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Biological Quality and Composition of Sweet Potato Protein Fractions

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The protein from "Jewel" and "Centennial" cultivar sweet potatoes was separated into a white protein fraction (WP) and a chromoplast protein fraction (CP). the fractions from each cultivar were purified by solvent extraction with ethanol, hexane–acetone (1:1), and ethyl ether, respectively. The protein content (Kjeldahl nitrogen × 6.25) of the fractions was as follows: "Jewel" WP, 98.1%; "Centennial" WP, 93.1%; "Jewel" CP, 70%; "Centennial" CP, 77.5%. As a result of the preparation procedure, both CP fractions had elevated ash, calcium, and iron levels. The purified protein fractions were incorporated into diets, and the protein efficiency ratio (PER) values were determined by using ANRC reference casein as the control protein. The test animals were weanling male Sprague–Dawley rats. It was found that the PER values from both CP and WP from "Jewel" and "Centennial" were equal to the ANRC reference casein PER value.

Sweet potato cultivars contain from 2.24 to 0.49% crude protein ($N \times 6.25$) on a fresh weight basis (Purcell et al., 1972). This represents from 9.14 to 1.73% of the dry solids of the roots. This large degree of variability has been attributed to genetic and environmental factors (Purcell et al., 1972, 1978a; Constantin et al., 1974). The two cultivars, "Jewel" and "Centennial", which make up more than 90% of plantings in the United States average 1.5% crude protein (fresh weight basis). At the present yield level of 10082 kg/ha (USDA, 1977), a hectare produces 185 kg of protein.

Sweet potatoes are a likely source of carbohydrate in the domestic production of ethyl alcohol by microbial fermentation. Such a process would lead to highly concentrated sweet potato protein which would be available for incorporation into human food. Sweet potatoes are consumed in large quantities in parts of Asia and, thus, are an important source of dietary protein. Amino acid analyses have shown that sweet potato protein is of good quality (Nagase, 1957; Purcell et al., 1972). No data are available concerning the nutritional quality of isolated sweet potato protein concentrates and isolates as determined by rat bioassays.

The purpose of this study was to prepare protein concentrates and isolates from "Jewel" and "Centennial" sweet potatoes and to measure the capacity of the protein fractions to support the growth of weanling rats.

MATERIALS AND METHODS

Protein Fractions. The protein concentrates and isolates from "Jewel" and "Centennial" sweet potatoes were prepared as previously described (Purcell et al., 1978b) but with some modification. Sweet potato proteins were fractionated according to solubility in a heated $CaCl_2$ solution (0.1%). Chromoplast protein precipitated at 65 °C and "white" protein precipitated at 90 °C (Figure 1).

Nitrogen Analysis. The nitrogen content of each diet and each fraction was determined by the macro-Kjeldahl method with copper and selenium catalysts. Protein was calculated as $N \times 6.25$.

Amino Acid Analysis. Samples of the protein fractions and casein were acid hydrolyzed and the amino acid content was measured by ion-exchange chromatography on a Durrum Model D-500 with a 1.75 mm × 48 cm column packed with Durrum high-resolution cation-exchange resin (Miller and Young, 1977). Tryptophan content was measured on a basic hydrolysate of the sample by the manual method of Amaya et al. (1977).

Mineral Analysis. The elemental composition of the protein fraction was performed by the Agronomic Division of the North Carolina Department of Agriculture. The samples were dry ashed and dissolved in nitric acid, and suitable aliquots were taken for the analysis. Phosphorus was measured by the colorimetric ammonium molybdate procedure; potassium and sodium were measured by flame emission spectrometry; calcium, magnesium, iron, manganese, zinc, and copper were measured by atomic absorption spectrometry.

Diets. The diets were prepared as described by the Association of Official Analytical Chemists (1975) for measurement of the protein efficiency ratio (PER). Vitamin and salt mixtures were formulated in our laboratory. The feeding study was conducted in two parts. For the first part, white protein from "Jewel" and "Centennial" were the test proteins and ANRC reference casein (United States Biochemicals, Cleveland, OH) served as the control protein. In addition, a fourth diet containing no protein was prepared so that the net protein ratio (NPR; Bender and Doell, 1957) could be evaulated. In the second part of this study, chromoplast protein from both cultivars was compared to the ANRC reference protein.

Feeding Studies. Weanling male Sprague–Dawley rats (Camm Laboratories, Wayne, NJ) were fed stock diet and water for 5 days and then placed in dietary groups whose initial mean weights varied by less than 1%. The standard deviation of the means was less than 5%. The animals were housed individually in stainless steel cages with mesh floors and were maintained on an altenating 12-h light/12-h dark schedule in a 22 °C environment. Food and water were provided ad libitum. Food consumption and weight changes were measured 3 times weekly. Groups fed protein and control casein diets containing 1.6% nitrogen consisted of 10 rats each, and the group that was fed on the no-protein diet contained 15 rats.

Statistical Analyses. Means and standard deviations for each diet group were calculated from weight changes and food consumption.

RESULTS AND DISCUSSION

The procedure used to obtain sweet potato protein fractions (Figure 1) worked well with both "Jewel" and "Centennial" roots. Our yields of white protein (WP) were about 0.5 and 0.9% (fresh weight basis) for "Jewel" and "Centennial", respectively. The apparently better yields

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Table I. Mineral Analyses of Protein Fractions from "Jewel" and "Centennial" Sweet Potatoes

protein fraction	% (dry wt) ash	P	K	Ca	Mg	Na
"Centennial" white	2.04	0.25	0.17	0.60	0.04	0.05
"Centennial" chromoplast	4.51	0.29	0.42	1.25	0.07	0.07
"Jewel" white	1.55	0.15	0.07	0.48	0.03	0.02
"Jewel" chromoplast	5.63	0.29	0.22	1.80	0.05	0.05

protein fraction	ppm (dry wt) Fe	Mn	Fn	Cu
"Centennial" white	31	64	107	13
"Centennial" chromoplast	398	57	143	102
"Jewel" white	36	56	93	30
"Jewel" chromoplast	665	41	122	95

obtained from "Centennial" are probably due to lower levels of nonprotein nitrogen (Purcell et al., 1978c). Due to the gelatinous nature of the chromoplast protein (CP) and the losses incurred during separations, we were not able to accurately measure yields.

Since the calcium chloride–heat precipitation used to obtain the CP could have altered the mineral profile of the fractions, an elemental analysis was performed. The amount of ash in both CP fractions was more than twice as great as the amount in the WP fractions (Table I), and as would be expected, the calcium levels of the CP fractions are also about twice those of the WP fraction. Potassium levels in CP were higher than those in WP. An interesting finding from this analysis is that the iron content of the CP fractions is very much greater than that of the WP fraction, indicating that the iron of sweet potatoes is either associated with the chromoplasts or is associated with a fraction precipitated by $CaCl_2$–heat. Calculations indicated that the Ca/P ratio was higher in the CP diets than in the WP diets. An increase of this magnitude in the calcium/phosphorus ratio would not have a deleterious effect on rat growth. Consequently, no attempt was made to alter the mineral mixture to bring the CP and WP calcium/phosphorus ratios into agreement. However, the total ash content was used to adjust the salt concentration used in each diet (Association of Official Analytical Chemists, 1975).

The protein content of both WP fractions was >90% and very similar to that of casein (Table II). The chromoplast fractions were a slightly less concentrated protein source at >70%. Amino acid analysis of the protein showed that the CP fraction had a slightly greater percentage of some of the essential amino acids than did the WP fraction (Table II). A comparison of the essential amino acids in any of the sweet potato protein fractions and casein revealed that casein had a poorer sulfur amino acid complement, although both sweet potato protein fractions and casein contained less than the FAO/WHO (1973) reference. The WP fraction was slightly deficient

Table II. Amino Acid Analyses of Protein Fractions from "Jewel" and "Centennial" Sweet Potatoes

	white protein fraction "Jewel"	"Centennial"	casein	chromoplast fraction "Jewel"	"Centennial"	FAO
essential[a]						
threonine	6.43	6.39	4.17	5.77	5.67	4.0
valine	7.90	7.89	7.32	7.83	7.68	5.0
methionine	2.03	1.84	2.13	2.26	2.10	3.5
half-cystine	1.08	0.91	0.40	1.78	0.67	
isoleucine	5.63	5.71	5.16	6.01	5.89	4.0
leucine	7.40	7.44	9.03	9.64	8.95	7.0
tyrosine	6.91	7.09	5.43	6.71	6.41	6.0
phenylalanine	8.19	7.94	4.96	7.08	7.15	
lysine	5.16	5.21	8.05	7.03	6.43	5.5
tryptophan[b]	1.23	1.44		1.56	1.77	1.0
nonessential[a]						
aspartic acid	18.89	18.88	6.90	15.78	16.30	
serine	6.61	6.55	5.07	6.31	5.80	
glutamic acid	9.63	9.85	18.96	12.98	11.86	
proline	4.15	4.60	9.19	5.53	5.03	
glycine	5.33	5.46	2.07	5.70	5.48	
alanine	5.42	5.44	2.84	6.29	6.02	
histidine	2.70	2.88	2.62	3.21	2.96	
NH_3	1.62	1.69	0.62	1.60	1.65	
arginine	5.90	5.91	4.91	6.33	6.34	
% nitrogen recovery	99.56	100.88	98.79	106.94	102.88	
% protein[c]	98.38	92.94	93.13	69.81	77.44	

[a] Grams of amino acid per 16 g of nitrogen. Means of duplicate analyses. [b] Tryptophan was measured by the method of Amaya et al. (1977). [c] Kjeldahl nitrogen × 6.25.

Table III. Protein Efficiency Ratio (PER)[a] and Net Protein Ratios (NPR) for Protein Fractions from Sweet Potatoes

protein fractions	PER	corrected PER[b]	wt gained, g	food consumed, g	initial group wt, g	NPR
white						
casein	2.81 ± 0.11	2.50 ± 0.09	134.3 ± 11.7	477.9 ± 37.7	78.3 ± 3.1	3.95
"Jewel"	2.91 ± 0.10	2.64 ± 0.09	138.9 ± 11.7	477.1 ± 29.0	78.3 ± 3.3	4.15
"Centennial"	2.96 ± 0.07	2.63 ± 0.07	140.3 ± 12.4	472.6 ± 35.3	78.4 ± 3.2	4.20
chromoplast						
casein	2.78 ± 0.10	2.50 ± 0.09	109.5 ± 7.8	394.0 ± 25.3	71.6 ± 2.9	
"Jewel"	2.73 ± 0.09	2.47 ± 0.09	117.6 ± 11.3	431.1 ± 39.5	71.1 ± 2.7	
"Centennial"	2.78 ± 0.10	2.50 ± 0.10	122.2 ± 14.9	437.9 ± 44.5	71.3 ± 2.7	

[a] Mean and standard deviation calculated from data from 10 rats per diet group. [b] Corrected by adjusting test diets to 2.50 for casein (AOAC).

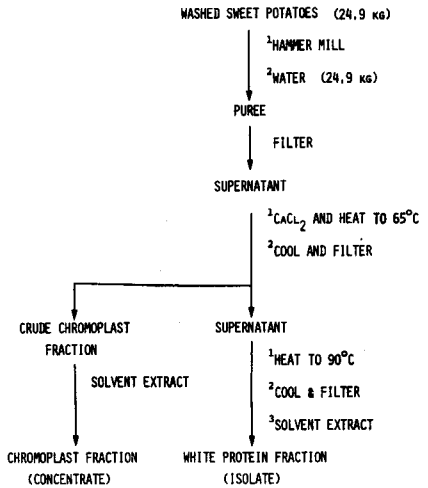

Figure 1. Flow diagram for preparation of sweet potato protein fractions.

in lysine as compared to the FAO standard, while the CP lysine content exceeded the FAO value. Both CP and WP contained less lysine than casein.

The amino acid analyses indicated that both protein fractions from "Jewel" and "Centennial" varieties were of good nutritional quality, and the rat bioassay studies confirmed this conclusion. The white protein from both cultivars had similar PER values and numerically exceeded the PER value for casein (Table III). The chromoplast protein PER values were also similar to the casein PER. Statistical analysis indicated that sweet potato protein fractions are equal in PER value to ANRC reference casein.

Because the chromoplast protein fractions are richer in total sulfur amino acids and lysine than is the white protein, we would expect PER values to differ. However, no difference was found. A possible explanation is nondigestibility of the protein, perhaps because of the preparation procedure. The elevated calcium to phosphorus ratio (Table I) of the chromoplast protein did not affect rat growth.

In view of the failure of PER values to credit dietary protein that is needed for maintenance, we measured the NPR on white protein from both sweet potato cultivars and compared them to casein. The data (Table III) indicate that sweet potato protein is equal to the NPR of casein, thus confirming that the white protein from sweet potato is of good quality.

It appears that the deficiency of lysine in sweet potato protein limits rat growth to about the same extent that total sulfur deficiency limits growth in casein, with the result that rats fed either protein grow at about the same rate. Supplementation studies should verify this.

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LITERATURE CITED

Amaya, F. J.; Young, C. T.; Chichester, C. O. *J. Agric. Food Chem.* **1977**, *25*, 139.
Association of Official Analytical Chemists "Official Methods of Analysis", 12th ed.; AOAC: Washington, DC, 1975; p 857.
Bender, A. E.; Doell, B. H. *Br. J. Nutr.* **1957**, *11*, 140.
Constantin, R. J.; Hernandez, T. P.; Jones, L. G. *J. Am. Soc. Hortic. Sci.* **1974**, *99*, 308.
FAO/WHO *W.H.O. Tech. Rep. Ser.* **1973**, *No. 522*.
Miller, J.; Young, C. T. *J. Agric. Food Chem.* **1977**, *25*, 653.
Nagase, T. *Fukuoka Igaku Zasshi* **1957**, *48*, 1828.
Purcell, A. E.; Swaisgood, H. E.; Pope, D. T. *J. Am. Soc. Hortic. Sci.* **1972**, *97*, 30.
Purcell, A. E.; Walter, W. M., Jr.; Giesbrecht, F. G. *J. Agric. Food Chem.* **1978a**, *26*, 362.
Purcell, A. E.; Walter, W. M., Jr.; Giesbrecht, F. G. *J. Agric. Food Chem.* **1978b**, *26*, 699.
Purcell, A. E.; Walter, W. M., Jr.; Giesbrecht, F. G. *J. Am. Soc. Hortic. Sci.* **1978c**, *103*, 190.
USDA, 1977, Statistical Bulletin No. 583.

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