Effects of Replacing Corn with Whole-Grain Paddy Rice in Laying Hen Diets on Egg Production Performance

Janjira Sittiya and Koh-en Yamauchi
Laboratory of Animal Science, Faculty of Agriculture, Kagawa University, Kagawa, Japan
Email: janjira_66@hotmail.com, yamauchi@ag.kagawa-u.ac.jp

Kenji Takata
Nichiwa Sangyo Co., Ltd., Kobe, Japan
Email: k-takata@nichiwasangyo.co.jp

***Abstract*—Two experiments were conducted to investigate the effect of replacing corn with whole-grain paddy rice (WPR) in laying hen diets on egg production performance and quality. Commercial layers (Sonia) were used in both Experiment 1 and 2. In Experiment 1, 80 layers were placed into 4 groups of 20 birds each: the corn in the basal diet was replaced with 0, 10, 30 and 50%WPR. Each group of 20 birds had 10 replicates of 2 birds. In Experiment 2, 45 layers were placed into 3 groups of 15 birds each: the corn in the basal diet was replaced with 0, 70 and 100%WPR. Egg production was recorded daily and feed consumption was measured weekly throughout the experiments. Eggs from each group were collected biweekly to measure egg quality. Egg production performance and quality were not different among the groups (P>0.05), except for a decreased (P<0.05) shell ratio in the 100%WPR group. Moreover, yolk color score decreased (P<0.05) with increasing levels of WPR (50%WPR or more). The present results reveal that WPR can replace up to 100% of corn in laying hen diets without harming egg production performance and quality.**

***Index Terms*—egg production, egg quality, laying hens, whole-grain paddy rice**

I. INTRODUCTION

Corn is the principal energy source in poultry diets, and it is also an important cereal for humans. In recent years, industry and human consumption of corn has been expanding rapidly, leading to inadequate supplies and high prices. This trend has necessitated a search for feedstuffs that could be used as an alternative to corn in poultry diets. Many studies have been published on replacing corn with alternative feedstuffs in layer diets such as water yam [1], pearl millet [2] as well as sweet potato and cassava meal [3]. One alternative is paddy rice (Momiroman; feed-type rice), which has been advocated for cultivation in Japan and is therefore available for use as a replacement for corn in poultry diets. Our previous results regarding chemical composition, digestibility of crude fiber, gross energy, and metabolizable energy of paddy rice demonstrated that paddy rice can probably be used as a good alternative cereal grain source in poultry diets [4]. Although the nutrient composition of paddy rice is slightly lower than maize, it is higher than for other cereal grains such as sweet potato tubers or cassava meal which are used in animal diets [5].

Currently, using whole grains in poultry diets has gained interest in many countries due to saving the cost of grinding [6]. Ref. [7] reported on the physiological function of the gastrointestinal tract affected by the particle size of feed such as whole grains. In addition, whole-grain feed improves gizzard activity [8] which is associated with increased starch digestibility [9]. Some reports have indicated that diets containing whole grains improve feed utilization [10]. Therefore, whole-grain paddy rice (WPR) was used in this experiment to decrease feed cost and also to increase the use of locally grown grains. It has been reported that WPR could be used as an ingredient in chicken diets [6]. Thus, the aim of this experiment was to study the effect of replacing corn with WPR in laying hen diets on egg production performance and quality.

II. MATERIALS AND METHODS

A. Diets and Animals

The experiment was managed in accordance with the guidelines and rules for animal experiments of Kagawa University, Japan. WPR was obtained from a rice farm at Kagawa University.

Eighty 23-week-old Sonia hens were placed into 4 groups of 20 birds each for Experiment 1, based on egg production rate and body weight. Each group of 20 birds had 10 replicates of 2 birds. The corn in the basal diet was replaced with 0, 10, 30 and 50%WPR. Feed and water were provided *ad libitum* during the experimental period of 15 weeks. Forty-five 48-week-old Sonia hens were placed into 3 groups of 15 birds each for Experiment 2. The corn in the basal diet was replaced with 0, 70 and 100%WPR. Feed and water were provided *ad libitum* during the experimental period of 10 weeks.

Manuscript received January 10, 2014; revised May 19, 2014.

doi: 10.12720/joaat.1.1.1-4

The experimental diets were formulated to be iso-caloric and iso-nitrogenous (Table I). All birds were placed in individual cages in an environmentally controlled room with a 16-h photoperiod.

TABLE I. COMPOSITION OF THE DIETS FOR EXPERIMENTS 1 AND 2

Ingredients	Level of corn replacement with WPR[1] (%)					
	0	10	30	50	70	100
Corn	50.00	45.00	35.00	25.00	15.00	-
WPR[1]	-	5.00	15.00	25.00	35.00	50.00
Milo	8.00	6.80	4.80	2.80	-	-
Soybean meal	20.00	20.50	21.20	21.90	21.50	21.50
Calcium carbonate	9.00	9.00	9.00	9.00	9.00	9.00
Rapeseed meal	5.00	5.00	5.00	5.00	3.00	3.00
Animal fat	3.00	3.70	5.00	6.30	8.10	9.50
Gluten meal	3.00	3.00	3.00	3.00	3.00	3.00
Fish meal (60%CP)	1.10	1.10	1.10	1.10	1.10	1.10
High protein defatted rice bran	0.05	0.07	0.09	0.11	3.39	1.99
Dibasic calcium phosphate	0.40	0.40	0.40	0.40	0.50	0.50
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Premix[2]	0.07	0.07	0.07	0.07	0.07	0.07
Methionine	0.04	0.04	0.04	0.04	0.06	0.06
Choline chloride	0.03	0.03	0.03	0.03	0.03	0.03
Lysine	0.06	0.04	0.02	-	-	-
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*
Calculated analysis (%)						
Crude protein	18.11	18.14	18.10	18.05	17.47	16.86
Metabolizable energy (kcal/kg)	2860.00	2859.00	2858.00	2860.00	2861.00	2859.00
Ether extract	5.68	6.24	7.26	8.28	9.78	10.82
Crude fiber	2.78	3.10	3.75	4.40	5.11	5.94
Crude ash	11.95	11.97	12.00	12.03	13.50	14.05
Lysine	0.95	0.95	0.95	0.95	0.95	0.95
Methionine	0.35	0.35	0.36	0.36	0.38	0.39
Calcium	3.59	3.59	3.60	3.60	3.61	3.61
Phosphorus, available	0.24	0.23	0.23	0.23	0.24	0.24

[1]WPR = whole-grain paddy rice

[2]Concentrate mixture including (per kg of diet): vitamin A 0.003 μg; vitamin D_3 0.05 mg; vitamin E 11.88 mg; vitamin B_1 3.65 mg; B_2 5.96 mg; vitamin B_6 2.3 mg; vitamin B_{12} 0.43 mg; niacin 65.41 mg; pantothenic acid 11.24 mg; choline 1267.6 mg; biotin 0.21 mg; folic acid 0.7 mg; manganese 70 mg; iron 55 mg; cobalt 0.2 mg; copper 5.5 mg; zinc 60 mg; iodine 0.1 mg; selenium 0.11 mg.

B. Egg Production Performance and Quality

Egg production was recorded daily and feed consumption was measured weekly throughout the experiment. Eggs from each group were collected biweekly to measure egg weight, shell-breaking strength, shell thickness, shell ratio, albumen ratio, yolk ratio, yolk color and Haugh units. Egg weight was measured using an electronic digital balance. Shell-breaking strength was measured using an egg shell strength instrument (accuracy: 0.1 kg/cm^2, Fujihira Industry Co., Ltd.). Individual eggs were broken on a metal plate. Height of the thick albumen was measured and then the weight of the albumen, egg yolk and egg shell were measured using an electronic digital balance. Values for shell ratio, albumen ratio and yolk ratio were calculated. Shell thickness was measured using a dial thickness gauge (Peacock, Tokyo, Japan) at three locations on the egg (air cell, equator and sharp end) after the shell membrane was removed from the shell. The mean of the three values was recorded as shell thickness per egg. Yolk color of eggs was measured using the Roche Yolk Color Fan (Roche Ltd., Basel, Switzerland). Values for shell ratio, albumen ratio, yolk ratio and Haugh units were calculated for each individual egg as follows:

$$Shell\ ratio = \frac{Shell\ weight \times 100}{Egg\ weight}$$

$$Albumen\ ratio = \frac{Albumen\ weight \times 100}{Egg\ weight}$$

$$Yolk\ ratio = \frac{Yolk\ weight \times 100}{Egg\ weight}$$

$$Haugh\ units = 100 \log (H - 1.7\ W^{0.37} + 7.6)$$

where

H = Observed height of albumen (mm)

W = Weight of egg (g)

C. Statistical Analysis

Data from both experiments on egg production performance and quality were statistically analyzed using one-way analysis of variance (ANOVA) of SPSS statistical software package (version 10.0 for Windows, SPSS Inc., Chicago, IL). Significant differences among the treatments were determined with Duncan's multiple range tests. Statistical significance was accepted at $P<0.05$.

III. RESULTS

A. Experiment 1

The effect of replacing corn with WPR on production performance of laying hens from 23 to 38 weeks of age is presented in Table II. Feed consumption, hen-day egg production, egg mass and feed efficiency did not differ significantly among groups. Yolk color score decreased ($P<0.05$) in the 50%WPR group, but there were no significant differences in shell-breaking strength, shell thickness, shell ratio, albumen ratio, yolk ratio and Haugh units.

B. Experiment 2

No differences were found in production performance in the 70 and 100%WPR groups (Table III). Shell ratio decreased (P<0.05) in the 100%WPR group, and yolk color score decreased (P<0.05) with increasing amounts of WPR, but there were no significant differences in other egg qualities.

TABLE II. PRODUCTION PERFORMANCE AND EGG QUALITY OF LAYING HENS AT VARIOUS LEVELS OF CORN REPLACEMENT WITH WHOLE-GRAIN PADDY RICE (WPR) DURING 23 TO 38 WEEKS OF AGE (MEANS ±SE, N=10), EXPERIMENT 1

Items	Level of corn replacement with WPR (%)			
	0	10	30	50
Feed consumption, g/(hen*day)	106.79±11.46	109.63±4.49	110.17±8.91	111.19±4.36
Hen-day egg production (%)	94.04±1.01	94.28±0.88	94.28±1.47	92.61±1.14
Egg mass, g egg/(hen*day)	58.60±0.66	60.63±1.28	62.53±0.91	59.36±1.23
Feed efficiency	0.63±0.09	0.55±0.01	0.61±0.07	0.53±0.02
Shell-breaking strength, kg/cm^2	4.10±0.18	4.12±0.14	3.94±0.11	3.61±0.20
Shell thickness, mm	0.38±0.002	0.39±0.005	0.37±0.003	0.36±0.01
Shell ratio (%)	11.11±0.14	11.33±0.14	10.97±0.12	11.01±0.16
Albumen ratio (%)	61.18±0.58	61.53±0.52	61.99±0.48	61.91±0.45
Yolk ratio (%)	27.69±0.46	27.13±0.42	27.03±0.43	27.07±0.41
Yolk color	7.23±0.08^a	7.00±0.05^a	7.09±0.07^a	6.50±0.31^b
Haugh units	90.35±86.32	94.69±91.39	91.83±89.60	84.42±73.40

^{a,b}Means within a row with different superscripts are significantly different (P<0.05).

TABLE III. PRODUCTION PERFORMANCE AND EGG QUALITY OF LAYING HENS AT VARIOUS LEVELS OF CORN REPLACEMENT WITH WHOLE-GRAIN PADDY RICE (WPR) DURING 48 TO 58 WEEKS OF AGE (MEANS ±SE, N=15), EXPERIMENT 2

Items	Level of corn replacement with WPR (%)		
	0	70	100
Feed consumption, g/(hen*day)	106.66±8.44	106.87±5.13	105.77±5.88
Hen-day egg production (%)	90.09±1.41	90.66±1.53	90.19±0.86
Egg mass, g egg/(hen*day)	55.57±1.08	56.75±1.15	56.48±1.06
Feed efficiency	0.59±0.07	0.50±0.04	0.55±0.03
Shell-breaking strength, kg/cm^2	3.29±0.13	3.38±0.17	3.36±0.13
Shell thickness, mm	0.37±0.52	0.37±0.56	0.36±0.65
Shell ratio (%)	11.24±0.11^a	11.18±0.19^a	10.71±0.11^b
Albumen ratio (%)	61.27±0.69	60.48±0.55	60.60±0.57
Yolk ratio (%)	28.26±0.40	28.33±0.46	28.69±0.52
Yolk color	7.33±0.14^a	6.60±0.11^b	5.57±0.12^c
Haugh units	88.89±1.07	88.64±0.75	86.95±2.25

^{a,b,c}Means within a row with different superscripts are significantly different (P<0.05).

IV. DISCUSSION

In our previous study [4], the gross energy content (3.77 kcal/g) of WPR was close to that of corn (3.85 kcal/g), and the apparent metabolizable energy of WPR (2.79 kcal/g air-dried) was slightly lower than that of corn (3.28 kcal/g air-dried). This observation suggests that WPR would be possible as a beneficial ingredient in dietary feed for poultry. In this study, feeding WPR to laying hens as a replacement for corn in diets led to a similar production performance to that of those fed basal diets, which demonstrated that WPR can safely replace up to 100% of corn in the laying hen diets.

Previous research has reported that a bird's gizzard can grind whole grains more effectively than a hammer mill [11]. Similarly, Ref. [12] reported that chickens can digest whole grains because the gizzard can grind the whole grains before they pass to the small intestine [13, 14]. In addition, whole grains have been reported to improve feed utilization [10]. Such a developed gizzard can help maintain production performance even when corn in a basal diet is completely replaced with WPR.

Egg quality traits in both experiments were not affected by replacing corn with WPR. These results indicate that laying hens can utilize WPR when it replaces up to 100% of corn in the diet without an adverse effect on egg production and quality except for decreased (P<0.05) shell ratio in the 100%WPR group. Moreover, yolk color score decreased (P<0.05) with increasing levels of WPR (50%WPR or more). As xanthophylls are primary contributors of yolk pigmentation [15], this decreased yolk color score is thought to be caused by decreased levels of xanthophylls due to WPR. It is not clear at present why shell ratio decreased in the 100%WPR group compared with the control group, but it is possibly related to the difference in non-starch polysaccharide (NSP) content in 100% WPR, because plant cell walls are known to include NSP. The increased NSP elevated the viscosity of digesta [16]. Because the high viscosity of intestinal content lowered mineral absorption [17], the present decreased shell ratio might be induced by decreased calcium absorption.

In conclusion, the present results reveal that WPR can totally replace corn in laying hen diets without harming egg production performance and quality. This suggests that WPR could be used as a feed ingredient in laying hen diets.

ACKNOWLEDGMENT

This study was supported by a grant from the research for production of valuable livestock by using self-sufficient forage crops in feed.

REFERENCES

[1] L. N. Agwunobi, "Dioscorea alata (water yam) as a replacement for maize in diets for laying hens," *Trop. Anim. Health. Prod.*, vol. 31, pp. 391-396, December 1999.

[2] S. M. Abd-Elrazig and E. A. Elzubeir, "Effects of feeding pearl millet on laying hen performance and egg quality," *Anim. Feed Sci. Technol.*, vol. 76, pp. 89-94, December 1998.

[3] A. B. J. Aina and A. O. Fanimo, "Substitution of maize with cassava and sweet potato meal as the energy source in the rations of layer birds," *Pertanika J. Trop. Agric. Sci.*, vol. 20, pp. 163-167, November 1997.

[4] J. Sittiya, K. Yamauchi, and M. Morokuma, "Chemical composition, digestibility of crude fiber and gross energy, and metabolizable energy of whole paddy rice of momiroman," *J. Poult. Sci.*, vol. 48, pp. 259-261, October 2011.

[5] National Agriculture and Food Research Organization, *Standard Tables of Feed Composition in Japan*, Japan Livestock Industry Association, Tokyo, 2009.

[6] J. Sittiya and K. Yamauchi, "Growth performance and histological intestinal alterations of Sanuki Cochin chickens fed diets diluted with untreated whole-grain paddy rice," *J. Poult. Sci.*, vol. 51, pp. 52-57, January 2014.

[7] R. M. Engberg, M. S. Hedeman, S. Steenfeldt, and B. B. Jensen, "Influence of whole wheat and xylanase on broiler performance and microbial composition and activity in the digestive tract," *Poult. Sci.*, vol. 83, pp. 925-938, June 2004.

[8] C. D. Bennett, H. L. Classen, K. Schwean, and C. Riddell, "Influence of whole barley and grit on live performance and health of turkey toms," *Poult. Sci.*, vol. 81, pp. 1850-1855, December 2002.

[9] H. Hetland, B. Svihus, and V. Olaisen, "Effects of feeding whole cereals on performance, starch digestibility and duodenal particle size distribution in broiler chickens," *Br. Poult. Sci.*, vol. 43, pp. 416-426, July 2002.

[10] I. Gabriel, S. Mallet, M. Leconte, A. Travel, and J. P. Lalles, "Effects of whole wheat feeding on the development of the digestive tract of broiler chickens," *Anim. Feed Sci. Technol.*, vol. 142, pp. 144-162, April 2008.

[11] B. Svihus, "Norwegian poultry industry converts to whole grain pellets," *World Poultry.*, vol. 17, pp. 20-21, 2001.

[12] P. D. Sturkie, *Avian Physiology*, 2nd ed. New York: Comstock, 1965.

[13] S. P. Rose, A. Burnetti, and R. A. Elmajeed, "Factors affecting the diet selection of choice-fed broilers," *Br. Poult. Sci.*, vol. 27, pp. 215-224, November 1986.

[14] M. J. Banfield and J. M. Forbes, "Effects of whole wheat dilution *v.* substitution on coccidiosis in broiler chickens," *Br. J. Nutr.*, vol. 86, pp. 89-95, July 2001.

[15] S. A. Roberts, H. Xin, B. J. Kerr, J. R. Russell, and K. Bregendahl, "Effects of dietary fiber and reduced crude protein on nitrogen balance and egg production in laying hens," *Poult. Sci.*, vol. 86, pp. 1716-1725, August 2007.

[16] M. Choct, R. J. Hughes, J. Wang, M. R. Bedford, A. J. Morgan, and G. Annison, "Increased small intestinal fermentation is partly responsible for the anti-nutritive activity of non-starch polysaccharides in chickens," *Br. Poult. Sci.*, vol. 37, pp. 609-621, July 1996.

[17] J. D. Van Der Klis, M. W. A Verstegen, and A. Van Voorst, "Effect of a soluble polysaccharide (carboxy methyl cellulose) on the absorption of minerals from the gastrointestinal tract of broilers," *Br. Poult. Sci.*, vol. 34, pp. 985-997, December 1993.

Janjira Sittiya was born in Tak, Thailand on June 20, 1983. She graduated from Maejo University, Thailand with a Bachelor of Science (2005) in Animal Science and a Master of Science (2012) in Agriculture (Animal Science) from Kagawa University, Japan.

Currently she is studying in Agriculture (Animal Science) at Ehime University, Japan. She is the author of 2 published articles. The published articles were as follows: (1) "Chemical composition, digestibility of crude fiber and gross energy, and metabolizable energy of whole paddy rice of Momiroman," *J. Poult. Sci.,* vol. 48, pp. 259-261, October 2011; (2) "Growth performance and histological intestinal alterations of Sanuki Cochin chickens fed diets diluted with untreated whole-grain paddy rice," *J. Poult. Sci.,* vol. 51, pp. 52-57, January 2014. She could present her results at the Japanese Journal of Poultry Science Conference in 2011, 2012, 2013. Her research interest is to investigate the effect of replacing corn with whole-grain paddy rice in chicken diets on histological alterations of the intestinal villi.

Ms. Sittiya is currently a member of Japanese Poultry Science. In 2012, she was awarded a Prize for Excellent announcement of Japanese Poultry Science.

Ko-en Yamauchi was born in Kagoshima, Japan on May 18, 1947. Dr. Yamauchi graduated from Miyazaki University, Japan with a Bachelor of Science (1970) in Agriculture (Animal Science), a Master of Science (1973) and a Ph.D. (1976) in Agriculture (Animal Science) from Nagoya University, Japan.

In 1977 he joined the Hirosaki University School of Medicine as an assistant of Department of Anatomy. He was subsequently promoted to Associate Professor in 1987 and Professor in 1992 of Laboratory of Animal Science, Faculty of Agriculture, Kagawa University, Japan. He is the author of 9 books, more than 120 scientific publications and 4 patents: (1) Digestive organs. In: Japanese Society of Veterinary Science, *The Textbook of veterinary histology 4th ed*. Gakusosha, Tokyo, 2008, pp. 288-295. (In Japanese); (2) Review of a histological intestinal approach to assessing the intestinal function in chickens and pigs. *Anim. Sci. J.*, vol. 78, pp. 356-370, 2007; (3) Effects of dietary red paper on egg yolk colour and histological intestinal morphology in laying hens. *Br. Poult. Sci*., vol. 50, pp. 592-597, 2009. His research focuses on the histological alterations of the intestinal mucosa induced by ingested feeds in chickens.

Prof. Yamauchi is currently a member of Japanese Society of Veterinary Science, Japanese Poultry Science, Japanese Animal Science, World Poultry Science, and Kansai Animal Science. He was awarded a Prize of Japanese Poultry Science in 2000, 2009 and 2012. In 2006, he was awarded a Prize of Excellent Paper of Animal Science Journal.

Kenji Takata graduated from Tottori University, Japan with a Bachelor degree (2006) in Veterinary Medicine and a Ph.D. (2013) in Veterinary Medicine from Yamaguchi University, Japan.

As of 2007, Dr. Takata is an assistant manager of Central Research Institute at Nichiwa Sangyo Co., Ltd. in Japan.

