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Effects of Genotype, Environment, and Postharvest Storage on the Total Ascorbate Content of Potato (*Solanum tuberosum*) Tubers

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The total ascorbate content of potato tubers from 33 *Solanum tuberosum* genotypes grown at three geographically diverse sites in Europe in each of two years was determined immediately postharvest and after approximately 4 months of storage at 4 °C. Statistically significant differences in total ascorbate concentration were observed between genotypes both at harvest and after storage. In all genotypes, the levels of ascorbate decreased during storage. These results are discussed in terms of their implications for diet and health as well as in terms of breeding for improved vitamin C content in potatoes.

KEYWORDS: Potato; *Solanum tuberosum*; ascorbic acid; ascorbate; vitamin C; storage

INTRODUCTION

The potato (*Solanum tuberosum* L.) is a proven source of good-quality protein and energy, with an average per capita consumption in the United Kingdom of approximately 106 kg annum^{-1} which, within the European Union, is second only to Ireland. It is also an important source of vitamins and minerals such as calcium, potassium, and phosphorus, and its value within the human diet is often underestimated or ignored, particularly as a source of ascorbic acid (vitamin C). There is increasing interest in the role of such antioxidant compounds within our diet, in fruit and vegetables, and also in the various environmental factors that can affect these levels.

In Australia, it is estimated that potatoes provide approximately 25% of vitamin C (*1*), while it has been calculated that, in the United Kingdom, with an estimated consumption of 200 g day^{-1}, over 30% of the intake of vitamin C from fruit and vegetables comes from potatoes (*2*). More recently, the United Kingdom's Reference Nutrient Intake (RNI), the amount of a nutrient sufficient for all the population, for vitamin C was estimated as 40 mg day^{-1} (*3*). However, recent research (*4*) indicates that 40 mg day^{-1} is inadequate for notable fractions of the population, particularly men compromised by smoking and/or ages over ca. 45 years. The Scottish Diet report proposed a vitamin C intake level of twice the 40 mg day^{-1} RNI, to be derived from increasing fruit and vegetable consumption (*5*). In a survey of British adult diets, it was estimated that men derived ca. 13 mg day^{-1} (32.5%) and women 8 mg day^{-1} (20%) of the RNI of 40 mg day^{-1} from potatoes, including chips (French fries) (*6*). Data from the National Food Survey in 1990 (*4*, *7*) indicated that potatoes contributed 8 mg and processed potato products a further 2 mg of vitamin C to the daily diet, but, notably, the proportion from fresh potatoes is decreasing while the contribution from processed potatoes is increasing. Scottish reports indicate that one-third to one-half of the vitamin C contribution from potatoes to the daily diet was sourced via chips. This figure in part reflects the balance, or lack of balance, of the Scottish diet as much as it does the positive qualities of potatoes.

While ascorbic acid is found in most plant tissues, its biosynthetic pathway has only recently been fully elucidated (*8*). As an antioxidant, ascorbic acid plays an important role in protection against oxidative stress and is also involved in various cell functions, including cell division (*9*−*11*) and cell growth (*12*, *13*), in organogenesis (*14*), and in collagen synthesis, since collagen deficiency results in symptoms of scurvy in humans; all these functions serve to emphasize the importance of this vitamin within our diet.

Potato tubers contain L-ascorbic acid and dehydroascorbic acid (*15*), both of which can be determined either separately or as a combined value by the reduction of dehydroascorbic to ascorbic acid prior to analysis (*8*). In the potato, dehydroascorbic acid accounts for considerably less than 10% of the total ascorbate content of the tubers, even after prolonged storage, and indeed the value for dehyroascorbate frequently falls within the standard deviation value for ascorbic acid content (*15*). Consequently, the total ascorbate content of tubers is an excellent approximation of the ascorbic acid (vitamin C) value of potatoes.

There is limited published data on the extent of variation with regard to antioxidant content and its stability within potato germplasm. A review of the nutritional status of potatoes reported a range of variation for vitamin C content from 15 to 25 mg 100 g^{-1} fresh weight (*16*). A large range of vitamin C content between potato cultivars, varying from 84 to 145 mg 100 g^{-1} on a dry weight basis, has been reported (*17*). Significant differences between 98 *S. tuberosum* genotypes for

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Table 1. Key Agronomic and Sampling Dates for Field Trials

year	site	planting date	burndown date	harvest date	weeks storage postharvest
1999	England	14 May	22 Sep	14 Oct	15
1999	Germany	3 May	11 Aug	14 Sep	17
1999	Italy	4 Mar	na[a]	30 Jul	16
2000	England	10 May	25 Sep	7 Oct	16
2000	Germany	5 May	11 Sep	23 Sep	17
2000	Italy	16 Mar	na	21 July	15

[a] Not applicable, potatoes harvested without burning down foliage.

their ascorbic acid contents have been identified, while further data on 10 different wild species related to *S. tuberosum* exhibited contents ranging from 5.3 mg 100 g^{-1} fresh weight in *S. bulbocastanum* to 25.4 mg 100 g^{-1} in *S. stoloniferum* (*18*).

However, ascorbic acid in fresh foods, including potatoes, is not stable, with levels decreasing with time postharvest to 30−60% of the original within the first 2 months of storage and subsequently stabilizing at ca. 25% of the original level (*19*, *20*). An increasing proportion of the potato crop in Europe and worldwide is being processed, with an accompanying significant shift in the variety base toward potato cultivars with specific processing attributes. Important attributes include the ability to be stored at relatively low temperatures (ca. 4−6 °C) for long periods to ensure factory supplies. Ascorbic acid is known to be sensitive to air, heat, and water and can easily be denatured or destroyed by prolonged storage, overcooking, and processing of potatoes.

The objective of this study was to determine the effects of environment and cold-temperature storage on the total ascorbate content of potato tubers from a range of processing germplasm. The study also investigated the inherent factors influencing ascorbate content and the prospects for increasing levels through breeding programs.

MATERIALS AND METHODS

Plant Material. The genotypes used in this study were selected to represent a range of breeding material with particular processing attributes, notably having acceptable agronomic characters, high dry matters, and pale colors after frying. The germplasm was principally derived from near-commercial *S. tuberosum* breeding material emanating from research programs at the Scottish Crop Research Institute (17 genotypes, prefixed "UK"), from a German potato breeding program (8 genotypes, prefixed "DE"), and a Dutch breeding program (2 genotypes, prefixed "NL"). Six processing (control) cultivars were also included. The field trials were conducted over a 2-year period (1999, 2000) at each of three sites: (1) Ely, England, (2) Bad Schwartau, Germany, and (3) Bologna, Italy. Each trial consisted of three replicated plots of each genotype arranged in a randomized block design, with 10 plants in each plot in 1999 and three plants in each plot in 2000. Planting and harvest dates are given in **Table 1**.

The 33 genotypes (including six control cultivars) were harvested from the field plots where they had been grown, using normal agronomic practices. The tubers at the English and German sites were harvested at maturity 2 weeks after foliage burndown, while tubers from the Italian site were harvested while the foliage was still green, as per local practice. All tubers were shipped as soon as possible to the Scottish Crop Research Institute at Dundee, where they were washed, dried, and allowed to stabilize at an ambient temperature of ca. 12 °C for approximately 2 weeks prior to sampling or storage. The tubers from each plot were then either sampled at harvest and analyzed or placed into storage at 4 °C for a number of weeks (see **Table 1**) prior to sampling and chemical analyses.

Each replicated tuber sample consisted of five tubers, 55−65 mm in size. The tuber sampling procedures have been described elsewhere (*21*), with tubers at the time of sampling being cut into eighths, and the two opposite eighths collected and bulked by replicate. The replicate samples were then manually diced and immediately frozen by immersion in liquid nitrogen. After the samples were freeze-dried, they were ground in a mill fitted with a 0.5-mm sieve and stored at −20 °C until analyzed.

Table 2. Dry Matter (%) of Material in 2000 Field Trials (Mean of Three Replicates)

	2000 mean	at harvest		
		England	Germany	Italy
Hermes	24.2	24.2	23.4	25.1
Erntestolz	25.4	23.7	23.9	26.3
Allure	26.1	28.8	28.3	28.6
Brodick	22.3	22.2	20.8	21.3
Eden	25.3	24.1	24.0	24.0
Saturna	26.1	25.1	24.3	27.7
DE.3146.91	23.6	25.5	24.3	28.9
UK.GL76B/102	24.7	24.2	23.0	21.0
DE.3539.91	22.6	27.2	21.7	26.9
UK.86 Q 35 (38)	21.2	20.9	20.7	18.8
UK.86 Q 35 (8)	22.7	21.3	20.6	21.9
DE.3098.91	25.5	25.3	23.7	26.2
DE.3077.91	25.4	26.9	24.1	27.4
UK.G6634 (1)	22.1	22.3	23.4	25.1
NL.DJ9006	19.2	19.0	19.5	20.5
UK.86 Q 35 (15)	21.2	20.9	21.6	19.0
NL.DJ9131	22.5	21.3	21.7	21.1
UK.10920 AD 9	23.0	22.2	23.2	24.6
UK.86 VT 125	23.3	23.4	22.9	23.7
UK.86 Q 34 (28)	22.8	23.7	22.6	23.6
UK.86 Q 10 (7)	22.5	23.0	20.6	22.1
UK.14020 A 8	22.6	22.6	22.3	23.9
UK.14025 A 3	21.6	22.1	20.8	22.9
UK.86 Q 13 (30)	23.0	19.9	21.0	22.0
DE.3132.91	24.9	25.1	26.1	28.0
UK.13676 AB 1	21.6	22.5	21.7	23.4
UK.H1H3 (140)	22.2	23.3	19.2	20.7
UK.14628 AC 22	24.9	24.1	24.0	24.1
DE.4435.91	23.3	25.3	25.1	26.5
UK.14016 A 7	23.3	22.7	23.1	19.5
UK.12601 AB 1	26.1	24.4	26.3	24.2
DE.58 1624 /4	27.2	26.1	27.1	27.7
DE.OO12.89	27.2	27.6	26.7	28.4
means	23.62	23.66	23.08	24.09

Chemical Analyses. The dry matter content of the individual genotypes for the year 2000 material only (**Table 2**) was determined on the basis of differences in weight before and after freeze-drying, and was expressed as grams of freeze-dried matter per 100 g of fresh weight (g FDM 100 g FWt^{-1}). No discernible relationship within the material included in the study was identified between the dry matter levels and any of the other data collected.

Ascorbic acid and any dihydroascorbic acid were extracted from the potato samples using a 5% w/v aqueous solution of metaphosphoric acid containing 1% w/v dithiothreitol (DTT). The DTT not only served as an antioxidant but also reduced any dehydroascorbic acid to ascorbic acid (*22*), thus allowing total ascorbate content to be determined. After centrifugation, a 20-μL aliquot was injected into a high-performance liquid chromatograph fitted with a 250-mm × 4.6-mm Spherisorb S5 SAX anion exchange column (Waters Ltd, Elstree, UK). Ascorbic acid was eluted isocratically using 100 mM sodium acetate (pH 5) at a flow rate of 1 mL min^{-1}, and the effluent was monitored at 254 nm. Standard solutions of ascorbic acid were prepared freshly each day, and, by suitable dilution, a standard curve was produced from which the concentration of total ascorbate in the potato extracts analyzed on the same day could be determined. The results were normally expressed in terms of milligrams per gram of freeze-dried matter (mg g FDM^{-1}).

Experimental checks indicated that there was no reduction in ascorbic acid content of the potato extracts over a period of 6 h at room temperature. Similarly, a comparison of samples extracted with and without DTT and analyzed immediately postextraction appeared to confirm earlier results (*15*) that raw potato tubers contained negligible

Table 3. Overall Mean Ascorbic Acid Values for Years, Sites, and Treatments (at Harvest, Stored)

	England	Germany	Italy	mean	LSD
harvest 1999	0.86	0.82	1.04	0.91	0.078
stored 1999	0.56	0.49	0.54	0.53	0.075
average % loss	35	41	49	42	
harvest 2000	0.96	0.77	1.55	1.09	0.078
stored 2000	0.53	0.47	0.71	0.57	0.075
average % loss	45	39	55	48	

quantities of dehydroascorbic acid. However, to ensure that no oxidation of the extracted ascorbic acid occurred prior to analysis, DTT was included in the extracting medium for all the analyses reported in this work.

Statistical Analyses. Analyses of variance and regression analyses were carried out using Genstat for Windows, 5th ed. (VSN Ltd., Oxford, U.K.).

RESULTS AND DISCUSSION

The data across years, sites, treatments (harvest vs storage), and genotypes were transformed using natural logarithms to normalize the data and subsequently subjected to analyses of variance. The dominant statistically significant effects were primarily storage as well as site, year, and genotype. There were also statistically significant site-by-storage and, to a lesser degree, year-by-storage interaction terms (analyses not presented). All other interaction items were relatively minor and did not contribute significantly to the observed variation.

The means presented in **Table 3** illustrate some of the major significant items identified within the analysis of variance. The prominent effect of storage over ca. 16 weeks at ca. 4 °C on the ascorbic acid levels is evident through comparison of the harvest data to stored data. Significant losses were observed during storage in both years and across all sites. The mean harvest values for 1999 and 2000 (0.907 and 1.000 mg g FDM^{-1}, respectively) are notably higher than the mean year values poststorage (0.528 and 0.529 mg g FDM^{-1}, respectively). These represent the major effect with losses during storage in the order of 35−55%.

The significant "year" item was due to the 2000 season generally producing higher ascorbic acid levels than in 1999, though most of the observed effect is attributable to the results from the Italian site. This site tended to have the highest ascorbic acid contents both before and after storage compared with the English and German sites, particularly during the 2000 season. This was confirmed by the significant site-by-storage interaction and year-by-storage interaction items. The Italian site also suffered the greatest losses (**Tables 3** and **6**), which may be attributable to the trial being harvested before the onset of full maturity and foliage senescence. The results from the Italian trials appear to support the earlier findings from trials in Japan that ascorbic acid levels were low during the early growth phase and then increased with growth and development until approximately mid-August, after which a gradual decrease was observed (*23*).

The mean ascorbic acid levels for the individual genotypes at the three sites in both years (1999 and 2000) are presented in **Table 4** (at harvest) and **Table 5** (post-4 °C storage) with appropriate summary statistics. All values are expressed as mg g FDM^{-1}. The values in **Table 4** are ranked from high to low values for ascorbic acid content within the control cultivar group and within the genotype group. The same ranking is used in the remaining tables to facilitate comparison of different genotypes.

Table 4. Mean[a] Vitamin C (mg g FDM^{-1}) Content at Harvest in 1999 and 2000[a]

	overall	1999	2000	England[iv]		Germany[iv]		Italy[iv]	
genotype	mean[i]	mean	mean	1999	2000	1999	2000	1999	2000
Hermes	1.14	1.03	1.25	1.00	1.14	0.84	0.82	1.24	1.80
Entestolz	1.04	1.00	1.08	0.91	0.95	0.97	0.74	1.13	1.54
Allure	0.94	0.88	1.00	0.84	0.80	0.86	0.75	0.94	1.46
Brodick	0.85	0.73	0.96	0.61	0.75	0.61	0.60	0.98	1.55
Eden	0.83	0.74	0.91	0.69	0.79	0.65	0.56	0.88	1.39
Saturna	0.75	0.68	0.81	0.57	0.62	0.63	0.56	0.85	1.25
DE.3146.91	1.54	1.41	1.67	1.32	1.37	1.31	1.26	1.59	2.39
UK.GL76B/102	1.30	1.23	1.36	1.15	1.37	1.28	1.02	1.25	1.70
DE.3539.91	1.29	1.16	1.42	1.12	1.16	1.04	1.17	1.33	1.92
UK.86 Q 35 (38)	1.27	1.16	1.38	1.08	1.49	1.21	0.88	1.18	1.76
UK.86 Q 35 (8)	1.24	1.13	1.35	1.02	1.25	1.20	1.01	1.16	1.82
DE.3098.91	1.23	1.13	1.32	1.05	1.13	0.99	1.05	1.35	1.79
DE.3077.91	1.20	1.13	1.26	1.27	1.22	1.09	0.75	1.03	1.83
UK.G6634 (1)	1.14	1.00	1.29	0.99	1.21	0.91	0.98	1.09	1.67
NL.DJ9006	1.14	1.10	1.18	1.00	1.03	0.97	0.81	1.33	1.69
UK.86 Q 35 (15)	1.12	0.95	1.28	1.24	1.34	0.81	1.19	0.82	1.30
NL.DJ9131	1.10	1.00	1.20	0.89	1.11	0.78	0.74	1.34	1.76
UK.10920 AD 9	1.04	0.98	1.10	1.00	0.89	0.78	0.76	1.18	1.65
UK.86 VT 125	1.01	0.90	1.11	0.77	0.87	0.79	0.81	1.14	1.66
UK.86 Q 34 (28)	0.96	0.85	1.07	0.74	0.84	0.67	0.83	1.12	1.54
UK.86 Q 10 (7)	0.94	0.89	0.99	0.76	0.81	0.70	0.54	1.19	1.62
UK.14020 A 8	0.94	0.89	0.98	0.89	0.83	0.86	0.66	0.91	1.46
UK.14025 A 3	0.91	0.81	1.00	0.80	0.94	0.66	0.59	0.96	1.48
UK.86 Q 13 (30)	0.90	0.82	0.97	0.75	0.93	0.84	0.56	0.88	1.43
DE.3132.91	0.90	0.81	0.98	0.79	0.89	0.65	0.58	0.99	1.48
UK.13676 AB 1	0.89	0.78	1.00	0.64	0.78	0.71	0.70	1.00	1.52
UK.H1H3 (140)	0.86	0.73	0.99	0.67	0.89	0.66	0.63	0.87	1.45
UK.14628 AC 22	0.85	0.75	0.95	0.68	0.80	0.68	0.61	0.89	1.45
DE.4435.91	0.85	0.76	0.94	0.72	0.79	0.62	0.68	0.93	1.35
UK.14016 A 7	0.83	0.75	0.90	0.78	0.77	0.68	0.65	0.80	1.28
UK.12601 AB 1	0.73	0.63	0.84	0.56	0.71	0.51	0.60	0.81	1.20
DE.58 1624 /4	0.66	0.55	0.76	0.53	0.64	0.53	0.57	0.60	1.08
DE.OO12.89	0.65	0.57	0.74	0.61	0.65	0.53	0.67	0.56	0.91
means	1.00	0.91[ii]	1.09[ii]	0.86[iii]	0.96[iii]	0.82[iii]	0.77[iii]	1.04[iii]	1.55[iii]

[a] Least significant differences (LSDs) between i, overall cultivars means averaged over all years and sites = 0.083; ii, year means averaged over all cultivars and sites = 0.045; iii, year and site means average over all cultivars = 0.078; and iv, individual cultivars values at each site and year = 0.212.

Within **Table 4**, substantial differences are evident between the overall mean contents of ascorbic acid at harvest from the lowest ranking genotype, NL.0012 89, at 0.65 mg gFDM^{-1}, to the highest ranking genotype, DE.3146.91, with 1.54 mg g FDM^{-1}, which exceeds the range observed for the established control cultivars (0.75−1.14 mg g FDM^{-1}). Following storage at 4 °C (**Table 5**), there was a notable decline in the overall levels. However, a large range of values is still evident, ranging from 0.37 to 0.79 mg g FDM^{-1}.

Comparison of mean data values for 1999 and 2000 at harvest (**Table 4**) and after storage (**Table 5**) indicates a high level of consistency with regard to the ranking of individual genotypes and cultivars across years (Spearmans rank correlation: rs = 0.95,harvest and rs = 0.95,storage). The observed average decreases across all genotypes for ascorbic acid levels were in the order of 42% in 1999 and 48% in 2000 (**Table 6**), ranging from 20% to 60% losses. A small, though significant, "genotype-by-storage" interaction indicates that not all the genotypes lose ascorbic acid to the same extent during the storage periods. There was no evidence in **Table 6** of any pattern relating the degree of loss from harvest to poststorage levels of ascorbic acid in terms of genotype or year. Some genotypes with high initial levels lost almost half their ascorbic acid content (e.g., DE.3146.91), while other high genotypes lost relatively smaller amounts (e.g., UK.86.Q.35 38 at average losses of 38%). Other genotypes with low initial levels lost relatively high proportions

Table 5. Mean[a] Vitamin C (mg g FDM^{-1}) Content after Storage in 1999 and 2000

genotype	overall mean[i]	1999 mean	2000 mean	England[iv] 1999	England[iv] 2000	Germany[iv] 1999	Germany[iv] 2000	Italy[iv] 1999	Italy[iv] 2000
Hermes	0.63	0.61	0.65	0.63	0.58	0.55	0.51	0.66	0.86
Entestolz	0.63	0.60	0.66	0.63	0.55	0.52	0.54	0.65	0.91
Allure	0.60	0.60	0.60	0.61	0.52	0.58	0.53	0.61	0.76
Brodick	0.42	0.43	0.41	0.45	0.37	0.37	0.36	0.46	0.51
Eden	0.43	0.42	0.44	0.42	0.41	0.35	0.37	0.50	0.55
Saturna	0.44	0.43	0.45	0.43	0.34	0.40	0.40	0.48	0.60
DE.3146.91	0.79	0.75	0.83	0.77	0.72	0.64	0.60	0.85	1.18
UK.GL76B/102	0.77	0.77	0.76	0.67	0.80	0.81	0.56	0.84	0.91
DE.3539.91	0.75	0.69	0.82	0.67	0.76	0.69	0.64	0.71	1.06
UK.86 Q 35 (38)	0.79	0.74	0.84	0.77	0.84	0.73	0.73	0.72	0.94
UK.86 Q 35 (8)	0.63	0.58	0.68	0.57	0.72	0.65	0.56	0.53	0.75
DE.3098.91	0.76	0.72	0.80	0.74	0.63	0.72	0.72	0.70	1.05
DE.3077.91	0.59	0.61	0.58	0.71	0.53	0.62	0.53	0.49	0.67
UK.G6634 (1)	0.66	0.61	0.71	0.68	0.69	0.48	0.49	0.66	0.94
NL.DJ9006	0.56	0.52	0.61	0.60	0.57	0.46	0.50	0.49	0.77
UK.86 Q 35 (15)	0.79	0.75	0.84	0.97	0.93	0.58	0.84	0.68	0.73
NL.DJ9131	0.52	0.51	0.52	0.60	0.58	0.38	0.33	0.56	0.65
UK.10920 AD 9	0.46	0.46	0.46	0.49	0.39	0.41	0.38	0.48	0.61
UK.86 VT 125	0.58	0.54	0.61	0.56	0.58	0.49	0.49	0.57	0.76
UK.86 Q 34 (28)	0.49	0.46	0.52	0.49	0.46	0.41	0.51	0.49	0.59
UK.86 Q 10 (7)	0.45	0.42	0.47	0.44	0.40	0.42	0.36	0.40	0.66
UK.14020 A 8	0.50	0.49	0.50	0.52	0.42	0.47	0.43	0.46	0.66
UK.14025 A 3	0.48	0.48	0.49	0.52	0.44	0.47	0.46	0.44	0.58
UK.86 Q 13 (30)	0.37	0.38	0.36	0.45	0.35	0.34	0.29	0.36	0.44
DE.3132.91	0.53	0.49	0.56	0.52	0.49	0.42	0.45	0.52	0.75
UK.13676 AB 1	0.42	0.39	0.45	0.41	0.42	0.34	0.37	0.42	0.54
UK.H1H3 (140)	0.38	0.35	0.41	0.36	0.35	0.35	0.41	0.33	0.47
UK.14628 AC 22	0.46	0.43	0.48	0.44	0.43	0.39	0.42	0.47	0.60
DE.4435.91	0.51	0.49	0.53	0.51	0.51	0.48	0.43	0.47	0.65
UK.14016 A 7	0.49	0.46	0.52	0.51	0.49	0.41	0.43	0.47	0.64
UK.12601 AB 1	0.41	0.41	0.41	0.45	0.39	0.35	0.29	0.42	0.57
DE.58 1624 /4	0.41	0.41	0.40	0.51	0.41	0.34	0.29	0.39	0.50
DE.OO12.89	0.42	0.42	0.41	0.43	0.37	0.41	0.42	0.41	0.45
means	0.55	0.53[ii]	0.57[ii]	0.56[iii]	0.53[iii]	0.49[iii]	0.47[iii]	0.54[iii]	0.71[iii]

[a] Least significant differences (LSDs) between i, overall cultivars means averaged over all years and sites = 0.052; ii, year means averaged over all cultivars and sites = 0.043; iii, year and site means average over all cultivars = 0.075; and iv, individual cultivars values at each site and year = 0.142.

Table 6. Percentage Decrease in Vitamin C Content between Harvest and Poststorage

genotype	overall mean	1999 mean	2000 mean	England 1999	England 2000	Germany 1999	Germany 2000	Italy 1999	Italy 2000
Hermes	44.7	40.8	48.0	37.0	49.1	34.5	37.8	46.8	52.2
Entestolz	39.4	40.0	38.9	30.8	42.1	46.4	27.0	42.5	40.9
Allure	36.2	31.8	40.0	27.4	35.0	32.6	29.3	35.1	47.9
Brodick	50.6	41.1	57.3	26.2	50.7	39.3	40.0	53.1	67.1
Eden	48.2	43.2	51.6	39.1	48.1	46.2	33.9	43.2	60.4
Saturna	41.3	36.8	44.4	24.6	45.2	36.5	28.6	43.5	52.0
DE.3146.91	48.7	46.8	50.3	41.7	47.4	51.1	52.4	46.5	50.6
UK.GL76B/102	40.8	37.4	44.1	41.7	41.6	36.7	45.1	32.8	46.5
DE.3539.91	41.9	40.5	42.3	40.2	34.5	33.7	45.3	46.6	44.8
UK.86 Q 35 (38)	37.8	36.2	39.1	28.7	43.6	39.7	17.0	39.0	46.6
UK.86 Q 35 (8)	49.2	48.7	49.6	44.1	42.4	45.8	44.6	54.3	58.8
DE.3098.91	38.2	36.3	39.4	29.5	44.2	27.3	31.4	48.1	41.3
DE.3077.91	50.8	46.0	54.0	44.1	56.6	43.1	29.3	52.4	63.4
UK.G6634 (1)	42.1	39.0	45.0	31.3	43.0	47.3	50.0	39.4	43.7
NL.DJ9006	50.9	52.7	48.3	40.0	44.7	52.6	38.3	63.2	54.4
UK.86 Q 35 (15)	29.5	21.1	34.4	21.8	30.6	28.4	29.4	17.1	43.8
NL.DJ9131	52.7	49.0	56.7	32.6	47.7	51.3	55.4	58.2	63.1
UK.10920 AD 9	55.8	53.1	58.2	51.0	56.2	47.4	50.0	59.3	63.0
UK.86 VT 125	42.6	40.0	45.0	27.3	33.3	38.0	39.5	50.0	54.2
UK.86 Q 34 (28)	49.0	45.9	51.4	33.8	45.2	38.8	38.6	56.3	61.7
UK.86 Q 10 (7)	52.1	52.8	52.5	42.1	50.6	40.0	33.3	66.4	59.3
UK.14020 A 8	46.8	44.9	49.0	41.6	49.4	45.3	34.8	49.5	54.8
UK.14025 A 3	47.3	40.7	51.0	35.0	53.2	28.8	22.0	54.2	60.8
UK.86 Q 13 (30)	58.9	53.7	62.9	40.0	62.4	59.5	48.2	59.1	69.2
DE.3132.91	41.1	39.5	42.9	34.2	44.9	35.4	22.4	47.5	49.3
UK.13676 AB 1	52.8	50.0	55.0	35.9	46.2	52.1	47.1	58.0	64.5
UK.H1H3 (140)	55.8	52.1	58.6	46.3	60.7	47.0	34.9	62.1	67.6
UK.14628 AC 22	45.9	42.7	49.5	35.3	46.3	42.6	31.1	47.2	58.6
DE.4435.91	40.0	35.5	43.6	29.2	35.4	22.6	36.8	49.5	51.9
UK.14016 A 7	41.0	38.7	42.2	34.6	36.4	39.7	33.8	41.3	50.0
UK.12601 AB 1	43.8	34.9	51.2	19.6	45.1	31.4	51.7	48.1	52.5
DE.58 1624 /4	41.4	35.4	47.4	3.8	35.9	35.8	49.1	35.0	53.7
DE.OO12.89	35.4	26.3	44.6	29.5	43.1	22.6	37.3	26.8	50.5
means	45.2	41.6	48.1	33.9	45.2	40.0	37.7	47.6	54.5

at an average of 55−59.0% (UK.H1H3 140 and UK.86.Q.13 30), while NL.0012.89 exhibited a relatively low loss at 35%. There was a reasonable level of agreement between years with regard to losses of ascorbic acid during storage (Spearman's rank correlation, rs = 0.7749). From **Table 6**, it is evident that there is a good degree of agreement within individual genotypes across years and sites, with genotypes such as UK.86.Q.13 30 and UK.H1H3 140 consistently losing a significant amount during storage (average 55−59%), while genotypes UK.86.Q.35 15 and NL.0012.89 lost a relatively modest 29−35% of the total harvest ascorbic acid level.

These results identify considerable variation within potato germplasm with regard to inherent levels of ascorbic acid. The levels observed are in general agreement with levels reported elsewhere (*15*, *17*), as are the degree of losses during storage. There is a notable range of ascorbic acid levels, with a 2.4 times difference between the lowest to highest levels at harvest and a 1.8 times difference in levels following storage, with the highest levels poststorage (genotype DE.3146.91) exceeding some of the levels observed at harvest. The significant genotype effects and the consistency of observed levels across sites and years would indicate a degree of heritablity that could be exploited within breeding programs to improve the nutritive status of this staple crop. The range of decreases in ascorbic acid levels observed between the genotypes and the consistency of the individual potato genotypes across years and sites also indicate a heritable component that is now the basis of further investigation.

Apart from being a plant antioxidant, ascorbic acid has been recognized as an important natural inhibitor of enzymic browning in potatoes, a detrimental characteristic in potatoes, particularly in the processing industry. It reduces the initial oxidation products (*o*-quinones) back to *o*-diphenols and is itself quantitatively oxidized to dehydroascorbic acid. Ascorbic acid can also directly inhibit potato phenol oxidases by blocking the copper atoms present in the active site of the enzyme (*24*). Increased levels of ascorbic acid in potatoes act to reduce the levels of enzymic browning and, consequently, losses to the processing industry.

Improvements in the inherent stability of ascorbic acid during storage would also be of particular value where potatoes represent a major proportion of the vitamin C consumed in the diet. Clearly, over an entire year, the majority of potatoes used either in the home or for processing will have been stored for a considerable length of time in many countries. This suggests that, as a breeding objective, ascorbic acid content poststorage would be the most important and could significantly contribute to improving the ascorbic acid intake within UK diets without requiring radical changes to eating habits.

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