Varietal Differences in Crude Protein, and Free and Hydrolyzed Amino Acid Compositions of Sweetpotato Roots

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Crude protein content, and free and hydrolyzed amino acid compositions of whole root flour of sweetpotato cultivars that included lines lacking β -amylase were investigated in 1990 and 1991. A statistic varietal difference in crude protein content was detected ; however, the order of the rank was largely different between the two years. The amino acid composition of whole root flour was similar among the cultivars and their profile was almost the same as in previous reports, although the aspartic acid content varied most greatly among the cultivars. The most predominant free amino acid was always asparagine in every cultivar, whereas the total free amino acid content largely varied among the cultivars. There was a large varietal difference in free asparagine content, which was quite altered between 1990 and 1991. However, the correlation coefficients between free asparagine content and hydrolyzed aspartic acid content in both years were above 0.9. Thus, most of the variabilities in aspartic acid contents among cultivars were the results of the variations in free asparagine content.

Sweetpotato is generally regarded as a high-carbohydrate, low-protein food compared with cereals. However, some genotypes of sweetpotatoes have a protein content as high as 8-9% on a dry weight basis¹⁾, which is almost comparable to that of cereals. Moreover, the nutritional value of the sweetpotato protein has been reported to be excellent¹⁾²⁾ based on the amino acid composition.

Varietal differences in crude protein contents have been reported to be 1.3-10% (dry weight basis) by WALTER *et al.*³⁾. On a fresh weight basis, the total protein of six American cultivars grown under identical conditions and analyzed immediately after harvest ranged from 1.36-2.13%⁴⁾. Variations in total protein contents within cultivars have also been studied by several groups. One group⁵⁾ found that the variation was slightly less, and another⁶⁾ found that it was as great among roots from the same plant as between plants. High field-to-field and location variabilities have

also been noted for cultivars⁵⁾. The varietal differences in the amino acid composition were also extensively studied by some researchers¹⁾³⁾⁶⁾⁷⁾.

However, there have been only a few reports on the protein contents and the amino acid compositions of Japanese cultivars²⁾⁸⁾. The data may not be sufficient to be reported at present because the data have been obtained from only one or two old cultivars. Moreover, a new cultivar lacking β -amylase was recently released for processing purpose⁹⁾, but the amino acid composition of this new cultivar has not been clarified yet. Thus, including the lines lacking β -amylase, analysis of the proteins and amino acids of greater numbers of sweetpotato cultivars of Japan is greatly needed.

On the other hand, PURCELL and WALTER¹⁰⁾ reported the composition of non-protein nitrogen using the Jewel cultivar after 107 days of storage. PURCELL *et al.*¹¹⁾ also reported that

amino acid composition varied significantly between the "syrup" fraction and the "protein" fraction. However, the free amino acid composition immediately after harvest has not been reported, and the varietal differences in that is still not evident. More studies on the differences in free amino acid contents of sweetpotatoes among varieties should be carried out.

In the present study, we investigated the varietal differences in crude protein content, free amino acid content and amino acid composition of sweetpotato roots to shed more light on the protein content and the amino acid composition of sweetpotato cultivars. The materials used in this study consisted mainly of Japanese cultivars including the lines lacking β -amylase.

Materials and Methods

Samples

All sweetpotato roots used in this study were grown in a field at Nishigoshi, Kumamoto, Japan. Immediately after harvest, each root was freeze-dried and milled until it passed through a 500 μ m sieve. All samples were stored at -30°C until analysis. Each datum was estimated by at least duplicate measurements.

Nitrogen analysis

The nitrogen content of the flour samples was determined by the macro-Kjeldahl method with least two replicate analyses. Protein content was calculated to be $\text{N} \times 6.25$. In 1990, the flour samples derived from three roots per each line were mixed and analyzed to assess the range in varietal difference. To investigate the variability within cultivars, nitrogen content was separately determined on three roots per each line using several representative Japanese cultivars in 1990 and 1991.

Amino acid analysis

Hydrolyzed and free amino acids were analyzed using the flour samples mixed from three roots in both years. In addition, samples oxidized with performic acid were also hydrolyzed for the determination of sulfur amino acids in the first year. In the determi-

Table 1 Crude protein contents of 46 sweetpotato cultivars in 1990

Cultivar name	Crude protein (%, dry basis)
Tsurusengan	9.22
Beniwase	7.06
Kyukei 114	6.84
Bougainville	6.84
Benihayato	6.75
Iigou	6.73
Norin 2	6.68
Kyukei 123	6.45
Kyushu 105	6.13
Unit 1 Port Rico	5.97
Ariakeimo	5.89
Gifu 1	5.85
Kenroku	5.81
Georgia Jet	5.73
Kyushu 91	5.58
Chicago	5.58
Shiroyutaka	5.45
Chugoku 25	5.45
Kyushu 104	5.40
Kyusyu 89	5.32
Kyushu 97	5.29
Yellow Butter	5.28
Beniotome	5.24
Satsumahikari	5.20
Kyukei 124	5.19
Okinawa 105	4.99
Tainong 16	4.86
Shirosatsuma	4.83
Chugoku 37	4.71
Kyushu 106	4.66
Kyushu 101	4.65
Oiransaitama 1	4.56
Benikomachi	4.52
Yoshida	4.49
Beniazuma	4.47
Philippine	4.47
Beniaka	4.44
Tinian	4.39
Koganesengan	4.32
Kyushu 95	4.30
Tachikagoshima	4.29
Kokei 14	4.27
Murasakibaru 2	4.06
Chushi 3	3.88
Toukai 5	3.79
Murasakibaru 3	2.89

Crude protein : Kjeldahl $\text{N} \times 6.25$.

1.5 g of whole root flour was used for analysis.

nation of hydrolyzed amino acid content, 100 mg of flour sample (for sulfur amino acids, samples oxidized by performic acid were used) was hydrolyzed with 6N-HCl containing 0.02% 2-mercaptoethanol at 110°C under vacuo for 24 h. Each hydrolyzed sample was filtered and filled to constant volume. An aliquot of the filtrate was evaporated and redissolved with sodium citrate buffer (pH 2.2). Free amino acids were extracted with 80% ethanol and filtered. An aliquot of the filtrate was evaporated and redissolved with lithium citrate buffer (pH 2.2). The following procedures were performed on HPLC as directed by the manufacturer. Identification of each HPLC peak was based on the retention times using authentic standards.

Results and Discussion

The crude protein contents of 46 lines are listed in Table 1. The protein content of the various lines ranged from 2.89 to 9.22%. Most

lines contained between 4–7% protein, which was almost the same as the range reported by PURCELL *et al.*¹⁾ The variability range of the protein content of the Japanese cultivars was not different from those of other regions. Three lines lacking β -amylase, Satsumahikari, Kyushu 89 and Chugoku 37, did not show a specific character in their crude protein content.

Fig. 1 Scattergram of crude protein contents between 1990 and 1991

Table 2 Within cultivar differences of crude protein contents of several sweetpotato cultivars in 1990 and 1991

Cultivar name	Crude protein content	
	1990	1991
Norin 2	6.68±0.768 (11.5)	4.34±0.746 (17.2)
Beniwase	7.06±1.25 (17.7)	N.D.
Koganesengan	4.32±0.359 (8.3)	4.19±1.37 (32.7)
Tsurusengan	9.22±1.36 (14.7)	4.61±0.636 (13.8)
Benihayato	6.75±0.500 (7.4)	4.89±0.738 (15.1)
Shiroyutaka	N.D.	5.26±0.362 (6.9)
Satsumahikari	5.20±0.718 (13.8)	5.38±0.872 (16.2)
Kyushu 89	5.32±0.473 (8.9)	4.55±0.783 (17.2)
Beniotome	N.D.	6.90±0.987 (14.3)
Kyukei 114	6.84±1.15 (16.8)	N.D.
Kokei 14	4.27±0.418 (9.8)	5.22±0.840 (16.1)
Murasakibaru 3	2.89±0.364 (12.6)	N.D.
Tachikagoshima	N.D.	3.46±0.100 (2.9)
Yellow butter	N.D.	3.67±0.829 (22.6)
Bougainville	6.84±2.38 (34.8)	5.48±1.69 (30.9)
Georgia Jet	5.73±0.269 (4.7)	5.46±0.895 (16.4)
Kyushu 108	N.D.	3.61±0.881 (24.4)

Crude protein content : %, (dry weight basis) ±SD (coefficient of variance).
N.D. : Not determined.

The coefficient of variance (CV) of the protein content among roots within each cultivar ranged from 4.7% to 34.8% in 1990 and from 2.94% to 32.7% in 1991 (Table 2). The variability was almost the same as that found by other researchers^{5,6)}. A statistic varietal difference was detected in both years ; however, the order of the rank in the crude protein content was greatly different between 1990 and 1991 (Fig. 1).

The correlation coefficient of crude protein contents between 1990 and 1991 was 0.083. BRADBURY *et al.*⁶⁾ also showed that year-to-year correlation of crude protein content was not significant ($r=0.393$, calculated by present authors using the data of Upper Mendi). Compared with the correlation of free sugar content between the two years¹²⁾, the correlation of crude protein content was obviously

Table 3 Amino acid contents of 8 sweetpotato cultivars in 1990 and 1991

	Kogane-sengan	Tsuru-sengan	Beni-hayato	Shiroyu-taka	Satsuma-hikari	Kyushu 89	Benio-tome	Kokei 14	Mean	C.V.
1990										
Alanine	281	273	286	246	273	297	258	274	274	6.0
Arginine	282	278	289	252	243	280	224	260	264	8.9
Aspartic acid	998	1 762	1 226	1 026	1 521	1 014	1 025	1 167	1 217	24.0
Glutamic acid	619	556	617	550	582	679	501	671	597	10.7
Glycine	263	254	266	248	234	272	247	248	254	5.0
Histidine	142	140	167	139	149	140	139	173	149	9.5
Proline	218	217	226	302	205	320	310	211	251	20.6
Serine	325	332	325	269	293	364	270	294	309	11.1
Threonine	295	305	303	265	273	343	265	303	294	9.2
Valine	388	437	415	353	363	437	357	363	389	9.6
Isoleucine	268	265	273	238	253	300	245	253	262	7.7
Leucine	392	365	400	330	352	396	343	374	369	7.3
Lysine	316	296	320	275	269	316	265	303	295	7.9
Total sulfur	191	216	229	185	163	189	220	200	199	11.3
Total aroma	547	589	585	612	543	593	574	498	568	6.6
1991										
Alanine	255	267	258	250	251	239	263	270	257	4.1
Arginine	218	264	278	262	243	236	262	228	249	8.6
Aspartic acid	853	884	804	997	1 241	653	1 351	1 444	1 028	28.7
Glutamic acid	576	473	465	569	488	437	548	620	522	12.9
Glycine	233	256	262	255	249	262	253	250	253	3.8
Histidine	183	159	160	160	152	140	146	169	159	8.8
Proline	209	229	298	271	336	324	238	195	263	20.9
Serine	286	307	266	284	274	276	298	291	285	4.9
Threonine	268	288	260	278	273	258	288	295	276	5.1
Valine	353	378	353	363	357	353	372	366	362	2.7
Isoleucine	248	250	255	250	253	243	260	270	253	3.5
Leucine	365	365	370	356	352	321	378	422	366	8.0
Lysine	286	252	292	323	252	258	289	275	278	9.1
Total sulfur										
Total aroma	547	578	536	585	547	536	589	581	562	4.2

All figures were calculated as mg of amino acid/g of N. CV : Coefficient of variance.

weak. Thus, these results show the unstable nature of the crude protein content of sweetpotato roots.

In the hydrolyzed amino acid analysis, the aspartic acid contents mostly varied among cultivars (Table 3). The far right column shows the mean and CV of eight cultivars. The CV of the aspartic acid content was largest among the amino acids; that indicates more variability in aspartic acid than in other amino acids. Furthermore, the profile of the varietal difference in aspartic acid content was different between the two years, i.e., Tsurusengan and Satsumahikari were high in the first year, and Satsumahikari, Beniotome and Kokei14 were high in the second year. The CV of the proline content was second largest in both years; however, this resulted from the low sensitivity of OPA-proline in the determination. The other amino acid contents of whole flour of each cultivar were almost similar because the CV of each amino acid was relatively small.

Generally, the storage root of sweetpotato has two kinds of predominant protein,

sporamin and β -amylase. Sporamin comprises 60–80% of the total proteins and β -amylase ca. 5%¹³⁾¹⁴⁾. Considering this protein composition of sweetpotato root, the lines lacking β -amylase were expected to have different amino acid composition. In this experiment, however, there was no large difference in amino acid composition among the Japanese cultivars including the lines lacking β -amylase, compared with the data obtained from U.S. cultivars¹⁾¹⁵⁾ and from Papua New Guinea cultivars⁶⁾⁷⁾.

Amino acid scores are shown in Table 4. Many authors have previously assessed the quality of sweetpotato protein by comparing it with a hypothetical reference protein (FAO/WHO, 1973). WALTER *et al.*³⁾ reported that total sulfur was always limiting, and leucine and lysine were limiting in most whole flour samples of sweetpotato cultivars. NAGASE²⁾ reported no limiting amino acids for the protein isolated from an unnamed Japanese cultivar. TAIRA and TAIRA⁸⁾ reported a varietal difference in the tyrosine and arginine content of hydrolyzed whole root flour. In the present

Table 4 Amino acid scores of 8 sweetpotato cultivars in 1990 and 1991

	Kogane-sengan	Tsurusengan	Beni-hayato	Shiro-yutaka	Satsuma-hikari	Kyushu 89	Beniotome	Kokei 14
1990								
Threonine	1.18	1.22	1.21	1.06	1.09	1.37	1.06	1.21
Valine	1.25	1.41	1.34	1.14	1.17	1.41	1.15	1.17
Isoleucine	1.07	1.06	1.09	0.95	1.01	1.20	0.98	1.01
Leucine	0.89	0.83	0.91	0.75	0.80	0.90	0.78	0.85
Lysine	0.93	0.87	0.94	0.81	0.79	0.93	0.78	0.89
Total sulfur	0.87	0.98	1.04	0.84	0.74	0.86	1.00	0.91
Total aroma	1.44	1.55	1.54	1.61	1.43	1.56	1.51	1.31
1991								
Threonine	1.07	1.15	1.04	1.11	1.09	1.03	1.15	1.18
Valine	1.14	1.22	1.14	1.17	1.15	1.14	1.20	1.18
Isoleucine	0.99	1.00	1.02	1.00	1.01	0.97	1.04	1.08
Leucine	0.83	0.83	0.84	0.81	0.80	0.73	0.86	0.96
Lysine	0.84	0.74	0.86	0.95	0.74	0.76	0.85	0.81
Total sulfur								
Total aroma	1.44	1.52	1.41	1.54	1.44	1.41	1.55	1.53

All figures were calculated by comparing them with a hypothetical reference protein (FAO/WHO, 1973).

study, leucine and lysine were always limited ; however, total sulfur amino acids of two cultivars (Benihayato and Beniotome) were not limited in 1990. Especially, Benihayato also showed a relatively good amino acid composition (the limiting amino acid was leucine ; 84%) in 1991, although sulfur amino acids were not determined. Considering the high β -carotene content of Benihayato¹⁶⁾, this cultivar is thought to be a useful cultivar based on nutritional aspects.

Table 5 shows the free amino acid content of each cultivar. Asparagine, aspartic acid and glutamic acid were predominant, and other amino acid contents were similar and less than 2 $\mu\text{mol/g}$ (dry weight basis; data are not shown) in all the cultivars. The most predominant free amino acid was always asparagine in every cultivar, whereas the total free amino acid content varied greatly among the cultivars. The increase in total free amino acid content depended greatly on the increase in free asparagine content. This corresponds well to the report by PURCELL and WALTER¹⁰⁾ that free asparagine was the largest constituent of the free amino acids in the sweetpotato roots. In the present study, we show the varietal difference in free asparagine content ; however, the profile of its varietal difference was very much changed between 1990 and 1991, i.e., Tsurusengan and Satsumahikari were high in 1990, and Satsumahikari, Beniotome and Kokei14 were high in 1991. Interestingly, this varietal difference was almost the same as

Fig. 2 Scattergrams of free asparagine content and hydrolyzed aspartic acid content in 1990 and 1991

Table 5 Free amino acid contents of 8 sweetpotato cultivars in 1990 and 1991

	Kogane-sengan	Tsuru-sengan	Beni-hayato	Shiro-yutaka	Satsuma-hikari	Kyushu 89	Beni-otome	Kokei 14
1990								
Asparagine	5.5	29.8	9.9	4.4	25.8	7.4	10.5	15.1
Aspartic acid	3.4	3.9	5.2	3.1	2.5	3.3	2.8	4.6
Glutamic acid	2.9	3.3	4.9	4.8	3.4	3.6	2.2	4.4
1991								
Asparagine	4.6	3.9	6.2	12.1	32.0	5.0	25.0	28.0
Aspartic acid	4.0	3.9	5.0	5.5	4.8	2.3	4.3	6.7
Glutamic acid	3.6	0.8	2.6	7.8	2.8	3.5	6.3	6.5

All figures were calculated as $\mu\text{mol/g}$ on a dry weight basis.

that of hydrolyzed aspartic acid content. Fig. 2 shows the scattergrams of free asparagine content and hydrolyzed aspartic acid content in both years. The correlation coefficients were 0.957 in 1990 and 0.915 in 1991. Thus, it is revealed that the largest variability in aspartic acid content among cultivars was the result of the variability in free asparagine content.

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サツマイモの粗蛋白含量および遊離・加水分解 アミノ酸組成の品種間差異

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サツマイモ塊根の粗蛋白含量および遊離・加水分解アミノ酸組成の品種間差異を2か年にわたり調査した。材料として近年育成されたβ-アミラーゼ欠損系統も含めた。粗蛋白含量については単一の年度内では品種間差が認められたが、年次間の傾向は大きく異なり不安定であった。加水分解アミノ酸の組成においてはアスパラギン酸含量の品種間差が大きく、その年次間の傾向は大きく異なった。その他のアミノ酸については品種間でほぼ同様であり、年次間比較でも組成としての大差はなかった。すなわち、β-アミラーゼ欠損系統も含めて、塊根の粗蛋白含量・アミノ酸組成には、年次間で安定した大きな品種間差は無かった。遊離アミノ酸についてはほとんどの品種でアスパラギンが最も多く含まれ大きな品種・年次間差が認められたが、この傾向は加水分解アミノ酸の組成におけるアスパラギン酸含量の品種・年次間差とよく一致した。