HortScience 29(3):209-210. 1994.

Kernel Protein Concentration in *sugary-1* and *shrunken-2 Sweet* Corn

I.L. Goldman[1] and W.F. Tracy[2]
University of Wisconsin–Madison, 1575 Linden Drive, Madison, WI 53706

Additional index words. Zea mays, corn, vegetable, nutrition

Abstract **Changes in endosperm type used for commercial sweet corn *(Zea mays* L.) production may affect corn protein levels. The two most widely used endosperm types are *sugary-1 (su1)* and *shrunken-2 (sh2).* To determine the effects of endosperm type on protein concentration, we calculated kernel N concentrations of dry mature kernels of seven inbreds near-isogenic for *su1* and *sh2* and of four samples of commercially canned *su1* and *sh2* sweet corn. Nitrogen values were converted to protein values using a standard conversion factor for maize. For the dry kernels and the canned samples, significant differences were detected between endosperm types for kernel protein concentration when measured on a weight basis. Averaged overall inbreds, the *sh2* dry kernels had 30% more protein than *su1* kernels. On a weight basis, the *sh2* canned samples averaged 22% more protein than the *su1* samples. When compared on a kernel basis, protein concentration of the two endosperm types did not differ. Thus, *sh2* sweet corn marketed as a frozen or canned product may be identified as a higher protein product when the serving size is based on weight or calories.**

Sweet corn is one of the most popular vegetables in the American diet. It is second in per capita consumption among processed vegetables after tomatoes and ranks seventh among the fresh vegetables (U.S. Dept. of Agriculture, 1990). While few Americans depend on vegetables as a major source of dietary protein, among vegetables, sweet corn is one of the most important protein sources because of its high consumption and relatively high protein concentration (3.5 g protein/100 g edible portion; U.S. Dept. of Agriculture, 1975).

Little information is available on variation in protein concentration in sweet corn. Sanderson et al. (1979) studied the changes in endosperrn protein concentration in three sug*ary-1 (su1)* hybrids over time. They found hybrid protein concentration to be ≈ 20% at 15 days after pollination (DAP). At 30 DAP, protein dropped to ≈ 12% and remained stable at 12% at 45 and 60 DAP. Differences among the hybrids were small.

Until recently, sweet corn was defined by the presence of the *su1* allele. However, other alleles at other loci are now coming into widespread commercial use, most notably *shrunkert-2 (sh2)* (Tracy, 1993). These genes code for enzymes important in endosperrn starch biosynthesis. The alleles important in sweet corn, *(su1)* and *(sh2),* reduce starch synthesis and increase the concentration of sugar, phytoglycogen, or both in the endosperm (Boyer and Shannon, 1983). Since starch concentration of corn kernels is inversely correlated with kernel protein concentration (Dudley and Lambert, 1992), mutants that affect starch synthesis may affect protein concentration as well. Several examples of corn endosperm mutants with a primary effect on starch synthesis and secondary effects on protein synthesis have been reported (Baudet et al., 1968, Wolf et al., 1975). Tsai et al. (1978) measured zein and non-zein protein concentration in a dent corn inbred, Oh43, near-isogenic for several mutants affecting kernel starch and protein biosynthesis. The *sh2* version had lower total protein concentrations when measured on an endosperm basis compared to the wild type. Recent evidence has suggested that kernel protein concentration may be genetically modified by alleles at or in close proximity to the *sh2* locus (Goldman et al., 1993), perhaps because of the inverse relationship between kernel protein and starch.

Previous work on *sh2's* effect on kernel protein has involved few genotypes, none of which were sweet corn. Given the increased consumption of *sh2* sweet corn, it is important to determine the effects of this allele on sweet corn protein. The objectives of this study were to measure protein concentration of sweet corn in inbreds near-isogenic for endosperm types *su1* and *sh2,* and to determine portion concentration of commercially canned *su1* and *sh2* sweet corn.

Materials and Methods

Seven sweet corn inbreds near-isogenic for *su1* and *sh2* were developed by Soberalske and Andrew (1978) (see Table 1). The inbreds were originally chosen because they were well adapted to Wisconsin, had similar flowering dates, and were genetically diverse. All 14 strains were grown at the West Madison Agricultural Research Station in 1992. At least six ears per strain were self-pollinated. The ears were harvested after physiological maturity, ≈ 45 days after pollination, and air-dried to ≈ 10% moisture. The kernels were shelled by hand and all kernels from all harvested ears of each strain were bulked. In addition to field-grown samples, canned samples of commercially available sweet corn were purchased from a supermarket in Madison, Wis. A total of four canned samples were obtained; one *su1* sample from each of two companies, and one *sh2* sample from each of the two companies. Liquids were drained from the canned samples and kernels were freeze-dried. Kernels from each of the endosperm types in each of seven inbreds and the canned samples were ground in a Wiley mill using a no. 30 mesh screen. A 0.250-g sample was analyzed for total N content via the Dumas procedure, using a LECO nitrogen analyzer according to standard procedures established for grains. This procedure, which is common in analysis of grain protein concentration, is more precise than methodologies based on near-infrared technology (B.L. Jones, personal communication). Nitrogen assessments were run twice. Nitrogen content in the sample was converted to total protein concentration by multiplying the

Table 1. Mean kernel protein concentration, kernel weight, and quantity of protein per kernel of three fresh sweet-corn endosperm types from seven genetic backgrounds.

Genetic background	Endosperm type	Protein concn (%)	Wt/ 100 kernels (g)	Protein/ kernel (mg/kernel)
Ia453	*su1*	14.1	16.8	2.37
	sh2	16.3	8.4	1.37
C23	*su1*	13.3	18.5	2.46
	sh2	18.0	10.6	1.91
C68	*su1*	13.6	19.9	2.70
	sh2	16.9	8.8	1.49
101t	*su1*	14.5	20.1	2.91
	sh2	18.2	11.5	2.09
P39	*su1*	14.7	11.3	1.66
	sh2	20.5	6.5	1.33
Ia5125	*su1*	11.6	15.0	1.75
	sh2	15.7	8.1	1.27
C40	*su1*	12.8	25.9	3.30
	sh2	17.3	17.2	2.90
$LSD_{0.05}$		1.02	6.6	NS

Received for publication 14 May 1993. Accepted for publication 19 Nov. 1993. Research supported by the College of Agricultural and Life Sciences, Univ. of Wisconsin-Madison. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Dept. of Horticulture.
[2]Dept. of Agronomy.

N percentage by the standard corn conversion factor (6.25; Villegas, 1975); the resulting values were reported as total protein concentration of the 0.250-g sample. Protein quantity on a kernel basis was determined by multiplying the protein percentage by the weight of an individual kernel in each endosperrn type/inbred combination. Data were subjected to analysis of variance, and mean differences among endosperm types were compared by least significant difference.

Results and Discussion

The analysis of variance combined over inbreds revealed highly significant differences between endosperm types for kernel protein concentration in the dry kernels and for kernel weight. Protein per kernel did not differ between endosperm types. Dry kernels of all *sh2* strains had significantly higher protein concentration than did kernels of their *su1* counterparts (Table 1). Averaged over all inbreds, the protein concentration of *sh2* corn (17.6%) was 30% higher than that of *su1* corn (13.5%). The protein concentration of the *su1* corn was similar to that reported by Sanderson et al. (1979). *sh2* kernels were significantly lighter than *su1* kernels in six of the seven near-isogenic comparisons (Table 1). While the difference was not significant, the *su1* strains had more protein per kernel in all comparisons.

The average protein concentration of the two canned samples of *sh2* corn (13.7%) was 22% higher than the protein concentration of the *su1* (11.3%) samples. However, mean separation procedures revealed only one of the *sh2* samples had significantly higher protein concentration than the *su1* samples (Table 2). The two *sh2* samples were not significantly different from one another. We have no information on the inbred backgrounds of the commercial samples, and it should not be assumed that these are isogenic comparisons. The data from the canned samples also indicate protein concentration was higher in *sh2* corn than in *su1* corn; however, the difference was slightly smaller at the eating (22%) than at the dry kernel stage (30%).

Table 2. Mean kernel protein concentration of two canned sweet-corn endosperm types from two genetic backgrounds.

Company	Endosperm type	Protein concn (%)
A	*su1*	11.2
B	*su1*	11.4
A	*sh2*	12.8
B	*sh2*	14.6
$LSD_{0.05}$		2.4

Results from this investigation demonstrate that protein concentration, on a weight basis (concentration), in dry *sh2* kernels is significantly higher than protein concentration in *su1* kernels. These differences should be reflected in the concentration of total zein, which typically accounts for 50% of the total kernel protein. An important distinction between protein percentage and total amount of protein per kernel must be made in interpreting these results. Weight per 100 kernels differs by about two-fold in comparisons of *sh2* and *su1* (Table 1). Kernels containing the sh2 mutant have a much smaller endosperrn than *su1* due to the effects of this mutant on starch synthesis. Reductions in endosperm size result in smaller, lighter kernels. Since *sh2* kernels weigh about one-half as much as *su1* kernels, protein concentration measured on a kernel basis does not differ.

In general, consumption of *sh2* sweet corn on a per ear basis would not result in a larger protein intake. When sweet corn is consumed or labeled on a volume basis, the protein concentration of *sh2* may be the same or lower than that of *su1* corn. However, when protein concentration is labeled on a weight or calorie basis, as is possible in frozen or canned products, protein concentration of *sh2* types is significantly higher.

Literature Cited

Baudet, J., A. Cauderson, G. Fauconneau, J. Mosse, and R. Pion. 1968. Sur un troisieme gene mutant *(amylose extender-)* qui accroit la en lysine du grain de mais et sur son effet cumulatif avec le gene *opaque-2*. C.R. Acad. Sci. Ser. D. 266:2260-2263.

Boyer, C.D. and J.C. Shannon. 1983. The use of endosperm genes for sweet corn improvement. Plant Breeding Revs. 1: 139–161.

Dudley, J. W. and R.J. Lambert. 1992. Ninety generations of selection for oil and protein in maize. Maydica 37:1–7.

Goldman, I.L., T.R. Rocheford, and J.W. Dudley. 1993. Quantitative trait loci influencing protein and starch concentration in the Illinois long term selection strains. Theor. Appl. Genet. 87:217–224.

Sanderson, J.E., J.W. Paulis, F.N. Porcuna, and J.S. Wall. 1979. Sweet corn:Varietal and developmental differences in amino acid content and composition of grain. J. Food Sci. 44:386-388.

Soberalske, R.M. and R.H. Andrew. 1978. Gene effects on kernel moisture and sugars of near-isogenic lines of sweet corn. Crop Sci. 18:743–746.

Tracy, W.F. 1993. Sweet corn, p. 777-807. In: G. Kalloo and B.O. Bergh (eds.). Breeding vegetable crops. Pergammon Press, Oxford, England.

Tsai, C. Y., B. A. Larkins, and D. V. Glover. 1978. Interaction of the *opaque-2* gene with starch-forming mutant genes on the synthesis of zein in maize endosperm. Biochem. Genet. 16:883–896.

U.S. Dept. of Agriculture. 1975. Handbook of the nutritional content of foods. Dover Press, New York.

U.S. Dept. of Agriculture. 1990. Agricultural statistics. U.S. Government Printing Office, Washington, D.C.

Villegas, E. 1975. An integral system for chemical screening of quality protein corn, p. 331–336. In: E.T. Mertz (ed.). High quality protein maize. Dowden, Hutchinson, and Ross, Stroudsburg, Pa.

Wolf, M. J., C.C. Harris, and G.L. Donaldson. 1975. Corn endosperm: Protein distribution and amino acid composition in amylocorn vs. normal dent hybrid, Cereal Chem. 52:765–770.