

The Effect of Storage Temperature on Sugar Accumulation in the Potato Line ND860-2 and Its Progeny Lines

A.A. Boe, D. Lopez-Portilla, R.H. Johansen and M.K. Ehlenfeldt

When stored at cold temperatures, tubers of conventional potato varieties accumulate sugars. High sugar concentrations in the tubers result in an objectionable sweet flavor in baked or boiled potatoes and result in dark colored chips and french fries (6). Potatoes that are destined for use as chips or fries are usually taken from cold storage and reconditioned at 55 to 60 degrees Fahrenheit (12 to 16 C) for a period of one to two weeks to reduce the sugars and make them satisfactory for processing. The process of reconditioning is energy consumptive and another expense for potato producers and processors.

Lauer and Shaw (3) found that potato lines developed by crossing the cultivated potato, *Solanum tuberosum*, with the diploid species, *Solanum phureja*, could be successfully chipped after cold storage without reconditioning. From their studies, they speculated that this characteristic was probably simply inherited and could be used to develop varieties with this characteristic. R.H. Johnson from the Department of Horticulture and Forestry incorporated this cold chipping characteristic into the potato breeding program at NDSU. The potato selection ND860-2 is one-eighth *S. phureja* and can be chipped out of cold storage without reconditioning (1,2).

This study reports the effects of storage temperatures on the accumulation of reducing and total sugars in ND860-2 in comparison with the varieties Norchip and Kennebec. Also reported are the effects of using ND860-2 and ND2221-6, another cold chipper, as parents on the reducing and total sugar accumulation of their progeny.

Tubers of Kennebec, Norchip and ND860-2 were divided into eight lots of approximately 50 lbs. (22.8 kg.) each. Four lots of each variety were placed in refrigerated storages at 38 F (3.3 C) and 45 F (7.2 C). Four tubers were removed from each lot at approximately two-week intervals and sampled to determine the total and reducing sugar accumulation.

For the breeding study, the varieties Kennebec, Norchip, ND860-2 and ND2221-6 were used as parents. Hand pollinations were made in the greenhouse. All possible crosses were made and seed was obtained for 11 families. The cross Kennebec x ND2221-6 did not produce any seed.

The true potato seed was sown in the greenhouse and the seedlings were transplanted into 6-inch (15 cm) plastic pots

containing a commercial soil mix. The tubers produced by these plants were harvested and stored for use in the field experiments.

Twenty hills of each family were grown under dryland conditions at two locations — the Agronomy Seed Farm at Casselton and the Horticulture Research Farm at Absaraka. The plantings were made in late May. Weed control was accomplished by cultivation and hand weeding. The potatoes were harvested by hand digging. The tubers from each plant were kept separate at harvest and were stored for 90 days at 40 F (4.4 C) prior to analysis for total and reducing sugar concentrations.

The tubers from five plants of each of the four replications grown in the field were used for the sugar analyses. The sampling process was the same as for the storage study.

RESULTS AND DISCUSSION

Both reducing and total sugar concentrations were elevated in the tubers stored at 38 F (3.3 C) compared to 45 F (7.2 C) (Table 1). The percentage of the total sugars present as reducing sugar was also increased at the lower temperature.

Of the three varieties used in this study, Kennebec accumulated the most sugar during the storage period and had the highest percentage of sugar present as reducing sugars (Table 2). Norchip contained nearly as much total sugar as Kennebec but a lower percentage of these sugars was converted to reducing sugars. This characteristic helps make Norchip the top chipping variety in the United States. ND860-2 had the lowest concentrations of both reducing and total sugars and also had the lowest conversion of total

Table 1. Effect of storage temperature on the reducing and the total sugar concentration in tubers summed over three varieties and eight storage dates (November 18 - March 6).

Temp.	Reducing Sugar (%)	Total Sugar (%)	Ratio Reducing/Total
38° F	0.77 a ¹	1.00 a	0.77
45° F	0.27 b	0.62 b	0.44

¹Values not followed by the same letter are different, based on the Student-Neuman-Keuls test for variability P = 0.05.

Boe is department chairman, Lopez-Portilla was a graduate student, Johansen is professor and Ehlenfeldt is research associate, Department of Horticulture and Forestry.

Table 2. Effect of the variety on the reducing and the total sugar concentrations summed over the duration of experiment (November 18 - March 6) at two temperatures; 38° F (3.3° C) and 45° F (7.2° C).

Cultivar	Reducing Sugar	Total Sugar	Ratio
	(%)	(%)	Reducing/Total
Kennebec	0.78 a ¹	0.93 a	0.84
Norchip	0.55 b	0.87 b	0.63
ND860-2	0.23 c	0.62 c	0.37

¹Values not followed by the same letter are different based on the Student-Neuman-Keuls test for variability P = 0.05.

sugar to reducing sugars. Because of their characteristic, ND860-2 can be successfully chipped after storage at low temperatures without reconditioning. During the storage period of the study, Kennebec and Norchip always had a higher concentration of sugars and a higher percentage of the total sugar present as reducing sugars than ND860-2 (Table 3). High reducing sugar concentrations are related to the browning of potato chips during frying (4,6) and therefore lower concentrations result in higher quality product.

In the potato breeding study, crosses with the low sugar accumulating lines, ND860-2 and ND2221-6, produced families that accumulated less sugar overall than either Norchip or Kennebec (Table 4). Although both reducing and total sugars were lowered in these crosses, the reducing sugars were lowered relatively more than total sugar. This is reflected in the ratio of reducing to total sugars. This value provides a useful guide to a line's potential to accumulated reducing sugars and in turn, as to its ability to chip directly from cold storage.

This low reducing sugar accumulation characteristic is readily transferred into new lines or clones. This makes it potentially possible to improve the storage and processing quality of all classes of potatoes. Also of interest is the decreased cost to the producer and processor if processing potatoes do not have to be reconditioned prior to chipping or frying.

LITERATURE CITED

- Coffin, R.H., R.Y. Yada, K.L. Parkin, B. Grodzinski and D.W. Staley. 1987. Effect of low temperature storage on sugar concentrations and chip color of certain processing potato cultivars and selections. *J. Food Sci.* 52:639-645.

Table 3. Effect of two storage temperatures on the ratio of reducing sugar to total sugar in tubers of three potato varieties at eight sampling dates, 1985-86.

Date	38° F (3.3° C)			45° F (7.2° C)		
	Kennebec	Norchip	ND860-2	Kennebec	Norchip	ND860-2
11/18/85	.99	.86	.31	.41	.23	.14
12/3/85	.97	.80	.52	.68	.37	.28
12/21/85	1.00	.88	.48	.46	.42	.21
1/9/86	1.00	.84	.42	.75	.52	.19
1/21/86	1.00	.71	.28	.59	.39	.17
2/6/86	1.00	.65	.65	.52	.36	.29
2/20/86	.79	.80	.54	.80	.45	.11
3/6/86	.95	.77	.55	.64	.34	.24
Average	.96	.79	.47	.61	.39	.20

Table 4. Ranking of parents and crosses for percent reducing sugars, percent total sugars and the ratio of reducing sugars to total sugars.

	Reducing Sugar (%)	Total Sugars (%)	Reducing/Total ¹
1	Norchip x Kennebec 1.37 a ²	Norchip x Kennebec 1.90 a	Kennebec 0.79
2	Kennebec 1.29 a	Kennebec x Norchip 1.72 ab	Kennebec x Norchip 0.75
3	Kennebec x Norchip 1.29 a	Kennebec 1.65 b	ND2221-6 x Kennebec 0.73
4	ND2221-6 x Kennebec 0.94 b	Norchip 1.43 c	Norchip x Kennebec 0.72
5	Kennebec x ND860-2 0.81 bc	ND860-2 x Kennebec 1.36 c	Kennebec x ND860-2 0.68
6	ND860-2 x Kennebec 0.75 bcd	ND2221-6 x Norchip 1.15 c	ND860-2 x Kennebec 0.55
7	Norchip x ND2221-6 0.68 cde	Norchip x ND2221 1.27 c	ND2221-6 x 860-2 0.54
8	Norchip 0.67 cde	Norchip x ND860-2 1.26 c	Norchip x ND2221-6 0.54
9	ND860-2 x Norchip 0.64 cde	ND860-2 x Norchip 1.21 c	ND860-2 x Norchip 0.53
10	Norchip x ND860-2 0.54 cde	Kennebec x ND860-2 1.21 c	Norchip 0.47
11	ND2221-6 x Norchip 0.53 def	ND2221-6 x Norchip 1.15 c	ND2221-6 x Norchip 0.46
12	ND2221-6 x ND860-2 0.47 efg	ND860-2 x ND2221-6 0.90 d	Norchip x ND860-2 0.45
13	ND860-2 x ND2221-6 0.41 fg	ND2221-6 x ND860-2 0.88 d	ND860-2 x ND2221-6 0.45
14	ND860-2 0.30 g	ND860-2 0.75 d	ND860-2 0.41
15	ND2221-6 0.29 g	ND2221-6 0.73 d	ND2221-6 0.39

¹Ratio — Reducing Sugar/Total Sugars

²Values not followed by the same letter(s) are different based on the Student/Newman/Keuls test for variability. P = 0.05.

2. Johansen, R.H. 1986. NDSU potato breeding program. *Valley Potato Grower* 52:32-33.
 3. Lauer, F. and R. Shaw. 1970. A possible genetic source for chipping potatoes from 40° F storage. *Am. Potato J.* 47:275-278.
 4. Mazza, G. 1983. Correlations between quality parameters of potatoes during growth and long-term storage. *Am. Potato J.* 60:145-159.
 5. Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153:375-380.
 6. Schimmer, S., C.E. Hendel, W.O. Harrington and R.L. Olson. 1957. Interrelationship among measurements of browning of processed potatoes and sugar components. *Am. Potato J.* 34:119-132.
-

Continued from page 6

mainly on sugars and specific gravity. Because these materials are in part composed of an exotic species, their yields are generally inferior. However, a few show some promise, and the best are being selected for further crossing.

Two current graduate students, Young-Doo Park and Byoung-OK Kim, are embarked on projects to generate varietal variants through tissue culture. These projects aim to produce useful variation in already highly selected materials by manipulating chromosome numbers and by altering fine scale DNA structure respectively. These projects may be expected to produce only minor changes and to yield elite lines which can be readily incorporated into advanced testing plots.

HOLLOW HEART

A new initiative being undertaken is the development of early generation screening methods for hollow heart susceptibility. This is an area of needed research since the large influence of environment on hollow heart makes it difficult to screen for susceptibility during early stages of a breeding program. Preliminary studies looking at several morphological characteristics of tuber tissue suggest that it may be possible with only modest effort to screen large numbers of clones quickly and retain only those with a low hollow heart susceptibility.