家蚕による人工飼料の消化と利用,特に飼料への大豆ミール添加量の多少と飼料効率との関係について

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Digestion and Utilization of Artificial Diet by the Silkworm, *Bombyx mori*, with Special References to the Efficiency of the Diet at Varying Levels of Dietary Soybean Meal

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In a recent decade the composition of the artificial diet of the silkworm has been greatly improved, and at present the larvae can grow well on the artificial diet as on the fresh mulberry leaves. However, as for the efficiency of the silk formation the artificial diet is still inferior to the natural leaves.

Previously, it was shown that the ratio of protein to sugar in the diet as well as the level of protein in the diet affected not only the rate of growth but also the rate of silk formation[6,7]. Considering the efficiency of artificial diet, it is important to investigate the digestion and utilization of the diet. There are so far a few papers on the digestion of artificial diets by the silkworm[8,9]. In the present paper further studies on the efficiency of the diet are reported with special references to the effects of the dietary levels of soybean meal and glucose on the efficiency. In addition, the utilization of nitrogen was compared among different diets.

MATERIALS AND METHODS

In the present study larvae of a hybrid of the silkworm, Kenko × Shunpaku, were used. Experiments were started with newly ecdysed 4th- and 5th-instar larvae in the year of 1965. When the 4th-instar larvae were to be used for the experiment, the larvae were reared on the fresh mulberry leaves from hatching to the end of the 2nd instar, then transferred on the artificial diet containing about 50% mulberry leaf powder[4] in the 3rd instar, during which the larvae were led to meet the artificial diet. When the 5th-instar larvae were to be used for the experiment, the rearing on mulberry leaves was continued to the end of the 3rd instar, and the 4th-instar larvae were allowed to be fed on the artificial diet,

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as above. Twenty 4th-instar larvae (not sexed) and ten 5th-instar larvae (males only) were used. Experiments were run in duplicates, and the results were expressed in terms of the mean value.

Newly ecdysed 4th- or 5th-instar larvae were divided into four groups, and started to be fed the four different test diets (Table 1). They contained 10 % mulberry leaf powder, and were prepared to contain 40 % (diet A), 30 % (diet B), 20 % (diet C), or 10 % (diet D) defatted soybean meal as a protein source, and the totals of the soybean meal plus glucose added to the experimental diets amounted to 45 % of the whole dry diet. In other respects the four diets were identical with each other. Rearing was carried out at 25°C. The diet was replaced twice daily.

Measurements of consumption and utilization of the diet were made by means of the usual gravimetric method. The rates of ingestion and digestion were measured every day at a definite time, and the larvae were weighed at 24-hour intervals. The approximate digestibility was calculated as {(dry weight of diet ingested − dry weight of feces)/dry weight of diet ingested} ×100. In the present paper, however, 'approximate digestibility' is referred to as 'digestibility' for the sake of brevity. The definition and terminology concerning the 'digestibility' are discussed in detail by WALDBAUER[12].

Aliquots of the diets used for the respective instar were analyzed for nitrogen by the micro-Kjeldahl method. Feces obtained during each of the 4th and 5th instars were combined respectively and ground, and were also analyzed for nitrogen and uric acid. Thus, aliquots of powdered feces were extracted with water at 60°C for 1 hour and the residue after filtration was re-extracted twice. The filtrates were combined and an aliquot was analyzed for uric acid according to the procedure modified from that presented by BROWN[1], by the use of a spectrophotometer.

Table 1. Composition of diets used

Substance	Dry diet (%)			
	A	B	C	D
Mulberry leaf powder	10	10	10	10
Glucose	5	15	25	35
Soybean meal, defatted	40	30	20	10
Soybean oil, refined	2	2	2	2
β-Sitosterol	0.3	0.3	0.3	0.3
Salt mixture, Wesson	2	2	2	2
Ascorbic acid	2	2	2	2
Cellulose powder	20.7	20.7	20.7	20.7
Potato starch	15	15	15	15
Powdered agar	3	3	3	3
Total	100	100	100	100
Vitamin B mixture*	Added	Added	Added	Added
Distilled water	2 ml/g dry diet			

* Nine B vitamins (biotin, choline, folic acid, inositol, niacin, pantothenic acid, pyridoxine, riboflavin, and thiamine) were added.

RESULTS

Growth

The four kinds of diets tested showed the different effect on the increase in the body weight of larvae (Table 2). No larva died during the experimental period. Both 4th and 5th-instar larvae grew well when they were fed on diet B, while their growth rate was slightly lowered on diet A and diet C and considerably inferior on diet D, as compared with that on diet B. The length of the 4th instar was longer by one day on diet D than those on the other diets. There was a similar tendency in the length of the 5th instar; that is, the larvae fed on diet D reached maturity about one day later than those on diet A and diet C, and the larvae on diet B became mature about half a day earlier than the ones on diet A and diet C.

Ingestion, digestion, and digestibility

The daily changes in the ingestion, digestion, and digestibility of the four kinds of diets by the 4th- and 5th-instar larvae are shown in Figs. 1 and 2, and the totals and means of these values during the instars are given in Table 3. In this table the dry weight of the diet ingested and digested in the 4th instar is indicated by the totals in 6 days from the start of the experiment for diet A, diet B, and diet C, whereas by the totals in 7 days for diet D. For the 5th instar two series of values, **a** and **b**, are given in Table 3. It is well known that silkworm larvae lose weight to some extent during the last one or two days of

Table 2. Growth during 4th and 5th instars expressed in terms of mean body weight (mg)

Age in days	Diet A	Diet B	Diet C	Diet D
4th instar				
0 (Newly ecdysed)	163	163	162	162
2	248	274	259	279
3	414	456	401	363
4	602	638	558	473
5	724	758	694	563
6	723*	776*	707*	608
7	—	—	—	588*
5th instar				
0 (Newly ecdysed)	676	675	674	675
2	1, 158	1, 357	1, 476	1, 257
3	1, 827	2, 025	2, 004	1, 434
4	2, 405	2, 690	2, 620	1, 735
5	2, 695	3, 045	2, 935	1, 870
6	2, 845	2, 985	2, 845	1, 905
7	2, 618**	2, 759**	2, 699**	1, 885
8	—	—	—	1, 744**

Number of replicates is two.
* Larvae molting.
** Larvae matured.

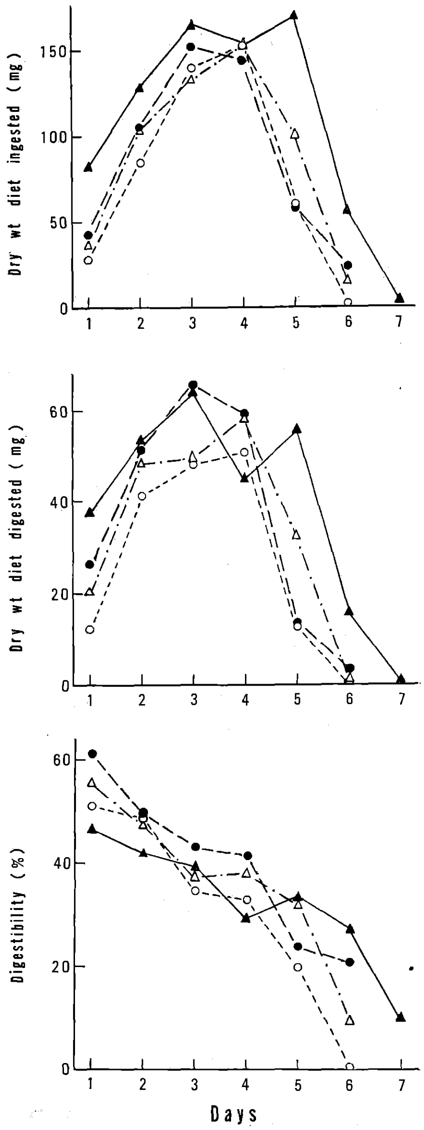

Figure 1. Daily changes of ingestion, digestion, and digestibility during the 4th instar. Means of duplicates, each 20 larvae, are represented.

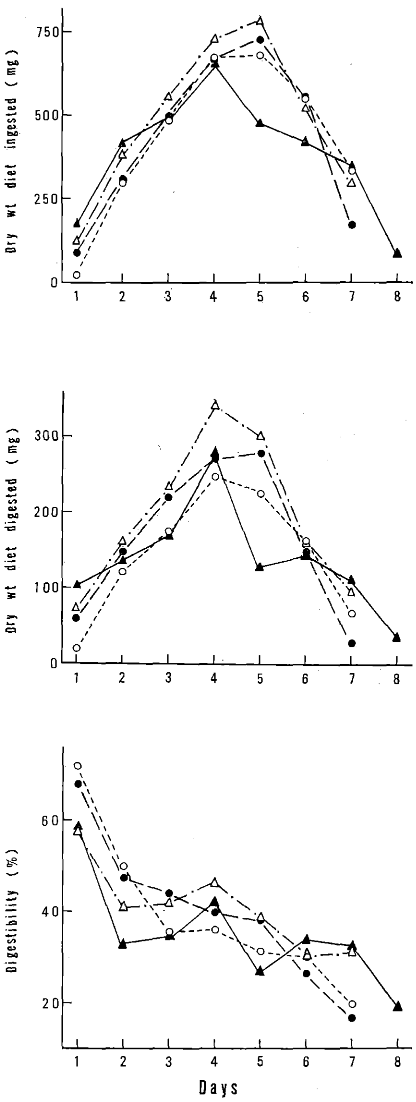

Figure 2. Daily changes of ingestion, digestion, and digestibility during the 5th instar. Means of duplicates, each 10 larvae, are represented.

○, diet A; ●, diet B; △, diet C; ▲, diet D.

the 5th instar, although they continue to take mulberry leaves[2]. This was also the case in the present experiment and the larvae reached their maximum weights one or two days before the maturity (Table 2). To compare the efficiency of conversion among the four kinds of diets, the body weights of the 6-day old larvae fed on diet A, diet B, or diet C and those of the 7-day old larvae fed on

Table 3. Ingestion, digestion, and digestibility of diet by single larva during 4th and 5th instars

Item	Diet A	Diet B	Diet C	Diet D
4th instar				
Dry wt. diet ingested (mg)	467	513	543	755
Dry wt. diet digested (mg)	165	220	211	274
Digestibility (%)	35.3	42.9	38.9	36.3
5th instar (**a**)*				
Dry wt. diet ingested (mg)	2,679	2,937	3,108	2,978
Dry wt. diet digested (mg)	955	1,130	1,265	1,062
Digestibility (%)	35.6	38.5	40.7	35.7
5th instar (**b**)*				
Dry wt. diet ingested (mg)	3,011	3,051	3,409	3,161
Dry wt. diet digested (mg)	1,014	1,161	1,361	1,098
Digestibility (%)	33.7	38.1	39.9	34.1

Number of replicates is two.
* See the text.

diet D were taken as the maximum weights, although these were mostly approximate maximum weights. Thus, the total amount of each diet ingested or digested for either 6 or 7 days, during which the larvae reached the maximum weights, is given in the series of **a** in Table 3. On the other hand, the total amount in the whole period of the 5th instar is given in the series of **b**.

The amount of the diet ingested and digested in the whole period of the 4th instar was the smallest in diet A, and increased in diet B and in diet C to some extent. It was considerably large in diet D, partly owing to the prolongation of the 4th instar. The digestibility throughout the 4th instar was high in diet B and low in diet A and diet D. As to the daily changes of ingestion, digestion, and digestibility, a similar tendency was observed; that is, the dry weight of the diet, both ingested and digested, was small in the first 24 hours, increased with the day of the 4th instar to reach the maximum in the mid-instar, and rapidly decreased toward the premolt stage. The rate of ingestion was larger in amount in diet D than in the others on the 1st or 2nd day of the 4th instar, and also of the 5th instar. Such a feeding acceleration is understood to have some connection with the composition of the diet. The digestibility was high at the beginning of the 4th instar, being as high as about 70 % in diet A, and declined with age within the instar.

In the 5th instar the amounts of ingested and digested diets were the largest in diet C, and the highest digestibility was obtained in diet C, in both **a** and **b** series. Diet B and diet D were the next to it in ingestion and digestion, but the diet D was fairly lower in the digestibility than diet B. The amount of the diet ingested and digested was the smallest in diet A. The digestibility of diet A was as low as that of diet D. The daily change in each of ingestion and digestion showed an increase in the middle of the 5th instar and then showed a decline with age. It is noted that the digestibility of the **a** series is more or less higher than that of the **b** series, as expected.

Table 4. Amounts of diet ingested and digested for gaining 100 g of live weight during 4th and 5th instars

Item	Diet A	Diet B	Diet C	Diet D
4th instar				
Dry wt. diet ingested (g)	83.4	83.7	99.6	169.3
Dry wt. diet digested (g)	29.5	35.9	38.7	61.4
5th instar (**a**)*				
Dry wt. diet ingested (g)	123.5	127.1	143.2	246.1
Dry wt. diet digested (g)	44.0	48.9	58.3	87.3
5th instar (**b**)*				
Dry wt. diet ingested (g)	155.0	146.4	168.3	295.7
Dry wt. diet digested (g)	52.2	55.7	67.2	102.7

Number of replicates is two.
* See the text.

Efficiency of diet for growth

In both 4th and 5th instars the amount of ingested diet necessary for an increase in the unit body weight was the smallest in diet A and diet B, and a little larger in diet C, but in diet D twice as much as diet A or diet B. The amount of digested diet necessary for the unit weight gain was the smallest in diet A and increased in the order of diet B, diet C, and diet D, as shown in Table 4. Comparing the 4th- and 5th-instar larvae fed on the same kind of diet, the latter needed 1.3-1.5 times as much diet as needed by the former for a gain of unit body weight. If the values of series **a** are compared with those of series **b** in Table 4, it is noticed that the efficiency of diet is higher in the former than in the latter. This is due to nothing but that larvae lose weight in the last stage of the 5th instar as mentioned above, although they still continue to feed until maturity.

Spinning, cocooning, and pupation

All the 5th-instar larvae used in the feeding experiment became mature, but one larva died on each of diet B and diet C and two larvae on diet D, after they had become mature and started spinning (Table 5). In addition, four larvae on diet D did not make normal cocoons, but span flatly. They, however, pupated almost normally (so-called nacked pupae).

The group of larvae fed on diet D was the most inferior in cocoon quaity.

Table 5. Cocoon-spinning, pupation, and cocoon quality

Item	Diet A	Diet B	Diet C	Diet D
Number of cocoons spun	20*	19*	19*	14*
Number of silkworms pupated	20*	19*	19*	18*
Mean weight of a cocoon (g)	1.15	1.29	1.27	0.97
Mean wt. of cocoon shell (g)	0.240	0.232	0.175	0.097
Mean ratio of cocoon shell (%)	20.9	18.0	13.8	10.0

Number of replicates is two.
* Number is the total of two batches, and is out of 20 matured larvae.

Cocoon weight was slightly lighter in the group on diet A than in those of diet B and diet C, but the highest values were obtained with diet A as for the cocoon shell weight and the cocoon shell ratio. Concerning the cocoon quality, diet B was somewhat inferior, and diet C was more inferior to diet A.

Efficiency of diet for silk formation

As shown in Table 6, the amount of ingested and digested diet necessary for the formation of the unit weight of the cocoon shell was the smallest in diet A,

Table 6. Amount of diet ingested and digested for producing 10 g of cocoon shell (not dry wt.) during 5th instar

Item	Diet A	Diet B	Diet C	Diet D
Dry wt. diet ingested (g)	125	132	195	326
Dry wt. diet digested (g)	42. 3	50. 0	77. 8	113. 2

Number of replicates is two.

and the efficiency was decreased in the order of diet B, diet C, and diet D. As compared with the necessary amount in diet A, it was about 1. 6 times (ingestion) and about 1. 8 times (digestion) in diet C, and about 2. 6 times (both ingestion and digestion) in diet D.

Utilization of nitrogen

As mentioned above, the diets tested here differ each other in the amounts of soybean meal and sugar added to the diets, which means a difference in nitrogen content of the diets and necessitates to compare the efficiencies of the diets from a view point of nitrogen economy. In this case, the fecal uric acid was previously determined (see Table 10), and the correction for uric acid was made when considering the utilization of nitrogen.

Table 7. Ingestion, digestion, and digestibility of nitrogen by single larva during 4th and 5th instars

Item	Diet A	Diet B	Diet C	Diet D
4th instar				
Nitrogen in diet ingested (mg)	18. 0	14. 9	11. 8	10. 3
Nitrogen in diet digested (mg)	12. 1	10. 6	8. 4	7. 2
Digestibility (%)	67. 2	71. 1	71. 2	69. 9
5th instar (**b**)*				
Nitrogen in diet ingested (mg)	114. 7	89. 4	69. 9	37. 6
Nitrogen in diet digested (mg)	56. 5	51. 1	42. 8	21. 9
Digestibility (%)	49. 3	57. 2	61. 2	58. 2

Number of replicates is two.
All data are corrected for uric acid nitrogen in feces.
* See the text.

The amounts of nitrogen ingested and digested per larva during the 4th and 5th instars are shown in Table 7. The values were smallest in diet D and increased as the nitrogen content of diets increased. The digestibility of nitrogen, corresponding to the coefficient of apparent digestibility (C.A.D.) for nitrogen offered by WALDBAUER[12], was markedly higher than the digestibility of the diet as a whole shown in Table 3, similar to the feeding experiment on mulberry leaves[2], and reached more than 70 % in some diets in the 4th instar. The digestibility was a little lower in diet A and diet D than the others, but there was rather little difference in the values among the diets. In the 5th instar the digestibility of nitrogen was lower than that in the 4th instar in each diet, by about 10 % at the least and about 18 % at the greatest. When comparison was made among the diets, the digestibility was the lowest in diet A, being slightly below 50 %. On the other diets the values ranged from 57 to 61 %.

The amounts of ingested and digested nitrogen necessary for the gain of the

Table 8. Amounts of nitrogen ingested and digested for gaining 100 g of live weight during 4th and 5th instars

Item	Diet A	Diet B	Diet C	Diet D
4th instar				
Nitrogen in diet ingested (g)	3. 21	2. 43	2. 17	2. 31
Nitrogen in diet digested (g)	2. 16	1. 73	1. 54	1. 61
5th instar (**b**)*				
Nitrogen in diet ingested (g)	5. 91	4. 29	3. 45	3. 52
Nitrogen in diet digested (g)	2. 91	2. 45	2. 11	2. 05

Number of replicates is two. All data are corrected for uric acid nitrogen in feces.
* See the text.

Table 9. Amounts of nitrogen ingested and digested for producing 10 g of cocoon shell (not dry wt.) during 5th instar

Item	Diet A	Diet B	Diet C	Diet D
Nitrogen in diet ingested (g)	4. 78	3. 85	3. 99	3. 88
Nitrogen in diet digested (g)	2. 35	2. 20	2. 45	2. 26

Number of replicates is two. All data are corrected for uric acid nitrogen in feces.

unit body weight were the largest in diet A, followed by diet B in both 4th and 5th instars, as shown in Table 8. This is a tendency opposite to that observed in the ingestion and digestion of diets as a whole (Table 4).

The nitrogen necessary for obtaining a certain quantity of cocoon shell was the largest in amount in diet A, and there was a small difference among the other three diets as for the efficiency of conversion of ingested nitrogen to the cocoon shell (Table 9). Furthermore, there was also a small difference in the efficiency of conversion of digested nitrogen to the silk formation among four diets tested, and no definite tendency due to the varying dietary composition was observed among them.

Uric acid excretion

Total excretion of uric acid per larva during the 4th and 5th instars was dependent on the dietary level of soybean meal, the largest in the group of larvae fed on diet A and the smallest on diet D, as shown in Table 10. Except for the case of diet D, the amount of uric acid excreted by single larva during

Table 10. Production of uric acid by single larva during 4th and 5th instars (mg per g of dry feces)

Instar	Diet A	Diet B	Diet C	Diet D
4th instar	12.73	5.21	2.49	1.39
5th instar (**b**)*	4.42	2.27	1.75	1.46

Number of replicates is two.
* See the text.

the 4th instar was larger than during the 5th instar. The present results confirm the previous report[5] that the excretion of uric acid by *Bombyx* larvae increases on a high-protein diet.

DISCUSSION

MUKAIYAMA and ITO[8,9] have reported in the silkworm that the ingestion, digestion, and digestibility of artificial diets are highly variable according to the different composition of the diets. The present study also showed that the difference in the dietary composition influenced the digestion and utilization of the diet. In the previous and present studies the gravimetric method was used, but recently the indirect method using chromic oxide was applied for the measurement of the utilization of the artificial diet by the silkworm[3].

The artificial diets used in the present study contained 10 % of mulberry leaf powder. With the diets including the leaf powder at this level it has been demonstrated that the larval growth and the cocoon quality are improved according to the elevation of the amount of the dietary soybean meal to a certain level[6,7]. This was also the case in the present experiment. Although the larval growth was somewhat better on diet B than on diet A, the former diet was slightly inferior to the latter as to the production of silk. On the low-protein diets, diet C and diet D, the cocoon quality was poor, especially in the latter diet. The soybean meal used in the present study contained about 50 % of protein.

Among diet A, diet B, and diet C, the digestibility of the whole diet during 5th instar was the highest in diet C and the lowest in diet A. This indicates that in considering the efficiency of the diet the comparison of the digestibility is sometimes meaningless, and furthermore it will come to a wrong conclusion, when the composition of the diets differs diversely. It has previously been reported that the digestibility of the artificial diet decreases according to the increase in the dietary level of cellulose powder, though the larval growth was accelerated largely by including it[9].

Among four diets, the amount of nitrogen ingested and digested was the largest and the digestibility of nitrogen was the lowest in diet A. Furthermore, more nitrogen was needed not only for the gain of the unit body weight in both 4th and 5th instars but also for the production of the unit weight of the cocoon shell, when diet A was used. The fact that diet A was inferior to the other diets, when examined from a view point of nitrogen economy, is considered to be due to that the comparison was made among the diets which were different in the nitrogen content, in other words, due to a larger amount of the dietary nitrogen in diet A than in the other diets. The efficiency of conversion of both ingested and digested diet as a whole to the growth and silk production was the best in diet A. Therefore, although there are many differences in the utilization and efficiency between diet A and diet B, it is hard to conclude which diet is superior.

The efficiency of conversion of ingested and digested diet to the unit weight of larvae or cocoon shell was the highest in diet A and the lowest in diet D. The ratio of the necessary amount of diet A to that of diet D during the 5th instar was approximately 1 : 2 in the increase in body weight, and approximately 1 : 2.5 for the production of the unit weight of cocoon shell. This indicates that unfavorable dietary conditions of diet D affect more adversely the cocoon production than the increase in body weight, and proves that the suitable amount of dietary protein is one of the necessary factors to elevate the efficiency of the diet for cocoon production. A similar result has been shown concerning the dietary efficiency and protein level with artificial diets by ITO and MUKAIYAMA[6]. In the feeding of silkworm larvae on mulberry leaves, it is well known that the unfavorable conditions including leaf quality and rearing environment affect badly the silk production at first, then the larval growth, and the egg production in the last[10, 11].

SUMMARY

Larvae of the silkworm were reared during the 4th and 5th instars on the four kinds of artificial diets, which are different in the amounts of soybean meal and sugar, and it was shown that the difference in the composition of the diet affected not only the growth and silk production but the digestion and utilization of the diet.

According to the increase in the dietary soybean meal, the silk production increased, but the approximate digestibility decreased, indicating that the digestibility could not necessarily be a criterion of the efficiency of the diet. The efficiency of conversion of ingested and digested diet to growth and silk production, however, increased on the high-protein diet. The amount of the 10%-meal diet necessary for growth and silk production was about twice and 2.5 times as much as that of the 40%-meal diet, respectively. This indicates that the unfavorable dietary conditions reduce silk production more markedly than weight gain.

The digestion and utilization of nitrogen were also varied among the four diets (corrected for uric acid nitrogen). As might be expected, the amounts of nitrogen ingested and digested increased with the elevation of levels of dietary meal. The digestibility of nitrogen was far higher than the overall digestibility of diet, but among the four diets it was low especially in the 40%-meal diet in the 5th instar. Somewhat more nitrogen was needed for weight gain with the increase of the dietary meal, but there was rather small difference as to the efficiency for silk formation from digested nitrogen among the four diets used.

Excretion of uric acid increased according to the increase in the dietary meal, similar to the previous report.

The amount of the whole diet and nitrogen necessary for the unit weight increase was larger in the 5th instar than in the 4th instar.

Nitrogen economy in the utilization and efficiency of conversion of the artificial diet was discussed briefly.

REFERENCES

1) BROWN, H. (1945): J. Biol. Chem. **158**, 601-609.
2) HIRATSUKA, E. (1917): Bull. Seric. Exp. Sta. **2**, 353-413.
3) HORIE, Y., K. WATANABE, and E. SHINOHARA (1969): Sansi-Kenkyû No. 71, 1-4.
4) ITO, T., Y. HORIE, M. TANAKA, N. ARAI, and K. WATANABE (1962): J. Seric. Sci. Japan **31**, 73-80.
5) ITO, T. and F. MUKAIYAMA (1964): J. Insect Physiol. **10**, 789-796.
6) ITO, T. and F. MUKAIYAMA (1970): Sansi-Kenkyû No. 77, 76-81.
7) ITO, T. and M. TANAKA (1962): Bull. Seric. Exp. Sta. **18**, 1-34.
8) MUKAIYAMA, F. and T. ITO (1962): J. Seric. Sci. Japan **31**, 317-322.
9) MUKAIYAMA, F. and T. ITO (1962): J. Seric. Sci. Japan **31**, 398-406.
10) TAKEUCHI, Y., I. FUTATSUGI, Y. HORIUCHI, T. NISHITAI, Y. SHIMURA, S. TAKASE, and S. TANAKA (1960): Tech. Bull. Seric. Exp. Sta. No. 76, 1-24.
11) UEDA, S., R. KIMURA, and K. SUZUKI (1969): Bull. Seric. Exp. Sta. **23**, 255-293.
12) WALDBAUER, G.P. (1968): Adv. in Insect Physiol. **5**, 229-288.

摘　要

家蚕による人工飼料の消化と利用，特に飼料への大豆ミール添加量の多少と飼料効率との関係について

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大豆ミールと糖の添加量の異なる人工飼料4種類を用い，4齢期と5齢期の家蚕幼虫を飼育し，このような飼料組成の相違が幼虫の成長と繭質のみでなく，飼料の消化と利用に対し著しく影響することを明らかにした。

大豆ミール添加量の多い場合に繭糸生産量は増加したが飼料全体の消化率はむしろ低下した。これに関連し，組成の異なる飼料の効率は消化率で比較評価できない点に論及した。しかし単位生体重増加のためおよび一定量の繭層をうるために必要な食下量と消化量は大豆ミール添加量の多いほうが少なく，添加量40%の飼料に比し，10%飼料では体重増加のために約2倍，繭層のために約2.5倍を必要とした。すなわち飼料条件の不良は繭生産をより一層低下させたのである。

飼料中の窒素の消化と利用も飼料間で異なった（あらかじめ糞中の尿酸態窒素の値を補正)。大豆ミール添加量の多い飼料ほど，当然のことながら窒素の消化量は多かった。また窒素の消化率は飼料全体のそれに比べ著しく高かったが，飼料間ではその値に若干の相違がみられ，特に5齢期における大豆ミール40%飼料では低かった。単位生体重増加に必要な窒素の食下量と消化量は，概して大豆ミール添加量の高いほど多い傾向にあった。一定量の繭層をうるために必要な消化窒素量については，飼料間での差は特に著しくなかった。

幼虫の尿酸排泄量は，既報の成績と同様，大豆ミール添加量の多い場合に増加した。

単位生体重の増加に必要な食下量と消化量とは，飼料全体の場合も窒素の場合も，4齢期よりも5齢期において多くが必要であった。

人工飼料の利用と効率における窒素経済についても若干の考察を加えた。