YIELD AND RELATIONSHIPS AMONG TUBER SIZE, SUCROSE AND CHIP COLOR IN SIX POTATO CULTIVARS ON VARIOUS HARVEST DATES[1]

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Abstract

Cultivars were harvested biweekly for yield, weekly for sucrose determinations, and stored for chipping. At the last harvest Crystal was highest in total and marketable yield. Specific gravity was higher in Lemhi, Russet Burbank, and Norchip than in Kennebec, Crystal and Dakchip. Storage tests showed Norchip had superior chipping color to other cultivars. Dakchip had better color after short rather than after long-term storage, while the opposite was true for Kennebec and Russet Burbank. Lemhi and Crystal were marginal in color throughout storage. Sucrose (mg sucrose/g fresh tuber) expressed as a sucrose rating (SR) ranged from 1.2 to 11.9 among the various cultivars and harvest dates. Correlation between SR's and tuber size within cultivars ranged from $-.91$ to $-.97$. Variability in sucrose content of immature tubers explained 70% of the variability in chip color among cultivars after storage from four to six months. Sucrose levels may be used to predict relative chipping quality of various cultivars after moderate to long-term storage if measured during early tuber development when differences in sucrose concentration are greatest among cultivars.

Resumen

Seis cultivares fueron cosechados cada dos semanas para rendimiento y semanalmente para determinaciones de sacarosa y almacenados para posterior procesamiento en hojuelas de papa frita. En la última cosecha, Crystal fue superior en rendimiento total y en tubérculos comerciables. La grave-

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dad específica fue más alta en Lemhi, Russet Burbank y Norchip que en Kennebec, Crystal y Dakchip. Pruebas en el almacén indicaron que Norchip tenía un color más apropiado en hojuelas que los otros cultivares. Dakchip tenía mejor color después de un almacenamiento breve que después de uno largo, mientras lo contrario fue el caso para Kennebec y Russet Burbank. Lemhi y Crystal presentaron bajos niveles de color durante todo el almacenamiento. La sacarosa (mg de sacarosa por g de tubérculo fresco) expresada como tasa de sacarose (TS) variaba de 1,2 a 11,9 entre los diferentes cultivares y fechas de cosecha. La correlación entre las TS y el tamaño de los tubérculos para cada cultivar variaba de $-0{,}91$ a $-0{,}97$. La variabilidad en el contenido de sacarosa en los tubérculos no maduros explicó 70% de la variabilidad en el color de las hojuelas entre los cultivares después de un almacenamiento de cuatro a seis meses. Los niveles de sacarosa pueden servir para pronosticar la calidad relativa de varios cultivares para su procesamiento en hojuelas de papa frita después de un almacenamiento a mediano o largo plazo, si esos niveles son medidos durante el desarrollo temprano del tubérculo, cuando son más grandes las diferencias en concentración entre los cultivares.

Introduction

Three new cultivars (Crystal, Dakchip and Lemhi) were compared with Kennebec, Norchip and Russet Burbank to determine comparative yields, grades, chipping quality, and tuber sucrose on various harvest dates. Norchip, Kennebec and Russet Burbank are commonly grown for processing. Lemhi (10) is a recent russet introduction from the Idaho USDA potato breeding program. Crystal (6) and Dakchip (5) were selected for their processing potential from the North Dakota State University potato breeding program.

The sugar content of potatoes is a major factor affecting processing quality of chips and french fries. Tuber levels of the non-reducing sugar sucrose (12-carbon sugar) are much higher when harvested early (1, 4, 7, 8, 9, 11, 12) while the reducing sugar content (6-carbon sugars) remains about the same. Chip color is generally not significantly different among tubers harvested at various times, but reducing sugars accumulate in storage and chip color becomes darker faster in more immature tubers (3).

Potato cultivars which have the inherent ability to reduce their translocated sucrose pool to about 0.25% (2.5 mg sucrose/g tuber) and also maintain an equilibrium level of reducing sugars of 0.15% or less in storage have the necessary chemical potential for satisfactory chip color after long-term storage (14). This prediction applies only to healthy, well-ventilated potatoes that are stored at a temperature near $10° \pm 1°C$ to ensure that the processes of heat or cold induced starch degradation are minimal.

The objectives of this study were to compare yield and quality of these cultivars and to investigate relationships among sucrose, harvest dates, and chip quality.

Materials and Methods

Cultivars were grown in 1979 and 1980 at the Potato Research Farm near Grand Forks, North Dakota on Bearden silt loam soil. Tubers were precut into 42 to 50 g seed pieces and suberized before planting at 36 cm on May 23, 1979 and May 6, 1980. Recommended fertilizer rates with standard cultural practices were used both years. Treatments, replicated six times, were arranged in a split plot design; the harvest dates were assigned to the large plots and the various cultivars to the sub-plots. Single rows spaced at 97 cm and 12 m long were harvested for yield on August 7 and 21, September 4 and 18, and October 2, 1979. Comparable harvests were two days earlier in 1980. Approximately five hills from each of four replicates were harvested at weekly intervals for 10 weeks beginning July 30 of each year to obtain tubers for sucrose analysis. Tubers selected for sucrose analysis were average size tubers for the particular cultivar on that particular harvest date. Sucrose was determined according to the low-temperature, KOH-anthrone method described previously (13). Following harvest, tubers were graded and sized; culls were first removed, then tubers were sized into three classes: small (2.5 to 3.8 cm), medium (3.8 to 8.9 cm) and large (over 8.9 cm) in diameter. After culls were removed, the remaining medium sized tubers were classified as marketable tubers. Subsamples of marketable tubers from the last two harvests were stored at 9-10°C until chipping on November 17, 1980 and January 29 and March 23, 1981. Chip color was measured using an Agtron Spectral Reflector with M00 and M97 calibration disks in the red mode.

Results and Discussion

Yield data (Table 1) for the two years were combined because of comparatively minor differences in yields between 1979 and 1980. Total and marketable yields averaged over cultivars and harvest dates were 201 and 136 kg/ha in 1979 and 184 and 127 kg/ha in 1980, respectively. The percentage of culls averaged 10.1% in 1979 and 11.3% in 1980. Only specific gravity was appreciably different between the two years averaging 1.083 in 1979 and 1.078 in 1980.

The six cultivars fell into three maturity classes based on early total yields; early (Norchip and Dakchip), midseason (Kennebec and Crystal) and late (Russet Burbank and Lemhi). By Septemer 3, Crystal was among the highest yielders, and on the last harvest Russet Burbank continued to be the lowest yielding while Crystal was the highest.

TABLE 1. — *Yield and specific gravity of potato cultivars harvested biweekly; 1979-80.*

	Cultivar					
	Kennebec	Norchip	Russet Burbank	Lemhi	Crystal	Dakchip
	August 6 harvest[1]					
Total yield (kg/ha)[2]	81 b	126 a	36 c	44 c	98 b	128 a
Marketable yield (kg/ha)	49 cd	75 ab	16 e	28 de	58 bc	84 a
% under 2.5 cm	28.7	35.5	45.7	23.4	34.2	23.9
% marketable	59.9	59.7	43.3	64.3	59.4	65.7
% over 3.8 cm	2.0	1.3	0	0	2.7	2.3
% culls	9.4	3.5	11.0	12.3	3.7	8.1
	August 20 harvest					
Total yield (kg/ha)	146 c	201 a	95 d	101 d	178 b	195 ab
Marketable yield (kg/ha)	110 b	140 a	35 c	49 c	133 a	145 a
% under 2.5 cm	13.0	21.7	47.8	45.3	18.0	11.9
% marketable	75.7	70.0	35.9	48.3	74.8	74.1
% over 3.8 cm	2.0	1.4	0	0.3	0.9	2.1
% culls	9.3	6.9	16.3	15.5	6.3	11.9
Specific gravity	1.068 b	1.083 a	1.071 b	1.069 b	1.068 b	1.073 b
	September 3 harvest					
Total yield (kg/ha)	214 b	238 a	157 c	175 c	245 a	256 a
Marketable yield (kg/ha)	151 b	184 a	87 d	122 c	195 a	179 a
% under 2.5 cm	7.7	13.9	27.9	21.1	10.2	8.0
% marketable	70.8	77.2	55.2	69.8	79.1	69.9
% over 3.8 cm	8.2	2.5	0.3	0.9	4.4	7.9
% culls	13.3	6.4	16.6	8.2	6.2	14.2
Specific gravity	1.078 b	1.092 a	1.083 b	1.083 b	1.079 b	1.084 b
	September 17 harvest					
Total yield (kg/ha)	256 a	242 a	178 c	217 b	261 a	259 a
Marketable yield (kg/ha)	171 ab	183 a	110 c	152 b	193 a	184 a
% under 2.5 cm	6.8	13.9	21.6	15.0	8.9	7.3
% marketable	67.3	75.2	61.4	70.4	73.8	70.8
% over 3.8 cm	12.6	4.4	0	1.7	8.1	10.2
% culls	13.3	6.4	17.0	12.8	9.2	11.6
Specific gravity	1.081 b	1.091 a	1.091 a	1.095 a	1.083 b	1.083 b
	October 1 harvest					
Total yield (kg/ha)	278 bc	273 bc	220 d	258 c	319 a	295 b
Marketable yield (kg/ha)	161 d	208 b	138 e	188 c	239 a	185 c
% under 2.5 cm	5.1	10.9	14.9	10.0	7.3	6.4
% marketable	58.3	76.3	62.7	73.1	74.7	62.9

	Cultivar					
	Kennebec	Norchip	Russet Burbank	Lemhi	Crystal	Dakchip
% over 3.8 cm	14.2	5.3	2.0	4.8	7.4	13.9
% culls	22.3	7.5	20.4	12.1	10.6	16.9
Specific gravity	1.083 b	1.093 a	1.094 a	1.096 a	1.083 b	1.082 b

[1]Harvest dates are average of 1979 and 1980.

[2]Total or marketable yields within harvest dates without a common letter are significantly different at p = .05 using Duncan's Multiple Range Test. Marketable yield was defined as sound tubers of good type between 2.5 and 3.8 cm in diameter.

In the final harvest Norchip, Crystal, and Lemhi had the highest percentage of marketable tubers. The percentage of marketable tubers was low because of oversize and culls in Kennebec and Dakchip and undersize and culls in Russet Burbank. Malformed and second growth tubers were the primary source of cull tubers found in Russet Burbank and Dakchip tubers, while sunburn and greening were a major source of culls in Kennebec.

Early in the season, specific gravity was highest in Norchip. On the last harvest, Norchip, Russet Burbank, and Lemhi were higher in specific gravity than Kennebec, Crystal, and Dakchip.

The correlation between average tuber size and mg sucrose/g tuber (*i.e.*, the sucrose rating or SR) for the six cultivars at each harvest is shown in Fig. 1. The data for 1979 and 1980 were pooled since there was no measurable difference attributable to years. Fig. 1 supports earlier findings (12, 13) that potato cultivars differ markedly in their sucrose content during growth and maturation. The relationship between tuber size and sucrose content was linear for Lemhi, Crystal, and Dakchip and curvelinear for Norchip, Kennebec, and Russet Burbank. Norchip, Kennebec, Russet Burbank, and Dakchip reached an SR of 2.5 at a tuber size of about 113, 204, 184, and 275 g, respectively. These weights represented average sized tubers of Norchip on August 15, and of Kennebec, Russet Burbank, and Dakchip between September 1 and 10. Lemhi and Crystal approached a similar sucrose level about October 1 at a size of 286 and 332 g, respectively.

Figure 2 represents the Agtron values attained at three chipping intervals averaged over two harvest dates. According to the PC/SFA[1] five-code color chart, chips of minimum color acceptability should give an Agtron value of 45 or above. Norchip produced the lightest colored chips on all chipping dates. Kennebec, Russet Burbank, and Lemhi tubers improved in chip color after storage while Dakchip and Crystal became darker. The response by Crystal, however, was not significantly different among the three chipping dates. These various trends in color are probably due to variable levels of reducing sugars among cultivars in storage (2).

[1]PC/SFA = Potato Chip/Snack Food Association.

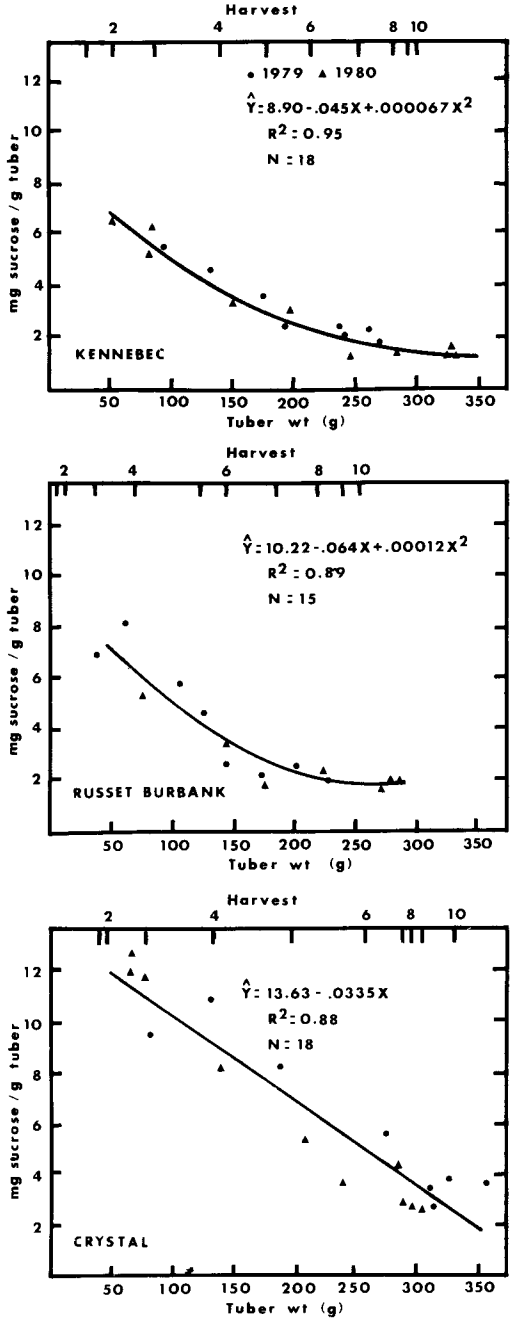
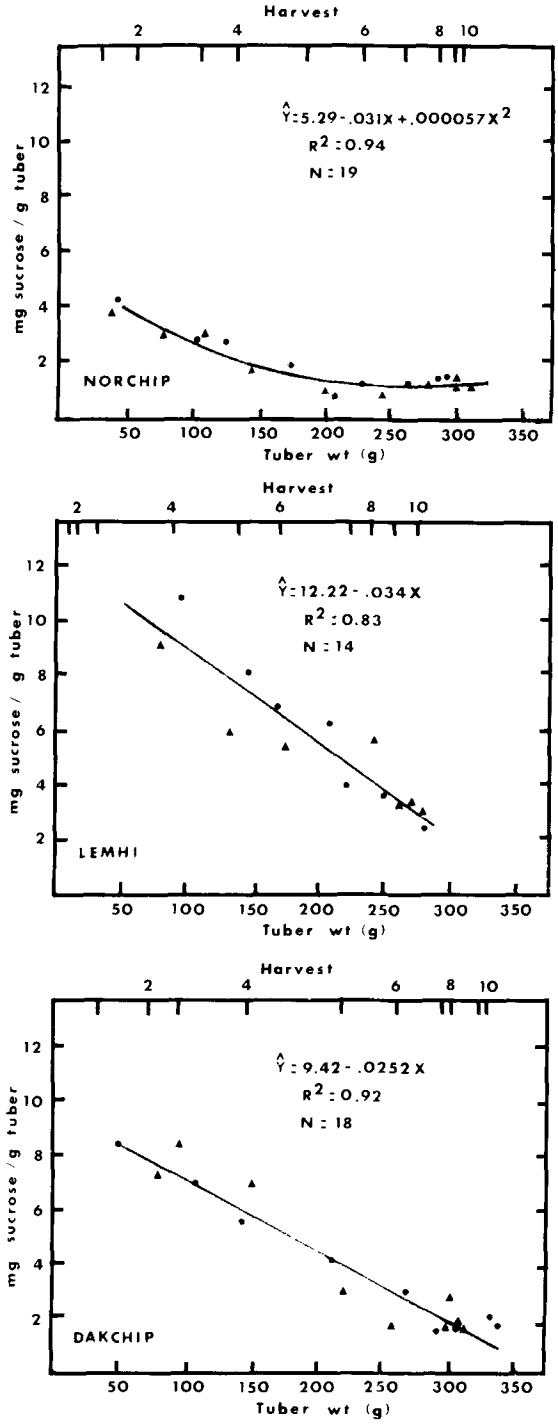


FIG. 1. Regressions of tuber sucrose on tuber weight in six cultivars. All R^2's are significant at $p = .0001$.


Harvest
2 4 6 8 10
$\hat{Y}$=5.29-.031X+.000057X^2
R^2=0.94
N=19
NORCHIP
mg sucrose / g tuber
Tuber wt (g)
50 100 150 200 250 300 350
Harvest
2 4 6 8 10
$\hat{Y}$=12.22-.034X
R^2=0.83
N=14
LEMHI
mg sucrose / g tuber
Tuber wt (g)
Harvest
2 4 6 8 10
$\hat{Y}$=9.42-.0252X
R^2=0.92
N=18
DAKCHIP
mg sucrose / g tuber
Tuber wt (g)

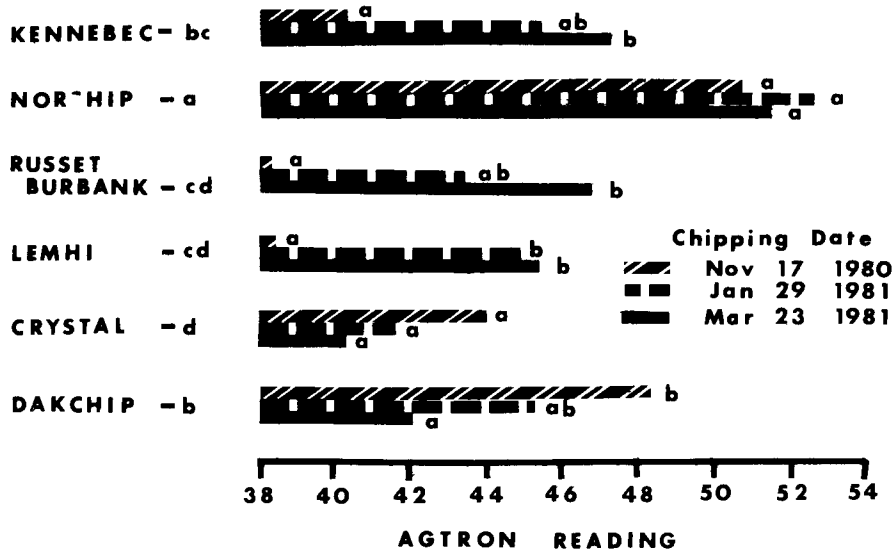


FIG. 2. Color of potato chips fried at three dates averaged over two harvests. Chipping dates within cultivars or cultivars averaged over chipping dates with the same letter are not different at p = .05 using Duncan's Multiple Range Test.

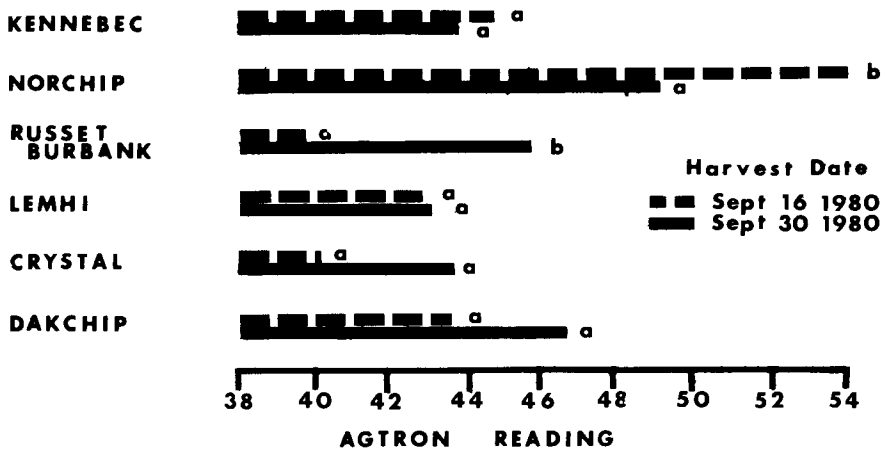


FIG. 3. Color of potato chips from tubers harvested at two dates averaged over three chipping dates. Harvest dates within cultivars with the same letter are not different at p = .05.

Figure 3 compares the color of chips from tubers harvested at two dates averaged over three chipping dates. The only significant difference was that Norchip produced lighter chips when harvested on September 16 versus September 30 while the reverse occurred in Russet Burbank.

TABLE 2. — *Coefficients of determination (r^2's) between tuber sucrose ratings on various dates and chip color from stored tubers of six cultivars; 1980-81*[1].

Date of chipping	Sucrose sampling sequence									
	1 Jul 30	2 Aug 6	3 Aug 13	4 Aug 20	5 Aug 27	6 Sept 3	7 Sept 10	8 Sept 17	9 Sept 24	10 Oct 1
Nov 17	.430	.195	.240	.206	.510	.228	.130	.185	.150	.213
Jan 29	.671*	.803**	.866**	.684*	.802**	.486	.472	.390	.378	.408
Mar 23	.415	.783**	.782**	.691*	.403	.454	.565	.421	.472	.423
Average	.767**	.790**	.856**	.717*	.918**	.572*	.519	.484	.467	.514

[1]Potatoes used for chipping were harvested Sept 17 and Oct 1. The regression equation was a power curve: $y = ab^x$; y = SR, x = Agtron value.
*Significant at p = .05. **Significant at p = .01.

To determine the value of sucrose ratings for predicting chip color, the SR at each harvest date was correlated to the color of chips on each of three chipping dates (Table 2). The regression equation used to determine the correlation was as follows:

$Y = ax^b$ with Y = SR, x = Agtron value, a = intercept and b = slope.

Sucrose was a poor predictor of differences in chip color among cultivars when chipped early (November 17) or at any of the three chipping dates when correlated to sucrose after August 27. The average of the coefficients of determination between the SR's taken from July 30 to August 27 and Agtron values on January 29 and March 23 was .70, leaving 30% of the variability in chip color among cultivars due to factors other than sucrose. The data suggest that sucrose levels among cultivars early to midway through the growing season are more accurate for predicting relative chipping quality of various cultivars from 10°C storage after four or more months than sucrose levels determined later in the season. It has been shown that the actual chip color involves the synergistic action of a number of important variables such as reducing sugars, sucrose, and tuber temperature (7). The relative importance of these depend on the age of the tubers, the year and the cultivar.

The results of this study support the contention that sucrose content could be used to predict the relative chipping quality of various cultivars after moderate to long-term storage. However, sucrose should be measured during the early part of tuber development when sucrose differences are greatest among cultivars.

Of the cultivars included in this study, Norchip was superior in chip color. Dakchip had better color after short than after long-term storage while the opposite was true for Kennebec. Crystal, Lemhi, and Russet Burbank were marginal to poor for chipping in this study.

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