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Investigation of ME Level of Molt Diet for Full Fed Induced Molting in Laying Hens

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This study investigated the suitable metabolizable energy (ME) level of molt diet for hens that cease producing eggs without being subjected to great stress. During the preliminary period, White Leghorn hens were fed a corn-soybean meal-based layer ration *ad libitum*. After a 4-wk preliminary period, the hens were randomly divided into 3 treatment groups and 1 control group; the control group was persistently fed the layer ration. The 3 treatment groups were fed the following diets *ad libitum* for 4 wk: (1) 100% molt diet based on corn, wheat bran, and corn gluten feed (ME 2.3 Mcal/kg M100:); (2) 85% molt diet with 15% rice hull (ME 1.9 Mcal/kg M85:); and (3) 70% molt diet with 30% rice hull (ME 1.6 Mcal/kg M70:). During the post-molt period, the hens were returned to the layer ration. During the molting period, the heterophil: lymphocyte (H:L) ratio, ovary and oviduct weights, and ME_n intake were measured. Egg production, egg weight, egg quality, body weight, and feed intake were measured throughout the experiment. During the molting period, the feed intake, body weight, and ovary and oviduct weights in the molted groups were significantly ($P < 0.01$) lower than those in the control group. In the M70 group, egg production ceased completely within 9 d; and decreased to 4.2% by day 10 and 9 in the M100 and M85 groups, respectively. The H:L ratio was the highest, intermediate, and least in the M70, M100 and M85, and control groups, respectively. At 1, 2 and 4 wk, the ME_n intake in the M70 group was lower than the requirement level. Throughout the post-molt period, the egg production and quality in the molted groups improved compared to that in the control. We assume that *ad libitum* access to low energy molt diet (ME 1.6 Mcal/kg) effectively induces molting and increases post-molt production.

Key words: energy level, induced molting, molt diet, post-molt performance

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Introduction

Induced molting has become an important management tool used by the layer industry to increase egg production rates in older hens and to increase egg size, decrease egg breakage, and improve shell quality (Seo *et al.,* 2001). Several programs are currently in use for successfully molting laying hens. Feed withdrawal is the primary method used in the layer industry to induce molting and stimulate multiple egg-laying cycles in hens (Brake, 1993; Holt, 1995). In recent years, concern for the well-being of hens during the molting period has been expressed when the feed withdrawal method is employed. Holt (1993) reported that birds that are molted using feed withdrawal may be more susceptible to *Salmonella* infection because molting induced by feed withdrawal depresses the cellular immune response. UEP (United Egg Producers, 2002) urges producers and researchers to work together to develop alternatives to feed withdrawal for inducing molting (Bell, 2003). Since January 1, 2006, all the egg producers that enrolled in the UEP animal care program (most US shell egg producers) have discontinued the use of feed withdrawal method for inducing molting (Wu *et al.,* 2007).

We have already reported that *ad libitum* feeding of the commercial molt diet that was used in our previous experiment did not completely stop egg production during the molting period (Hnin Yi Soe *et al.,* 2007a). The energy level of the diet appears to be an important factor in causing a rapid reduction in egg production (Biggs *et al.,* 2004). Based on the results of our experiment, we considered the level of energy intake to be the primary factor responsible for causing only the partial cessation of egg production during the molt-inducing period; therefore, we conducted another experiment to determine the effects of the restricted feeding of the commercial molt diet on molt induction. The restricted feeding of the commercial molt diet (60 g/d per hen) may cause the complete cessation of egg production during the molting period (Hnin Yi Soe *et al.,* 2007b). However, the feasibility of this practice for rearing of commercial flocks is questionable due to the

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following factors: the use of automatic feeding systems, capacities of poultry houses for the accommodation of large flocks, and the existence of multiple hen cages with hens occupying different ranks in the social hierarchy within a cage.

Therefore, the commercial molt diet (2.3 Mcal/kg) was mixed with 15% or 30% of rice hull to reduce the ME level of the molt diet (1.9 Mcal/kg or 1.6 Mcal/kg) for the complete arrest of egg production during the molting period by *ad libitum* feeding of the molt diet. The objective of the present study was to investigate the suitable ME level of molt diet for hen that cease producing eggs during the molt-inducing period without being subjected to great stress.

Materials and Methods

A commercial flock of 100 single comb White Leghorn hens of the Julia strain (aged between 60 to 74 wk) were used in this experiment. It was conducted from September to December 2006. The hens were given 4 wk for adaptation (preliminary period). During this time, the lighting program employed was 15 h light: 9 h darkness, and the hens were fed a conventional layer ration based on corn and soybean meal (crude protein (CP) 17.3% and ME 2.85 Mcal/kg) *ad libitum* and allowed complete access to water. Except during the molt-inducing period, this diet was fed until the end of the experiment. During this time, egg production was monitored to ensure that all the hens were healthy and actively producing eggs. The experimental period consisted of a 4-wk molt period followed by a 6-wk post-molt production period. Following complete adaptation, the hens were divided into 4 groups (3 treatment groups and 1 control group) that exhibited minimal variation in the rate of egg production. Treatments were randomly assigned to the cages throughout the entire house to eliminate variability in egg production or reproductive tract regression due to light stimulation. During the molt-inducing period, the control group was persistently fed the layer ration *ad libitum.* The others (the 3 treatment groups) were induced to molt by employing specific diets. In this experiment, low-protein, low-energy diet (commercial molt diet) (CP 13.7% and ME 2.27 Mcal/kg) based on rice bran and corn gluten feed was used to induce molting. It was mixed with 15% or 30% rice hull to reduce the ME level (1.9 Mcal/kg or 1.6 Mcal/kg). The 3 treatment groups were fed the following diets: (1) 100% molt diet (M100), (2) 85% molt diet with 15% rice hull (M85), and (3) 70% molt diet with 30% rice hull (M70) *ad libitum* for 4 wk. The light period was reduced to 12 h of light per day. During the post-molt production period, all the hens were returned to the conventional layer ration, and the photoperiod was gradually increased by 1 h of light per week until a photoperiod of 15 h light/9 h darkness was achieved. The ingredients and compositions of the experimental diets are shown in Table 1.

During the adaptation and experimental periods, egg production, shell breakages, egg weight, and mortality rate were recorded daily; feed intake and individual body weight were recorded weekly. The specific gravity of eggs was measured weekly using the flotation method with NaCl solutions varying from 1.065 g/cm^3 to 1.100 g/cm^3 in 0.005 increments. Eggs from 4 replicates per group were used to measure the specific gravity. During the molt-inducing period, the number of hens that started molting was recorded daily. At weeks 1 and 3, blood samples were taken from 5 hens per group to determine the heterophil: lymphocyte (H:L) ratio by using the methods described by McKee and Harrison (1995). At weeks 2 and 4, four hens per group were decapitated, and the ovary and oviduct of each hen were weighed. During the molt-inducing period, the nitrogen-corrected metabolizable energy (ME_n) intake, i.e., the ME determined from gross energy intake and energy output as measured from the excreta and corrected for the amount of nitrogen retained, was measured weekly in 4 replicates for each group. The correction factor used was 8.22 kcal/g nitrogen (Scott *et al.,* 1982). The ME_n intake was measured by using a total collection procedure for 2 successive days. The gross energy of the feed and in the excreta was determined using a bomb calorimeter (CA-4PJ; Shimadzu Co., Kyoto, Japan) with benzoic acid as a standard; the nitrogen content of the feed and in the excreta was measured (Association of Official Analytical Chemists, 1980) for the determination of the amount of nitrogen retained.

All statistical analyses were subjected to analysis of variance (ANOVA) using the JMP software (version 5.0.1). When differences in treatment means were detected by ANOVA, Tukey's HSD test was applied to separate the means (SAS Institute Inc., 2002).

Results

Except during the molt-inducing period, the feed intake (Table 2) and body weight (Table 3) among all the groups did not significantly differ ($P>0.05$). The feed intake during the 28-d molt-inducing period varied greatly among the treatment groups. The hens of the M70 group consumed much less feed during the first week than the hens of the M100 or M85 group, but the converse was observed for the next 3 wk. When feed intake was summarized for the entire 4-wk molt-inducing period, it was observed to be higher in the M70 group than in the M100 or M85 group. The post-molt feed intake did not differ ($P>0.05$) among the treatment groups. During the molt-inducing period, the body weights in the molted groups were significantly ($P<0.01$) reduced compared to those in the control group. At week 3, the maximum body-weight losses recorded were 18.5%, 19.4% and 21.8% in the M 100, M85 and M70 groups, respectively. After the molt-inducing period, the hens of the molted groups regained all the body weight that they had previously lost, as shown in Table 3.

As presented in Fig. 1, all the hens in the M100, M85, and M70 groups started molting on 21, 18 and 17 d of the experimental period, respectively. At week 2, the weights

Table 1. Ingredient and composition of experimental diets

Ingredient and content	Layer ration	Molt diets		
		M100[1)]	M85[2)]	M70[3)]
		(%)		
Corn	60.600	34.500	29.320	24.139
Defatted rice bran	2.000	10.000	8.498	6.997
Wheat bran	—	30.000	25.496	20.991
Corn gluten feed	—	20.000	16.997	13.994
Soybean meal	14.300	—	—	—
Rapeseed meal	3.000	—	—	—
Gluten meal	4.000	—	—	—
Fish meal	3.000	—	—	—
Animal fat	2.500	—	—	—
Rice hull	—	—	15.000	30.000
Calcium carbonate	9.205	4.700	3.994	3.289
Dicalcium phosphate	0.800	0.660	0.561	0.462
Salt	0.300	—	—	—
DL-methionine	0.055	—	—	—
Choline chloride	0.040	0.040	0.034	0.028
Paprika	0.100	—	—	—
Vitamin-mineral premix[4)]	0.100	0.100	0.100	0.100
Calculated content (%)				
CP	17.3	13.7	11.6	9.6
ME (Mcal/kg)	2.85	2.27	1.93	1.59
Ca	4.02	2.11	1.79	1.48
Av.P	0.36	0.40	0.34	0.28
Na	0.15	0.04	0.03	0.03

[1)] M100: 100% molt diet.
[2)] M85: 85% molt diet+15% rice hull.
[3)] M70: 70% molt diet+30% rice hull.
[4)] Provided per kilogram of diet: vitamin A, 8000 IU; vitamin D_3, 1600 IU; vitamin E, 5 IU; vitamin K_3, 1 mg; vitamin B_1, 0.7 mg; vitamin B_2, 2.5 mg; vitamin B_6, 2.5 mg; niacin, 10 mg; pantothenic acid, 2 mg; folic acid, 0.25 mg; vitamin B_{12}, 0.003 mg; biotin, 0.1 mg; manganese, 50 mg; zinc, 50 mg; copper, 5 mg; and iodine, 0.2 mg.

of the ovary and oviduct in the M100 (34.5 g, 2.6% of the body weight), M85 (19.1 g, 1.5% of the body weight), and M70 (16.5 g, 1.3% of the body weight) groups were significantly ($P<0.01$) lesser than those in the control group (115.0 g, 7.4% of the body weight) as indicated in Table 4. At week 1 of the molt-inducing period, the H:L ratios in the molted groups were significantly ($P<0.01$) higher than that in the control group; the H:L ratio was the highest in the M70 group, intermediate in the M100 and M85 groups, and least in the control group, as shown in Table 5. Additionally, the ME_n intake in the molted groups was significantly ($P<0.01$) lower than that in the control group (Table 6); the lowest energy intake among the molted groups was observed in the M70 group.

In this experiment, we assessed the daily and weekly rates of egg production, excluding the incidence of egg breakage (broken, cracked, soft, and shell-less eggs). The decrease in daily hen-day egg production during the 28-d molt-inducing period is shown in Fig. 2, and the increase in daily hen-day egg production during the post-molt production period is shown in Fig. 3. The weekly rates of egg production are presented in Table 7. In the M70 group, egg production ceased completely by day 9 and resumed 40 d after molt induction. The egg production in the M100 and M85 groups reached 4.2% at days 10 and 9, respectively. The M100, M85, and M70 groups achieved 50% egg production at days 42, 41 and 45, respectively. At week 7, egg production did not differ significantly ($P>0.05$) among the groups. At weeks 9 and 10, the egg production in the molted groups was significantly ($P<0.01$) higher than that in the control group. There were no significant differences ($P>0.05$) in the weights of the eggs among the treatment groups during weeks 8 to 10, as shown in Table 8. The specific gravity of the eggs was not significantly ($P>0.05$) different among the groups (weeks 0 to 7); but it was improved in the molted groups than in the control group during the post-molt period (weeks 8 to 10), as shown in Table 9.

Discussion

Poultry require energy for growth, maintenance of body tissue, production of eggs, regulation of body temperature, and daily activity. Under normal environmental conditions, when the ME content of the diet is considerably less

Table 2. Effect of induced molting on feed intake of laying hens

Periods		Control	M100[1)]	M85[2)]	M70[3)]	*P*
	(wk)	(g/hen/d)				
Pre-molt	0	112.7± 2.1[4)]	108.9± 4.3	109.9± 5.9	109.8± 2.5	NS
Molting	1	104.7±10.0[a]	65.9± 6.3[b]	60.9± 3.5[b]	58.0± 6.7[b]	**
	2	96.2±14.2[a]	65.8± 7.6[b]	69.2± 1.1[b]	72.1± 6.1[b]	**
	3	103.5±10.0[a]	73.1±11.5[b]	76.1± 5.4[b]	83.2± 7.5[b]	**
	4	108.5± 6.9[a]	73.8± 8.1[c]	82.0± 1.4[bc]	87.2± 2.3[b]	**
Post-molt	5	114.0± 7.1	119.4± 0.1	119.7± 0.1	119.5± 0.2	NS
	6	119.0± 0.8	119.5± 0.6	119.8± 0.1	119.7± 0.2	NS
	7	118.9± 1.5	119.8± 0.1	119.8± 0.2	119.2± 1.1	NS
	8	118.9± 1.5	119.8± 0.1	119.9± 0.1	119.3± 0.9	NS
	9	117.0± 3.3	119.8± 0.1	119.5± 0.5	119.0± 1.8	NS
	10	118.4± 2.2	119.1± 0.9	119.2± 1.3	118.3± 1.7	NS

1) M100: molting with 100% molt diet (0–4 wk).
2) M85: molting with 85% molt diet+rice hull (0–4 wk).
3) M70: molting with 70% molt diet+rice hull (0–4 wk).
4) Data are presented as the mean±SD of 4 replicates per treatment.
** $P<0.01$, NS: not significant.
abc Means within a row followed by a common superscript are not significantly different.

Table 3. Effect of induced molting on body weight of laying hens

Periods		Control	M100[1)]	M85[2)]	M70[3)]	*P*
	(wk)	(g)				
Pre-molt	0	1617± 55[4)]	1615±54	1606±59	1560±78	NS
Molting	1	1590± 81[a]	1379±52[b]	1374±53[b]	1321±57[b]	**
	2	1537± 94[a]	1342±61[b]	1335±56[b]	1275±60[b]	**
	3	1545±120[a]	1317±61[b]	1294±46[b]	1220±60[b]	**
	4	1571± 99[a]	1346±87[b]	1320±67[b]	1258±57[b]	**
Post-molt	5	1588± 79	1561±82	1530±64	1442±49	NS
	6	1612± 62	1624±62	1626±35	1580±54	NS
	7	1619± 57	1614±56	1611±51	1577±84	NS
	8	1624± 39	1619±60	1626±30	1587±77	NS
	9	1618± 59	1619±48	1646±51	1583±80	NS
	10	1640± 46	1652±44	1649±43	1615±77	NS

1) M100: molting with 100% molt diet (0–4 wk).
2) M85: molting with 85% molt diet+rice hull (0–4 wk).
3) M70: molting with 70% molt diet+rice hull (0–4 wk).
4) Data are presented as the mean±SD of 4 replicates per treatment.
** $P<0.01$, NS: not significant.
ab Means within a row followed by a common superscript are not significantly different.

than 2500 kcal/kg, poultry may not consume a diet providing adequate energy to meet their requirements, because of the diet's bulkiness and the physical limitations of the gastrointestinal tract with respect to the amount of feed that it can accommodate (Richard, 1995). Corn gluten feed, bran and rice hulls are economical and readily available ingredients. In this experiment, all the molt diets resulted in decreased egg production and body weight during the molt-inducing period. In addition, the feed intake in the treatment groups was lower than that in the control group (Table 2). Nevertheless, these results clearly confirmed that the molt diet was accepted by the egg-laying hens. During the molt-inducing period, the feed intake in the M70 group was higher than that in the M100 or M85 group, as shown in Table 2. The result of the present study was in agreement with the report of Richard (1995), who established that feed intake was inversely related to the ME concentration of the feed. The low feed consumption during the first week could be a result of reduced palatability or the change in energy level of the diet. The increased in feed consumption during the subsequent week was probably due to adaptation to the feed or compensation for the lower energy levels and any palatability effects.

The physiological responses (weight loss in hens, feather molting, and complete cessation of egg laying) that occur during traditional molting are used as the indicators of molt effectiveness. These responses are considered as the important factors that improve post-molt egg production (Brake and Thaxton, 1979). However, the regression of the ovary is the most important factor responsible for molt induction because the loss of reproductive organ weight is linked to the overall rejuvenation process (Brake and Thaxton, 1979; Brake, 1993). Therefore, in the present study, ovarian weight was measured as an indicator of molting. As shown in Table 4, the large individual variation was observed in the hens of the M100 and M85 groups at wk 2 and wk 4, respectively, but the large individual variation was not observed in the hens of the M70 group. We suggest that it may be due to the effects of the large individual variation of the nutrient sufficiency.

The ME values of the experimental diets were calculated based on the quantities of feed intake and energy intake of each hen. Those were measured weekly during the molt-inducing period by using a total collection procedure for 2 successive days. The ME value of the layer ration was 2.93±0.02 Mcal/kg; the ME values of the molt diet of the M100, M85, and M70 groups were 2.37±0.11, 2.05 ±0.09 and 1.69±0.06 Mcal/kg, respectively. These values were nearly the same as the calculated ME values (Table 1) of the layer ration (2.85 Mcal/kg) and the molt diet of the M100, M85, and M70 groups (2.27, 1.93 and 1.59 Mcal/kg, respectively). The ME requirement (National Agriculture and Bio-oriented Research Organization, 2004) for all the groups was also calculated. Table 10

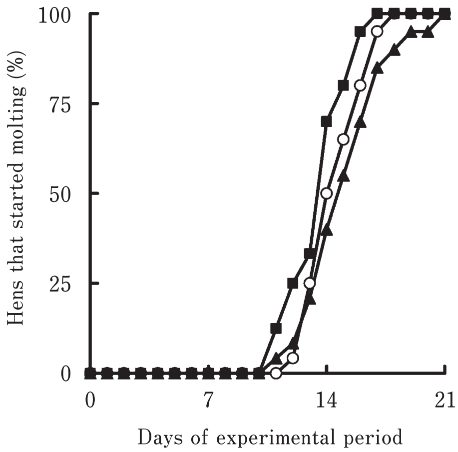

Fig. 1. The percentage of hens that started molting during the molt-inducing period of the hens of molting with 100% molt diet (M100 group: ▲), the hens of molting with 85% molt diet+rice hull (M85 group: ○), and the hens of molting with 70% molt diet+rice hull (M70 group: ■).

Table 4. Effect of induced molting on ovary and oviduct weight of laying hens

Periods	Control	M100[1)]	M85[2)]	M70[3)]	*P*
(wk)	(g)				
0	117.6 ±10.8[4)]	—	—	—	—
2	115.0 ±11.1^{a}	34.5 ±28.8^{b}	19.1 ± 4.5^{b}	16.5 ± 2.4^{b}	**
4	114.3 ± 7.8^{a}	12.6 ±10.0^{b}	31.0 ±39.5^{b}	7.4 ± 1.2^{b}	**
(wk)	% (live weight)				
0	7.49± 0.65	—	—	—	—
2	7.43± 0.62^{a}	2.61± 2.01^{b}	1.51± 0.31^{b}	1.33± 0.15^{b}	**
4	7.22± 0.85^{a}	1.01± 0.79^{b}	2.49± 3.03^{b}	0.68± 0.07^{b}	**

[1)] M100: molting with 100% molt diet (0–4 wk).
[2)] M85: molting with 85% molt diet+rice hull (0–4 wk).
[3)] M70: molting with 70% molt diet+rice hull (0–4 wk).
[4)] Data are presented as the mean±SD of 4 hens per treatment.
** $P<0.01$.
[ab] Means within a row followed by a common superscript are not significantly different.

Table 5. Effect of induced molting on heterophil: lymphocyte ratio (H:L ratio)

Periods	Control	M100[1)]	M85[2)]	M70[3)]	*P*
(wk)	(H:L ratio)				
1	12.2±0.6^{c}[4)]	29.6±3.6^{b}	29.3±11.1^{b}	42.7±6.3^{a}	**
3	12.7±1.5^{b}	19.9±4.9^{ab}	18.6± 5.0^{ab}	24.7±5.4^{a}	**

[1)] M100: molting with 100% molt diet (0–4 wk).
[2)] M85: molting with 85% molt diet+rice hull (0–4 wk).
[3)] M70: molting with 70% molt diet+rice hull (0–4 wk).
[4)] Data are presented as the mean±SD of 5 hens per treatment.
** $P<0.01$.
[abc] Means within a row followed by a common superscript are not significantly different.

Table 6. Effect of induced molting on ME_n intake of laying hens

Periods	Control	M100[1)]	M85[2)]	M70[3)]	*P*
(wk)		(kcal/hen/day)			
1	293.5±25.9[a4)]	147.1±12.1[b]	115.0± 8.8[bc]	100.9± 8.7[c]	**
2	261.7±37.5[a]	159.2±19.3[b]	139.5± 6.0[b]	114.2±10.6[b]	**
3	288.5±27.6[a]	169.1±12.9[b]	153.2±10.7[b]	140.3± 9.5[b]	**
4	299.1±26.3[a]	165.9± 4.9[b]	158.2± 7.3[b]	143.8±10.2[b]	**
(wk)		(kcal/kg$^{0.75}$/day)			
1	204.0±14.2[a]	110.3± 8.7[b]	86.3± 7.9[c]	79.1± 5.6[c]	**
2	188.0±19.1[a]	126.3±12.0[b]	111.2± 6.3[bc]	94.0± 8.3[c]	**
3	208.3±10.4[a]	136.3± 9.6[b]	123.7± 9.0[b]	118.3± 7.6[b]	**
4	212.2±17.5[a]	136.9± 1.9[b]	132.8± 7.2[b]	126.7±10.0[b]	**

[1)] M100: molting with 100% molt diet (0–4 wk).
[2)] M85: molting with 85% molt diet+rice hull (0–4 wk).
[3)] M70: molting with 70% molt diet+rice hull (0–4 wk).
[4)] Data are presented as the mean±SD of 4 replicates per treatment.
** $P<0.01$.
[abc] Means within a row followed by a common superscript are not significantly different.

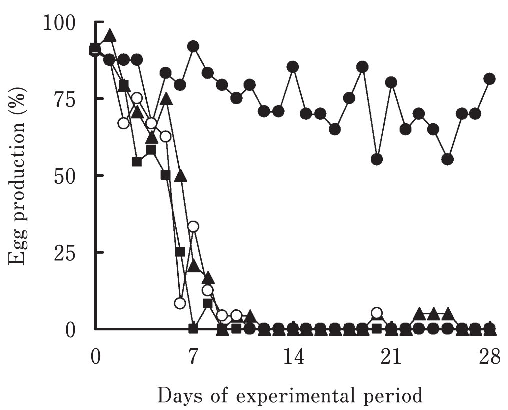

Fig. 2. Daily egg production (excluding egg breakage (broken, cracked, soft and shell-less eggs)) during the molt-inducing period of the hens of control group (●), the hens of molting with 100% molt diet (M100 group: ▲), the hens of molting with 85% molt diet+rice hull (M85 group: ○), and the hens of molting with 70% molt diet+rice hull (M70 group: ■).

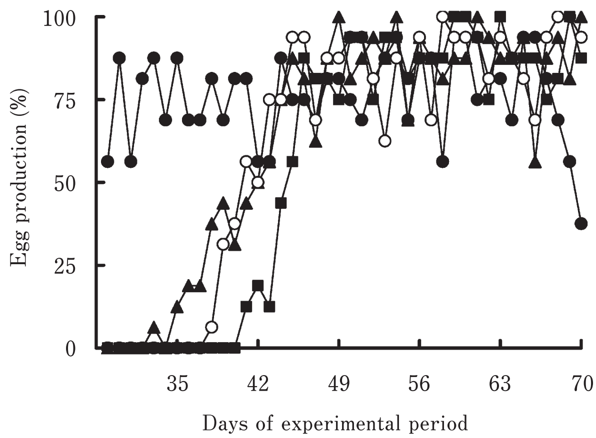

Fig. 3. Daily egg production (excluding egg breakage (broken, cracked, soft and shell-less eggs)) during the post-molt period of the hens of control group (●), the hens of molting with 100% molt diet (M100 group: ▲), the hens of molting with 85% molt diet+rice hull (M85 group: ○), and the hens of molting with 70% molt diet+rice hull (M70 group: ■).

shows the ME requirement, ME intake, and sufficiency rate of all the groups during the molting period. The ME intake of the M70 group was 76∼116 kcal/d/kg of the body weight. The result of our experiment was in agreement with the report of Kosaka (1993), who stated that for the maintenance of the physiological functions, a hen being fed under normal condition requires an ME of 115 kcal/d/kg of the body weight. At weeks 1 and 2, the ME intake was relatively lower than the ME requirement for the M70 group; hence, the M70 group showed complete cessation of egg production by day 9 of the experimental period.

In general, the percentage of lymphocytes decreased and the percentage of heterophils increased as a result of exposure to stressors. The H:L ratios of the molted groups were found to be higher than those of the control group. Similar results were reported by Wolford and Ringer (1962), Alodan and Mashaly (1999), Davis *et al.* (2000), Webster (2003), and Hnin Yi Soe *et al.* (2007a, b); in these studies, the H:L ratios were increased during induced molting.

The specific gravity of the eggs in the molted groups was higher than the industry standard of 1.080 g/cm^3 throughout the post-molt period. These results indicate that hens can be successfully molted by *ad libitum* feeding of the molt diet (1.6 Mcal/kg) without substantially reduced eggshell quality.

In this experiment, the weekly egg production of the

Table 7. Effect of induced molting on egg production[1)] of laying hens

Periods		Control	M100[2)]	M85[3)]	M70[4)]	*P*
	(wk)	(%)				
Pre-molt	0	89.9± 2.7[5)]	91.4±3.3	90.9± 1.4	91.4± 2.6	NS
Molting	1	83.3± 5.8[a]	64.9±6.2[b]	57.1± 6.4[bc]	50.6± 6.9[c]	**
	2	77.0± 8.8[a]	3.6±5.5[b]	3.0± 3.5[b]	1.2± 1.8[b]	**
	3	71.4±13.6[a]	0.7±1.6[b]	0.7± 1.6[b]	0.0± 0.0[b]	**
	4	67.5±13.7[a]	2.1±3.2[b]	0.0± 0.0[b]	0.0± 0.0[b]	**
Post-molt	5	75.0±14.6[a]	2.7±3.4[b]	0.0± 0.0[b]	0.0± 0.0[b]	**
	6	72.3±12.5[a]	34.8±9.4[b]	25.9±12.8[bc]	4.5± 3.4[c]	**
	7	75.0±12.7	78.6±4.1	83.0± 5.4	62.5±15.0	NS
	8	80.4±10.3	87.5±6.2	84.8± 3.4	88.4± 9.4	NS
	9	81.2± 4.5[b]	89.3±2.9[a]	89.3± 2.9[a]	92.0± 4.5[a]	**
	10	71.4± 7.7[b]	85.7±6.5[a]	89.3± 2.9[a]	86.6± 7.4[a]	**

1) Excluding egg breakage (broken, cracked, soft and shell-less eggs).
2) M100: molting with 100% molt diet (0–4 wk).
3) M85: molting with 85% molt diet+rice hull (0–4 wk).
4) M70: molting with 70% molt diet+rice hull (0–4 wk).
5) Data are presented as the mean±SD.
** $P<0.01$, NS: not significant.
abc Means within a row followed by a common superscript are not significantly different.

Table 8. Effect of induced molting on egg weight of laying hens

Periods		Control	M100[1)]	M85[2)]	M70[3)]	*P*
	(wk)	(g)				
Pre-molt	0	68.1±1.8[4)]	66.8±3.4	65.9±2.0	64.8±1.9	NS
Molting	1	67.6±2.2[a]	64.1±2.4[ab]	63.6±1.7[b]	63.2±1.5[b]	*
	2	67.6±1.6	61.0±2.9	61.8±4.8	61.1±6.2	NS
	3	67.0±0.6	—	—	—	—
	4	67.3±2.2	60.1±4.9	—	—	—
Post-molt	5	69.9±2.8	68.8±9.2	—	—	NS
	6	69.8±2.8[a]	64.9±5.1[ab]	62.4±1.5[b]	61.8±2.3[b]	*
	7	69.9±1.8[a]	67.0±3.2[ab]	65.8±1.9[ab]	63.3±2.4[b]	*
	8	68.6±1.5	67.4±3.2	66.9±3.0	66.7±3.2	NS
	9	69.8±0.9	66.8±2.9	66.4±2.5	66.1±2.6	NS
	10	69.5±1.9	67.6±3.2	66.5±2.8	65.6±3.2	NS

1) M100: molting with 100% molt diet (0–4 wk).
2) M85: molting with 85% molt diet+rice hull (0–4 wk).
3) M70: molting with 70% molt diet+rice hull (0–4 wk).
4) Data are presented as the mean±SD.
* $P<0.05$, NS: not significant.
ab Means within a row followed by a common superscript are not significantly different.

M100 group did not show complete cessation during the molt-inducing period; this result was in agreement with that of our previous experiment (Hnin Yi Soe *et al.,* 2007 a). In addition, most of the hens in the M85 group stopped laying eggs; but few of the hens laid eggs intermittently during the molt-inducing period. We have considered that the individual variation in the high feed intake may be the primary reason for the partial cessation of egg production. The initial low feed intake may be the primary reason for the complete cessation of egg production in the M70 group. These results suggest that feeding low-energy (1.6 Mcal/kg) diet may be a particularly preferable alternative to feed withdrawal in induced molting programs. However, due to the continuous decreases in body weight and egg production during the 4-wk molt-inducing period, the hens of the M70 group were unable to replenish their lost body reserves, and consequently, they resumed egg production later than the hens in the other treatment groups. In this experiment, the resting period in the M70 group was 31 d; it was longer than that in our previous experiments in which molting was induced by starvation (20 d or 25 d). In this experiment, the molt-inducing period lasted for 4 wk; in our previous experiment, the starvation period lasted for 2 wk. We only

Table 9. Effect of induced molting on egg specific gravity of laying hens

Periods		Control	M100[1)]	M85[2)]	M70[3)]	*P*
	(wk)	(g)				
Pre-molt	0	1.084±0.003[4)]	1.084±0.003	1.084±0.003	1.083±0.003	NS
Molting	1	1.083±0.005	1.078±0.003	1.078±0.002	—[5)]	NS
	2	1.083±0.004	—[5)]	—[5)]	—[5)]	—
	3	1.084±0.004	—[5)]	—[5)]	—	—
	4	1.088±0.003	—[5)]	—	—	—
Post-molt	5	1.084±0.004	1.090±0.007	—	—	NS
	6	1.085±0.004	1.090±0.002	1.089±0.002	1.093±0.008	NS
	7	1.087±0.004	1.090±0.002	1.091±0.002	1.090±0.002	NS
	8	1.086±0.003[b]	1.093±0.003[a]	1.095±0.003[a]	1.091±0.002[ab]	**
	9	1.082±0.003[b]	1.092±0.002[a]	1.093±0.002[a]	1.093±0.003[a]	**
	10	1.079±0.006[b]	1.093±0.003[a]	1.091±0.003[a]	1.087±0.004[ab]	*

[1)] M100: molting with 100% molt diet (0–4 wk).
[2)] M85: molting with 85% molt diet+rice hull (0–4 wk).
[3)] M70: molting with 70% molt diet+rice hull (0–4 wk).
[4)] Data are presented as the mean±SD of 4 replicates per treatment.
[5)] Egg production was zero at the day of egg specific gravity measured.
** $P<0.01$, * $P<0.05$, NS: not significant.
[ab] Means within a row followed by a common superscript are not significantly different.

Table 10. ME requirement[1)], intake[2)] and sufficiency rate[3)] of laying hens during molting period

Periods	Control	M100[1)]	M85[2)]	M70[3)]	*P*
(wk)	ME requirement (kcal/hen/day)				
1	271.5±27.8[a7)]	191.2±12.2[b]	174.1±11.1[b]	177.9± 4.9[b]	**
2	264.8±26.2[a]	139.5±10.4[b]	136.9± 4.4[b]	126.8± 7.9[b]	**
3	270.5±28.4[a]	137.3±12.9[b]	121.9± 3.3[b]	117.2± 6.2[b]	**
4	265.5±35.5[a]	182.1±25.8[b]	180.4±13.4[b]	184.7± 5.5[b]	**
(wk)	ME intake (kcal/hen/day)				
1	305.6±27.0[a]	150.7±12.5[b]	116.3± 8.9[c]	100.3± 8.6[c]	**
2	272.1±38.8[a]	163.0±20.6[b]	141.1± 6.9[b]	115.6±11.0[b]	**
3	299.5±28.2[a]	173.7±13.4[b]	156.2±11.2[b]	142.0±10.0[b]	**
4	310.6±26.9[a]	170.0± 4.4[b]	161.7± 7.2[b]	146.1±10.8[b]	**
(wk)	Sufficiency Rate (%)				
1	112.8± 5.8[a]	97.1± 8.9[b]	67.1± 8.2[bc]	56.5± 6.1[c]	**
2	102.8± 9.9[a]	116.7± 9.6[ab]	103.2± 6.3[ab]	91.1± 6.2[b]	**
3	111.1± 7.4[b]	126.9±10.6[ab]	128.0± 6.8[a]	121.2± 4.5[ab]	*
4	117.8± 8.9[a]	94.6±11.5[b]	89.9± 5.8[b]	79.1± 5.9[b]	**

[1)] $$110\times\frac{(-0.081\times(22-T)^2+2\times(22-T)+94)}{94}\times W^{0.75}+2.2\times \text{E mass}+2\times\Delta W$$

T: Temperature inside the hen house (℃).
W: Body weight in kilograms.
E mass: Egg mass (average daily egg production in grams).
ΔW: The change in body weight in grams per day.
[2)] Calculated from gross energy of feed and feces from 4 replicates per treatment.
[3)] ME Intake/ME Requirement×100.
[4)] M100: molting with 100% molt diet (0–4 wk).
[5)] M85: molting with 85% molt diet+rice hull (0–4 wk).
[6)] M70: molting with 70% molt diet+rice hull (0–4 wk).
[7)] Data are presented as the mean±SD of 4 replicates per treatment.
** $P<0.01$, * $P<0.05$.
[abc] Means within a row followed by a common superscript are not significantly different.

studied the effects of ME on the induced molting in this experiment. However, using a rice hull in the molt diet not only reduces the energy level but also decrease the CP level. Thus, we assume that decrease in CP level may also effect on the induced molting with feed. Therefore, further research will be conducted to shorten the rest period by shortening the molt-inducing period and to determine the effects of CP level of the molt diet for maximizing molt induction and post-molt egg quality.

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