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The free amino acids of tubers of potato varieties grown in England and Ireland

A. M. C. DAVIES[1]

Research Department, Reckitt & Colman Food Division, Carrow, Norwich, NR1 2DD, England and Agricultural Research Council's Food Research Institute, Colney Lane, Norwich, NR4 7UA, England

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Summary

The results of 91 analyses of the free amino acids of potato tubers, comprising a total of 31 varieties grown in England and Ireland between the years 1968–1973, are reported. Whilst a discriminant-analysis test on part of these results strongly indicated quantitative differences of amino acids between varieties, there was also evidence of differences due to location and year of growth.

Introduction

Free amino acids have been shown to be relevant to problems of potato processing (Habit & Brown, 1957; Mapson et al., 1963; Fitzpatrick & Porter, 1966) and to the flavour of cooked potato (Self, 1967). As the free amino acids of potato tubers may account for more than half the total amino acid nitrogen, they also have a bearing on the nutritive value of the potato (Burton, 1966). Talley et al. (1970) have studied systematically the variation of free amino acids in potato tubers grown in North America according to location, year and variety; Mulder & Bakema (1956) have reported on varieties grown in the Netherlands. However, there is a scarcity of information about varieties grown in Great Britain and Ireland (Synge, 1977). The results reported in this paper are from potato tubers grown during the seasons 1968, 1969, 1970 and 1973. The samples analysed in 1968 were all grown in Ireland and the four varieties chosen were those commonly used for processing. Encouraging results were obtained from these samples and it was decided to extend the work to as many varieties as were available. We were fortunate in receiving a total of 27 varieties grown in the 1969 season and a further sample of the majority of the same varieties in the 1970 season. The 1973 samples were analysed as part of other research (Davies & Laird, 1976) but are included for comparison.

[1] Present address: Agricultural Research Council's Food Research Institute, Colney Lane, Norwich, NR4 7UA, England.

Materials and methods

Potato samples. Samples of varieties of potato tubers were obtained from the A.R.C. Food Research Institute, Norwich; the National Institute of Agricultural Botany, Cambridge; the Norfolk Agricultural Station, Morley; the Experimental Husbandry Farm, Terrington, Norfolk; and from Newry, Northern Ireland. Sample size varied from 1–50 kg. The samples were stored in a basement without temperature control; the normal temperature range was 10–20°C.

Dry matter. Sliced potatoes (500 g) were dried in a hot-air dryer at 80°C until brittle. The dry slices were weighed, broken into pieces and ground in a UNO coffee mill. The residual moisture content of the powdered potato was then determined on 1 g samples by drying to constant weight in an oven at 105°C. Dry matter percentage (D) was calculated using the equation:
$D = W \times (100 - M)/500$
W = weight of potato slices after drying (g) and M = residual moisture content of potato powder (%).

Extraction of free amino acids. Talley et al. (1958) have reported on the extraction of free amino acids from potato tubers using 70% (v/v) aqueous ethanol. Their method requires five extractions with 70% (v/v) aqueous ethanol followed by four Soxhlet extractions. Thus, this method requires many manipulations and is very time consuming. An alternative method which is less laborious and has been found to give reproducible results has been used for the majority of this work.

Mechanically peeled potatoes (500 g) were triturated in an electrical blender, for 30 seconds, with 850 ml absolute alcohol (giving approximately 70% ethanol, assuming the potatoes to contain 20% dry matter). A portion of the slurry (250 ml, representing 100 g tuber fresh weight) was then mixed with 50 g Celite 545 (Kock-Light Laboratories, Ltd.)

This mixture was poured into a 50 cm × 3 cm glass column fitted with a sintered-glass end, previously covered with a slurry of Celite 545 in aqueous ethanol to a depth of 1 cm. Aqueous ethanol (70% v/v) was percolated overnight through the column from a reservoir and the eluate was collected in a two-litre flask. After 1900 ml of eluate had been collected the flask was made up to volume and thoroughly mixed. A sample of the extract (500 ml) was stored at -20°C. When required for analysis, the solution was warmed to room temperature and 100 ml of the extract was reduced to a volume of about 10 ml using a rotary evaporator, at a temperature not exceeding 40°C. The contents of the evaporator flask was transferred quantitatively, with water, to a 100-ml volumetric flask; 0.1 *M* HCl (10 ml) was added and the contents made to volume with de-ionized water. A sample of this solution (1.0 ml) was applied to the chromatographic column with 1.0 ml of solution containing 0.1 μmole norleucine as internal standard. The 1973 samples were extracted according to the method of Laird, Mbadiwe & Synge (1976).

Amino acid analysis. The free-amino acid analysis of potato tubers is complicated by the presence of large amounts of glutamine and asparagine. For the 1968 samples a standard Technicon NC-1 amino acid analyser was used according to the recommended method as detailed by Boulter (1966). This method uses sodium citrate buffers, which do not separate glutamine and asparagine. The amides are eluted between threonine and serine, but in potato samples these amino acids are also unresolved from the amide peak because of the much larger amounts of amides. Asparagine can be mathematically resolved from glutamine, threonine and serine by the difference in the E 440 nm/E 570 nm ratios (Holy, 1966) and this method was used to estimate the asparagine content of the samples. The chromatographic column was operated at 60 °C at which temperature glutamine is lost by cyclization to pyrrolidonecarboxylic acid (Oreskes & Kupfer, 1967). Although the standardization was carried out under the same conditions, there must be considerable doubt about the accuracy of the glutamine results.

For the 1969 and 1970 samples the analyser was modified to give stepwise buffer elution, temperature programming and automatic sample addition (Davies, 1973). Lithium buffers have been shown to separate asparagine and glutamine (Benson et al., 1967), but it was found very difficult to separate glutamine from glutamic acid in potato extracts and it was decided to accept the non-separation of these two amino acids, (but cf. Oulevey & Heitefuss, 1974). The 1973 samples were analysed at the Food Research Institute on a standard Technicon NC-1 analyser according to the method of Nunn & Vega (1968), which succeeded in separating asparagine, glutamine and glutamic acid.

Quantitation was initially carried out by manual measurements of peak heights and widths at half height and using a computer program to make the necessary calculations. For the 1970 samples, the peak areas were integrated by a computer using a punched-paper-tape data system (Davies, 1973).

Results

The results, expressed as mg/100 g dry matter, are summarized in Tables 1, 2, 3 and 4. Table 1 gives the results for each variety. Where there were three or more samples of the same variety, the average and range are reported, otherwise the actual results are given. Table 2 compares potatoes grown in England and Ireland and was obtained by averaging the average results for the seven varieties grown in both areas. Table 3 gives the overall and yearly averages and Table 4 gives the results for some of the 1968 samples which were analysed during storage.

Discussion

The 1968 results, which were from four varieties, were subjected to stepwise discriminant analysis using ratios of amino acids as variables for the test, as described by Powers & Keith (1968). The samples were correctly classified into varieties in three

Table 1. Free amino acids of potato tubers (mg amino acid/100 g tuber dry matter). Threonine and serine were not determined in the 1968 samples; glutamine results for the 1969 and 1970 samples include glutamic acid.

Amino acid[1]	Majestic 1968 (4), 1969 (5), 1970*	Arran Victory 1968 (4), 1969 (3), 1970	Kerr's Pink 1968 (6), 1969 (2)
Aspartic acid	182 (119–211)	119 (64–183)	134 (34–227)
Asparagine	1717 (1022–2068)	800 (371–1673)	967 (483–1567)
Threonine	54 (34–65)	44 (23–91)	39 (18–60)
Serine	52 (35–63)	39 (21–86)	59 (29–88)
Glutamine	2656 (677–7156)	2328 (623–6533)	3034 (631–9122)
Glutamic acid	350 (329–371)	263 (238–297)	268 (238–282)
Proline	57 (38–87)	43 (24–88)	73 (28–119)
Glycine	9 (6–12)	9 (1–20)	7 (4–18)
Alanine	24 (13–37)	21 (6–48)	21 (8–39)
Valine	148 (77–195)	84 (38–154)	63 (34–129)
Methionine	58 (43–79)	45 (25–102)	39 (14–65)
Isoleucine	72 (53–92)	33 (14–65)	37 (19–103)
Leucine	32 (20–48)	26 (10–97)	28 (12–87)
Tyrosine	145 (57–203)	88 (17–191)	69 (32–153)
Phenylalanine	78 (62–96)	58 (17–136)	57 (32–104)
Tryptophan	50 (20–113)	60 (38–112)	25 (11–48)
Lysine	94 (37–204)	70 (10–114)	74 (28–146)
Histidine	131 (50–328)	81 (43–161)	82 (35–222)
Arginine	184 (123–246)	255 (138–548)	157 (71–269)
4-Aminobutyric acid	155 (56–201)	104 (15–159)	143 (42–282)
Ornithine	18 (8–50)	26 (6–75)	15 (10–32)

Amino acid[1]	Arran Consul 1969 (6), 1969	King Edward 1969 (5), 1970	Pentland Crown 1969 (3), 1970 (2)
Aspartic acid	169 (144–213)	181 (128–201)	153 (32–250)
Asparagine	1056 (429–1779)	1221 (948–1856)	1055 (513–1775)
Threonine	- (46—)	50 (40–73)	36 (20–52)
Serine	- (36—)	67 (50–111)	44 (19–64)
Glutamine	3177 (835–5397)	1284 (634–2429)	1077 (684–1530)
Glutamic acid	307 (255–370)	– (—)	– (—)
Proline	33 (24–47)	99 (57–217)	66 (0–201)
Glycine	9 (5–15)	12 (7–20)	13 (7–20)
Alanine	23 (12–32)	44 (15–99)	29 (6–65)
Valine	57 (41–93)	111 (15–255)	128 (59–211)
Methionine	37 (32–41)	55 (39–95)	50 (38–68)
Isoleucine	26 (21–35)	57 (46–80)	40 (25–59)
Leucine	11 (8–20)	29 (9–49)	21 (14–25)
Tyrosine	72 (40–102)	80 (66–103)	76 (47–119)
Phenylalanine	43 (30–56)	72 (55–98)	68 (51–103)
Tryptophan	45 (27–69)	97 (7–164)	62 (8–113)
Lysine	65 (50–86)	78 (21–319)	36 (23–47)
Histidine	86 (41–230)	89 (65–139)	99 (62–140)
Arginine	117 (64–166)	97 (7–164)	187 (140–272)
4-Aminobutyric acid	143 (49–272)	182 (112–298)	97 (49–137)
Ornithine	9 (6–14)	34 (14–53)	45 (2–113)

able 1. Continued.

Amino acid[1]	Redskin 1969 (3), 1970, 1973*	Pentland Dell 1969 (3), 1970	Golden Wonder 1969, 1970, 1973
rtic acid	228 (109–320)	215 (155–248)	175 (150–214)
ragine	1577 (603–2871)	1659 (1410–1986)	1239 (580–2148)
nine	42 (21–56)	52 (39–69)	18 (14–23)
[illegible]	51 (16–91)	79 (59–107)	27 (15–34)
amine	1237 (623–2394)	1317 (919–2064)	863 (220–1607)
tamic acid	– (289—)	– (—)	– (289—)
line	72 (35–169)	71 (2–104)	109 (42–187)
ycice	11 (7–14)	22 (12–35)	8 (4–16)
anine	39 (12–81)	41 (24–65)	29 (22–41)
aline	126 (60–232)	176 (86–370)	101 (26–237)
lethionine	55 (35–94)	57 (49–73)	24 (9–40)
oleucine	61 (46–84)	74 (46–132)	34 (16–63)
eucine	40 (28–55)	44 (30–66)	20 (8–38)
yrosine	67 (48–85)	119 (68–187)	45 (18–87)
henylalanine	77 (57–94)	101 (51–163)	22 (17–26)
Tryptophan	52 (33–82)	85 (9–174)	– (111—)
Lysine	57 (18–88)	57 (32–95)	24 (9–38)
Histidine	105 (47–238)	164 (38–254)	60 (17–125)
Arginine	266 (60–627)	361 (179–736)	288 (140–436)
4-Aminobutyric acid	172 (74–448)	138 (15–265)	178 (59–375)
Ornithine	59 (4–244)	50 (9–117)	40 (5–89)

Amino acid[1]	Record 1969 (2), 1970	Désirée 1969, 1970, 1973	Maris Piper 1969, 1970 (2)
Aspartic acid	259 (199–376)	183 (162–212)	190 (153–214)
Asparagine	1937 (1200–2594)	2183 (1518–2756)	1646 (909–2444)
Threonine	69 (40–103)	62 (48–74)	38 (30–43)
Serine	63 (43–83)	66 (52–86)	69 (52–95)
Glutamine	1479 (973–2050)	1630 (822–2450)	1325 (770–1918)
Glutamic acid	– (—)	– (345—)	– (—)
Proline	130 (42–303)	79 (48–137)	212 (45–484)
Glycine	11 (7–18)	13 (8–17)	9 (7–12)
Alanine	24 (23–25)	29 (19–45)	37 (18–66)
Valine	152 (74–281)	251 (179–312)	186 (63–302)
Methionine	48 (32–64)	95 (76–108)	55 (43–72)
Isoleucine	58 (42–88)	131 (109–165)	68 (47–109)
Leucine	33 (25–38)	58 (43–71)	38 (25–63)
Tyrosine	66 (51–93)	229 (174–316)	79 (34–119)
Phenylalanine	81 (49–102)	149 (91–204)	82 (45–119)
Tryptophan	– (42—)	79 (67–91)	– (13—)
Lysine	52 (33–64)	112 (84–144)	49 (23–98)
Histidine	163 (85–247)	161 (71–239)	159 (79–244)
Arginine	434 (258–670)	326 (196–419)	360 (207–643)
4-Aminobutyric acid	171 (49–326)	206 (50–398)	260 (144–350)
Ornithine	– (26—)	75 (5–148)	32 (7–49)

Table 1. Continued.

Amino acid[1]	Alpha 1969, 1970*	Avenir 1969, 1970	Bintje 1969, 1970	Maris Page 1969, 1970
Aspartic acid	247, 233	155, 200	197, 249	94, 213
Asparagine	1159, 1947	519, 2084	1230, 2554	1673, 2339
Threonine	39, 34	23, 40	45, 63	53, 32
Serine	47, 53	39, 56	44, 47	111, 75
Glutamine	871, 1260	1166, 1492	984, 1861	1648, 1683
Glutamic acid	–, –	–, –	–, –	–, –
Proline	62, 201	64, 44	49, 297	75, 132
Glycine	9, –	9, 27	9, 20	24, 19
Alanine	24, 30	18, 34	36, 118	36, 35
Valine	60, 182	52, 140	110, 220	150, 226
Methionine	55, 56	71, 69	51, 72	62, 10
Isoleucine	45, 52	27, 31	59, 67	76, 62
Leucine	16, –	24, 24	31, 44	38, 40
Tyrosine	36, 27	31, 18	59, 33	117, 67
Phenylalanine	56, 50	43, –	55, 27	160, 90
Tryptophan	–, –	88, –	145, –	94, –
Lysine	39, 75	19, 44	32, 45	62, 67
Histidine	62, 107	75, 30	91, 183	200, 164
Arginine	181, 298	180, 341	143, 280	215, 329
4-Aminobutyric acid	66, 310	151, 228	146, 442	42, 178
Ornithine	–, –	–, –	–, –	–, 76

Amino acid[1]	Maris Peer 1969, 1970	Orion 1970, 1973	Ulster Glade 1969, 1970	Aura 1970	Gladstone 1969	Dr. McIntosh 1969
Aspartic acid	148, 225	232, 291	157, 213	171	251	232
Asparagine	1865, 2284	1688, 1243	1312, 2591	1936	2232	1629
Theonine	60, 60	45, 38	44, 31	78	39	62
Serine	86, 92	73, 106	72, 69	58	55	103
Glutamine	1292, 1420	1128, 719	1013, 1943	1240	1211	1250
Glutamic acid	–, –	–, 225	–, –	–	–	–
Proline	73, 143	250, 75	59, 227	8	51	–
Glycine	15, 17	26, 19	8, 17	16	5	16
Alanine	44, 117	42, 71	23, 52	23	14	39
Valine	153, 267	296, 251	119, 227	239	112	241
Methionine	76, 92	93, 79	51, 83	53	43	104
Isoleucine	91, 88	87, 148	30, 55	87	55	89
Leucine	33, 49	69, 131	11, 30	32	40	62
Tyrosine	165, 123	124, 192	56, 71	170	146	199
Phenylalanine	121, 128	104, 181	33, 46	177	129	128
Tryptophan	51, –	–, –	68, –	–	18	–
Lysine	85, 35	53, 136	39, 41	58	70	94
Histidine	177, 196	247, 97	109, 213	128	89	254
Arginine	290, 541	653, 448	161, 318	286	173	298
4-Aminobutyric acid	72, 346	215, 121	82, 376	396	23	21
Ornithine	21, –	108, 18	29, –	–	–	-

Table 1. Continued.

Amino acid[1]	Duke of York 1969*	Itoning 1970	Red Craig's Royal 1969	Red King Edward 1969	Sientjes 1969	Sirtema 1969	Stormont Enter-prise 1969	Ulster Concord 1970	Woudster 1969
Aspartic acid	179	269	184	136	158	152	308	323	242
Asparagine	2305	3490	1619	989	2057	1415	1694	2731	1870
Threonine	143	34	38	41	52	75	50	56	43
Serine	128	34	36	46	77	93	65	58	38
Glutamine	1793	1186	873	1129	1003	1246	1407	1235	1466
Glutamic acid	–	–	–		–	–		–	–
Proline	49	101	64	61	89	123	50	277	35
Glycine	16	–	18	16	12	21	9	10	8
Alanine	37	24	34	27	30	42	30	41	18
Valine	275	217	104	102	76	186	75	152	100
Methionine	103	80	61	50	59	91	60	49	57
Isoleucine	144	84	53	47	66	83	33	55	47
Leucine	76	54	35	28	35	54	16	33	29
Tyrosine	282	99	79	59	73	153	40	60	70
Phenylalanine	190	172	92	57	70	122	34	30	120
Tryptophan	–	–	106	107	83	115	–	–	–
Lysine	37	109	43	27	57	47	42	30	81
Histidine	221	131	153	58	142	154	71	170	83
Arginine	335	356	319	132	401	126	184	311	536
4-Aminobutyric acid	52	271	115	120	76	115	49	172	58
Ornithine	81	39	17	–	–	–	6	156	

* Year (and number of samples) - *Jahr (und Zahl der Proben)* - *Années (et nombre des échantillons).*

[1] *Aminosäure* - *Acide aminé.*

Tabelle 1. Freie Aminosäuren in Kartoffelknollen (mg Aminosäure pro 100 g Knollentrockensubstanz). Threonin und Serin wurden 1968 nicht bestimmt. Die Ergebnisse der Jahre 1969 und 1970 für Glutamin schliessen Glutaminsäure ein.
Tableau 1. Teneur en acides aminés libres des tubercules de pommes de terre (mg acide aminé/100 g de matière sèche). La thréonine et la sérine ne sont pas déterminées dans les échantillons de 1968; les résultats donnés pour la glutamine dans les échantillons de 1969 et 1970 comprennent l'acide glutamique.

Table 2. Comparison of free amino acids of potato tubers for varieties for which samples grown in England and Ireland were available (mg amino acid/100 g tuber dry matter). Threonine and serine were not determined in 1968 samples; glutamine results for 1968 samples include serine and threonine and for 1969 and 1970 samples include glutamic acid; glutamic acid was determined in 1968 and 1973 samples.

Amino acid[1]	England (17 samples[2])	Ireland (23 samples)
Aspartic acid	170 (77– 227)	165 (120– 248)
Asparagine	1441 (669–1859)	1214 (818–1774)
Threonine	44 (30– 60)	48 (33– 69)
Serine	55 (21– 88)	64 (45– 107)
Glutamine	1023 (725–1344)	2737 (1057–5339)
Glutamic acid		297 (263– 350)
Proline	109 (24– 264)	43 (2– 107)
Glycine	12 (4– 18)	12 (6– 35)
Alanine	25 (6– 39)	37 (18– 66)
Valine	115 (38– 183)	154 (51– 370)
Methionine	51 (25– 65)	46 (36– 62)
Isoleucine	56 (14– 103)	55 (24– 132)
Leucine	37 (10– 87)	28 (10– 66)
Tyrosine	84 (17– 153)	111 (57– 187)
Phenylalanine	67 (17– 104)	81 (41– 129)
Tryptophan	51 (25– 85)	40 (25– 60)
Lysine	62 (36– 146)	74 (25– 163)
Histidine	155 (74– 230)	113 (62– 254)
Arginine	227 (126– 425)	263 (115– 736)
4-Aminobutyric acid	100 (41– 247)	182 (113– 287)
Ornithine	31 (27– 37)	39 (9– 117)

[1] *Aminosäure – Acide aminé*; [2] *Proben – Echantillons.*

Tabelle 2. Vergleich der freien Aminosäuren von Kartoffelknollen von Sorten, von denen Proben, gewachsen in England und Irland, erhältlich waren (mg Aminosäure pro 100 g Knollentrockensubstanz). Threonin und Serin wurden 1968 nicht bestimmt; die Ergebnisse für Glutamin schliessen 1968 Serin und Threonin ein und enthalten 1969 und 1970 Glutaminsäure; 1968 und 1973 wurde Glutaminsäure bestimmt.

Tableau 2. Comparaison entre les acides aminés libres des tubercules pour les variétés de pommes de terre dont les échantillons cultivés en Angleterre et en Irlande sont valables (mg d'acides aminés/100 g de matière sèche). La thréonine et la sérine ne sont pas déterminées dans les échantillons de 1968; les résultats donnés pour la glutamine dans les échantillons de 1968 comprennent la sérine et la thréonine et pour les échantillons de 1969 et 1970 l'acide glutamique; l'acide glutamique a été déterminé dans les échantillons de 1968 et 1973.

Table 3. Means and ranges for free amino acids of potato tubers (mg amino acid/100 g tuber dry matter).

Amino acid[1]	All results[2] (91 samples[3])	1968 (20 samples)	1969 (45 samples)	1970 (22 samples)	1973 (4 samples)
Aspartic acid	184 (32-376)	158 (34-213)	175 (32-308)	221 (71-376)	214 (162-291)
Asparagine	1487 (371-3490)	1007 (371-1985)	1408 (513-2305)	2145 (640-3490)	1149 (580-1518)
Threonine	48 (14-143)		48 (17-143)	50 (23-103)	34 (14-48)
Serine	60 (15-128)		57 (15-128)	65 (22-111)	62 (32-106)
Glutamine	1820 (220-9122)	3956 (1366-9122)	1116 (623-2698)	1543 (634-2429)	596 (220-822)
Glutamic acid	294 (225-371)	295 (238-371)			287 (225-345)
Proline	88 (0-484)	48 (24-119)	61 (24-123)	164 (0-484)	68 (48-98)
Glycine	12 (1-35)	8 (4-13)	12 (4-27)	16 (1-35)	10 (5-19)
Alanine	32 (6-118)	20 (8-37)	28 (6-54)	51 (18-118)	39 (19-71)
Valine	133 (15-370)	85 (37-195)	106 (15-275)	229 (87-370)	145 (26-251)
Methionine	55 (9-108)	43 (14-79)	57 (9-108)	62 (10-100)	65 (38-79)
Isoleucine	58 (14-165)	38 (19-88)	58 (14-165)	67 (22-132)	91 (16-148)
Leucine	33 (8-131)	18 (8-32)	34 (9-97)	39 (10-69)	66 (8-131)
Tyrosine	95 (17-316)	92 (32-203)	98 (17-316)	90 (18-198)	113 (18-192)
Phenylalanine	77 (0-204)	57 (30-96)	79 (17-204)	83 (0-177)	110 (24-181)
Tryptophan	66 (7-174)	35 (11-69)	76 (7-174)	41	54 (40-67)
Lysine	65 (9-319)	92 (47-204)	48 (10-146)	72 (25-319)	77 (9-136)
Histidine	117 (17-328)	68 (35-109)	121 (38-328)	164 (30-254)	58 (17-97)
Arginine	251 (60-736)	162 (64-372)	222 (60-548)	391 (191-736)	247 (96-448)
4-aminobutyric acid	156 (15-448)	160 (93-282)	95 (15-208)	286 (132-448)	106 (59-170)
Ornithine	36 (2-244)	13 (6-32)	24 (2-81)	97 (39-244)	8 (4-18)

[1] *Aminosäure – Acide aminé*; [2] *Gesamtergebnis – Tous les résultats*; [3] *Proben – Échantillons.*

Tabelle 3. Mittelwerte und Schwankungsbereich der freien Aminosäuren in Kartoffelknollen (mg Aminosäure/100 g Knollentrockensubstanz).

Tableau 3. Moyenne et écarts pour les acides aminés libres des tubercules de pommes de terre (mg d'acides aminés/100 g de matière sèche).

Table 4. Free amino acids of potato tubers during storage (mg amino acid/100 g dry matter).

Amino acid[1]	Arran Consul			Kerr's Pink		Kerr's Pink	
	0*	5	11	0	3	0	6
Aspartic acid	174	213	211	173	148	34	150
Asparagine	900	982	1779	1167	1483	645	951
Glutamine	4048	4385	5397	9122	2896	3947	1813
Glutamic acid	321	370	309	282	272	274	270
Proline	–	24	27	119	77		28
Glycine	8	10	8	8	8	6	5
Alanine	27	20	32	29	16	8	8
Valine	58	59	52	96	72	48	46
Methionine	34	37	32	14	58	47	34
Isoleucine	27	22	21	46	33	26	24
Leucine	8	11	14	25	27	18	22
Tyrosine	87	102	83	91	81	52	49
Phenylalanine	45	55	39	78	61	51	60
Tryptophan	40	27	69	48	-	11	
Lysine	68	86	71	101	93	61	57
Histidine	58	84	71	93	109	49	48
Arginine	64	166	151	227	257	82	145
4-aminobutyric acid	143	148	140	282	238	120	93
Ornithine	6	14	6	11	32	13	13

* Weeks since first test – *Wochen nach der ersten Bestimmung* – *Nombre de semaines depuis le premier test.*

[1] *Aminosäure* – *Acide aminé.*

Tabelle 4. Freie Aminosäuren in Kartoffelknollen während der Lagerung (mg Aminosäure/100 g Knollentrockensubstanz).
Tableau 4. Teneur en acides aminés libres des tubercules de pommes de terre pendant la conservation (mg d'acides aminés/100 g de matière sèche).

steps. This result was evidence for varietal differences in amino acid composition and prompted the wider survey of varieties.

No detailed statistical analysis of the complete results has as yet been carried out. The 1969 results showed evidence of variation due to location and due to variety but it is considered that these questions can only be resolved by a properly designed experiment. The only general conclusion that can be reached from the data is, in agreement with Talley et al. (1970), that location, weather conditions, soil conditions etc. are as important variables as variety in determining the levels of free amino acids in potato tubers.

The comparison of potatoes grown in England and Ireland (Table 2) indicates that soil and climatic variations influence the concentrations of a few amino acids more than those of the rest. The amino acids which show appreciable variation are: glutamine, proline, alanine, valine, tyrosine, 4-aminobutyric acid and histidine. The glutamine results must be treated cautiously because most of the Irish samples were analysed in 1968. The amino acid which was most variable between the two areas was proline, which is in agreement with the American work (Talley et al., 1970). Proline is accumulated in plant leaves during wilting (Kemble & Macpherson, 1954; Singh et al., 1972; Stewart, 1973) and also during stress caused by freezing, u.v. radiation or high salt concentrations (Levitt, 1972; Stewart & Lee, 1974). It is not known if proline accumulation in potato tubers may also be caused by stress conditions. Mapson et al. (1963) proved a correlation of the tyrosine content of potatoes with rainfall. An important climatic difference between Ireland and Eastern England is that rainfall and humidity tend to be higher in Ireland. Thus the observed variations of proline and tyrosine between tubers from the two areas are in agreement with the known effects of water availability on the levels of these amino acids. The results averaged by year (Table 3) indicate that the general pattern of amino acid composition is consistent. However, the actual quantities of amino acids show some year-to-year variation. The 1970 results tended to be higher than the average and the 1968 results tended to be lower than the average. The general agreement between the 1973 results and the overall average results was satisfactory and suggested that the different methods of extraction were equally efficient.

The limited storage tests were carried out on the 1968 samples because of the time delay in extracting the samples. The results, in Table 4, show that the overall free-amino acid content is consistent during storage over short periods and that differences between samples are independent of the time of storage. Apart from glutamine, the only other amino acid to show consistent change during storage was arginine. Talley et al. (1958) found that arginine is the most difficult amino acid to extract and this apparent increase during storage may indicate a change in the binding or location of arginine, rather than its formation.

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Zusammenfassung

Freie Aminosäuren in Knollen von Kartoffelsorten, die in England und Irland aufwuchsen

Die freien Aminosäuren von 91 Proben von Kartoffelknollen, die insgesamt 31 Sorten vertreten, wurden mit 70% wässrigem Äthanol extrahiert (ausgenommen die 4 Proben des Jahres 1973) und durch Ionenaustauschchromatographie bestimmt. Der hohe Gehalt an Asparagin und Glutamin in diesen Extrakten verursachte grosse Schwierigkeiten und die Ergebnisse für diese Amide sollten mit Vorsicht betrachtet werden. Die Ergebnisse sind bezogen auf die Sorte (Tabelle 1), die Standorte (Tabelle 2), das Jahr (Tabelle 3) und auf die Zeit der Lagerung (Tabelle 4).

Eine bis ins Einzelne gehende statistische Analyse der gesamten Ergebnisse wurde nicht durchgeführt, aber die Aminosäureanalysen der 4 Sorten (gewachsen 1968) wurden der Diskriminanzanalyse unterworfen. Sie deuten auf sortenabhängige Unterschiede in der Zusammensetzung der Aminosäuren hin. Tabelle 2 vergleicht die Durchschnittsergebnisse der in England und Irland gepflanzten selben Sorten. Einige Aminosäuren scheinen durch den Standort stärker beeinflusst zu sein und von diesen können die Veränderungen bei Prolin und Tyrosin durch bekannte klimatische Einflüsse erklärt werden. Die jährlichen Durchschnittsergebnisse (Tabelle 3) zeigten, dass Veränderungen im Gehalt an Aminosäuren auftraten, aber dass das Gesamtbild der Aminosäurezusammensetzung im allgemeinen stabil blieb. Die Zusammensetzung der Aminosäuren in den Kartoffeln wurde durch eine kurze Lagerungsperiode nicht stark beeinflusst (Tabelle 4), obwohl Arginin eine beständige Zunahme zeigte. Das mag eher auf einer Änderung der Bindung oder Anlagerung beruhen als auf einer Synthese von Arginin.

Résumé

Les acides aminés libres contenus dans les tubercules des variétés de pommes de terre cultivées en Angleterre et en Irlande

Les acides aminés libres de 91 échantillons de pommes de terre comprenant au total 31 variétés ont été extraits par de l'alcool à 70% (excepté pour les quatre échantillons provenant des cultures de l'année 1973) et déterminés par chromatographie sur colonne. Les grandes quantités d'asparagine et de glutamine présentes dans les extraits sont la cause de difficultés considérables et les résultats obtenus avec ces amides seront à considérer avec prudence. Les résultats sont donnés par variétés (tableau 1), par lieu de culture (tableau 2), par année (tableau 3), et par durée de conservation (tableau 4).

L'analyse statistique détaillée de l'ensemble de ces résultats n'a pas été effectuée mais les quatre variétés cultivées en 1968 ont été classées par une analyse discriminante indiquant l'interdépendance des variétés sur la base de leur composition en acides aminés. Le tableau 2 permet de comparer la moyenne des résultats obtenus pour une même variété cultivée en Angleterre et en Irlande. Un petit nombre d'acides aminés apparaît être grandement influencé par le lieu de culture et la variation des teneurs en proline et en tyrosine pourrait s'expliquer par l'effet bien connu des conditions climatiques. Les résultats moyens annuels (tableau 3) indiquent qu'il y a des variations dans les teneurs en acides aminés mais que globalement leur proportion par rapport à l'ensemble est généralement stable. Les tests de conservation (tableau 4) indiquent que la composition en acides aminés des pommes de terre n'est pas fortement affectée par le stockage pendant une courte période bien que la teneur en arginine montre une augmentation importante. Ceci pourrait être attribué à une modification de son mode de fixation ou à sa localisation plutôt qu'à sa formation dans les tubercules.

References

Benson, J. V. jr., M. J. Gordon & J. A. Patterson, 1967. Accelerated chromatographic analysis of amino acids in physiological fluids containing glutamine and asparagine. *Analyt. Biochem.* 18: 228–240.

Boulter, D., 1966. An introduction to automatic amino acid analysis with plant extracts. In: Techniques in amino acid analysis. p. 93–107. Technicon Instrument Company, Geneva.

Burton, W. G., 1966. The potato: a survey of its history and of factors influencing its yield, nutritive value, quality and storage (2nd Edn). H. Veenman & Zonen N.V., Wageningen.

Davies, A. M. C., 1973. Automation of a Technicon NC-1 amino acid analyzer. *Lab. Pract.* 22: 627–637.

Davies, A. M. C. & W. M. Laird, 1976. Changes in some nitrogenous constituents of potato tubers during aerobic autolysis. *J. Sci. Fd Agric.* 27: 377–382.

Fitzpatrick, T. J. & W. L. Porter, 1966. Changes in the sugars and amino acids in chips made from fresh, stored and reconditioned potatoes. *Amer. Potato. J.* 43: 238–248.

Habib, A. T. & H. D. Brown, 1957. Role of reducing sugars and amino acids in the browning of potato chips. *Fd Technol., Champaign* 11: 85–89.

Holy, H. W., 1966. Mathematical resolution of overlapping peaks. In: Techniques in amino acid analysis. p. 155–156. Technicon Instrument Company, Geneva.

Kemble, A. R. & H. T. Macpherson, 1954. Liberation of amino acids in perennial rye grass during wilting. *Biochem J.* 58: 46–49.

Laird, W. M., E. I. Mbadiwe & R. L. M. Synge, 1976. A simplified procedure for fractionating plant materials. *J. Sci. Fd Agric.* 27: 127–130.

Levitt, J., 1972. Response of plants to environmental stress. Academic Press, London.

Mapson, L. W., T. Swain & A. W. Tomalin, 1963. Influence of variety on enzymic-browning of potato tubers. *J. Sci. Fd Agric.* 14: 673–684.

Mulder, E. G. & K. Bakema, 1956. Effect of nitrogen, phosphorus, potassium and magnesium nutrition of the potato plants on the content of free amino acids and on the amino acid composition of the proteins of the tubers. *Pl. Soil* 7(2): 135–166.

Nunn, P. B. & A. Vega, 1968. Use of lithium buffers with a single column amino acid analyzer. In: 6th Colloquium in amino acid analysis. p. 80–86. Technicon Instrument Company, Geneva.

Oreskes, I. & S. Kupfer, 1967. Degradation of glutamine at elevated temperatures in ion exchange chromatography. *Anal. Chem.* 39: 397–398.

Oulevey, J. & R. Heitefuss, 1974. Ein verbessertes Einsaulenprogramm zur Analyse der freien Aminosäuren und Säureamide in Pflanzenextrakten. *J. Chromat.* 94: 283–286.

Powers, J. J. & E. S. Keith, 1968. Stepwise discriminant analysis of gas chromatographic data as an aid in classifying the flavor quality of foods. *J. Fd Sci.* 33: 207–213.

Self, R., 1967. The flavour of cooked potatoes. In: The chemistry and physiology of flavours. P. 362–389. Avi, New York.

Singh, T. N., D. Aspinall & L. G. Paley, 1972. Proline accumulation and varietal adaptability to drought in barley: a potential metabolic measure of drought resistance. *Nature New Biol.* 236: 188–189.

Stewart, C. R., 1973. The effect of wilting on proline metabolism in excised bean leaves in the dark. *Pl. Physiol., Lancaster* 51: 508–511.

Stewart, G. R. & J. A. Lee, 1974. The role of proline accumulation in halophytes. *Planta (Berl.)* 120: 279–289.

Synge, R. L. M., 1977. Free amino acids of potato tubers: a survey of published results set out according to potato variety. *Potato Res.* 20: 1–7.

Talley, E. A., F. L. Carter & W. L. Porter, 1958. Determination of end point in extraction of free amino acids from potatoes. *J. agric. Fd Chem.* 6: 608–610.

Talley, E. A., T. J. Fitzpatrick & W. L. Porter, 1970. Chemical composition of potatoes. VIII. Effect of variety, location and year of growth on the content of nitrogen compounds. *Amer. Potato J.* 47: 231–244.