watery diarrhea.

2.3. Meat quality analysis

After the experiments, all the ewes were slaughtered at a commercial abattoir and meat samples were vacuum packed and frozen at −20 °C in a freezing chamber. Loin chops of each animal were used in chemical and physical analyses. All subsequent measurements were carried out on meat thawed for 24 h at 4 °C.

The water holding capacity (WHC) of the meat samples were determined using the centrifugal method (Quéqiner et al. 1989). Samples (0.5 g) were placed on polyester membranes, which were kept in the middle of centrifuge tubes using plastic beads. The samples were centrifuged at 2200 × *g* for 30 min. WHC was expressed as a percentage of the initial water content of the meat.

Cooking loss was assessed using 50-g samples placed in polyethylene bags. It was calculated based on the meat weight before and after cooking in a water bath for 1 hour until an internal temperature of 73 °C was reached.

Instrumental tenderness (shear force) was analyzed using the cooked samples. The shear force was measured using a 2-mm-thick plunger attachment of a CR-500DX-S rheometer (SUN scientific Co., Tokyo, Japan). The mean maximal cutting strength was obtained from four technical replicates.

Crude fat content was determined using the Soxhlet method, in which the samples used for the water content analyses were first subjected to acid hydrolysis by boiling with ether for 16 h, and then weighed after drying for 2 h at 103 ± 2 °C. The melting point of the fat samples was determined using the capillary tube method according to the Association of Official Analytical Chemists, 2005 official method.

2.4. Data analysis

Repeated-measures Analysis of Variance was used to test for statistically significant differences in body weight between treatments. *t*-test was used to test for statistically significant differences in shear force and melting point in the meat between treatments, while Mann–Whitney *U test* was used to test for significant differences in crude fat, WHC, and cooking loss in the meat between treatments. The analyses were performed using Statistica v12 (Dell Statistica, Tulsa, OK, USA, 2013). Differences with $P \leq 0.05$ were considered significant.

3. Results and discussion

The daily intake of the RBSR-fed group was 269 g per lamb on mean, which was less than that of the control group (500 g, $P < 0.01$) While one of the lambs in the RBSR group consumed all the feed supplied, the other four consumed relatively less amounts. Therefore, feed intake among the five lambs was considerably different (SD = 133.63 g). Conversely, all the control group consumed all the corn and wheat bran supplied daily.

According to the clinical severity scores for diarrhea, the RBSR-fed sheep produced 70% level 1 and 2 feces, and 30% level 3 feces, implying that the sheep could digest the feed without developing diarrhea.

Daily body weight gain per lamb in the RBSR-fed group was approximately 2.2–fold that in the control group (Fig. 1), although there were no significant differences in body weight gain between the groups ($F = 2.79$, $P = 0.21$). In addition, although the mean total blood protein and glucose concentrations were tended to increase in the RBSR-fed group ($P = 0.06$ and 0.07, Fig. 2), there were no significant changes in total cholesterol and NEFA content ($P = 0.27$ and 0.15).

In another study, lambs that received diets that replaced barley with feed containing more than 45% rice bran had lower feed intake and lower mean daily gain, potentially due to the adverse effects of rich fat on ruminal digestibility (Table 1, Tabeidian & Sadegh, 2009). Nevertheless, the enhanced animal nutrition in lambs fed on RBSR in the

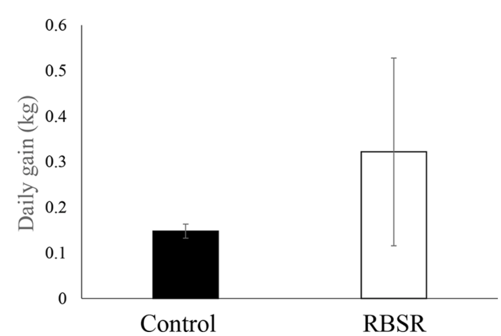

Fig. 1. Daily gain of lamb (mean ± standard error) between the control and the rice bran and soybean curd fed (RBSR) groups on the final date of the feeding experiments.

Table 1
Chemical composition (%) of the dry matter feed used in the present study. The crude protein concentrations were measured by determining N, using the Kjeldahl method, and a factor of 6.25 was used for the conversion of N into crude protein. The ether extracts and fibers were determined using the diethyl ether and detergent methods. The crude ash was determined by incineration at 600 °C for 3 h. Nitrogen free extracts were calculated by total concentrations (100%) minus other compositions.

Feed name	Crude protein	Ether extract	Nitrogen free extracts	Crude fiber	Acid detergent fiber	Neutral detergent fiber	Crude ash	Total Digestible Nutrients
Corn	9.2	4.4	82.9	2.0	3.0	10.5	1.5	93.6
Wheat bran	17.7	4.5	61.5	10.5	14.2	38.8	5.8	72.3
Rice bran	16.8	21	43.4	8.8	11.7	28.3	10	91.5
Soybean curd residue	26.1	11.5	42.3	16	22.3	33.6	4.1	93.4
Timothy	14.7	4.3	45.7	25	29.3	53.8	10.3	65.8

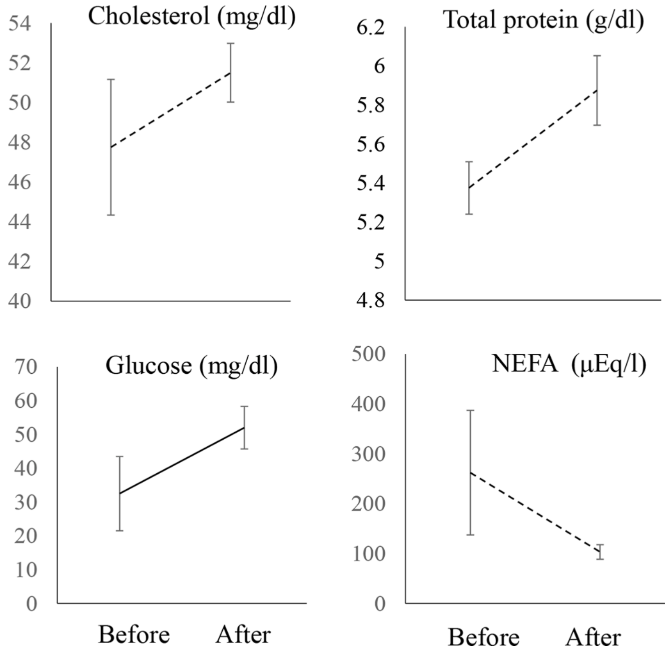

Fig. 2. Changes in body weight and blood properties of lamb (mean ± standard error) before and after feeding experiments after feeding with rice bran and soybean curd.

present study could be due to the high nutrient content and preference for Tofu (Table 1, Cao et al., 2009). Indeed, the TDN of soybean curd residue (93.4%) is much greater than nutritional needs of growing (81.8%) and finishing lambs (75. 8%, National Research Council, 2007). Goats supplied with feed with 20% Tofu with RBSR had 15% higher plasma cholesterol and 50% less free fatty acid content than did goats fed corn mixed with wheat bran (Nagamine, Sunagawa, & Kina, 2013), which indicated that the combination of soybean curd residue rich in protein and rice bran rich in fat has synergistic effects that increase nutrients.

Shear force decreased and crude fat increased in lambs fed on the RBSR when compared with lambs fed the control feed (Table 2, $P <$ 0.01). However, there were no significant differences in WHC ($P =$ 1.00), cooking loss ($P = 0.53$), and melting point ($P = 0.38$). Supplying rice bran does not increase fat in carcass (Sun et al. 2016, Cutrim et al., 2012, Tabeidian & Sadegh, 2009); therefore, the high nutrient levels (e. g. crude protein) in soybean curd residue could have increased the fat content, which led to the tender meat (Moon, Yang, Park & Joo, 2006). Although low fat content in meat, in particular, is a major consumer preference in European societies (Koistinen et al., 2013), Japanese consumers still prefer meat with high fat content, which has a sweet, fatty and butter-like flavor, in addition to tender and juicy characteristics (Sasaki et al., 2017).

4. Conclusion

Based on the blood properties and body weight, animal nutrition in the RBSR-fed sheep was superior. Moreover, eco-feed (rice bran and soybean curd residue) could replace conventional feed (imported corn and wheat bran) for Japanese sheep, and the eco-feed can not only reduce feed and disposal costs but also enhance livestock production and meat quality.

Ethical statement

All authors stated the ethics procedures guidelines which have been followed in the Methods section of their research, and to detail any ethical review permissions which have received. The experimental procedure was approved by the ethical committee of Mie university.

Table 2
Meat quality in the control and the rice bran and soybean curd residues fed groups.

	Control Mean	Standard Error	Significant difference	RBSR Mean	Standard Error
Water holding capacity (%)	71.15	1.81		71.60	2.49
Cooking loss (%)	17.44	2.48		19.90	0.96
Melting point of fat (°C)	45	0.3		43.71	1.42
Shear force (N/cm^3)	6.86	2.14	*	3.69	0.60
Crude fat (%)	49.21	3.34	*	69.08	2.69

Declaration of competing interest

The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

Acknowledgments

We thank the K. Kasada and Y. Matsuo in the Iwanuma sheep farm, for their kind help with the field survey.

References

Association of Official Analytical Chemists. (2005). *Association of official analytical chemists official methods of analysis* (18th ed.). AOAC International. Washington, DC (2005).

Cao, Y., Takahashi, T., & Horiguchi, K. I. (2009). Effects of addition of food by-products on the fermentation quality of a total mixed ration with whole crop rice and its digestibility, preference, and rumen fermentation in sheep. *Animal Feed Science Technology, 151*, 1–11. https://doi.org/10.1016/j.anifeedsci.2008.10.010.

Cutrim, D. O., Alves, K. S., Oliveira, L. R. S., dos Santos, R. D. C., da Mata, V. J. V., & do Carmo, D. M. (2012). Elephant grass, sugarcane, and rice bran in diets for confined sheep. *Tropical Animal Health Production, 44*, 1855–1863. https://doi.org/10.1007/s11250-012-0148-7.

Koistinen, L., Pouta, E., Heikkilä, J., Forsman-Hugg, S., Kotro, J., & Mäkelä, J. (2013). The impact of fat content, production methods and carbon footprint information on consumer preferences for minced meat. *Food Quality and Preference, 29*, 126–136. https://doi.org/10.1016/j.foodqual.2013.03.007.

Maeda, K., Kohira, K., Kubota, H., Yamanaka, K., Saito, K., & Irie, M. (2017). Effect of dietary kapok oil supplementation on growth performance, carcass traits, meat quality and sensory traits of pork in finishing pigs. *Animal Science Journal, 88*, 1066–1074. https://doi.org/10.1111/asj.12731.

Moon, S. S., Yang, H. S., Park, G. B., & Joo, S. T. (2006). The relationship of physiological maturity and marbling judged according to Korean grading system to meat quality traits of Hanwoo beef females. *Meat Science, 74*, 516–521. https://doi.org/10.1016/j.meatsci.2006.04.027.

Nagamine, I., Sunagawa, K., & Kina, T. (2013). Use of Awamori-pressed lees and Tofu lees as feed ingredients for growing male goats. *Asian-Australasian Journal of Animal Science, 26*, 1262–1275. https://doi.org/10.5713/ajas.2012.12717.

National Agricultural and Food Research Organization (NARO). (2010). *Standard tables of feed composition in japan. national agricultural and food research organization*. Tokyo (in Japanese): Japan Livestock Industry Association.

National Research Council. (2007). *Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids*. Washington, DC: National Academy of Sciences. https://doi.org/10.17226/11654.

Sasaki, K., Ooi, M., Nagura, N., Motoyama, M., Narita, T., & Oe, M. (2017). Classification and characterization of Japanese consumers' beef preferences by external preference mapping. *Journal of Science Food Agriculture, 97*, 3453–3462. https://doi.org/10.1002/jsfa.8204.

Sugiura, K., Yamatani, S., Watahara, M., & Onodera, T. (2009). Ecofeed, animal feed produced from recycled food waste. *Veterinaria Italiana, 45*, 397–404.

Tabeidian, S. A., & Sadeghi, G. H. (2009). Effect of replacing barley with rice bran in finishing diet on productive performance and carcass characteristics of Afshari lambs. *Tropical Animal Health Production, 41*, 791–796. https://doi.org/10.1007/s11250-008-9253-z.

Yoshihara, Y., Tada, C., Takada, M., Purevdorj, N. O., Chimedtseren, K., & Nakai, Y. (2016). Effects of water source on health and performance of Mongolian free-grazing lambs. *Small Ruminant Research, 137*, 81–84. https://doi.org/10.1016/j.smallrumres.2016.02.017.