Quality Components in Fodder Beets

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INTRODUCTION

Fodder beet cultivars, which are included within the broad species *Beta vulgaris* L., have been selected and bred for their large size and their total dry matter, making them a useful livestock feed. They are widely grown in Europe for this purpose, but have been of limited importance in the U.S. They have come to recent attention, however, because of their reputed potential as sources of fermentable sugars for ethanol production (2).

In sugarbeets, which are conspecific with fodder beets, chemical quality of the large taproot is of great interest and concern because certain root constituents are recognized as especially detrimental to factory recovery of the economic product, sucrose (5). Sodium, potassium, and amino nitrogen (amino N) are important in this respect (6) and in addition are the components most often used to determine a calculated "purity," the fraction of soluble solids that is sucrose. In contrast, little is known about the concentrations of these components in current fodder beets, particularly as grown in the U.S. Thus, there exists a basic interest in comparing concentrations of sodium, potassium, and amino N in these two *B. vulgaris* genotypes, which are believed to be derived from the same ancestral stock (3) but have been selectively separated by human intervention for about two hundred years. In addition, there have been suggestions that fodder beets might be hybridized with sugarbeets to produce "all-purpose" beets which under various economic scenarios might some-

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times be processed for sucrose end-product recovery, or sometimes used as a fermentation feed-stock for ethanol fuel production. Although recent studies have refuted this idea on the basis of economics of sucrose production per unit area as well as for other reasons (1), the lack of knowledge of concentrations of fodder beet impurities has prevented any evaluation of the potential range of impurities in sugarbeet X fodder beet crosses. In this study we explored the concentrations of sodium, potassium, and amino N in a range of current fodder beet cultivars, and compared these data with those for a commercial sugarbeet cultivar.

MATERIALS AND METHODS

Data for this study were obtained from fodder beet and check sugarbeet cultivars grown in 1980 and 1981 in the field at Fort Collins, Colorado, as part of the National Cooperative Bio-Energy Project (7). As part of this project, a selected group of the most productive current European fodder beet varieties was planted at six locations and compared at each site with a locally adapted commercial sugarbeet check and with a national check, GW Mono-Hy D2. We note that many if not all of the "fodder beet" cultivars, as we shall continue to call them for convenience, undoubtedly include some introgressed sugarbeet germplasm.

The 1980 test at Ft. Collins included 14 fodder beet (FB) cultivars and two sugarbeet (SB) cultivars, and the 1981 test included 12 FB and 4 SB; although some FB cultivars were grown both years, the two experiments were not duplicates and the data are not combined over years. In this paper, the fodder beets are compared primarily with the locally adapted commercial sugarbeet check, GW Mono-Hy D2. Zwaan Poly, a high yielding Netherlands sugarbeet with introgressed fodder beet, was included in both years, and two other U.S. commercial sugarbeets, Beta 1237 and GW Mono-Hy E4, were included in the 1981 test; these data are included in this report for those who might wish to compare them with the fodder beet data.

In each year the experiment was a randomized complete block with six replications. Each plot consisted of four rows, each 6.1 m long and spaced 56 cm apart. At the four- to six-leaf stage, plants were thinned to one plant every 25 cm in each row. Fertilization, furrow irrigation, and disease control typical of commercial sugarbeet production practices in the area were applied.

The two center rows of each four-row plot were harvested and analyzed separately. A standard aluminum-clarified (1.0 g/L aluminum chloride) brei extract (4) was prepared; determined from this extract were sucrose by polarimetry, sodium and potassium by flame photometry with lithium internal standard, and amino N by spectrophotometry after reaction with ninhydrin. Within each year, data were analyzed by analysis of variance.

RESULTS AND DISCUSSION

There were significant differences among the cultivars for all four variables determined, in both years of the study (Tables 1 and 2). The results for each year are discussed in comparison with the locally adapted sugarbeet check, GW Mono-Hy D2. Because sugarbeets have been selected primarily for their sucrose content and fodder beets have not, the significantly lower sucrose concentration found in every FB cultivar relative to the SB check was to be expected. The sucrose content of all cultivars was somewhat depressed in 1981 because of environmental conditions including an early-season hail storm, but the sucrose concentrations of the FB cultivars were from 50 to 74% of that of the sugarbeet check in 1980, and 58-72% in 1981.

Amino N concentrations of the FB cultivars in each year were comparable to that of the check, with a few being significantly different (1 lower and 1 higher in 1980; 3 lower in 1981). It is particularly interesting that the sugarbeet cultivars were not generally lower than the fodder beets in this character, despite considerable effort by sugarbeet breeders to reduce extractable nitrogenous compounds because of their detrimental effects on

Table 1. Mean sucrose, sodium, potassium, and amino N concentration in extracts from 14 fodder beet cultivars and two sugarbeet cultivars, 1980 test.

Description	% Sucrose	mg/100 ml aluminum-clarified filtrate		
		Sodium	Potassium	Amino N
Fodder Beets				
Lamono I	12.54 cd	9.6 bc	24.6 bcd	2.77 bc
Lamono II	11.40 ef	12.9 ab	22.7 cd	2.77 bc
Kyros	11.13 ef	12.1 ab	23.7 bcd	2.20 c
Monovigor	11.35 ef	13.4 ab	27.7 abc	3.80 ab
Barsein	12.65 cd	11.2 abc	24.6 bcd	2.82 bc
Monriac	11.67 def	10.5 abc	26.5 abcd	3.15 abc
Monorosa	13.00 c	11.7 ab	27.0 abc	4.20 a
Yellow Daeno	10.05 gh	13.6 ab	27.2 abc	2.93 bc
Monoblanc	11.95 cde	13.5 ab	26.6 abcd	3.63 ab
Monara	9.03 i	13.4 ab	31.4 a	2.82 bc
Eckdobarres	8.79 i	13.5 ab	26.0 abcd	2.78 bc
Oscar	9.62 hi	13.9 a	28.0 abc	2.80 bc
Beta Rose Sugar	10.85 fg	12.5 ab	29.1 ab	3.22 abc
Monorosover	11.79 def	11.6 ab	29.2 ab	3.83 ab
Sugarbeets				
GW Mono-Hy D2	17.59 a	3.0 d	21.5 d	3.60 ab
Zwaan Poly	15.92 b	7.8 c	25.2 bcd	2.98 abc
F-test	55.2**	5.78**	2.39**	2.13*

*,** Significan at the 0.05 or 0.01 level of probability, respectively.
% Sucrose = sucrose as percent of root fresh weight.

Within a column, means followed by the same letter do not differ significantly at the 0.05 probability level according to Duncan's Multiple Range Test.

sucrose recovery. The introgression of sugarbeet into modern "fodder beets" could partly explain the lack of difference in amino N concentration, but another possible explanation is that the amino acid pool and amino N compounds observed are necessary components of the plants' metabolism, and relatively little reduction may be possible.

Sodium and potassium concentrations of the FB cultivars, on the other hand, always averaged higher than those of the SB check, although the differences were not always significant in the case of potassium. Sodium was strikingly more prevalent in the FB, with a 1980 range relative to the sugarbeet check of 320-460% and a 1981 range of 240-400%. In this case, the fodder beet values presumably

Table 2. Mean sucrose, sodium, potassium, and amino N concentration in extracts from 12 fodder beet cultivars and four sugarbeet cultivars, 1981 test.

Description	% Sucrose	mg/100 ml aluminum-clarified filtrate Sodium	Potassium	Amino N
Fodder Beets				
Lamono I	10.83 cde	12.9 cd	29.6 ab	3.62 bc
Lamono II	9.44 f	19.8 a	26.8 cde	4.03 bc
Kyros	9.62 ef	16.1 abcd	28.6 abc	2.65 c
Monovigor	11.17 cd	14.0 bcd	30.1 ab	3.69 bc
Barsein	10.85 cde	14.9 bcd	24.7 ef	3.12 bc
Monriac	9.75 ef	14.1 bcd	29.0 abc	4.18 bc
Monorosa	11.65 c	12.6 cde	29.4 ab	3.80 bc
Hugin	10.22 def	16.7 abc	29.0 abc	3.53 bc
Monovert	9.97 def	18.4 ab	24.9 def	3.87 bc
TC5/45-9	9.91 def	15.2 bcd	27.8 bc	2.92 c
Barb 79-1	10.34 def	13.3 cd	30.2 a	2.63 c
TC 2018	11.76 c	11.7 de	23.9 fg	3.80 bc
Sugarbeets				
GW Mono-Hy D2	16.41 a	4.9 f	21.8 g	4.48 ab
Zwaan Poly	14.41 b	11.8 de	26.9 cd	5.62 a
Beta 1237	16.58 a	8.4 ef	22.5 g	2.90 c
GW Mono-Hy E4	16.63 a	6.3 f	22.0 g	3.77 bc
F-test	38.4**	7.98**	16.8**	2.75**

** Significant at the 0.01 level of probability

% Sucrose = sucrose as percent of root fresh weight

Within a column, means followed by the same letter do not differ significantly at the 0.05 probability level according to Duncan's Multiple Range Test.

reflect the heritage of both FB and SB as highly salt-tolerant, perhaps halophytic plants, whereas sugarbeets have had this uptake pattern modified through selective breeding for lower sodium and potassium. Potassium concentrations of the FB cultivars versus the sugarbeets also follow this pattern, although not as uniformly, with seven FB cultivars in 1980 and one in 1981 not significantly higher in potassium than the sugarbeet check.

If data are expressed on the basis of impurity concentration per unit of sucrose, the much lower sucrose content of the FB cultivars results in even greater differences between the fodder beets and the SB check (Table 3). The glucose and fructose content of fodder beets, once thought to be much greater than that of sugarbeets, has

Table 3. Comparison of fodder beets with a sugarbeet check, data in g/100 g sucrose.

	Concentration in SB check		Concentration in Fodder Beets, % of SB check	
Component	1980	1981	1980	1981
Sodium	0.13	0.24	460-920	330-740
Potassium	0.94	1.04	160-290	150-230
Amino N	0.16	0.22	94-160	95-160

been shown to be low, averaging 0.32% of fresh weight for the 14 FB cultivars in 1980 vs 0.14% in GW Mono-Hy D2 in the 1980 test, for example (6). Thus, inclusion of other sugars in the computation would not significantly change these results.

The data presented here are based on a comparable weight of tissue extracted in a proportional amount of liquid; the weight-to-volume ratio was identical for both SB and FB. Because FB have much higher tonnage root yield than SB (in 1980: 70-88 Mg ha^{-1} for the FB cultivars, vs. 57 Mg ha^{-1} for the SB check (D2); in 1981: 82-100 Mg ha^{-1} for FB, vs. 59 Mg ha^{-1} for the SB check), this would further magnify the amounts of these impurities that would be extracted from FB per hectare. These impurities, of course, probably would be of little or no significance if the beets were to be used as a feedstock for fermentation procedures. However, we can conclude from these impurity levels in modern fodder beets, which no doubt already contain some introgressed sugarbeet germplasm, that sodium and potassium contents of future sugarbeet X fodder beet crosses would impede use of such developments for sucrose recovery.

SUMMARY

Twelve fodder beet cultivars in 1980 and 14 in 1981 were compared with a sugarbeet check cultivar for extracted sucrose, sodium, potassium, and amino nitrogen. Sucrose was significantly lower in every fodder beet cultivar relative to the check, with the range among the fodder beet cultivars 50-74% of the check in 1980 and 58-72% in 1981. Sodium content of the fodder beets similarly was significantly greater for each cultivar than that of the

check, with a relative range of 320-460% of the check in 1980 and 240-400)% in 1981. One fodder beet cultivar in 1980 and seven in 1981 did not differ significantly from the check in extract potassium concentration, and several fodder beet cultivars were significantly lower in amino N concentration than the sugarbeet check. The data permit an examination of how long-term selection for different purposes has altered chemical composition in these conspecific plant cultivars, and the Na, K, and amino N contents of fodder beets lend support to the conclusion that there is little merit in a sugarbeet X fodder beet "all purpose" food and fuel beet.

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