Utilization of Different Basal Diets for Molt Induction in a Strain of Commercial Laying Hens

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ABSTRACT

The objective of the study was to evaluate a nonfasting method for induced molting of laying hens by using different basal diets. An experiment was conducted using 300 H&N Brown hens (aged 95 wk) randomly assigned to one of five treatment groups: group 1 (NC), which served as the non-molt control group, was provided with a layer ration and exposed to a 16:8 daylight:dark (L:D) photoperiod daily throughout the study, whereas groups 2 (BR), 3 (RB), 4 (C) and 5 (CM) were subjected to an induced molting program. Hens in the BR group were fully fed with a broken rice molt diet, whereas for 14 days, hens in the RB, C and CM groups received rice bran, corn mash and cassava mash molt diets, respectively. During the 2 wk molt period, all birds were exposed to an 8L:16D photoperiod and had access to drinking water at all times. Following the molting period, all hens were fed the layer ration and provided with 16 h of light per day, and production performance was measured for 20 wk. The CM treatment resulted in total cessation of egg production within 7 d. Egg production of hens in the BR, RB and C treatments all decreased to 3.7, 2.6 and 8.7%, respectively. Bodyweight loss ranged from 6.0 to 22.0%, with the highest value for the CM treatment. At the end of the molt period, no significant differences in the mortality rate, the ratio of heterophil to lymphocyte numbers and plasma cortisol concentrations were found among the experimental bird groups. No consistent differences were observed among the molt treatments throughout the 20 wk postmolt period for egg production, egg weight or egg quality. However, the peak of egg production of hens in the CM treatment reached a level of 70% of hen-day egg production, which was higher than those of the other treatments. In addition, during the early phase of the postmolt period, egg production and albumen quality of the CM treatment were significantly improved as compared to those of the control group. At week 2 of the postmolt period, the egg shell thickness of the CM treatment was significantly lower than that of the control group. The results indicated that feeding the cassava molt diet is an effective non-feed removal method for molting laying hens. However, the technique needs to be adjusted to improve egg production and egg shell quality.
Keywords: molting, laying hen, cassava, egg quality, cortisol

INTRODUCTION

Molting in avian species is characterized by the orderly replacement of feathers and is accompanied by the regression of reproductive organs and the cessation of egg laying (Johnson, 1986). Commercial laying hens also experience naturally occurring molts but these are usually incomplete, and hens continue to lay eggs at a low rate for a prolonged period of time. This creates

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a period of unprofitability to the commercial egg producer due to a reduction in egg production and the end of the useful life of the flock (Berry, 2003). It is generally accepted that induced molting is an effective tool for the economic management of laying flocks to extend the productive life of aged laying hens. Egg shell quality (Hurwitz *et al*., 1975; Roland and Brake, 1982; Christmas *et al*., 1985) and albumen quality (Hembree *et al*., 1980; Lee, 1982; Tona *et al*., 2002) are also improved by induced molting in the subsequent laying cycle. Conventional induced molting involves removing feed (Christmas *et al*., 1985; Park *et al*., 2004), water (North and Bell, 1990) or both from the hens and reducing the photoperiod to that of natural day length or less (Hembree *et al*., 1980). In recent years, the induction of molting by fasting has become the target of vigorous criticism with regard to animal welfare concerns. Therefore, alternative methods for molt induction that avoid feed withdrawal have been investigated. There are many effective methods that can be used to induce the molt such as feeding a low-Na diet and high-dietary Zn (Berry and Brake, 1985), or low-Ca diets (Breeding *et al*., 1992), or high-fiber and low-energy diets (Woodward *et al*., 2005). Other nonfasting molt methods include the feeding of high wheat middlings (Biggs *et al*., 2003), a combination of wheat middlings and corn (Biggs *et al*., 2004; Mazzuco and Hester, 2005; Koelkebeck *et al*., 2006), various ratios of alfalfa or layer ration (Donalson *et al*., 2005), a whole-grain barley diet (Onbasilar and Erol, 2007), diets containing different levels of dried corn-based distillers grains with solubles (DDGS) with corn, wheat middlings, soybean hulls and dried corn-based distillers grains with soluble corn (Mejia *et al*., 2011) or a combination of soy-hull diet and corn (Mazzuco *et al*., 2011). Induced molting programs generally range from 5 to 9 wk in length. The degree of improvement in postmolt performance is associated with an increase in the number of days during which no eggs are produced (Berry, 2003). However, from an animal welfare standpoint, the use of a long-term forced molt period may actually be stressful and traumatic to the overall well-being of the birds. The present study was undertaken to determine the effects of a short-term induced molt program by full-feeding basal molt diets on gonadal morphology, physiological stress, postmolt egg production and egg quality in a strain of commercial laying hen.

MATERIALS AND METHODS

Experimental birds and molt procedure

All animal care procedures were approved by the Animal Ethics Committee of Kasetsart University, Thailand. An experiment was conducted using 300 H&N Brown hens (aged 95 wk). The hens were housed in a caged layer house of commercial design, with water and feed provided for *ad libitum* consumption, and the hens were exposed to a 16 h photoperiod (16L:8D) daily before the start of the experiment. The mean temperature of the house was 20.7 °C, and the mean light intensity was 3.9 lux. The feed was a commercial layer diet calculated to contain 17% CP, 2,800 kcal of metabolizable energy per kilogram of feed, and 3.5% calcium. Five replicate groups of 12 hens each (four adjacent cages containing three hens per cage, cage size 40 × 45 cm) were allotted to five treatments in a completely randomized design. The five treatments were designated as follows: non-molt control (NC), fully fed one of a broken rice molt diet (BR), a rice bran molt diet (RB), a corn mash molt diet (C), or a cassava mash molt diet (CM). Birds were weighed and allocated to each replicate to achieve a similar mean body weight (BW) for each treatment. Egg production, egg weight and egg quality were measured for 2 wk (95 to 97 wk of age), in an attempt to keep a similar distribution of production rate, egg weight and egg quality among the experimental treatments. At age 97 wk, the control group was moved carefully and properly into a similar nearby house and maintained under an artificial lighting program of 16L:8D and provided access *ad libitum* to the commercial layer ration and drinking water throughout the experimental period, whereas the remaining groups were induced to molt for 14 d according to the molting procedure as shown in Table 1. Daily egg production, feed consumption, body weight loss and mortality rate were recorded during the 14 d molt period. Thereafter, the birds were moved to the house where the control group was being kept and maintained under the same management regime throughout the experimental period. The ingredient composition and calculated chemical analyses of the experimental molt diets are given in Table 2.

Table 1 Molting procedure used in the experiment.

Treatment	Feed	Water	Light ($hr.d^{-1}$)	Length (d)
NC	Layer diet, *ad libitum*	Provided	16	throughout the experimental period
BR	Broken rice molt diet, *ad libitum*	Provided	8	14
RB	Rice bran molt diet, *ad libitum*	Provided	8	14
C	Corn mash molt diet, *ad libitum*	Provided	8	14
CM	Cassava mash molt diet, *ad libitum*	Provided	8	14

NC = non-molt control; BR = broken rice molt diet; RB = rice bran molt diet; C = corn mash molt diet; and CM = cassava mash molt diet.

Table 2 Ingredient composition and calculated nutrient analysis of the experimental molt diets.[1]

Item	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients		(%)		
Broken rice	96.72	–	–	–
Rice bran	–	97.00	–	–
Corn mash	–	–	96.60	–
Cassava mash	–	–	–	96.62
Limestone	1.50	2.40	1.62	1.60
Dicalcium phosphate	1.38	0.20	1.38	1.38
Vitamin mineral premix[2]	0.40	0.40	0.40	0.40
Calculated analysis				
ME[3] ($kcal.kg^{-1}$)	3,385.20	2,628.70	3,255.40	3,381.70
Crude protein (%)	7.73	11.64	7.72	1.93
Crude fiber (%)	0.96	17.46	2.41	3.62
Calcium (%)	0.93	1.10	0.95	1.05
Available phosphorus (%)	0.24	0.49	0.25	0.29

[1]Diet 1 = broken rice molt diet (BR); diet 2 = rice bran molt diet (RB); diet 3 = corn mash molt diet (C); and diet 4 = cassava mash molt diet (CM).

[2]Provided the following (per kilogram of diet): vitamin A, 20,000 International units (IU); vitamin D_3, 4,800 IU; vitamin E, 16 IU; vitamin K_3, 2.4 mg; vitamin B_1, 32 mg; vitamin B_2, 8 mg; vitamin B_6, 4.8 mg; vitamin B_{12}, 0.01 mg; pantothenic acid, 15.04 mg; nicotinic acid, 20 mg; folic acid, 0.8 mg; biotin, 0.144 mg; selenium, 0.16 mg; copper 16 mg; manganese, 96 mg; iron, 64 mg; zinc, 80 mg; cobalt, 0.32 mg; and iodine, 3.2 mg.

[3]Metabolizable energy.

Hematological study

Blood samples (5 mL) were obtained from the brachial vein of one hen at age 99 wk from each replicate. The time of bleeding was between 0900 and 1100 hours. The physiological stress of hens was determined by counting leukocytes in the blood and calculating the heterophil:lymphocyte ratio (an elevated ratio indicating increased stress) using methods described by McKee and Harrison (1995). Next, the remainder was centrifuged at 1,090×*g* for 15 min. The plasma cortisol concentration was measured by chemiluminescent enzyme immunoassay on an IMMULITE/ IMMULITE 1000 Cortisol analyzer Model PILKCO-9 (Diagnostic Products Corporation; Los Angeles, CA, USA). The analytical sensitivity of the assay was 0.2 $\mu g.dL^{-1}$. The intra-assay coefficient of variation (CV) was 8.8%, whereas the inter-assay CV was 10.0%.

Gonadal morphology

At the termination of the molt period (age 99 wk), one bird of each replicate was killed for observation of the morphological characteristics of the reproductive organs. The birds were killed by cervical dislocation, and the ovary and oviduct were removed and measured for weight and length according to the method of Waddington *et al*. (1985).

Post-molt productive performance and egg quality

Egg production was recorded daily and expressed as a percentage of hen-day egg production on a weekly basis for 20 wk of the postmolt period. Eggs from each replicate laid on three consecutive days in each week were weighed and the average was calculated for each replicate. All eggs from each replicate laid on the last day of the week were collected in each 2 wk period and measured for egg and eggshell quality. The eggs were broken at the equatorial region and the interior contents were allowed to drain out. The internal quality of eggs was assessed according to albumen height, Haugh unit, and yolk color using specialized equipment (Technical Services and Supplies; York, UK.). The yolk weight was determined after it was separated from the adhering albumen and then weighed on an electric balance (Model PB 1501 Mettler-Toledo; OH, USA). The egg shell along with membranes was washed with tap water and dried at room temperature (around 28 °C) for 1 wk. After drying, the egg shell was weighed and the shell thickness was measured in millimeters using a digimatic micrometer (Mitutoyo Corporation; Kanagawa, Japan). Three measurements were taken on the equatorial region of each egg shell; the mean of three measurements was calculated. The albumen weight was determined by subtracting the yolk plus shell weight from the total egg weight. Feed intake data were determined on a biweekly basis and the feed conversion ratios were calculated during the postmolt period.

Statistical analysis

The experiment was conducted as a completely randomized design with five treatments. Data were analyzed using the statistical software package SAS, version 9.0 (SAS Institute, 2002). The GLM procedure was used to analyze the effect of the treatment on BW, feed intake, mortality rate, egg production, egg and egg shell quality, hematological values and gonadal characteristics. An arcsine transformation was used for all percentage data. When the means of the GLM procedure were statistically different, these means were further compared between the control and the experimental groups using Duncan's multiple range test. Significance was based on $P < 0.05$. The experimental unit was a group of 12 hens for all traits studied. For the determination of hematological parameters and gonadal morphology, only one sample per replicate was used. Data were presented as means and the pooled standard error of the means.

RESULTS

Gonadal regression

A summary of the morphological characteristic of the gonads of the experimental birds sacrificed at the end of the molt period is shown in Table 3. The ovary weight of the NC treatment was significantly greater than those of the C and CM treatments, whereas the means of the BR and RB treatments were not significantly different from that of the NC treatment. There was no significant difference in the ovary weight among the molt treatment groups. Similar observations were also found for the means of the oviduct weight. The oviduct length of the BR and RB treatments were comparable to that of the control treatment and were significantly greater than those of the C and CM treatments.

Performance and physiological stress during the molt period

The effects of molt diets on the BW, feed intake, egg production, mortality rate, heterophil:lymphocyte ratios and plasma cortisol concentrations during the molt period are presented in Table 4. At the end of the 14 d molt period, the CM hens had lost 21.9% of their original body weight, which was significantly greater than

Table 3 Effect of molt diets on gonadal characteristics of the experimental hens at the end of the molting period (age 99 wk).

Item	Treatment[1]					SEM[2]	*P*-value
	NC	BR	RB	C	CM		
Ovary weight (g)	48.6[a]	24.3[ab]	20.0[ab]	4.7[b]	1.3[b]	8.8	.008
Oviduct weight (g)	61.8[a]	34.6[ab]	24.8[ab]	16.4[b]	14.6[b]	7.4	.003
Oviduct length (cm)	68.5[a]	56.6[a]	52.6[a]	41.8[b]	37.6[b]	4.3	.022

[a,b] = Means within the same row without a common superscript are significantly different ($P < 0.05$).
[1]NC = non-molt control; BR = broken rice molt diet; RB = rice bran molt diet; C = corn mash molt diet; and CM = cassava mash molt diet.
[2]SEM = Pooled standard error of the mean (5 replicates of 1 sample each per treatment).

Table 4 Effects of molt diets on performance, egg production, mortality, heterophil:lymphocyte (H:L) ratios and plasma cortisol concentrations of the experimental hens during the molt period (97 to 99 wk of age).

Treatment[1]	Initial BW (kg)	BW loss (%)	FI (g per hen per day)	EP (%)		Mortality (%)	H:L	Cortisol (μg.dL^{-1})
				Wk 1	Wk 2			
NC	1.92	0.8[c]	130.7[a]	44.1[a]	45.0[a]	0.0	.57	0.13
BR	1.97	6.0[bc]	125.9[ab]	14.8[b]	3.7[b]	1.5	.67	0.19
RB	1.90	10.5[b]	107.4[b]	20.4[b]	2.6[b]	1.5	.49	0.11
C	1.95	9.3[bc]	107.8[b]	23.7[b]	8.7[b]	0.0	.65	0.14
CM	2.02	21.9[a]	70.2[c]	17.5[b]	0.0[b]	0.0	.39	0.05
SEM[2]	0.07	4.4	11.4	7.8	6.7	2.1	.17	0.06
P-value	.13	<.001	<.001	<.001	<.001	.57	.10	.05

[a,b,c] = Means within the same column without a common superscript are significantly different ($P < 0.05$); BW = Body weight; FI = Feed intake; EP = Egg production.
[1]NC = non-molt control; BR = broken rice molt diet; RB = rice bran molt diet; C = corn mash molt diet; and CM = cassava mash molt diet.
[2]SEM = pooled SEM (5 replicates of 12 hens each per treatment).

those of the other treatment groups. There were no significant differences in the means of body weight loss among the remaining molted groups. Hens in the RB group lost 10.5% of their initial body weight, which was significantly greater than those in the NC group. The BR hens lost only 6.0% body weight, which was not significantly different from those of the RB, C and NC birds. During the molt period, feed consumption of the CM hens (70.2 g per hen per day) was the lowest ($P < 0.05$) compared to those of the other treatments, whereas the BR hens maintained a comparable value to those of the NC, RB and C birds. Feed intakes of the RB and C hens were 107.4 and 107.8 g per hen per day, respectively, which were significantly lower than that of the NC hens. During the first week of the molt period, egg production rates of the BR, RB, C and CM hens were 14.8, 20.4, 23.7 and 17.5%, respectively, which were significantly lower than for the nonmolt control birds (44.1%). The CM hens exhibited more rapid reductions in egg production, reaching zero on day 7, and they completely stopped laying whereas none of the other molt treatment groups totally ceased egg production (Figure1). There were no significant differences in mortality rates, heterophil:lymphocyte ratios or plasma cortisol concentrations between treatments during the molt period. The mortality rate was low, ranging from 0 to 1.5% among the experimental bird groups.

Postmolt egg production and egg quality

Postmolt feed consumption, egg weight and feed conversion ratios are depicted in Table 5. There were no significant differences in egg weight among the treatment groups throughout the experimental period. During the first 2 wk of the postmolt period, the averages of feed intake of the birds in all molt treatment groups were significantly lower than that of the control treatment. For the molt treatment groups, the mean during the first 2 wk was lowest for hens that were fed the broken rice molt diet, which was significantly lower than those of the RB and CM treatments. Thereafter, there was no significant difference in feed intake among the molt treatment groups throughout the experimental period. During the next 2 wk, hens in the NC group had a comparable level of feed consumption to those in the molt treatment groups except for the CM treatment, in which the NC hens (115.4 g per hen per day) consumed less feed than did the CM birds (137.6 g per hen per

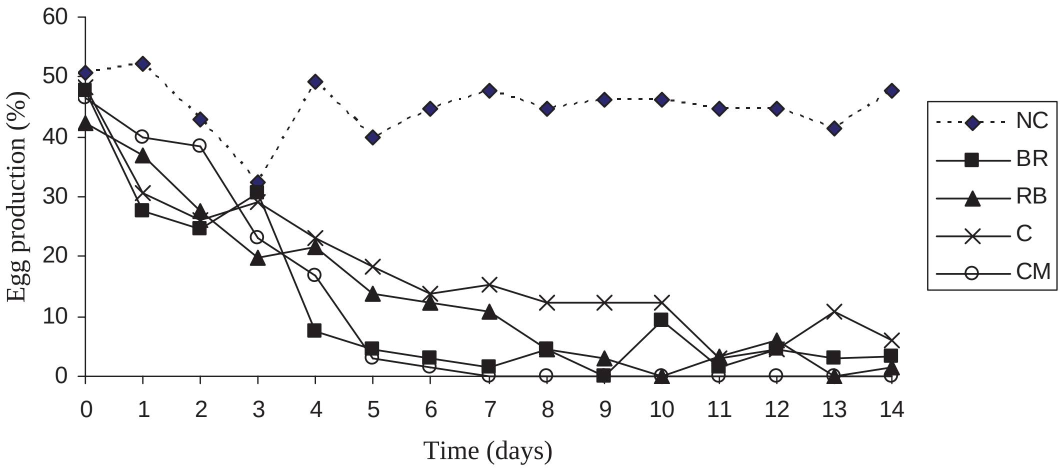

Figure 1 Daily hen-egg production during the molt period. NC = non-molt control; BR = broken rice molt diet; RB = rice bran molt diet; C = corn mash molt diet; and CM = cassava mash molt diet.

day) ($P < 0.05$). A similar observation was also found during weeks 8 to 10 of the postmolt period. During the first 2 wk, feed conversion ratios of the BR, RB and C treatments were similar to that of the NC group, which were significantly lower than that of the CM treatment. Thereafter, there were no significant differences in feed conversion ratios between treatments, except during weeks 6 to 8 when the means of all molt treatments were significantly lower than that of the control group.

Weekly hen-day egg production during the postmolt period is presented in Figure 2. During the first wk, the egg production rate of the control group was 49.0% which was significantly higher than those of the BR (8.9%), RB (2.7%), C (15.9%) and CM (0%) groups. During the second week postmolt, egg production rates of the BR, RB and C treatments increased rapidly up to 44.0, 29.6 and 38.2%, respectively, which were similar to that of the control group (48.3%). These were significantly higher than that of the CM treatment

Table 5 Egg weight, feed consumption and feed conversion ratios during the postmolt period.

Treatment[1]	Period during the postmolt period (wk)							
	0-2	2-4	4-6	6-8	8-10	10-12	14-16	18-20
	Egg weight (g)							
NC	67.6	71.6	72.6	69.3	70.7	69.0	72.0	72.8
BR	67.8	73.3	72.1	69.1	72.0	71.0	71.3	71.3
RB	67.8	73.2	71.9	70.6	69.4	70.7	70.9	70.6
C	66.4	73.0	72.1	69.0	71.7	71.3	70.7	71.4
CM	67.7	73.5	71.9	70.6	72.1	71.4	70.2	71.5
SEM[2]	2.2	2.4	2.9	2.5	2.2	2.2	2.3	2.9
P-value	.727	.755	.996	.725	.338	.473	.790	.842
	Feed intake (g per hen per day)							
NC	179.7^{a}	115.4^{b}	116.0	119.8	101.9^{b}	109.2	105.1	107.0
BR	100.6^{c}	121.4^{ab}	116.5	92.3	111.0^{ab}	117.8	115.5	120.2
RB	125.1^{b}	123.8^{ab}	122.1	94.9	118.7^{ab}	117.4	117.6	121.0
C	108.8^{bc}	125.9^{ab}	114.4	87.1	111.5^{ab}	112.6	107.6	118.0
CM	125.2^{b}	137.6^{a}	137.2	95.1	122.0^{a}	122.4	124.5	121.4
SEM[2]	7.8	9.1	17.2	18.8	8.6	9.8	13.9	9.2
P-value	<.001	.016	.249	.098	.014	0.283	0.221	.114
	Feed conversion ratio (kg feed per kilogram egg weight)							
NC	6.15^{b}	3.92	3.07	3.84^{a}	3.13	3.55	3.36	3.53
BR	5.80^{b}	3.12	2.60	2.47^{b}	2.87	2.61	2.88	2.66
RB	12.80^{b}	3.25	2.53	2.22^{b}	2.76	2.93	3.04	2.56
C	6.12^{b}	3.55	2.70	2.64^{b}	3.41	3.07	3.12	3.41
CM	30.1^{a}	3.61	2.79	2.26^{b}	2.89	2.80	2.94	2.90
SEM[2]	5.23	0.65	0.57	0.67	0.43	0.47	0.54	0.73
P-value	<.001	.358	.622	.006	.187	.053	.668	.181

[a,b,c] Means within the same column in each parameter without a common superscript are significantly different ($P < 0.05$).

[1]NC = non-molt control; BR = broken rice molt diet; RB = rice bran molt diet; C = corn mash molt diet; and CM = cassava mash molt diet.

[2]SEM = pooled SEM (5 replicates of 12 hens each per treatment).

(14.5%). A significant difference was recorded again at week 8, in which only hens in the CM treatment had a significantly higher level of the production rate than those of the control group (59.5 versus 42.3%).

Table 6 demonstrates the influence of the molt diets on egg and egg shell quality measured at weeks 2 and 8 of the postmolt period. At week 2, the albumen height expressed as Haugh units of the CM and BR treatments was significantly higher than that of the control group, whereas the means of the RB and C treatments were comparable to that of the control group. At week 8, the mean of the Haugh units of the CM treatment (90.8) was still significantly higher than that of the control group (78.0), whereas the mean of the BR treatment was similar to that of the control group. A significant difference in egg shell thickness was observed only at week 2 of the postmolt period, when the mean of the CM treatment was significantly lower than those of the NC and C treatments. The significant difference in yolk weight noticed among the experimental bird groups at week 2 was assumed to be because of variations of the experimental birds within treatments rather than due to an effect of the treatment. Hens in all molt treatment groups produced few eggs during that period as they had just returned to egg production. Obviously, the chalaziferous layer of eggs in the molt treatment groups was viscous and difficult to separate from the yolk. There were no significant differences in the yolk color and accumulation of egg production throughout the study between treatments (data not shown).

DISCUSSION

A shortage of replacement pullets during the past few years has caused many problems for egg producers throughout the country. The crisis resulted from the inability of hatcheries to produce chickens in the quantities required by farmers. The objective of the present study was to search for alternatives for farmers to extend the productive life of a flock of hens by molting the birds using a nonfasting method.

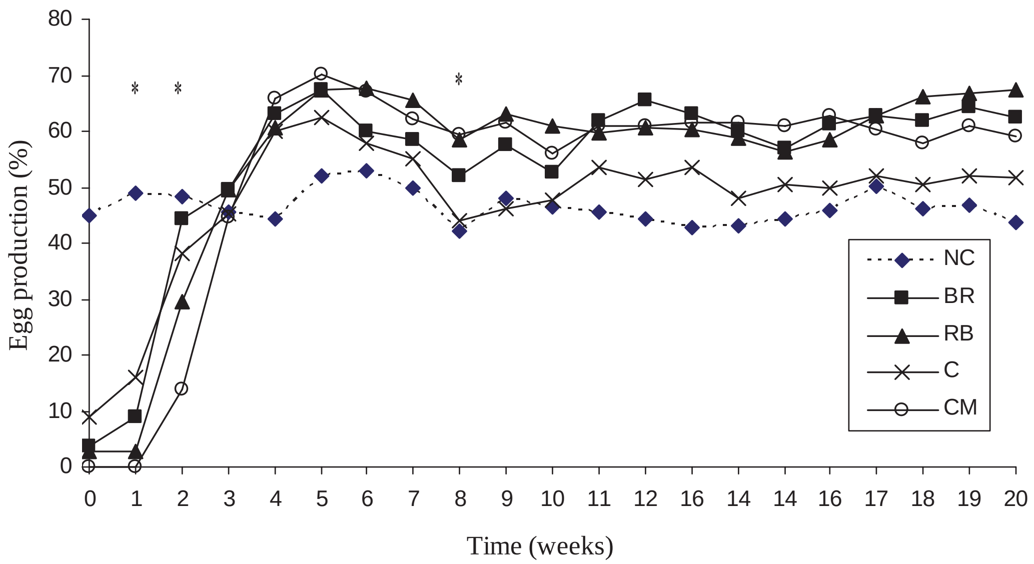

Figure 2 Weekly postmolt hen-day egg production during the 20 wk of the production period. NC = non-molt control; BR = broken rice molt diet; RB = rice bran molt diet; C = corn mash molt diet; and CM = cassava mash molt diet. * indicates statistical significance among groups ($P < 0.05$).

From the results of the present study, it is apparent that all molt diets used in this study resulted in decreased egg production and body weight during the molt period. Interestingly, the cassava mash molt diet (CM) was the most effective in causing egg production to rapidly decrease and completely cease by day 7 of the molt period. The broken rice (BR), rice bran (RB) and corn (C) diets also resulted in decreased egg production, but egg production did not cease completely. In addition, hens fed the CM diet had the lowest oviduct and ovary weights, suggesting effective ovarian regression for this treatment. The energy level of the diet is an important factor causing a rapid reduction in egg production (Biggs *et al*., 2004). Hens fed the CM diet had very low feed intakes during the molt period resulting in insufficient energy consumption for the requirements of their bodies. The low feed consumption could have been a result of reduced palatability as the CM diet is very bulky. Therefore, during the subsequent 6 wk of the postmolt period, the increased feed intake of this treatment was probably due to adjusting or compensating for the lower energy level and any palatability effects (Table 5).

During the postmolt period, the birds in the CM treatment returned to egg production at a slower rate than the BR, RB and C treatments. However, there were no significant differences in egg production among the molt treatment groups throughout the postmolt period. It is of interest to note that the peak of egg production for the CM treatment was higher than those of the other treatment groups, being approximately 70% of hen-day egg production at week 5 (Figure 2). In addition, at week 8, the average of egg production

Table 6 Effects of molt diets on egg and eggshell quality of the experimental hens at wk 2 and 8 of the postmolt period.

Treatment[1]	Yolk weight (%)	Albumen weight (%)	Haugh units	Shell weight (%)	Shell thickness (mm)
			Week 2		
NC	24.6[b]	67.6	76.4[b]	7.6	.271[a]
BR	25.9[ab]	66.5	88.5[a]	7.5	.255[ab]
RB	26.3[a]	66.2	82.2[ab]	7.3	.247[ab]
C	25.2[ab]	67.0	83.5[ab]	7.7	.269[a]
CM	25.8[ab]	67.4	89.2[a]	6.7	.233[b]
SEM[2]	0.8	1.1	5.5	0.5	.017
P-value	.036	.310	.011	.063	.013
			Week 8		
NC	23.1	68.3	78.0[b]	8.4	.276
BR	22.6	68.7	83.9[ab]	8.6	.288
RB	22.7	68.6	86.5[a]	8.5	.310
C	22.5	68.9	85.9[a]	8.5	.282
CM	22.6	68.8	90.8[a]	8.2	.273
SEM	0.8	0.9	3.8	0.4	.020
P-value	.820	.894	.001	.758	.066

[a,b] Means within the same column in each period without a common superscript are significantly different ($P < 0.05$).

[1]NC = non-molt control; BR = broken rice molt diet; RB = rice bran molt diet; C = corn mash molt diet; and CM = cassava mash molt diet.

[2]SEM = pooled SEM (5 replicates of 12 hens each per treatment).

of the CM treatment was significantly higher than that of the control group. During weeks 3 to 20, birds in all molt treatment groups consistently had higher percent hen-day egg production than the birds in the control group, although these differences were not statistically significant due to the variations within treatments. The improved feed conversion ratio for the molt treatment groups, as compared with the control group during weeks 6 to 8, is suggested to be due to a combination of consuming less feed and producing more eggs during those periods. Albumen height measured both at weeks 2 and 8 was also significantly greater for the CM treatment compared to those of the control group. The results were in agreement with those of some investigators (Hembree *et al*., 1980; Lee, 1982; Tona *et al*., 2002) who reported that albumen quality could be improved by induced molting in the subsequent laying cycle. From the present study, however, it was found that the means of egg shell quality were not significantly different among the experimental bird groups. In particular, at week 2, the average shell thickness of the CM treatment (0.23 mm) was significantly lower than that of the control group (0.27 mm) possibly due to the severe decrease in body weight and egg production during the molt period. It is possible that the birds were not able to replenish their lost body stores, and, consequently, they returned to egg production at a slower rate than hens on the other molt treatments. Many researchers have shown that the return to egg production with improved egg production and eggshell quality following a period of feed removal in the molt period requires time to replenish body stores (Harms, 1983; Andrews *et al*., 1987; Koelkebeck *et al*., 1999). The period during and following refeeding when egg production is essentially zero is referred to as the rest period (Berry, 2003). From the present study, the birds in the CM treatment had a rest period of only 7 d. Hurwitz *et al*. (1995) reported that the eggshell quality could be improved when the birds had rest periods of at least 14 to 21 d.

CONCLUSION

The results indicated that feeding the cassava molt diet was an effective nonfeed removal method for induced molting laying hens with advantages of improved albumen quality and least economic cost. Nonetheless, further experimentation is suggested to enhance the efficiency of the molting technique for improvement of egg production and egg shell quality during the subsequent laying cycle.

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