アミノ酸の期別給与が産卵鶏の産卵期における成績に及ぼす影響

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Effect of Phase Feeding of Amino Acid on Performance of Laying Hens During Laying Period

Yukinori OKAZAKI[1)], Akira FUKASAWA[2)], Sonosuke ADACHI[2)], Ryuichi OHISHI[2)] and Teru ISHIBASHI[1)]

[1)] Faculty of Agriculture, Niigata University, Niigata-shi 950-21
[2)] C. Itoh Feedmills Co., LTD., Kuroiso-shi 325-01

To investigate the effect of phase feeding of amino acids for laying hens during laying period, the laying period from 20 to 80 weeks of age was divided into 3 phases as 20-30, 30-60 and 60-80 weeks of age, and the hens were fed with 8 feeding programs. Five dietary amino acids (lysine, methionine, threonine, isoleucine and tryptophan) levels were adjusted to 100, 115 and 130% of the NRC requirement. The hens in non-phase feeding groups were fed 130, 115, 100% (groups 1, 2, 3) and commercial diet as a reference (group 9). The hens in phase feeding groups were fed with following programs : 130-115-115 (group 4), 130-115-100 (5), 130-100-130 (6), 115-115-100 (7) or 100-130-130% (8) for phase Ⅰ-Ⅱ-Ⅲ. The oviposition was recorded every day and egg weight was measured every Monday, Wednesday and Friday throughout the experimental period. And the eggshell strength, eggshell weight and Haugh unit were estimated every 10 weeks after 30 weeks of age.

The first egg age and egg weight were not different among dietary amino acid levels. However the hens in 100% diet groups decreased their body weight considerably after the start of laying. Their performance was also inferior to other groups. When the dietary amino acid level was decreased from 130 to 115 to 100% gradually (group 5), there was no difference in the performance throughout the experimental period compared with 130% diet (group 1). However, the length of laying peak in experimental groups was shorter than that in reference group. The egg weight of hens fed 130% diet was the largest. The eggshell strength and Haugh unit were decreased with age. But the effective phase feeding program to maintain the egg quality was not determined.

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Key words : amino acid, phase feeding, performance, egg quality, laying hens

Introduction

The performance of laying hens is not constant throughout their laying life. Therefore, the nutrient requirement of hens changes accompanying with changes of their laying performance. However, the only one pattern of requirement is shown in NRC (1984) or Japanese Feeding Standard for Poultry (1992). Especially, dietary protein or amino acid level influences on laying performance directly, so it is necessary to feed laying hens with diets containing optimal protein or amino acid level in order to improve efficiency of diets for egg production.

As for protein, there have been some reports that the step-down phase feeding do not have worse effects on laying performance (FERNANDEZ *et al* 1973 ; HAMILTON, 1978 ; OUSTERHOUT, 1981 ; CAVE and HAMILTON, 1982 ; PROUDFOOT *et al.*, 1988). But it is not clarified about amino acids. OKAZAKI *et al.* (1994) estimated amino acid requirements of

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hens every 10 weeks in laying period to establish effective phase feeding of amino acids, and concluded that the dietary amino acid level could be decreased gradually as follows : 20-30 weeks of age, 130% of NRC requirement ; 30-60, 115% ; and 60-80, 100%. Therefore, it is necessary to confirm whether the program is acceptable or stress of shifting diet does not affect the laying performance throughout their productive lives.

In the present study, the step-down phase feeding program of amino acid, i.e., 130 -115-100% of the NRC requirement was compared to other programs. In addition, some feeding programs were organized to investigate 1) whether hens could recover their laying performance, when they were fed a high amino acid diet after a low amino acid diet during early or middle laying period and 2) if it is possible to keep egg quality by manipulating dietary amino acid levels from the early laying period.

Materials and Methods

1. Animals

One hundred and fifty commercial Leghorn hens (Shaver Starcross 288) were housed in individual wire cages at 18 weeks of age and accustomed to environmental condition. One hundred and twenty three hens out of them were divided into 9 groups with same average body weight at 20 weeks of age. The hens started laying before 20 weeks of age were excluded. Environmental temperature was kept at 22± 2℃ (20±2℃ in winter). The hens were exposed to light for 16 h (4 : 00-20 : 00).

2. Diets

The composition of basal diets is shown in Table 1. The contents of 5 essential amino acids (lysine, methionine, threonine, isoleucine and tryptophan) were adjusted to be 100 or 130% of the NRC requirements. The amino acids deficient in the feedstuffs were added as a crystalline form. The crude protein (CP) content of 100 or 130% diet was 12.5 or 15.8% and the metabolizable energy (ME) was 2,901 or 2,905 kcal/kg, respectively. The 115% diet was formulated by mixing both basal diets equally. And a commercial diet containing 18.0% of CP and 2,850 kcal/kg (of ME) was prepared as a reference diet.

3. Feeding programs

The laying period from 20 to 80 weeks of age was divided into 3 phases as follows : phase I, 20-30 ; II, 30-60 ; and III, 60-80 weeks of age. The hens were divided into 9 groups ; 5 phase feeding groups of 15 hens each and 4 non-phase feeding groups of 12 hens each. As shown in Table 2, the hens in phase feeding program were fed 130-115 -115% diets (group 4), 115-115-110% diets (group 5), or 130-100-130% diets (group 8) at phase I-II-III, respectively. To investigate the effect of abrupt shift-down of dietary amino acid level on laying performance or whether laying performance decreased by feeding a low amino acid diet during active laying period could be recovered after switching to high amino acid diet, the hens in group 6 were fed 130-100-130% diet at phase I-II-III. And to investigate the effect of feeding a low amino acid diet during early laying period on the laying performance in the rest of laying life, the hens in group 8 were fed 100-130-130% diets in phase I-II-III, respectively.

The hens in non-phase feeding program were fed 130% diet (group 1), 115% diet

Table 1. Composition of basal diets (%)

Ratio to NRC (%)	100	130
Corn	71.3	65.7
Soybean meal	6.1	13.7
Fish meal (CP 60%)	2.8	4.1
Defatted rice bran	7.8	4.6
Soybean oil	2.2	2.4
Ground limestone	7.8	7.7
Tricalcium phosphate	1.0	0.7
Choline-chloride	0.1	0.1
NaCl	0.25	0.25
Vitamin-mineral premix*	0.25	0.25
L-Lysine-HCl	.106	.064
DL-Methionine	.143	.224
L-Threonine	.014	.023
L-Isoleucine	.040	.040
L-Glutamic acid	.097	.149
CP (%)	12.5	15.8
ME (kcal/kg)	2901	2906
Ca (%)	3.5	3.5
Available P (%)	0.43	0.42

* Vitamin-mineral premix contains (mg/kg) : retinol acetate, 1600 IU/g ; cholecalciferol, 200 IU/g ; α-tocopherol acetate, 2000 ; menadione, 200 ; thiamin, 320 ; riboflavin, 880 ; pyridoxine, 1200 ; niacin, 4000 ; pantothenic acid, 880 ; folic acid, 100 ; cyanocobalamine, 1.6 ; biotin, 40 ; Mn, 12000 ; Fe, 20000 ; Cu, 3200 ; Zn, 20000 ; 1, 120 and Mg, 200000.

Table 2. Feeding programs of amino acid for hens from 20 to 80 weeks of age

Phase	I	II	III
Weeks of age	20-30	30-60	60-80
Non-phase feeding			
1	130	130	130
2	115	115	115
3	100	100	100
Phase feeding			
4	130	115	115
5	130	115	100
6	130	100	130
7	115	115	100
8	100	130	130
Reference			
9		commercial diet	

Values are ratio to NRC requirement.

(group 2), 100% diet (group 3) or commercial diet as a reference (group 9) throughout the experimental period.

4. Parameters

The oviposition was recorded every day and the egg weight was measured every Monday, Wednesday and Friday throughout experimental period. The body weight was determined every 2 weeks during phase I and every 4 weeks during phases II and III. The feed intake was recorded every 4 weeks. These data were calculated every 4, 8 or 12 weeks. The eggshell strength and Haugh unit were evaluated and the eggshell

Table 3. Effects of dietary amino acid levels on laying performance, feed intake and feed conversion ratio of hens during phase I (20-30 weeks of age)

Parameter	Group	Ratio to NRC (%)	Weeks of age		
			20-24	24-30	20-30
Egg production (%)					
	1·4·5·6	130	86.4	96.3[a]	93.1[a]
	2·7	115	85.9	97.6[a]	93.0[a]
	3·8	100	82.4	90.3[b]	86.1[b]
	9	Reference	88.7	95.8[a]	93.3[a]
Pooled S.E.			1.0	0.6	0.7
Egg mass (g/hen/day)					
	1·4·5·6	130	44.7	56.4[a]	51.6[a]
	2·7	115	42.8	55.7[a]	50.1[a]
	3·8	100	41.8	50.8[b]	46.4[b]
	9	Reference	44.6	55.2[a]	50.8[a]
Pooled S.E.			0.6	0.5	0.5
Egg weight (g/egg)					
	1·4·5·6	130	51.8	58.6[a]	55.5
	2·7	115	50.1	57.1[ab]	54.0
	3·8	100	50.4	56.3[b]	53.7
	9	Reference	50.2	57.6[ab]	54.4
Pooled S.E.			0.4	0.3	0.4
Feed intake (g/hen/day)					
	1·4·5·6	130	95.5	110.3	104.3
	2·7	115	95.0	110.7	103.8
	3·8	100	94.9	108.7	102.2
	9	Reference	99.8	110.6	105.5
Pooled S.E.			0.9	1.0	0.9
Feed conversion ratio (feed/egg)					
	1·4·5·6	130	2.22	1.97[a]	2.03[a]
	2·7	115	2.26	1.99[a]	2.08[a]
	3·8	100	2.34	2.14[b]	2.23[b]
	9	Reference	2.28	2.01[a]	2.09[a]
Pooled S.E.			0.03	0.02	0.03

Each value is mean of group (n=57 for group 1·4·5·6, 27 for 2·7, 24 for 3·8 or 12 for 9).

[a,b] Values with different superscript letters in each period are significantly different ($P<0.05$).

was weighed after washing and drying every 10 weeks after 30 weeks of age.

5. Statistical analysis

Statistical significance was determined by analysis of variance and Duncan's new multiple range test using the General Linear Model procedure of Statistical Analysis System (SAS Institute, 1985).

Results

1. Phase I from 20 to 30 weeks of age

Since groups 1, 4, 5 and 6 were fed 130% diet, groups 2 and 7, 115%, and groups 3 and 8, 100% diet and there was no difference in the performance of hens among the same diet groups, the data were merged into 4 groups, group 1·4·5·6 as 130%, 2·7 as 115%, 3·8 as 100%, and reference. The dietary amino acid level did not affect the first egg age and egg weight, which ranged from 145.7 to 147.5 days and from 42.7 to 44.5 g respectively. The laying performance, feed intake and feed conversion ratio are summarized in Table 3. In group 3·8, the egg production, egg mass, egg weight, feed conversion ratio were inferior to other groups. However, there was no difference among other groups, except that the increase of egg weight was a little greater in group 1·4·5·6 increased more than other groups. This increment of egg weight was reflected to egg mass. The body weight change is shown in Fig. 1. Though the body weight of each group increased in a similar way from 20 to 22 weeks of age, that of all the experimental diet groups dropped at 24 weeks of age but that of reference group continued to increase. Especially in group 3·8, the body weight decreased to the value at the commencement and did not increase even at 30 weeks of age. The body weight

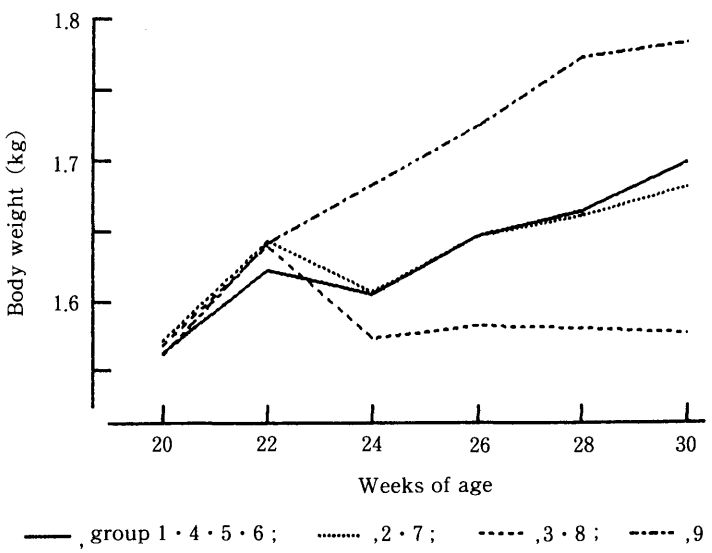

Fig. 1. Effect of dietary amino acid levels on body weight change of hens during phase I (20–30 weeks of age).

in groups 1·4·5·6 and 2·7 decreased from 22 to 24 weeks, and then increased soon after 24 weeks of age and reached to 1700 g at 30 weeks of age. The body weight of reference group were about 100 g heavier than experimental groups after 24 weeks of age.

2. Phase II from 30 to 60 weeks of age

The groups with same feeding programs during phase I - II, i.e., groups 4 and 5 as 130-115% and groups 2 and 7 as 115-115%, were analyzed together. The laying performance, feed intake and feed conversion ratio are shown in Table 4. The egg production of group 4·5 was not affected by shifting diet. But in group 6, the egg production decreased rapidly to less than that of group 3 which fed 100-100% diet. The egg production of reference group tended to be higher than that of all experimental groups, so the performance of reference group was the best at all times. The egg weight was the largest, when the hens were fed 130% diet. The tendency of egg mass was similar to that the egg weight. The feed intake and feed conversion ratio of groups fed 100% diet were significantly inferior, but there was no difference among other groups. The change of body weight is shown in Fig. 2. The average body weight of reference group was 1870 g at 60 weeks of age, but that of group 1 was only 1770 g. The body weight of hens in group 1 fed 130% diet during phases I and II was heavier than other groups except group 8. The body weight in group 8 fed 100% diet in phase I and 130% diet during phase II increased sharply from the lightest to the same weight in group 1 until 55 weeks of age. The body weight of hens fed 115% diet remained constant at average 1730 g, and that fed 100% diet decreased from 30 to 40 weeks of age, and then remained constant at 1570 g.

3. Phase III from 60 to 80 weeks of age

The laying performance, feed intake and feed conversion ratio are shown in Table 5. The egg production in group 2 tended to be higher than group 1. But the egg weight in group 1 was heavier than that in group 2, so there was no difference in egg mass. In group 6, the diet was shifted from 100 to 130%, the performance recovered to the same levels as group 1. The performance of group 3 tended to increase after 68 weeks of age. There was no difference in feed intake. The body weight change is shown in Fig. 3. The hens in reference group were heaviest in all groups. The body weight of hens in group 3 was lighter than other groups, increased only 120 g from 60 to 72 weeks of age, and after then stopped to increase. There was no negative effect of shifting diets on the body weight in groups 5 and 7. The body weight of hens in group 6 increased rapidly after changing from 100 to 130% diet.

4. Phase I-II-III from 20 to 80 weeks of age

The laying performance, feed intake and feed conversion ratio throughout the experimental period are shown in Table 6. The egg production rate exceeded 90% only in the reference group. The production in groups 3 and 6 was worse. But in other groups, it ranged 82-83% regardless of feeding programs. The egg weight of group 1 was the largest. And the egg weight was larger in the groups which were fed 130% diet for long period. The same tendency occurred in the egg mass. The feed intake and feed conversion ratio were inferior in group 3.

Table 4. Effects of feeding programs of amino acid on laying performance, feed intake and feed conversion ratio of hens during phase II (30-60 weeks of age)

Parameters	Group	Feeding program	Weeks of age				
			30-36	36-44	44-52	52-60	30-60
Egg production (%)							
	1	130-130	97.8^{a}	91.5^{ab}	84.1^{b}	78.7^{b}	87.3^{a}
	2·7	115-115	97.6^{a}	88.4^{ab}	85.4^{ab}	82.0^{ab}	86.2^{a}
	3	100-100	84.1^{b}	72.5^{c}	68.2^{c}	63.7^{c}	71.3^{b}
	4·5	130-115	96.6^{a}	86.0^{b}	86.3^{ab}	84.2^{ab}	87.4^{a}
	6	130-100	88.7^{b}	65.8^{c}	63.5^{c}	63.6^{c}	68.3^{b}
	8	100-130	95.8^{a}	89.7^{ab}	92.5^{a}	85.9^{ab}	87.4^{a}
	9	Reference	97.8^{a}	95.2^{a}	92.9^{a}	89.3^{a}	93.5^{a}
Pooled S.E.			0.7	1.4	1.3	1.4	1.2
Egg mass (g/hen/day)							
	1	130-130	60.9^{a}	58.3^{a}	54.8^{bc}	51.8^{b}	56.1^{ab}
	2·7	115-115	58.9^{a}	53.4^{ab}	53.4^{c}	51.7^{b}	53.1^{b}
	3	100-100	48.2^{b}	43.3^{c}	41.4^{d}	39.5^{c}	42.8^{c}
	4·5	130-115	58.6^{a}	52.5^{b}	54.0^{c}	53.3^{ab}	54.0^{ab}
	6	130-100	53.5^{b}	39.6^{c}	39.0^{d}	40.3^{c}	41.8^{c}
	8	100-130	59.2^{a}	56.6^{ab}	60.2^{a}	56.8^{ab}	55.9^{ab}
	9	Reference	59.0^{a}	58.7^{a}	59.2^{ab}	57.9^{a}	58.7^{a}
Pooled S.E.			0.6	0.9	0.9	0.9	0.8
Egg weight (g/egg)							
	1	130-130	62.2^{a}	63.8^{c}	65.2^{a}	66.0^{a}	64.3^{a}
	2·7	115-115	60.4^{a}	60.5^{bc}	62.7^{ab}	63.1^{ab}	61.8^{ab}
	3	100-100	56.5^{b}	59.5^{c}	60.5^{b}	62.0^{b}	59.7^{b}
	4·5	130-115	60.7^{a}	61.2^{abc}	62.8^{ab}	63.6^{ab}	62.0^{ab}
	6	130-100	60.2^{a}	60.6^{bc}	61.6^{b}	63.9^{ab}	61.6^{ab}
	8	100-130	61.8^{a}	63.0^{ab}	64.9^{a}	65.9^{a}	63.7^{a}
	9	Reference	59.8^{a}	61.1^{abc}	63.6^{ab}	64.5^{ab}	62.3^{ab}
Pooled S.E.			0.4	0.3	0.4	0.4	0.5
Feed intake (g/hen/day)							
	1	130-130	108.5^{ab}	107.1^{ab}	105.3^{b}	107.3^{ab}	107.0^{a}
	2·7	115-115	110.3^{ab}	102.4^{abc}	104.6^{b}	107.2^{ab}	105.5^{ab}
	3	100-100	105.6^{b}	96.6^{c}	94.3^{c}	100.4^{b}	98.8^{bc}
	4·5	130-115	111.0^{ab}	100.1^{bc}	108.3^{ab}	111.4^{a}	107.8^{a}
	6	130-100	104.9^{b}	87.6^{d}	92.1^{c}	99.5^{b}	95.0^{c}
	8	100-130	115.8^{a}	104.8^{abc}	113.7^{a}	114.9^{a}	110.0^{a}
	9	Reference	109.7^{ab}	109.1^{a}	111.4^{ab}	113.3^{a}	111.3^{a}
Pooled S.E.			1.0	1.2	1.2	1.1	1.0
Feed conversion ratio (feed/egg)							
	1	130-130	1.79^{a}	1.87^{a}	1.94^{a}	2.10^{a}	1.92^{a}
	2·7	115-115	1.88^{a}	1.93^{a}	1.96^{a}	2.09^{a}	1.99^{a}
	3	100-100	2.33^{b}	2.29^{b}	2.34^{b}	2.58^{b}	2.36^{b}
	4·5	130-115	1.90^{a}	1.91^{a}	2.01^{a}	2.10^{a}	2.00^{a}
	6	130-100	1.96^{a}	2.30^{b}	2.44^{b}	2.54^{b}	2.31^{b}
	8	100-130	1.96^{a}	1.87^{a}	1.90^{a}	2.05^{a}	1.99^{a}
	9	Reference	1.86^{a}	1.87^{a}	1.90^{a}	1.96^{a}	1.92^{a}
Pooled S.E.			0.03	0.03	0.03	0.03	0.03

Each value is mean of group (n=12 for group 1, 3, 8, 9, 27 for 2·7, 30 for 4·5 or 15 for 6).

^{a,b,c,d} Values with different superscript letters in each period are significantly different ($P<0.05$).

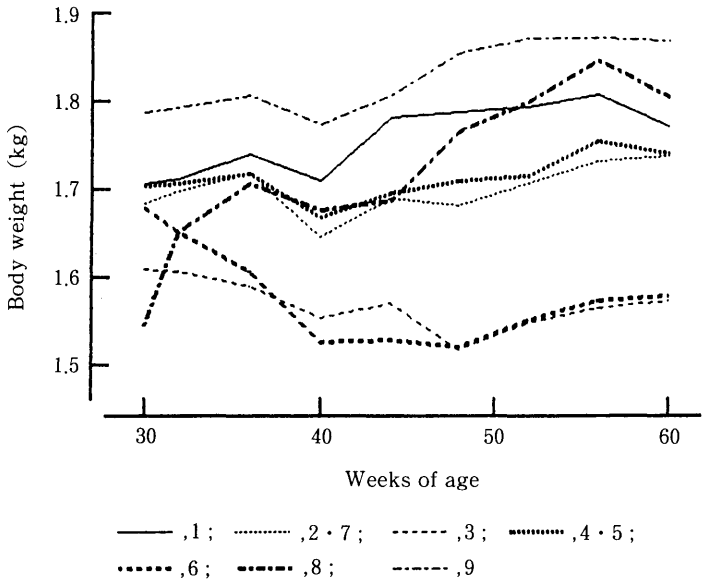

Fig. 2. Effect of feeding program of amino acid on body weight change of hens during phase II (30-60 weeks of age).

5. Quality of eggs

The data of eggshell strength, eggshell weight and Haugh unit every 10 weeks are summarized in Table 7. The eggshell strength was weakened with age generally. The eggshell strength tended to be weakened rapidly by increasing amino acid level from 100 to 130% diet in group 8 and 6. The eggshell weight tended to increase with age. But the increase was depressed, when dietary amino acid level was decreased. Although the Haugh unit was decreased with age, the effect of amino acid levels and feeding programs were not apparent.

Discussion

The hens in group 3 decreased their body weights considerably after the start of laying. And their peak of egg producion was lower and shorter than other groups. These results show that amino acids at 100% of the requirements of NRC is insufficient for the maximum performance and the feeding of amino acid deficient diet after the start of laying has worse effect on laying and growth. Although the decrease of body weight after the start of laying was seen in groups fed 130 or 115% diet, it did not occur in reference group. OKAZAKI *et al.* (1994) reported that there was no difference in body weight gain between hens fed 160 and 130% diet during 20-24 weeks of age. The CP contents of both diets were 19.0 and 15.7%, respectively. Therefore, it seems unlikely that only the CP content of reference diet promoted growing of hens during phase I. Because the 130% diet was adjusted their amino acid level by adding crystalline form, the ratio of essential amino acids to total dietary amino acids was higher than reference diet. The optimum ratio of essential and non-essential amino acids has not yet been

Table 5. Effects of feeding programs of amino acid on laying performance, feed intake and feed conversion ratio of hens during phase III (60–80 weeks of age)

Parameters	Groups	Feeding program	Weeks of age		
			60–68	68–80	60–80
Egg production (%)					
	1	130–130–130	76.3[b]	72.3	73.9
	2	115–115–115	80.0[ab]	80.1	79.4
	3	100–100–100	67.1[c]	73.2	70.8
	4	130–115–115	77.5[ab]	77.0	77.1
	5	130–115–100	74.0[bc]	78.0	76.9
	6	130–100–130	81.4[ab]	79.4	80.8
	7	115–115–100	74.4[bc]	79.7	76.2
	8	100–130–130	83.1[ab]	74.9	78.2
	9	Reference	86.4[a]	82.5	84.0
Pooled S.E.			1.0	1.1	0.9
Egg mass (g/hen/day)					
	1	130–130–130	51.2[ab]	50.4	50.7
	2	115–115–115	50.7[ab]	52.3	51.1
	3	100–100–100	42.9[c]	48.8	46.4
	4	130–115–115	50.8[ab]	52.1	51.3
	5	130–115–100	46.7[bc]	51.8	49.8
	6	130–100–130	54.5[a]	53.0	53.9
	7	115–115–100	47.2[bc]	52.6	49.7
	8	100–130–130	55.4[a]	50.8	52.8
	9	Reference	56.7[a]	54.9	53.9
Pooled S.E.			0.7	0.8	0.6
Egg weight (g/egg)					
	1	130–130–130	67.2	69.8	68.7
	2	115–115–115	63.6	65.2	64.3
	3	100–100–100	63.8	66.5	65.5
	4	130–115–115	65.7	67.9	66.5
	5	130–115–100	63.5	66.2	65.2
	6	130–100–130	67.2	65.9	66.6
	7	115–115–100	63.4	66.0	65.2
	8	100–130–130	66.4	67.6	67.4
	9	Reference	64.7	65.8	64.1
Pooled S.E.			0.4	0.6	0.4
Feed intake (g/hen/day)					
	1	130–130–130	110.2	118.4	115.1
	2	115–115–115	110.1	116.1	112.8
	3	100–100–100	106.2	114.8	111.4
	4	130–115–115	109.3	114.0	113.5
	5	130–115–100	114.9	123.7	120.2
	6	130–100–130	115.8	117.3	116.9
	7	115–115–100	108.2	116.3	112.8
	8	100–130–130	113.7	115.3	114.2
	9	Reference	112.3	114.4	113.6
Pooled S.E.			1.0	1.1	0.9
Feed conversion ratio (feed/egg)					
	1	130–130–130	2.17[ab]	2.36	2.28
	2	115–115–115	2.19[ab]	2.27	2.24
	3	100–100–100	2.51[c]	2.46	2.46
	4	130–115–115	2.16[ab]	2.22	2.24
	5	130–115–100	2.47[c]	2.41	2.42
	6	130–100–130	2.15[ab]	2.52	2.23
	7	115–115–100	2.31[bc]	2.23	2.29
	8	100–130–130	2.08[a]	2.34	2.21
	9	Reference	1.99[a]	2.12	2.14
Pooled S.E.			0.03	0.06	0.03

Each value is mean of group (n=12 for group 1, 2, 3, 8, 9 or 15 for 4, 5, 6, 7).

[a,b,c,d] Values with different superscript letters in each period are significantly different ($P < 0.05$).

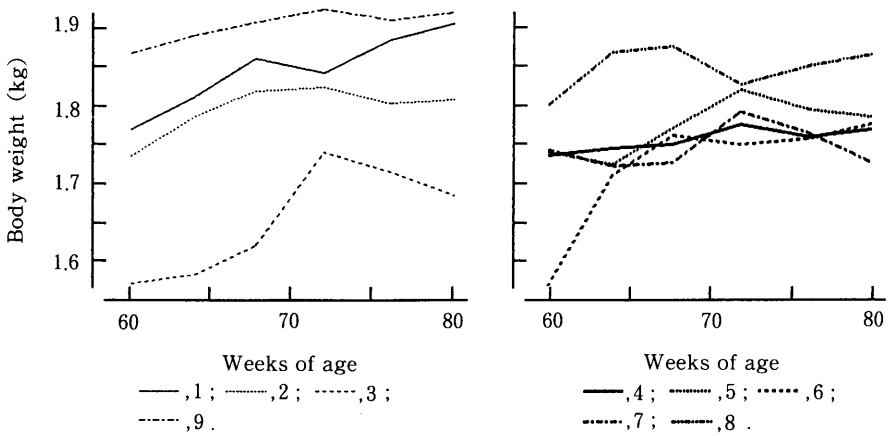

Fig. 3. Effect of feeding program of amino acid on body weight change of hens during phase III (60-80 weeks of age).

Table 6. Effects of feeding programs of amino acid on laying performance, feed intake and feed conversion raito of hens through laying period

Group	Feeding program	Egg			Feed	
		Production (%)	Mass (g/hen/day)	Weight (g/egg)	Intake (g/hen/day)	Conversion ratio (feed/egg)
1	130-130-130	82.8^{ab}	53.3^{a}	64.4^{a}	109.2	2.06^{a}
2	115-115-115	84.2^{ab}	51.0^{ab}	60.7^{ab}	107.0	2.11^{a}
3	100-100-100	73.0^{c}	44.3^{c}	60.5^{ab}	103.7	2.37^{b}
4	130-115-115	82.2^{b}	51.1^{ab}	62.3^{ab}	106.1	2.09^{a}
5	130-115-100	83.7^{ab}	51.5^{ab}	61.6^{ab}	111.0	2.16^{a}
6	130-100-130	75.2^{c}	46.7^{bc}	62.2^{ab}	102.6	2.21^{ab}
7	115-115-100	84.5^{ab}	52.2^{ab}	61.8^{ab}	108.0	2.08^{a}
8	100-130-130	83.8^{ab}	52.8^{a}	62.7^{ab}	109.4	2.11^{a}
9	Reference	90.4^{a}	54.1^{a}	59.6^{b}	110.5	2.09^{a}
Pooled S.E.		0.9	0.6	0.4	0.9	0.02

Each value is mean of group (n=12 for group 1, 2, 3, 8, 9 or 15 for 4, 5, 6, 7).

^{a,b,c,d} Values with different superscript letters in each period are significantly different ($P<0.05$).

clarified, but the ratio in the 130% diet might not be ideal.

The laying performance of reference group was the best. There were no differences in the performance at the peak of egg production among the experimental groups. But the length of laying peak of experimental groups was shorter compared with reference group, so the performance was inferior as a result. The feeding of low CP diet or restricting the amount of diet before the start of laying is generally carried out in order to delay the start of laying, and to increase the body weight at the start of laying. The primary object of those feeding programs is to increase the egg weight in the early laying period. LEESON and SUMMERS (1987) showed that the hens with heavy

Table 7. Effects of feeding programs of amino acid on eggshell strength, eggshell weight and Haugh unit of hens

Parameter	Group	Feeding program	Weeks of age					
			30	40	50	60	70	80
Eggshell strength (kg/cm^2)								
	1	130-130-130	3.47^{b}	3.38	3.01^{ab}	2.90	3.20	2.88
	2	115-115-115	3.18^{b}	3.20	2.59^{b}	3.02	2.96	2.63
	3	100-100-100	3.55^{b}	3.47	2.67^{b}	2.65	3.18	2.81
	4	130-115-115	3.53^{b}	3.55	3.13^{ab}	3.03	2.70	2.63
	5	130-115-100	3.77^{ab}	4.09	3.40^{a}	3.13	3.11	2.76
	6	130-100-130	3.41^{b}	3.44	3.27^{ab}	3.14	2.74	2.49
	7	115-115-100	3.09^{b}	3.60	3.09^{ab}	3.09	3.07	2.68
	8	100-130-130	4.38^{a}	3.39	3.05^{ab}	2.48	2.90	2.48
	9	Reference	3.52^{b}	3.39	3.12^{ab}	3.04	3.18	2.56
Pooled S.E.			0.08	0.09	0.07	0.06	0.06	0.07
Eggshell weight (g/egg)								
	1	130-130-130	5.65^{ab}	5.74	5.25^{b}	5.56	6.01	5.93
	2	115-115-115	5.43^{ab}	5.61	5.73^{ab}	5.42	5.51	5.46
	3	100-100-100	5.76^{ab}	5.62	5.45^{ab}	5.37	5.74	5.78
	4	130-115-115	5.50^{ab}	5.54	5.69^{ab}	5.60	5.54	5.67
	5	130-115-100	5.41^{ab}	5.72	5.50^{ab}	5.69	5.60	5.62
	6	130-100-130	5.63^{ab}	5.58	5.69^{ab}	5.84	5.79	5.59
	7	115-115-100	5.51^{ab}	5.82	6.12^{a}	5.72	5.73	5.61
	8	100-130-130	5.97^{a}	5.60	6.10^{a}	5.45	5.83	5.77
	9	Reference	5.35^{b}	5.58	5.71^{ab}	5.68	5.89	5.60
Pooled S.E.			0.06	0.07	0.08	0.06	0.06	0.06
Haugh unit								
	1	130-130-130	90.3^{ab}	85.2	88.0	81.2	79.2^{b}	75.0
	2	115-115-115	91.9^{ab}	89.0	86.3	82.9	80.1^{b}	78.2
	3	100-100-100	86.8^{b}	84.7	84.8	82.9	80.7^{ab}	75.2
	4	130-115-115	88.0^{ab}	84.1	82.3	84.2	82.7^{ab}	80.4
	5	130-115-100	88.5^{ab}	83.7	82.9	84.1	82.0^{ab}	78.2
	6	130-100-130	89.2^{ab}	86.1	88.7	84.4	81.4^{ab}	79.5
	7	115-115-100	94.2^{a}	89.0	88.4	84.5	85.5^{a}	80.6
	8	100-130-130	91.6^{ab}	85.3	86.8	85.5	84.3^{ab}	77.1
	9	Reference	90.9^{ab}	83.8	82.5	81.9	80.3^{b}	75.3
Pooled S.E.			0.6	0.8	0.8	0.7	0.7	0.7

Each value is mean of group (n=12 for group 1, 2, 3, 8, 9 or 15 for 4, 5, 6, 7).

[a,b] Values with different superscript letters in each period are significantly different ($P<0.05$).

body weight consumed more feed before or at sexual maturity and laid larger eggs. Thus, it is necessary to keep growth by consuming enough diet during phase I for bringing out the maximum performance throughout laying period. Therefore, it seemed that the less of body weight gain of hens in experimental groups during phase I caused the shorter peak of egg production, although their performance at peak was not different from the reference group.

The egg weight increased with increasing dietary amino acid level. And the body weight of hens tended to increase by switching from 100 to 130% diet. The body weight of hens fed the 130% diet throughout experimental period was the heaviest, so the 130% diet was better than 100 and 115% diets for heavy the egg weight. The protein and energy intake are known to be major factors affecting egg weight. But the dietary CP content of reference diet was the highest, so the hens in reference group consumed more CP. As for energy, the ME contents of reference and 130% diets were 2,850 and 2,906 kcal/kg, respectively. Thus, there were no large differences between the ME intake of hens fed 130 and reference diets. Therefore, there might be factors other than ME afecting the egg weight. Though the egg production of reference group was higher than 130% group, the egg weight of the former was lighter than the latter. POURREZA and SMITH (1988) reported that the egg weight increased with dietary methionine content. Methionine contents of reference diet was estimated to be about 105% of the NRC requirement from the amino acid analysis. Consequently, since the feed intake of hens was the same between reference and 130% diets, the CP intake of hens fed reference diet group was more than 130% diet, but methionine intake in reference diet was less than in 130% diet group. Thus the difference of methionine intake might affect on egg weight.

The comparison of performance of hens before and after 2 weeks of shifting diet at 30 or 60 weeks of age is shown in Table 8. At 30 weeks of age, although the performance of hens in group 4·5 was not changed, that in group 6 decreased. The decrease of performance in group 6 showed that the stress of extreme shift-down of dietary amino acid level from 130 to 100% was very serious. At 60 weeks of age, the 115% diet was shifted to the 100% diet in groups 5 and 7, but the extent of decrease of egg production in group 7 tended to be larger than group 5. The hens in group 7 were fed the 115% diet, while group 5 was fed the 130% diet during phase I. Therefore, the

Table 8. Effects of switching diet on laying performance, feed intake and body weight of hens at 30 or 60 weeks of age

Group	Feeding program	Production (%)		Egg mass (g/hen/day)		Weight (g/egg)		Feed intake (g/hen/day)		Body weight(g)	
		Before[1]	After[1]	Before	After	Before	After	Before	After	Before	After
30 weeks of age											
4・5	130-115	98.0	97.3	58.6	58.8	59.9	60.4	114.0	111.4	1703	1706
6	130-100	96.7	91.9	58.0	54.9	60.0	59.6	110.8	105.2	1679	1647
8	100-130	85.7	92.9	49.2[b]	55.9[a]	57.4	60.1	104.6	117.6	1543	1650
60 weeks of age											
5	115-100	78.6	75.0	50.1	47.4	64.1	63.5	111.4	113.0	1741	1727
6	100-130	64.8	74.3	41.7	48.7	64.9	65.9	100.5[b]	112.6[a]	1577	1655
7	115-100	77.0	70.9	49.5	44.9	64.1	63.4	108.3	105.6	1743	1724

Each value is mean of group (n=30 for group 4·5, 15 for 5, 6, 7 or 12 for 8).

[1] Data were measured before and after 2 weeks of shifting diet.

[a,b] Values with different superscript letters in each column are significantly different ($P<0.05$).

reserved body protein of hens in group 7 seemed less than in group 5, so the hens in group 7 might be susceptible to the decrease of dietary amino acid level. On the other hand, when the 100% diet was switched to 130% diet at 30 weeks of age in group 8 and at 60 weeks of age in group 6, the reduced performances were remarkably recovered. This result showed that, though the hens could not bring out their maximum performance by lack of dietary amino acid during early or peak of laying, the hens could achieve their genetical performance when the lack of dietary amino acid was removed.

The eggs are marketed according to their weight. And the M (58-64 g) or L (64-70 g) eggs have higher commercial values. But the hens lay small eggs weighing 40-45 g at the start of laying. So it is important to increase their weight from S to M or L size as early as possible. To increase the egg weight, 130% diet is superior to the reference diet. But the egg weight increases with ages. Thus, the egg weight is affected by body weight and dietary amino acid levels. Thererfore, increase of egg weight with age might be controlled by keeping the body weight of hens at constant levels and by feeding low amino acid diets. In group 5, the decrease of amino acid level from 130 to 115 to 100% controlled the egg weight. It was shown that the phase feeding of amino acid for hens could control their egg weight.

The eggshell strength decrease with age. It becomes an importnat parameter when the egg quality is evaluated. However, effective phase feeding program for egg quality was not drown in this study.

Although the performance of hens fed experimental diets were worse than that fed the reference diet, it may conclude that 100% amino acid level is insuficient and 130% is desirable during phase I, and it is possible to decrease from 130 to 115 and 100% during phase II and III, respectively. It will be necessary more study to establish effective phase feeding program.

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アミノ酸の期別給与が産卵鶏の産卵期における成績に及ぼす影響

岡崎　幸則[1]・深沢　　晃[2]・安達宗之介[2]
大石　隆一[2]・石橋　　晃[1]

[1] 新潟大学農学部　新潟市 950-21
[2] 伊藤忠飼料(株)　黒磯市 325-01

産卵鶏の産卵期におけるアミノ酸期別給与の影響を調べるために，20から80週齢までの産卵期を20-30，30-60および60-80週齢の3期（P hase Ⅰ，ⅡおよびⅢ）に分け，8種類の給与プログラムで飼養した。飼料中5アミノ酸（リジン，メチオニン，スレオニン，イソロイシン，トリプトファン）レベルは，NRCの要求量に対して100，115および130%となるように配合した。通期給与区はアミノ酸レベルが130，115，100%の飼料（1，2，3区）と，参考として市販飼料（9区）をそれぞれ給与した。期別給与区ではPhase Ⅰ-Ⅱ-Ⅲの順に，130-115-115%（4区），130-115-100%（5区），130-100-130%（6区），115-115-100%（7区），100-130-130%（8区）のプログラムに従って給与した。試験期間中産卵は毎日記録し，卵重は月，水，金曜日に測定した。また30週齢以降，10週毎に卵殻強度，卵殻重量とハウ・ユニットを調査した。

初産日齢，初卵重には飼料中アミノ酸レベルの影響はなかった。しかし，100%飼料給与区では産卵開始後に体重が大きく減少し，産卵成績も他の区に比べて劣っていた。飼料中アミノ酸レベルを130から115，100%と段階的に低下させても，産卵成績は130%通期区（1区）と差がなかった。しかし，試験飼料区のピーク産卵の期間は参考区に比べると短かった。卵重は130%飼料を給与したときに最も大きかった。卵殻強度やハウ・ユニットは加齢とともに低下した。しかし，卵質の維持に有効な期別給与プログラムは明らかではなかった。

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