《Research Note》

Effects of Feeding Dried Concentrated Rice-Washing Water on Growth Performance and Skeletal Muscle Lipid Peroxidation in Broiler Chickens

Daichi Ijiri¹, Shogo Nakamura¹, Kenji Tatsugawa², Satoru Ijiri² and Akira Ohtsuka¹

¹Department of Biochemical Science and Technology, Kagoshima University,
1-21-24 Korimoto, Kagoshima 890-0065, Japan

²Shokkyo Co., Ltd., 5-9 Matsukawacho, Minami-ku, Hiroshima 732-0826, Japan

This study was conducted to examine the effect of feeding concentrated rice-washing water (CRWW) on growth performance and lipid peroxidation levels in broiler chickens. CRWW (89.8% moisture) was dried at either a high (130°C) or low temperature (60°C). Three experimental diets were formulated as follows: 1) control diet; 2) diet containing 20% high-temperature dried CRWW (HT-CRWW); and 3) diet containing 20% low-temperature dried CRWW (LT-CRWW). Twenty-one chicks were divided into a control group and two treatment groups (seven chicks per group) at 15 days of age. The control group was fed the control diet, and the treatment groups were fed either an HT-CRWW or LT-CRWW-containing diet for 12 days. The growth performance (body weight, weight gain, feed intake, and feed efficiency) and the weight of the pectoral muscles were not different between treatment groups. Both HT-CRWW and LT-CRWW had a higher total polyphenol content and free radical scavenging activity than corn meal. Malondialdehyde (MDA) content, a marker of lipid peroxidation, was significantly lower in the skeletal muscle of chicks fed the HT-CRWW-containing diet compared with chicks fed the control diet; however, MDA content in chicks fed the LT-CRWW-containing diet did not differ from that of controls. CRWW has promise as a high-energy feed resource, and CRWW dried at high temperatures might affect lipid peroxidation in broiler chickens through higher antioxidant activity.

Key words: antioxidant, broiler chickens, concentrated rice-washing water, growth, lipid peroxidation

J. Poult. Sci., 50: 370-374, 2013

Introduction

Feed costs are a major part of the total cost of poultry production (Donohue and Cunningham, 2009). Corn is the main energy source used in poultry rations. In the past decade, the price of corn and other grains has increased because of limited supply and increasing human and livestock needs (Donohue and Cunningham, 2009). Therefore, it is important to explore cheaper dietary energy sources, which may provide alternatives to the use of corn in poultry production.

Food-processing by-products are a valuable source of protein and energy, and efficient use of these products is an important challenge facing society. A wide variety of food by-products have been used in poultry diets; these include

fish waste (Hammoumi *et al.*, 1998), bakery waste (Al-Tulaihan *et al.*, 2004), tea waste (Murugesan *et al.*, 2005), and rice bran (Warren and Farrell, 1990; Chae *et al.*, 2002; Gallinger *et al.*, 2004).

Wash-free rice, which is widely used in Japan, is a pre-treated rice that is not necessary to wash before cooking. In the process of manufacturing wash-free rice by the super jiff rice method, wastewater containing rice bran is discharged as a by-product (concentrated rice-washing water, CRWW). CRWW is 89.8% moisture, 1.7% crude protein, 1.5% crude fat, 0.1% crude fiber, and 0.8% crude ash. It has been reported that CRWW contains sufficient nutrients to be an ingredient in swine feed (Tatsugawa *et al.*, 2011), and use of CRWW as feed reduces the environmental impact associated with the wastewater treatment and discharge of rice-washing water (Ogino *et al.*, 2012). However, there have been very few reports on the use of CRWW in poultry feed.

Plants containing high concentrations of antioxidants have substantial antioxidative activity (Deighton *et al.*, 1993; Milos *et al.*, 2000) and their intake reduces lipid peroxida-

Received: February 21, 2013, Accepted: April 2, 2013

Released Online Advance Publication: May 25, 2013

Correspondence: Dr. D. Ijiri, Department of Biochemical Science and Technology, Kagoshima University, 1-21-24 Korimoto, Kagoshima 890-0065, Japan. (E-mail: ijiri@chem.agri.kagoshima-u.ac.jp)

tion in chicken muscle (Zhang *et al.*, 2009; Choi *et al.*, 2010). Rice bran contains high amounts of beneficial antioxidants, including tocopherols, tocotrienols, and oryzanols (Lloyd *et al.*, 2000). In the present study, we evaluated the α -tocopherol content, total polyphenol content, and free radical scavenging activity (FRSA) in CRWW. It was necessary to dry the CRWW because of its 89.8% moisture content. Since drying temperature influences the antioxidant activity and stability of polyphenols (Larrauri *et al.*, 1997), CRWW that was dried at a high (130°C) temperature was compared with CRWW that was dried at a low temperature (60°C). We found higher total polyphenol content and FRSA in both high and low-temperature dried CRWW than corn meal. Therefore, we examined the effect of CRWW on growth performance and skeletal muscle lipid peroxidation in broiler chickens.

Materials and Methods

Preparation of CRWW

CRWW collected from a wash-free rice processing plant (Shokkyo Co., Ltd, Hiroshima, Japan) was dried at either a high (HT-CRWW) or low temperature (LT-CRWW). HT-CRWW was dried at 130°C using conductive heating dryers (SCD2A, Nishimura Works Co., Ltd., Saga, Japan), and LT-CRWW was dried at 60°C for 36 h using a convection oven (NDO-400, Tokyo Rikakikai Co., Ltd., Tokyo, Japan). The moisture content of HT-CRWW and LT-CRWW were determined by air oven moisture content determination methods, and the protein content of the CRWW was determined by the dry combustion method using an NC analyzer (JM1000CN, J-Science Lab Co., Ltd, Kyoto, Japan).

Determination of α -tocopherol Content

The α -tocopherol content of corn meal, HT-CRWW, and LT-CRWW was determined by Shimadzu HPLC model LC6A with Shim-Pack CLC-ODS column (6.0×150 mm) according to the method described by Faustman *et al.* (1989).

Free Radical Scavenging Activity

DPPH (1,1-Diphenyl-2-picrylhydrazyl) radical scavenging method was carried out to evaluate free radical scavenging activity of corn, HT-CRWW, and LT-CRWW according to the method described by Nara *et al.* (2009). In brief, 2 g of each ingredient was homogenized 10 times with 80% ethanol (20 mL) at room temperature for 10 minutes, and the homogenate was filtrated. Then 50 μ L of each ingredient extract

in ethanol was mixed with 50 μ L of 0.2 M 2- (N-Morpholino) ethanesulfonic acid buffer, 50 μ L of ethanol, 50 μ L of 1.2 M DPPH. After incubation for 20 minutes at room temperature, absorption measurements were taken at 517 nm. Trolox was used as a control standard, and data are expressed as mmol of trolox equivalent/ g ingredient.

Determination of Total Polyphenol Content

Folin-Ciocalteu method was carried out to evaluate total polyphenol content in CRWW according to the method described by Anesini *et al.* (2008). In brief, 0.4 g of each ingredient (corn, HT-CRWW, and LT-CRWW) was homogenized 5 times with 80% ethanol (2 mL) at room temperature for 10 minutes, and the homogenate was centrifuged. Then, 100 μ L of supernatants of each ingredient extract or gallic acid standard solution were mixed with 100 μ L of 10 % sodium carbonate, 50 μ L of Folin-Ciocalteu reagent, and 750 μ L of distilled water. After incubation for 60 minutes at room temperature, absorption measurements were taken at 700 nm.

Experimental Diet

Three experimental diets were formulated as follows: 1) control diet; 2) diet containing 20% HT-CRWW; and 3) diet containing 20% LT-CRWW. Each diet was designed to satisfy the requirements detailed in “The Japanese Feeding Standard for Chickens” (Agriculture, Forestry and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries of Japan, Tokyo, Japan). The crude protein content of each experimental diet was calculated using the actual values for HT-CRWW and LT-CRWW (Table 1). Metabolized energy (ME) was estimated using the ME value for rice bran (2790 kcal/kg), because the ME of CRWW has not been described in “The Japanese Feeding Standard for Chickens”. The ingredients and nutrient composition of the experimental diets are shown in Table 2.

Animals and Experimental Design

This experiment was conducted in accordance with the guidelines of the Animal Care and Use Committee of Kagoshima University. One-day-old male broiler chicks (Chunky strain ROS308) were kindly provided by the Kajiki Kumiai Hina Center (Kagoshima, Japan), a local commercial hatchery. Chicks were housed in an electrically heated battery brooder and provided water and a commercial starter diet (23% crude protein and 3081 kcal/kg metabolizable energy; Nichiwa Sangyou Company, Kagoshima, Japan) *ad libitum*.

Table 1. Moisture, crude protein, α -tocopherol content, FRSA, and polyphenol content of corn meal and CRWW

	Corn meal	HT-CRWW	LT-CRWW
Moisture (%)	14.50*	8.38	6.17
Crude protein (%)	7.60*	14.67	13.67
α -tocopherol (mg/kg ingredient)	18.40	9.47	22.47
FRSA (mmol eq.trolox/g ingredient)	38.34	133.04	385.27
Polyphenol (mg/100 g ingredient)	200.29	251.76	390.98

* Values from “The Japanese Feeding Standard for Chickens”.

FRSA, free radical scavenging activity; CRWW, concentrated rice-washing water.

Table 2. Composition of experimental diets

	Control diet	HT-CRWW diet	LT-CRWW diet
Ingredients (g/100 g)			
Corn meal	52.92	36.01	35.38
Alfalfa meal	2.79	1.90	1.86
Soybean meal	35.31	32.31	32.80
Corn oil	5.20	6.10	6.20
HT-CRWW		20.00	
LT-CRWW			20.00
CaCO ₃	0.66	0.66	0.66
CaHPO ₄	2.00	2.00	2.00
NaCl	0.50	0.50	0.50
DL-Methionine	0.13	0.13	0.14
Mineral and vitamin premix ¹	0.50	0.50	0.50
Calculated analysis			
Crude protein (%)	20.7	20.7	20.7
Metabolizable energy (kcal/kg)	3098	3095	3095

¹ Content per kg of the vitamin and mineral premix: vitamin A 90 mg; vitamin D3 1 mg; DL-alpha-tocopherol acetate 2000 mg; vitamin K3 229 mg; thiamin nitrate 444 mg; riboflavin 720 mg; calcium d-pantothenate 2174 mg; nicotinamide 7000 mg; pyridoxine hydrochloride 700 mg; biotin 30 mg; folic acid 110 mg; cyanocobalamin 2 mg; calcium iodinate 108 mg; MgO 198,991 mg; MnSO₄ 32,985 mg; ZnSO₄ 19,753 mg; FeSO₄ 43,523 mg; CuSO₄ 4019 mg and choline chloride 299,608 mg. CRWW, concentrated rice-washing water.

for 12 days. On day 12, birds of similar body weight were selected and individually housed in wire-bottomed aluminum cages (40×50×60 cm) in a temperature-controlled room at 25°C. All chicks were allowed free access to a semi-purified corn/soybean meal diet (the control diet described in Table 2) and water for the next 3 days. At the start of the experiment, the 15-day-old chicks in each pen were randomly allocated to receive one of the three experimental diets (seven birds per diet). Body weight and feed intake were measured to calculate feed efficiency. At the end of the experiment, all chicks were weighed and then killed by cervical dislocation under ether anesthesia. The pectoral muscles, abdominal fat, and livers were collected and weighed. The pectoral muscles were immediately frozen and stored at -30°C until analysis.

Determination of Skeletal Muscle Malondialdehyde (MDA) Content

MDA is one of the most frequently used indicators of lipid peroxidation. To evaluate lipid peroxidation levels in skeletal muscle of chickens, MDA content was determined colorimetrically as a 2-thiobarbituric acid reactive substance (TBARS) according to the method described by Azad *et al.* (2010). In brief, skeletal muscle was homogenized in 154 mM KCl, centrifuged at 700×g and supernatant was collected. Forty µL of the homogenate was mixed with 40 µL of 8.1% SDS, 300 µL of 20% acetic acid (pH 3.5), and 300 µL of 0.8% 2-thiobarbituric acid. After vortexing, samples were incubated at 95°C for 1 hour and then transferred to ice. The samples were mixed by vortexing and centrifuged at 1,200 ×g for 10 min after adding 1 mL of butanol-pyridine 15:1 (v/v). Absorbance of the supernatant, consisting of the

butanol-pyridine layer, was measured at 532 nm. The content of TBARS is expressed as the MDA equivalent.

Statistical Analysis

Differences between groups were tested using Tukey's multiple comparisons test. P values under 5% were considered to indicate statistical significance. All analyses were performed with a general liner model using SPSS Statistics 17.0 (Statistical Packages for the Social Sciences, released 23 August 2008).

Results and Discussion

Table 1 shows the α-tocopherol content, total polyphenol content, and FRSA in corn meal, HT-CRWW, and LT-CRWW. According to standard feed composition tables in Japan (2009), the vitamin E content of rice bran (66 mg/kg) is 2.5 times higher than the vitamin E content of corn (26 mg/kg). However, in this study the α-tocopherol content of both HT- and LT-CRWW was similar to that of corn meal. On the other hand, the FRSA of HT- and LT-CRWW were 3.5 times and 10.0 times higher than that of corn, respectively, suggesting that both HT- and LT-CRWW might contain high concentrations of antioxidants other than α-tocopherol and/or vitamin E. In this study, the total polyphenol content of HT- and LT-CRWW was 1.3 times and 2.0 times higher than that of corn meal. It has been well demonstrated that the phenolic compounds contained in rice have high FRSA (Chi *et al.*, 2007; Rattanachitthawat *et al.*, 2010). Antioxidative phenols in rice bran include ferulic acid and its esterified derivatives, oryzanols (Kaneko and Tsuchiya, 1955; Cicero and Gaddi, 2001). Our results suggest that the higher FRSA of HT-

Table 3. Effect of CRWW on growth performance of broiler chickens

	Control diet	HT-CRWW diet	LT-CRWW diet
Body weight (g)	1065.49±155.60	995.23±172.28	917.84±77.40
Body weight gain (g/ 12 days)	661.87±146.14	591.43±153.24	514.23±82.95
Feed intake (g/ 12 days)	1040.63±167.35	998.00±240.39	885.22±67.68
Feed efficiency (BWG/FI)	0.63±0.03	0.58±0.02	0.59±0.02
Pectoral muscle (g)	165.01±36.58	163.48±24.02	154.39±22.54
Abdominal fat (g)	6.80±2.81	10.81±5.47	9.43±5.05
Liver (g)	22.70±3.28	24.11±4.48	23.33±3.28

Values are means±SE ($n=7$). BWG, body weight gain; FI, feed intake; CRWW, concentrated Rice-washing water.

Fig. 1. Effects of feeding dried CRWW on skeletal muscle lipid peroxidation in broiler chickens. Data are the mean±SE of seven broiler chickens per group. Different superscript letters indicate significantly different values ($P < 0.05$). CRWW, concentrated rice-washing water.

CRWW might be due to phenolic compounds, such as oryzanols derived from the remaining aleurone layer on the surface of polished rice. Furthermore, since drying temperature influences the antioxidant activity and stability of polyphenols (Larrauri *et al.*, 1997), it is unsurprising that the FRSA and total polyphenol content of LT-CRWW is higher than that of HT-CRWW.

The animal experiment was conducted to examine the effect of CRWW on growth performance and skeletal muscle lipid peroxidation in broiler chickens. Body weight, weight gain, feed intake, and feed efficiency did not differ between treatment groups (Table 3). The weights of the pectoral muscles, abdominal fat, and livers were also unaffected by the different diets (Table 3). These results suggest that CRWW might be a promising alternative to corn meal as a high-energy feed resource for poultry. However, although no statistical significance was observed, the body weight of chicks fed the LT-CRWW diet tended to be lower relative to that of chicks fed either the HT-CRWW or the control diet, suggesting that the LT-CRWW diet may be more difficult for the chicks to use. One possible explanation is a difference in

gelatinization of the rice starch at the different drying temperatures. Gelatinization of starch may enhance nutrient use. It has been reported that heat-processed rice enhances diet digestibility and production performance in pigs (Vicente *et al.*, 2008). In chickens, the growth performance of broilers fed well-gelatinized corn was also improved compared with that of broilers fed non-gelatinized corn (Moritz *et al.*, 2005). Rice starch is a polymer of glucose, which is gelatinized at 65–77°C (Biliaderis *et al.*, 1986). Therefore, the starch in HT-CRWW might be well gelatinized compared with that in LT-CRWW, with the result that the chicks fed the diet containing HT-CRWW may grow better than chicks fed the LT-CRWW containing diet.

Figure 1 shows the effect of CRWW on the skeletal muscle MDA content of chicks. Chicks fed the HT-CRWW diet had significantly lower MDA in their skeletal muscle than chicks fed the control diet. This suggests that lipid peroxidation in the skeletal muscle of chicks fed the HT-CRWW diet is relatively lower than that of control chicks. However, although both the FRSA and the polyphenol content of the LT-CRWW diet were higher than in the other two diets, the skeletal muscle MDA content of chicks fed the LT-CRWW diet did not differ from that of chicks fed the control diet. The reason for this disagreement between FRSA and MDA content remains unknown. It may be that the chicks fed the LT-CRWW-containing diet have higher levels of oxidative stress, which could cancel out the effect of the higher antioxidant activity of LT-CRWW. In this study, the feed efficiency of chicks fed LT-CRWW was the lowest of the three groups. Bottje *et al.* (2002) reported that broilers with lower feed efficiency exhibited greater H_2O_2 production, which is responsible for ROS production and/or oxidative stress, in both pectoral and leg muscles compared with broilers with higher feed efficiency. These results support the hypothesis that chicks fed the diet containing LT-CRWW might have had higher levels of oxidative stress. Further studies are needed to determine the influence of a diet containing LT-CRWW on oxidative stress levels.

In conclusion, HT-CRWW may be an alternative to corn as a source of energy in broiler diets, and it has an antioxidant effect on skeletal muscle lipid peroxidation because of its higher polyphenol content.

Acknowledgments

We are grateful to Kagoshima Chicken Foods Company, Limited (Kagoshima, Japan) for the supply of broiler chicks. This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

- Al-Tulaihan AA, Najib H and Al-Eid SM. The nutritional evaluation of locally produced dried bakery waste (DBW) in the broiler diets. *Pakistan Journal of Nutrition*, 3: 294–299. 2004.
- Anesini C, Ferrado GE and Filip R. Total polyphenol content and antioxidant capacity of commercially available tea (*Camellia sinensis*) in Argentina. *Journal of Agricultural and Food Chemistry*, 56: 9225–9229. 2008.
- Azada MAK, Kikusato M, Maekawaa T, Shirakawa H and Toyomizu M. Metabolic characteristics and oxidative damage to skeletal muscle in broiler chickens exposed to chronic heat stress. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 155: 401–406. 2010.
- Biliaderis CG, Page CM, Maurice TJ and Juliano BO. Thermal characterization of rice starches: a polymeric approach to phase transitions of granular starch. *Journal of Agricultural and Food Chemistry*, 34: 6–14. 1986.
- Bottje W, Tang Z, Iqbal M, Cawthon D, Okimoto R, Wing T and Cooper M. Association of mitochondrial function with feed efficiency within a single genetic line of male broilers. *Poultry Science*, 81: 546–555. 2002.
- Chae BJ, Lee KH and Lee SK. Effects of feeding rancid rice bran on growth performance and chicken meat quality in broiler chicks. *Asian-australasian Journal of Animal Sciences*, 15: 266–273. 2002.
- Chi HY, Lee CH, Kim KH, Kim SL and Chung IM. Analysis of phenolic compounds and antioxidant activity with H4IIE cells of three different rice grain varieties. *European Food Research and Technology*, 225: 887–893. 2007.
- Choi IH, Park WY and Kim YJ. Effects of dietary garlic powder and {alpha}-tocopherol supplementation on performance, serum cholesterol levels, and meat quality of chicken. *Poultry Science*, 89: 1724–1731. 2010.
- Cicero AFG and Gaddi A. Rice bran oil and g-oryzanol in the treatment of hyperlipoproteinaemias and other conditions. *Phytotherapy Research*, 15: 277–289. 2001.
- Deighton N, Glidewell SM, Deans SG and Goodman BA. Identification by EPR spectroscopy of carvacrol and thymol as the major source of free radicals in the oxidation of plant essential oils. *Journal of the Science of Food and Agriculture*, 63: 221–225. 1993.
- Donohue M and Cunningham DL. Effects of grain and oilseed prices on the costs of US poultry production. *Journal of Applied Poultry Research*, 18: 325–337. 2009.
- Faustman C, Cassens RG, Schaefer DM, Buege DR, Williams SN and Scheller KK. Improvement of Pigment and Lipid Stability in Holstein Steer Beef by Dietary Supplementation with Vitamin E. *Journal of Food Science*, 54: 858–862. 1989.
- Gallinger CI, Suárez DM and Irazusta A. Effects of rice bran inclusion on performance and bone mineralization in broiler chicks. *Journal of Applied Poultry Research*, 13: 183–190. 2004.
- Hammoumi A, Faïd M, Yachoui ME and Amarouch H. Characterization of fermented fish waste used in feeding trials with broilers. *Process Biochemistry*, 33: 423–427. 1998.
- Kaneko R and Tsuchiya T. New compound in rice bran and germ oils. *Chemical Abstracts*, 49: 4897. 1955.
- Larrauri JA, Ruperez P and Saura-Calixto F. Effect of drying temperature on the stability of polyphenols and antioxidant activity of red grape pomace peels. *Journal of agricultural and food chemistry*, 45: 1390–1393. 1997.
- Lloyd BJ, Siebenmorgen TJ and Beers KW. Effects of commercial processing on antioxidants in rice bran. *Cereal Chemistry*, 77: 551–555. 2000.
- Milos M, Mastelic J and Jerkovic I. Chemical composition and antioxidant effect of glycosidically bound volatile compounds from oregano (*Origanum vulgare* L. ssp. *hirtum*). *Food Chemistry*, 71: 79–83. 2000.
- Moritz JS, Parsons AS, Buchanan NP, Calvalcanti WB, Cramer KR and Beyer RS. Effect of gelatinizing dietary starch through feed processing on zero- to three-week broiler performance and metabolism. *Journal of Applied Poultry Research*, 14: 47–54. 2005.
- Murugesan GS, Sathishkumar M and Swaminathan K. Supplementation of waste tea fungal biomass as a dietary ingredient for broiler chicks. *Bioresource Technology*, 96: 1743–1748. 2005.
- Nara K, Yamaguchi A, Maeda N and Koga H. Antioxidative activity of water soluble polysaccharide in pumpkin fruits (*Cucurbita maxima* Duchesne). *Bioscience, Biotechnology, and Biochemistry*, 73: 1416–1418. 2009.
- National Agricultural Research Organization. Standard tables of feed composition in Japan. Japan Livestock Industry Association. 2002.
- Ogino A, Ishida M, Ohmori H, Tanaka Y, Yamashita T, Yokoyama H, Tatsugawa K, Ijiri S and Kawashima T. Life cycle assessment of animal feeds prepared from liquid food residues: a case study of rice-washing water. *Journal of Environmental Quality*, 41: 1982–1988. 2012.
- Rattanachitthawat S, Suwannalert P, Riengrojpitak S, Chaiyasut C and Pantuwatana S. Phenolic content and antioxidant activities in red unpolished Thai rice prevents oxidative stress in rats. *Journal of Medicinal Plants Research*, 4: 796–801. 2010.
- Tatsugawa K, Ohmori H, Tajima K, Tachikawa H, Ijiri S and Kawashima T. Improvement of the preservative quality of concentrated rice washing water and evaluation of its feed characteristics (In Japanese). *Japanese Journal of Swine Science*, 48: 169–176. 2011.
- Vicente B, Valencia DG, Pérez-Serrano M, Lázaro R and Mateos GG. The effects of feeding rice in substitution of corn and the degree of starch gelatinization of rice on the digestibility of dietary components and productive performance of young pigs. *Journal of Animal Science*, 86: 119–126. 2008.
- Warren BE and Farrell DJ. The nutritive value of full fat and defatted Australian rice bran. I. Chemical composition. *Animal Feed Science and Technology*, 27: 219–228. 1990.
- Zhang GF, Yang ZB, Wang Y, Yang WR, Jiang SZ and Gai GS. Effects of ginger root (*Zingiber officinale*) processed to different particle sizes on growth performance, antioxidant status, and serum metabolites of broiler chickens. *Poultry Science*, 88: 2159–2166. 2009.