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Varietal Differences in Nutritive Values of Mulberry Leaves for Rearing Silkworms

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Abstract

Varietal differences of nutritive values of mulberry leaves were examined with special emphasis placed on nitrogen and amino acid contents. In this connection, production efficiency of cocoon shell of silkworms, Bombyx mori L., was compared among several varieties both in the spring and late-autumn rearing seasons. In the spring season, Hikojiro was most excellent in terms of percentage of cocoon shell weight, digestibility and production efficiency of cocoon shell (PECS) in six domestic varieties under testing. In the late-autumn season, Shimanouchi showed the highest PECS. Among the introduced varieties, Kashmir 7, Kashmir 11, Pakistan 4, Pakistan 14 and Turkey 3 showed high PECS in spring, among which only three varieties, i.e. Kashmir 7, Kashmir 11 and Pakistan 4 indicated high PECS values in late-autumn. This result indicates that there are varietal differences in nutritive values of mulberry leaves. There were high correlations between PECS and nitrogen content of mulberry leaves, as well as between PECS and amino acid contents including methionine, histidine and threonine. The former two are restriction amino acids for the growth of silkworms, and the last amino acid is required for the synthesis of silk protein.

Discipline: Sericulture
Additional key words: food efficiency, leaf component, methionine, *Morus* spp., restriction amino acids

Introduction

Effective ways of increasing yield of cocoon per unit area of mulberry fields are, among others, to improve nutritive values of mulberry leaves as well as quantitative level of leaf yields. In evaluating nutritive values of mulberry leaves, some methods are available, including molting test[10], artificial diet method[1] and early mounting method[11].

Nutritional efficiency of the food ingested by silkworms is usually evaluated in terms of the proportion of cocoon shell weight to the amount of food ingested, i.e. production efficiency of cocoon shell (PECS). Extensive studies have been undertaken for many years since Hiratsuka's work[4], indicating that PECS is a final indicator for the evaluation of nutritive values of mulberry leaves, and that mulberry varieties with high PECS are generally rated high quality[5]. In fact, there are a considerable number of reports on PECS available with reference to mulberry varieties[2,8]. However, the factors relating to those varietal differences on nutritive values have to be fully identified yet.

The present paper attempts to review the results of the studies pertaining to the factors related to varietal differences of nutritive values of mulberry leaves, with special emphasis placed on PECS and its relationship with some nutritional components such as nitrogen and amino acid contents.

Mulberry varieties

Table 1 shows the mulberry varieties under the test, including domestic and introduced materials for rearing silkworms. Original sources of those varieties introduced from overseas are also presented.

Kashmir 7 and Kashmir 11 originated from the seeds collected in Kashmir, India in 1964, and Pakistan 4 and Pakistan 14 were from the seeds collected in Peshawar, Pakistan in 1969. Turkey 3 and Turkey 4 were supplied by the Sericultural Experiment Station of Turkey in 1973, and Debabi and Hazzaz were introduced from the Silk Department of Lebanon in 1970. All those materials introduced from overseas have been maintained at the Sericultural Experiment Station in Japan. All the names of those varieties, except Debabi and Hazzaz, were tentatively given by the Sericul. Exp. Sta., Japan, for the convenience of the experiment.

Table 1. Domestic and introduced mulberry varieties used for silkworm-rearing experiment

	Spring rearing season	Late-autumn rearing season
Domestic variety	Ichinose, Ohshimaso, Kairyoroso, Shimanouchi, Nakazawaso, Hikojiro	Ichinose Kairyoroso Shimanouchi
Introduced variety	Kashmir 7, Kashmir 11 Pakistan 4, Pakistan 14 Turkey 3, Turkey 4 Debabi, Hazzaz	Kashmir 7 Kashmir 11 Pakistan 4

Results of the silkworm-rearing experiment

Table 2 shows the results of the experiment in the spring rearing season. This table indicates that the feeding periods of the 5th larval stage are almost the same among the mulberry varieties tested. Among the domestic varieties, Nakazawaso and Hikojiro are greater in cocoon weight, cocoon shell weight, and percentage of cocoon shell weight. Among the introduced varieties, Kashmir 7, Kashmir 11 and Pakistan 4 are heavier in cocoon weight and cocoon shell weight than the domestic varieties.

Digestion percentages vary in the range of 36.8% in Hazzaz to 42.8% in Hikojiro. PECSs are generally high in the introduced varieties: i.e. 1.39 in Turkey 4 and 1.37 in Kashmir 7. Coefficients of variations of PECS are 7.8 and 6.7 per dry and fresh weight, respectively. The high PECSs are observed in Hikojiro among the domestic varieties, and in Kashmir 7, Kashmir 11, Pakistan 4, Pakistan 14 and Turkey 3 among the introduced varieties, with an exception of Hazzaz which shows a very low PECS.

Table 3 presents the experimental results obtained in the late-autumn rearing season. As compared

Table 2. Results of silkworm-rearing experiment in spring, 1984

Variety	Time of 5th larva (h)	Amount of food ingested (g)	Cocoon weight (g)	Cocoon shell weight (cg)	PCSW[a] (%)	Digestibility (%)	CEP[b] (DW)	PECS[c] (DW, %)	PECS[c] (FW, %)
Ichinose	143	25.0	3.14	66.3	21.1	39.8	1.24	10.4	2.65
Ohshimaso	148	23.4	3.08	65.2	21.1	40.5	1.20	10.3	2.79
Kairyoroso	144	25.0	3.11	67.4	21.6	39.6	1.23	10.6	2.70
Shimanouchi	141	23.7	3.16	66.3	20.9	41.9	1.31	11.5	2.80
Nakazawaso	145	24.0	3.24	70.0	21.7	41.1	1.33	11.9	2.92
Hikojiro	144	25.1	3.20	71.1	22.2	42.7	1.29	12.2	2.83
Kashmir 7	145	25.1	3.29	74.9	22.7	40.7	1.37	12.6	2.98
Kashmir 11	146	22.6	3.14	70.4	22.3	41.7	1.26	11.8	3.12
Pakistan 4	145	23.3	3.25	72.7	22.3	40.7	1.32	12.0	3.11
Pakistan 14	146	23.2	3.22	72.0	22.3	41.0	1.36	12.5	3.10
Turkey 3	146	23.3	3.33	70.5	21.1	41.0	1.35	11.7	3.02
Turkey 4	149	23.5	3.15	65.9	20.8	38.9	1.39	11.3	2.80
Debabi	151	26.2	3.05	68.8	22.4	37.0	1.30	10.8	2.63
Hazzaz	148	24.6	3.00	62.5	20.7	36.8	1.27	9.7	2.54
Mean	146	24.1	3.17	68.9	21.7	40.2	1.30	11.4	2.85
cv[d] (%)	1.8	4.2	2.9	5.0	3.2	4.2	4.4	7.8	6.7

a): PCSW; Percentage of cocoon shell weight,
b): CEP; Efficiency of cocoon production,
c): PECS; Production efficiency of cocoon shell,
d): cv; Coefficient of variation.

with the rearing results in the spring season, the feeding period for female silkworms is longer in the late-autumn rearing season, but the amount of food ingested is much less. The cocoon weight and cocoon shell weight are both lower in autumn, but the percentage of cocoon shell weight is slightly higher. The average digestion percentage in autumn was lower by 8.4% as compared with that in spring. Shimanouchi was the highest, reaching the level of 33.4%. The average PECS in dry weight in autumn was lower by 1.8%. Among the domestic varieties, Shimanouchi was of the highest PECS, while Kairyoroso was the lowest. All the introduced varieties were higher than Ichinose, which is the most popular variety in Japan. Especially, Kashmir 11 was 10% higher than Ichinose in fresh weight.

Regarding the nutritive values of mulberry varieties, it is generally recognized that Shimanouchi is high and Kairyoroso is low in quality[7]. This grading is supported by those results as described above. Attention should also be paid to the results that Hikojiro, Kashmir 7, Kashmir 11 and Pakistan 4 are superior to Shimanouchi in nutritive values.

Comparisons of the rearing results between male

Table 3. Results of silkworm-rearing experiment in late-autumn, 1984

Variety	Sex	Time of 5th larva (h)	Amount of food ingested (g)	Cocoon weight (g)	Cocoon shell weight (cg)	PCSW (%)	Digestibility (%)	CEP (DW)	PECS (DW, %)	PECS (FW, %)
Ichinose	♀	163	18.8	2.25	53.2	23.5	31.3	1.27	9.26	2.83
Kairyoroso	♀	174	20.1	2.09	50.1	23.9	28.7	1.29	8.86	2.49
Shimanouchi	♀	156	18.6	2.51	57.4	22.7	33.4	1.35	10.30	3.08
Kashmir 7	♀	164	19.5	2.48	58.1	23.3	33.1	1.25	9.67	2.98
Kashmir 11	♀	174	16.7	2.16	53.4	24.7	33.0	1.20	9.81	3.20
Pakistan 4	♀	167	17.8	2.29	54.4	23.6	31.1	1.36	9.67	3.05
Mean		166	18.5	2.30	54.4	23.6	31.8	1.29	9.60	2.94
cv (%)		4.1	6.6	7.4	5.4	2.8	5.6	4.7	5.1	8.5
Ichinose	♂	163	16.7	1.79	51.4	28.7	30.1	1.17	10.09	3.08
Kairyoroso	♂	167	18.3	1.79	46.5	25.9	29.3	1.19	9.04	2.54
Shimanouchi	♂	151	16.3	2.01	52.8	26.2	32.9	1.25	10.83	3.24
Kashmir 7	♂	162	17.1	2.03	54.5	26.8	32.0	1.20	10.34	3.19
Kashmir 11	♂	165	14.8	1.83	50.7	27.6	31.8	1.20	10.51	3.43
Pakistan 4	♂	166	16.0	1.92	52.2	27.2	33.4	1.14	10.36	3.27
Mean		162	16.4	1.90	51.4	27.1	31.6	1.19	10.20	3.13
cv (%)		3.6	7.1	5.7	5.3	3.8	5.0	3.1	6.0	9.9

PCSW, CEP, PECS and cv: Refer to Table 2.

Table 4. Correlation between PECS and other characteristics of silkworms

Characteristic	PECS					
	Spring rearing season		Late-autumn rearing season			
	(♀, FW)	(♀, DW)	(♀, FW)	(♀, DW)	(♂, FW)	(♂,DW)
Time of 5th larva	−0.18	−0.29	−0.29	−0.60	−0.30	−0.62
Amount of food digested	−0.69*	−0.28	−0.82*	−0.53	−0.91*	−0.77
Cocoon weight	0.75**	0.82**	0.47	0.73	0.43	0.63
Cocoon shell weight	0.76**	0.89**	0.64	0.79	0.75	0.83*
PCSW	0.51	0.66	0.03	−0.37	0.43	0.25
Digestibility	0.65*	0.69**	0.87*	0.88*	0.78	0.83*
PEC	0.45	0.67**	−0.09	0.21	0.08	0.32

*, ** Significant at 5 and 1%, respectively.

and female silkworms in the late-autumn rearing season showed that there was no significant difference in digestibility, but a slight difference in PECS. The mulberry varieties which showed high PECS for female silkworms had the same tendency for male silkworms. This result indicates that in estimating nutritive values of mulberry leaves, it is not always required to test them both in male and female silkworms.

PECS, which is generally used as an indicator of nutritional food efficiency for silkworms, consists of three components: digestibility (D), efficiency of cocoon production (ECP) and percentage of cocoon shell weight (PCSW)[9]. Taking these components into account, PECS is estimated with the following formula:

$$\begin{aligned} PECS &= CSW/AFI \\ &= AFD/AFI \times CW/AFD \times CSW/CW \\ &= D \times ECP \times PCSW, \end{aligned}$$

where CSW: cocoon shell weight; AFI: amount of food ingested; AFD: amount of food digested; and CW: cocoon weight.

Table 4 presents that PECS highly correlates with digestibility in both the spring and late-autumn rearing seasons. It shows however that PECS has a close correlation with ECP only in spring. No correlation was observed between PECS and PCSW in neither spring nor late-autumn. From these results, the main reason why PECS was lower by 1.8% in the late-autumn rearing season could be attributed to the reduction in digestibility. This suggests that in improving nutritional food efficiency for silkworm, it be important to increase the digestibility.

Relationship between PECS and contents of nitrogen and amino acids in mulberry leaves

Tables 5 and 6 show nitrogen and amino acid contents in mulberry leaves. Nitrogen contents varied in the range from 3.29% in Ohshimaso to 4.59% in Kashmir 7 in spring, and 3.84% in Kairyoroso to 4.32% in Shimanouchi in late-autumn. Fig. 1 shows correlations between nitrogen contents and PECS, indicating that the correlations are 0.91** and 0.90* in spring and late-autumn, respectively.

The major component of amino acids was glutamic acid, followed by aspartic acid, and leucin in this order. Amount of the total amino acid and each of its individual components increased with the increment of nitrogen contents. Varietal differences in each amino acid content were larger in spring than in late-autumn. However, no varietal difference was observed regarding the proportion of individual components of amino acids.

Table 7 shows correlations between each component of amino acids and PECS. Regarding the relationships of PECS in dry weight with methionine as well as with histidine, which are restriction amino acids in major amino acids for silkworms[1,3,6], there were high correlations with some exceptions: i.e. r = 0.80* (♀) and 0.94** (♂), respectively, in the spring rearing season; r = 0.56 (♀), r = 0.35 (♂), r = 0.98* (♀) and r = 0.90* (♂), respectively, in

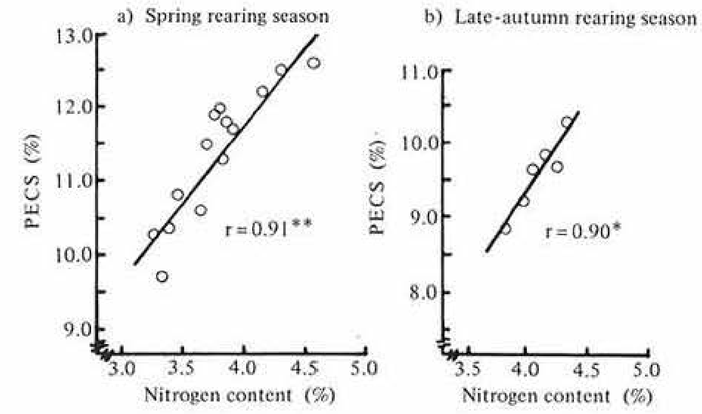

Fig. 1. Correlation between PECS and leaf nitrogen contents of mulberry varieties
*, ** Significant at 5 and 1%, respectively.

Table 5. Nitrogen and amino acid contents of mulberry leaves in the spring rearing season, 1984

Amino acid[a)]	Ichinose	Ohshimaso	Kairyoroso	Shimanouchi	Nakazawaso	Hikojiro
Asp	16.4 (9.0)	17.2 (8.9)	16.9 (9.2)	19.0 (9.1)	20.4 (9.5)	19.9 (9.1)
Thr	9.0 (5.1)	9.3 (4.9)	9.2 (5.0)	10.6 (5.1)	10.8 (5.1)	11.0 (5.0)
Ser	8.9 (5.0)	9.2 (4.8)	9.1 (4.9)	10.3 (4.9)	10.6 (4.9)	10.9 (5.0)
Glu	21.8(12.3)	21.9(11.4)	21.9(11.8)	25.9(12.4)	24.9(11.6)	26.7(12.2)
Pro	6.0 (3.4)	14.9 (7.8)	8.6 (4.7)	8.2 (4.0)	8.2 (3.8)	6.9 (3.2)
Gly	10.4 (5.9)	10.8 (5.6)	10.6 (5.7)	12.2 (5.9)	12.5 (5.9)	12.9 (5.9)
Ala	14.2 (8.0)	14.3 (7.4)	14.1 (7.6)	16.4 (7.9)	16.7 (7.8)	16.5 (7.5)
Val	11.2 (6.3)	11.7 (6.1)	11.6 (6.3)	13.2 (6.3)	13.6 (6.4)	14.0 (6.4)
Cys	1.4 (0.8)	1.2 (0.6)	1.4 (0.8)	1.5 (0.7)	1.6 (0.8)	1.5 (0.7)
Met	2.7 (1.5)	2.7 (1.4)	2.5 (1.3)	3.0 (1.4)	2.8 (1.3)	2.9 (1.3)
Ileu	9.0 (5.1)	9.3 (4.9)	9.3 (5.0)	10.6 (5.1)	10.8 (5.0)	11.0 (5.0)
Leu	16.7 (9.4)	17.2 (8.9)	17.1 (9.3)	19.6 (9.4)	20.0 (9.3)	20.4 (9.2)
Tyr	7.0 (3.9)	6.8 (3.5)	7.1 (3.8)	8.1 (3.9)	8.1 (3.8)	8.3 (3.8)
Phe	10.6 (6.0)	10.7 (5.6)	10.8 (5.9)	12.5 (6.0)	12.6 (5.9)	12.9 (5.9)
γ-ABA	2.4 (1.2)	2.3 (1.2)	3.5 (1.9)	2.0 (1.0)	3.9 (1.8)	4.6 (2.1)
NH_3	2.1 (1.2)	2.2 (1.2)	2.2 (1.2)	2.4 (1.2)	2.8 (1.3)	2.6 (1.2)
Lys	12.7 (7.2)	13.6 (7.1)	13.2 (7.2)	14.8 (7.1)	15.0 (7.0)	16.4 (7.5)
His	3.9 (2.2)	4.3 (2.3)	4.1 (2.2)	4.7 (2.2)	4.7 (2.2)	5.1 (2.3)
Arg	11.5 (6.4)	12.3 (6.4)	11.5 (6.2)	13.6 (6.5)	14.0 (6.5)	14.9 (6.8)
Total	178.7 (100)	192.0 (100)	184.6 (100)	208.5 (100)	214.0 (100)	219.4 (100)
Nitrogen[b)]	3.40	3.29	3.68	3.73	3.78	4.19

Amino acid[a)]	Kashmir 7	Kashmir 11	Pakistan 4	Pakistan 14	Turkey 3	Turkey 4	Debabi	Hazzaz	Mean	cv (%)
Asp	23.9 (9.6)	19.7 (9.0)	20.7 (9.1)	23.1(10.0)	20.9 (9.2)	19.2 (9.3)	16.3 (9.1)	16.6 (9.2)	19.3 (9.3)	12.6
Thr	12.1 (4.8)	10.8 (4.9)	11.1 (4.9)	11.7 (5.1)	11.0 (4.8)	10.5 (5.1)	8.8 (4.9)	9.0 (5.0)	10.4 (5.0)	10.5
Ser	11.8 (4.7)	10.5 (4.8)	11.1 (4.9)	11.3 (4.9)	10.9 (4.8)	10.3 (5.0)	8.9 (5.0)	9.0 (5.0)	10.2 (4.9)	9.8
Glu	29.1(11.7)	26.2(11.9)	26.2(11.6)	27.5(12.0)	25.9(11.4)	23.9(11.5)	20.6(11.6)	21.0(11.6)	24.5(11.8)	10.9
Pro	11.5 (4.6)	11.8 (5.3)	13.9 (6.2)	6.2 (2.7)	15.7 (6.9)	10.6 (5.1)	9.3 (5.2)	9.6 (5.3)	10.1 (4.8)	30.9
Gly	14.0 (5.6)	12.6 (5.7)	12.9 (5.7)	13.3 (5.8)	12.7 (5.6)	12.1 (5.8)	10.2 (5.7)	10.4 (5.8)	12.0 (5.8)	10.4
Ala	18.4 (7.4)	16.8 (7.6)	16.9 (7.5)	18.3 (8.0)	16.9 (7.4)	16.4 (7.9)	13.3 (7.4)	13.5 (7.5)	15.9 (7.6)	10.7
Val	15.0 (6.0)	13.6 (6.2)	13.9 (6.1)	14.5 (6.3)	13.8 (6.1)	13.0 (6.2)	11.1 (6.2)	11.0 (6.1)	12.9 (6.2)	10.5
Cys	1.9 (0.7)	1.5 (0.7)	1.6 (0.7)	1.7 (0.7)	1.6 (0.7)	1.5 (0.7)	1.3 (0.7)	1.3 (0.7)	1.5 (0.7)	12.0
Met	3.4 (1.4)	3.1 (1.4)	3.3 (1.5)	3.2 (1.4)	2.8 (1.2)	2.3 (1.1)	2.4 (1.3)	2.2 (1.2)	2.8 (1.3)	13.2
Ileu	12.0 (4.8)	10.8 (4.9)	11.1 (4.9)	11.5 (5.0)	10.9 (4.8)	10.3 (5.0)	8.8 (5.0)	9.0 (5.0)	10.3 (4.9)	10.1
Leu	22.3 (8.9)	20.2 (9.2)	20.6 (9.1)	21.3 (9.3)	20.4 (8.9)	19.4 (9.4)	16.3 (9.1)	16.8 (9.2)	19.2 (9.2)	10.2
Tyr	9.3 (3.7)	8.2 (3.7)	8.5 (3.8)	8.6 (3.8)	8.2 (3.6)	7.5 (3.6)	6.7 (3.7)	6.7 (3.7)	7.8 (3.7)	10.5
Phe	14.2 (5.7)	13.0 (5.9)	13.0 (5.8)	13.7 (6.0)	12.9 (5.7)	12.4 (6.1)	10.4 (5.8)	10.7 (5.9)	12.2 (5.9)	10.5
γ-ABA	3.5 (1.4)	3.4 (1.5)	3.4 (1.5)	3.4 (1.5)	4.2 (1.9)	3.3 (1.6)	3.4 (1.9)	3.6 (2.0)	3.4 (1.6)	23.6
NH_3	3.2 (1.3)	2.6 (1.2)	2.8 (1.2)	3.1 (1.4)	2.9 (1.3)	2.7 (1.3)	2.2 (1.2)	2.2 (1.2)	2.6 (1.2)	14.1
Lys	17.9 (7.2)	15.9 (7.2)	15.8 (7.0)	16.9 (7.3)	16.0 (7.0)	14.5 (7.0)	13.0 (7.3)	13.0 (7.2)	14.9 (7.1)	11.0
His	5.4 (2.2)	4.9 (2.2)	5.0 (2.2)	5.3 (2.3)	5.0 (2.2)	4.7 (2.3)	4.1 (2.3)	4.0 (2.2)	4.7 (2.3)	10.7
Arg	20.7 (8.3)	14.4 (6.5)	14.3 (6.3)	15.4 (6.7)	14.6 (6.4)	12.9 (6.2)	11.5 (6.4)	11.4 (6.3)	13.8 (6.6)	17.7
Total	249.5 (100)	220.1 (100)	226.3 (100)	229.8 (100)	227.5 (100)	207.4 (100)	178.5 (100)	181.2 (100)	208.5 (100)	10.7
Nitrogen[b)]	4.59	3.88	3.83	4.33	3.92	3.85	3.33	3.47	3.81	9.9

a): mg/g DW, b): %/dry matter, ( ): Ratio.

Table 6. Nitrogen and amino acid contents of mulberry leaves in the late-autumn rearing season, 1984

Amino acid[a)]	Ichinose	Kairyoroso	Shimanouchi	Kashmir 7	Kashmir 11	Pakistan 4	Mean	cv(%)
Asp	20.9(10.0)	21.2(10.1)	22.2 (9.7)	21.5 (9.9)	21.2 (9.7)	23.1(10.2)	21.6 (9.9)	3.8
Thr	10.7 (5.1)	10.8 (5.1)	11.6 (5.0)	11.1 (5.1)	11.4 (5.2)	11.5 (5.1)	11.1 (5.1)	3.4
Ser	10.4 (4.9)	10.4 (4.9)	11.0 (4.7)	10.5 (4.8)	10.8 (4.9)	11.2 (4.9)	10.7 (4.9)	3.1
Glu	25.0(12.0)	24.2(11.6)	28.1(12.3)	25.9(12.0)	27.0(12.3)	26.4(11.7)	26.1(12.0)	5.4
Pro	8.2 (3.9)	6.5 (3.1)	10.4 (4.5)	6.6 (3.0)	3.3 (1.5)	7.8 (3.4)	7.2 (3.3)	33.0
Gly	13.5 (6.5)	13.4 (6.4)	14.7 (6.4)	14.2 (6.5)	14.9 (6.8)	14.5 (6.4)	14.2 (6.5)	4.4
Ala	13.8 (6.5)	14.0 (6.7)	15.8 (6.9)	14.5 (6.7)	15.3 (7.0)	15.8 (7.0)	14.9 (6.9)	6.0
Val	12.6 (6.0)	12.8 (6.1)	13.8 (6.0)	13.4 (6.2)	13.5 (6.1)	13.7 (6.1)	13.3 (6.1)	3.7
Cys	2.1 (1.0)	1.7 (0.8)	1.7 (0.7)	1.9 (0.8)	2.0 (0.9)	2.0 (0.9)	1.9 (0.9)	8.8
Met	2.1 (1.0)	2.6 (1.2)	2.8 (1.2)	2.7 (1.2)	2.9 (1.3)	2.7 (1.2)	2.6 (1.2)	10.6
Ileu	10.0 (4.7)	10.2 (4.8)	10.8 (4.7)	10.3 (4.7)	10.8 (4.9)	10.7 (4.7)	10.5 (4.8)	3.3
Leu	18.5 (8.8)	18.8 (8.9)	20.5 (8.9)	19.4 (8.9)	20.0 (9.1)	19.9 (8.8)	19.5 (9.0)	3.9
Tyr	7.9 (3.8)	8.2 (3.9)	8.9 (3.9)	8.5 (3.9)	8.9 (4.0)	8.5 (3.8)	8.5 (3.9)	4.6
Phe	12.6 (6.0)	13.1 (6.2)	14.0 (6.1)	13.3 (6.1)	14.1 (6.4)	13.5 (6.0)	13.4 (6.2)	4.2
γ-ABA	2.3 (1.0)	3.2 (1.5)	1.7 (0.7)	2.8 (1.2)	2.5 (1.1)	3.2 (1.4)	2.6 (1.2)	22.1
NH_3	2.6 (1.2)	2.9 (1.4)	2.6 (1.1)	2.7 (1.2)	2.6 (1.1)	2.9 (1.2)	2.7 (1.2)	5.4
Lys	17.3 (8.3)	16.8 (8.0)	18.2 (7.9)	17.6 (8.1)	17.9 (8.2)	17.6 (7.8)	17.6 (8.1)	2.8
His	4.7 (2.2)	4.6 (2.2)	5.2 (2.2)	5.0 (2.3)	5.0 (2.3)	5.0 (2.2)	4.9 (2.3)	4.5
Arg	12.9 (6.1)	13.2 (6.3)	14.3 (6.2)	13.8 (6.4)	13.9 (6.3)	14.5 (6.4)	13.8 (6.4)	4.5
Total	208.1 (100)	208.7 (100)	215.6 (100)	215.6 (100)	217.9 (100)	224.5 (100)	217.2 (100)	2.8
Nitrogen[b)]	3.98	3.84	4.32	4.06	4.16	4.29	4.10	4.5

a), b): Refer to Table 5.

Table 7. Correlations between amino acid contents in mulberry leaves and PECS of silkworms

Amino acid	PECS					
	Spring rearing season		Late-autumn rearing season			
	(♀, FW)	(♀, DW)	(♀, FW)	(♀, DW)	(♂, FW)	(♂, DW)
Asp	0.82**	0.92**	0.39	0.48	0.33	0.40
Thr	0.83**	0.94**	0.79	0.87*	0.69	0.75
Ser	0.83**	0.95**	0.67	0.70	0.60	0.63
Glu	0.81**	0.94**	0.86*	0.98**	0.79	0.90*
Pro	0.37	-0.01	-0.11	0.28	-0.11	0.21
Gly	0.83**	0.95**	0.92**	0.88*	0.84*	0.82*
Ala	0.85**	0.93**	0.75	0.82*	0.66	0.71
Val	0.84**	0.96**	0.77	0.86*	0.67	0.74
Cys	0.70**	0.87**	0.37	-0.08	0.50	0.25
Met	0.81**	0.80**	0.50	0.56	0.37	0.35
Ileu	0.83**	0.95**	0.75	0.78	0.64	0.65
Leu	0.83**	0.94**	0.77	0.90*	0.66	0.75
Tyr	0.81**	0.95**	0.73	0.82*	0.61	0.65
Phe	0.83**	0.94**	0.70	0.77	0.58	0.59
γ-ABA	0.43	0.63*	-0.43	-0.66	-0.42	-0.64
NH_3	0.80**	0.89**	-0.52	-0.53	-0.55	-0.62
Lys	0.81**	0.93**	0.91**	0.99**	0.86*	0.96**
His	0.83**	0.94**	0.86*	0.98*	0.79	0.90*
Arg	0.64*	0.82**	0.70	0.77	0.61	0.66
Total	0.85**	0.92**	0.72	0.58	0.68	0.58

*, ** Significant at 5 and 1%, respectively.

the late-autumn season. The correlations of PECS with threonine, which is used a lot for the synthesis of silk protein, were also high: i.e. r = 0.94** (♀) in spring, and r = 0.87* (♀) and r = 0.75 (♂) in late-autumn. Table 7 indicates that there are rather high correlations between PECS and other components of amino acids, such as glutamic acid, glycine and lysine.

From the above results, it may be concluded that mulberry varieties containing higher contents of nitrogen in leaves have higher PECS. This indicates that nutritive values of mulberry leaves depend on nitrogen contents in general, and on amount of amino acids in particular. In breeding programs of mulberry varieties, it is recommended therefore that high contents of nitrogen in leaves be adequately taken into account in selecting materials nutritive for silkworms. As a matter of fact, it was reported that among the 119 mulberry varieties tested, several materials contain very high contents of both nitrogen and amino acids in their leaves[6].

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