IMPROVEMENT OF POTATO PROTEIN II. SELECTION FOR PROTEIN AND YIELD[1]

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Abstract

The improvement of potato protein appears feasible by selecting high protein parents and crossing them with adapted Group Tuberosum parents. Initial hybrids were obtained with about 10% protein which is double that of Red Pontiac. This protein is of high nutritional value when compared to whole egg protein. Some of the hybrids appear to have yields approaching standard varieties. Specific gravity values are also comparable.

Resumen

El mejoramiento del contenido protéico de la papa parece factible cruzando progenitores seleccionados por alto contenido protéico con progenitores del Grupo Tuberosum. Los híbridos obtenidos inicialmente tuvieron alrededor de 10% de proteína, contenido que representa el doble de aquél del cultivar Red Pontiac. Esta proteína es de un alto valor nutritivo comparada a la del huevo. Algunos híbridos tuvieron rendimientos próximos a los de los cultivares standard. Los valores de gravedad específica fueron también comparables.

Introduction

Protein production appears independent of high nitrogen fertilization. In general, as long as there is an adequate supply of nitrogen the potato protein quality appears to be genetically controlled and is not significantly altered by the growing conditions of the plant. As early as 1956 Mulder and Bakema (15) found no effect of mineral nutrition on the amino acid composition of potato protein. Hoff et al. (6) applied nitrogen at rates up to 336 lbs/acre and found that the total amino acid pool almost doubled, indicating excess nitrogen was not incorporated into protein. Mica (14) also found increasing nitrogen fertilization did not increase the content of protein. Similar observations were made by Coutrez-Geerink (2) who states that protein-bound amino acids are normally affected to a much lesser extent by plant nutrition, or not affected at all, while the free amino acid pool is.

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Other workers have pointed out that protein yield per acre is dependent on tuber yield as well as on the protein content of the tubers. Loginow and Klupczynski (13) and Varis (20) found the best yield of protein per acre at "standard" nitrogen fertilization rates of 100-120 kg N/ha., because higher levels of nitrogen suppress starch production. No correlation was found between tuber size and protein content by Desborough and Weiser (4).

The nutritional quality of potato protein has been well established. In 1928, Kon and Klein (11) performed a 167 day experiment in which humans were maintained at nitrogen equilibrium on a potato diet. The complementary action of protein nitrogen and non-protein nitrogen was demonstrated in diets for weanling rat growth (1). Hughes (7) suggested that the high proportion of free lysine and arginine in potato would provide a supplement to a cereal protein diet. Schuphan (18, 19) concludes that nitrogen balance studies on adults done since the end of the 19th century have repeatedly confirmed the biological value of potato protein and he gives EAA indices in the range of 61-89 for potato varieties. With a Tetrahymena assay Labib (12) found potato protein had an EAA index of 89% compared to casein and 65% compared to whole egg. A mixture of 35% whole egg protein plus 65% potato protein was found to be exceptionally high in biological value by Kofranyi and Jehat (8). Kaldy (10) states, on the basis of protein quality criteria, that the potato would satisfy the protein requirement of more people per hectare than any major crop. Johnson and Lay (9) rank potato protein in current varieties next to soybean protein in U.S. production. Compelling evidence from Irish history of the 1800's suggests the high nutritional quality of the potato since this was the major food of an entire country. (17).

Materials and Methods

About four years were spent selecting stocks with high protein for use in a breeding program. The original crosses were made between Group Phureja and Group Tuberosum Haploids at Sturgeon Bay, Wisconsin. The Phureja parents were the source of high protein and the Tuberosum haploid parents were derived from adapted cultivars. These progenies were grown in 1970 through 1973. Individual seedlings were tested in 1970 and 1971 for total tuber protein and amino acids in representative tubers were determined; the procedures and data are given in references 3 and 4. Four progenies were obtained with tuber protein averaging 11-13% protein in 1972 and three averaging 14-18% in 1973 (Table 1).

The Phureja-Haploid (DH) hybrids were selected on the basis of protein quality and quantity. These were doubled with colchicine by IR-1 personnel and then crossed to adapted Tuberosum clones and grown at Grand Rapids in 1973, Crookston in 1974 and Grand Rapids and Grand Forks in 1975 (Table 1). Emphasis in selection of the latter group of hybrids

TABLE 1. —*Percent average tuber protein on a dry weight basis of DH and DH-Tub progenies. (Experimental error is about ± 1.5% and n is the number of progeny in a family.*

DH Progeny			
1972		*1973*	
Protein	*n*	*Protein*	*n*
13.2%	37	14.5%	31
11.1%	38	18.6%	23
11.9%	15	-	-
12.8%	35	18.2%	16

DH-Tub Progeny					
1973		*1974*		*1975*	
Protein	*n*	*Protein*	*n*	*Protein*	*n*
7.9%	24	6.6%	96	7.5%	365

was on both protein and tuber yield. These hybrids are designated below as DH-Tub. Comparative data for protein were also obtained from Group Phureja, Group Andigena and Group Tuberosum clones.

Results and Discussion

Table 2 gives the percent protein in some DH-Tub hybrid selections. Variation from year to year can be observed; however, hybrids have higher amounts of protein than Red Pontiac, which averages about 6%. One hybrid, 2699, was stable at about 9% protein for two years.

TABLE 2. —*Percent protein on a dry weight basis in selected DH-Tub hybrids.*

DH-Tub hybrid	Crookston 1974	Grand Rapids 1975	Grand Forks 1975
2518	—	9.1	—
2526	—	8.3	—
2550	—	8.3	—
2712	—	4.4	—
2974	8.7	6.5	—
3095	8.0	5.1	—
2617	12.4	6.1	6.8
2628	10.3	6.7	7.2
2636	9.3	6.7	7.1
2694	10.7	6.2	6.0
2699	9.2	9.2	9.5
2702	8.9	7.4	8.7
2703	11.8	6.3	9.3
2734	8.0	6.5	7.9
3179	8.2	5.6	6.0
Red Pontiac	6.7	6.1	5.1

Tuber yields of the hybrids and Red Pontiac grown at Grand Rapids (1975) are given in Table 3. These data were derived from increase-plots rather than from replicated yield trials. There are several hybrids, 2617, 2628, 2702 and 3179, which show promise. These will be grown (1976) in replicated yield trials at several locations in Minnesota to assess their yield potential.

TABLE 3. — *Tuber yield of selected DH-Tub hybrids grown at Grand Rapids, 1975.*

DH-Tub	*lbs/hill*
2518	1.4
2526	1.3
2550	2.4
2712	.1
2974	1.4
3095	3.5
2617	4.0
2628	3.6
2636	2.9
2694	1.4
2699	1.8
2702	3.8
2703	2.2
2734	3.1
3179	3.9
Red Pontiac	4.2

The specific gravities of the hybrids and 5 cultivars grown at 2 locations are given in Table 4. Several hybrids have higher specific gravities

TABLE 4. — *Specific gravity of DH-Tub hybrids in 1975.*

DH-Tub hybrid	*Grand Rapids*	*Grand Forks*
2518	1.065	—
2526	1.067	—
2550	1.064	—
2974	1.074	—
3095	1.073	—
2617	1.073	1.085
2628	1.068	1.074
2636	1.067	1.077
2694	1.065	1.081
2699	1.077	1.088
2702	1.071	1.084
2703	1.080	1.089
2734	1.068	—
3179	1.080	—
Red Pontiac	1.060	1.071
Russet Burbank	1.074	1.070
Kennebec	1.070	1.078
Norchip	1.079	1.089
Norland	1.062	1.078

than Red Pontiac, Norland and Kennebec and three hybrids are comparable to Russet Burbank and Norchip.

The quality of the potato protein can be evaluated from its amino acid composition. The Essential Amino Acid Index is calculated by using whole egg protein as a standard with a value of 100; soybean flour is 85 by this method (16). These data are given in Table 5 for selected DH and DH-Tub hybrids. The values compare favorably with egg protein indicating that the protein is of high nutritional quality (5).

TABLE 5. —*Essential Amino Acid Indices of Selected high protein DH and DH-Tub hybrids.*

DH hybrid	*EAA*	*DH-Tub hybrid*	*EAA*
9302-5	76.6	2994	72.4
9302-34	72.7	3005	82.4
		3012	75.7
9303-23	89.8	3032	74.7
9303-25	80.7	3035	81.8
		3062	75.4
9304-7	76.7		
9304-23	70.0	egg	100.0
9305-2	100.0		
9305-56	88.7		

It is interesting to compare the major Groups of *S. tuberosum* for their average protein content. The initial DH progenies in 1973 had 17.1%, n=70; where n=number of progeny in a family. In 1975, Group Phureja had 17.87%, n=63; Group Andigena had 6.9%, n=22 and Group Tuberosum had 5.7%, n=32. Thus it can be readily observed that the DH hybrids and Group Phureja have significantly higher tuber protein than Group Tuberosum and Group Andigena clones. Significant gains in protein production, however, can only be obtained if the DH-Tub selections have yields competitive with standard cultivars. The DH-Tub selections, although lower in protein percentage than DH selections, may have the possibility of substantial yield when compared to Group Tuberosum.

Literature Cited

1. Chick, H. and E.B. Slack. 1949. Distribution and nutritive value of nitrogenous substances in the potato. Biochem J 4:211-221.
2. Coutrez-Geerinck, D. 1975. The effect of mineral nutrition on the distribution of free amino acids in tubers of cv. Gari. Potato Res 18:16-27.
3. Desborough, S. and C.J. Weiser. 1972. Protein comparisons in selected Phureja-Haploid Tuberosum families. Am Potato J 49:227-233.
4. Desborough, S. and C.J. Weiser. 1974. Improving Potato Protein I. Evaluation of Selection Techniques. Am Potato J 51:185-196.

5. Eggum, B.D. 1968. Evaluation of protein quality and development of screening techniques. Panel on new approaches to breeding for plant protein improvement at Svalof, Sweden (17-21 June 1968).
6. Hoff, J.E., C.M. Jones, G.E. Wilcox and M.D. Castro. 1971. The effect of nitrogen fertilization on the composition of the free amino acid pool of potato tubers. Am Potato J 48:390-391.
7. Hughes, B.P. 1958. The amino acid composition of potato protein and of cooked potatoes. Br J Nutr 12:188-185.
8. Kofranyi, E. and Jekat. 1965. The determination of the biological value of food protein. Hoppe Seylers' Z Physiol Chem 348:84-88.
9. Johnson, V.A. and C.L. Lay. 1974. Genetic improvement of plant protein. J Agric Food Chem 22:558-566.
10. Kaldy, M.S. 1972. Protein yield of various crops as related to protein value. Econ Bot 26:142-144.
11. Kon, S.L. and A. Klein. 1928. The value of the whole potato in human nutrition. Biochem J 22:258-260.
12. Labib, A.J. 1963. Potato proteins. Their properties and nutritive value. Nutr Abstr Rev 33:39.
13. Loginow, W. and Z. Klupczynski. 1969. Intensive mineral fertilization on the content and yield of starch and protein. Pamiet Pulawski 37:113-122.
14. Mica, B. 1971. Einfluss der Dungung auf den Gehalt an essentiellen Aminosauven im Kartoffeleiweiss. Potato Res 14:19-28.
15. Mulder, E.G. and K. Bakema. 1956. Effect of the nitrogen, phosphorous, potassium and magnesium nutrition of potato plants on the content of free amino acids and on the amino acid composition of the protein of tubers. Plant Soil 7:135-166.
16. Oser, B.L. 1951. Method for integrating essential amino acid content in the nutritional evaluation of protein: J Am Diet Assoc 27:396-402.
17. Salaman, R.N. 1949. Social History of the Potato. Camb Univ Press p. 685.
18. Schuphan, W. 1959. Studies on the essential amino acids in potatoes. III. The biological value of protein of potato (*Solanum tuberosum* L.) with special reference to nutritional experiments and to essential amino acids. Qual Plant Mater Veg 6:16-38.
19. Schuphan, W. 1960. The biological value of proteins as a scale for quality of potatoes in evaluating different varieties and optimum conditions of fertilization. Qual Plant Mater Veg 6:293-298.
20. Varis, E. 1973. Factors affecting the yield and quality of protein in the potato. Acta Agral Fenn 128:1-12.