Some Factors that Affect the Respiration Rate of Sugar Beets

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Temperature

Temperature probably affects the respiration rate of sugar beets more than any other environmental factor. Average values obtained by several investigators (1) (3) (4)[2] indicate that the respiration rate is approximately doubled for each 15° F. increase in temperature. Beets grown in a cool environment also respire more rapidly than similar beets grown in a warmer environment and tested at a uniform temperature. This cool-temperature carry-over effect on respiration rate is lost when the beets are stored for a few weeks at room temperature. The respiration rate appears to be correlated with the rise and fall of thermal induction of reproductive development (5) .

Carbon Dioxide Concentration

When sugar or other carbohydrates are used up in the aerobic respira-tion process, the molecular quantities of O_2 and CO_2 involved should be 1:1 or a respiratory quotient (RQ = 1.00). Several tests, however, have shown that CO_2 is soluble in sugar-beet tissue and may thereby indicate a false respiratory quotient value. The CO_2 retained by the beets also reduces the oxygen uptake. In one test, beets were sealed in a 55-gallon drum fitted with a small electric fan to circulate the air inside the drum before analyses were made for O_2 and CO_2 content of the storage atmos-phere. The temperature was held at 21° C. Less CO_2 was given off than O_2 was taken up by the beets, resulting in a CO_2 deficit of 1.6 percent fifty-six hours after the test was started. After seventy hours from the start of the test, the beets were removed, the drum quickly flushed with air and the beets were again sealed in the drum. The data in Figure 1 show that within about two hours 1.5 percent more CO_2 was released than oxygen was ab-sorbed by the beets. Sixteen hours after the beets were aired out and re-sealed in the drum, the 1.6 percent CO_2 deficit in the first part of the test

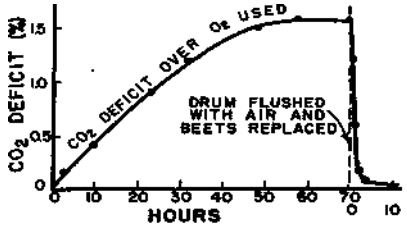

Figure 1.—CO_2 is solu-ble in sugar beet tissues when its concentration in the storage atmosphere is increased. This absorbed CO_2 is rapidly given off when the concentration is reduced.

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[2] Numbers in parentheses refer to literature cited.

was restored, indicating a true respiratory quotient of unity. At lower tem-peratures, the apparent respiratory quotient was even lower. Another lot of beets held at 16° C. removed oxygen and added CO_2 to the storage atmosphere at the rate of 0.522 percent and 0.306 percent, respectively, for 30 hours. The apparent respiratory quotient was only 0.587. The beets were placed in baskets and covered with wet burlap for 24 hours and resealed in the drum. The storage atmosphere was then enriched with CO_2 up to a concentration of 12 percent. Within six hours, the CO_2 con-centration was reduced to 9.8 percent although 2.7 percent of oxygen had been absorbed during this time. At the end of 30 hours, the CO_2 concen-tration was 15.7 percent and the O_2 concentration had been reduced by 13.0 percent. The rate of 0_2 uptake was only 0.433 percent per hour as compared to the initial rate of 0.522 percent per hour. The over-all increase in CO_2 percent was only 0.123 percent per hour as compared to the initial rate of 0.306 percent per hour. Evidently, 12 percent of CO_2 in the stor-age atmosphere reduced the oxygen uptake by 0.089 percent per hour, or 17 percent.

Another test showed that even small concentrations of CO_2 reduced the respiration rate. Duplicate sets of drums containing. similar weights of beets were ventilated with air at three carefully controlled rates. The first pair allowed the CO_2 to increase to only 0.25 percent. The second pair allowed the CO_2 to increase to 1.69 percent and the third pair were ven-tilated still more slowly so that the CO_2 increased to 5.05 percent. After equilibrium had been established for several days, the respiration rates were found to be 13.52, 12.81 and 12.28 milligrams of CO_2 per kg. of beets per hour for the 0.25, 1.69 and 5.05 percent CO_2 atmospheres, respectively. The data are shown in Figure 2.

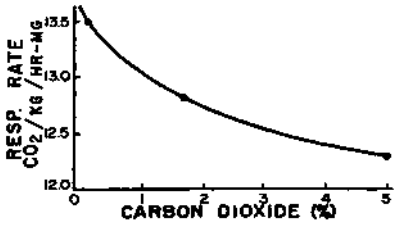

Figure 2. — Even small amounts of CO_2 reduce the respiration rate of sugar beets.

Oxygen Concentration

Two series of tests were conducted in which the storage atmospheres were free of CO_2 but the oxygen concentration was varied between 1.65 percent and 35.3 percent. The beets were different in the two separate tests and, therefore, the respiration rates at normal oxygen concentration were different. The data in one test were all corrected percentage-wise to

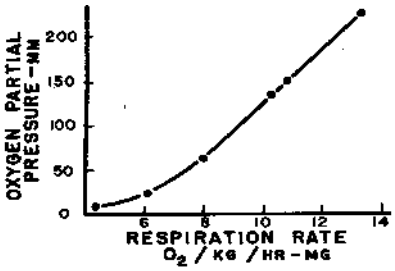

Figure 3.—The relationship between respiration rate of beets and O_2 concentration is apparently linear down to about 5 percent O_2.

correspond to the relative rate of the other test at normal oxygen concen-tration. The data in Figure 3 then showed a linear relationship between O_2 concentration or partial pressure and respiration rate down to a con-centration of about 4 percent to 5 percent oxygen. Below this point, some anaerobic respiration apparently occurred. The beets held at the lower O_2 concentrations for several weeks also spoiled more rapidly than those above 10 percent O_2.

Size of Beet or Cut Tissue The respiration rates of beets of the same variety but differing in aver-age weight from about 0.7 to nearly 5.0 pounds each were determined. Each sample consisted of 40 kilograms of beets and measurements were made over a period of weeks. The data in Figure 4 show that large beets respired more slowly than an equal weight of small beets. The rate ap-pears to be correlated with the surface area per unit of weight. Small or thin slices of tissue (2) also respire more rapidly than larger pieces (6) . These facts appear to be due to reduced gaseous exchange in the interior cells of larger beets or pieces of tissue.

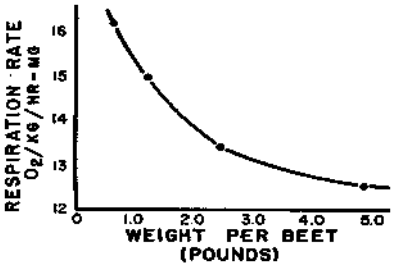

Figure 4. — Small beets respire more rapidly than large beets. The rate appears to be correlated with surface area per unit of weight.

Preliminary Study of Weight and Chemical Analysis of Individual Beets with Respiration Rate

A study of respiration, weight, sugar, amino nitrogen, sodium, and potassium on an individual beet basis between several commercial varieties, inbreds, tetraploids, mangels, and red beets indicated a negative but prob-ably insignificant correlation between weight and respiration when the beets

were tested for respiration by the 10-gram piece technique (6) . With whole beets, as shown above, the correlation was very definitely negative. The lack of definite correlation when using the 10-gram piece technique makes this method much more desirable for selection purposes. In this study respiration rate was positively correlated with sugar percentage, although not highly significant. Respiration rate was not definitely correlated with amino N content although the mean *r* value was slightly positive. Respiration rate was negatively correlated with sodium content. Respiration rate was not significantly correlated with potassium content. Further studies in progress should yield more definite values for these and other relationships.

Normal Diploid vs. Polyploid Sugar Beets

Polyploid sugar beets have been included in respiration rate studies for four years. In each case, the polyploids respired more slowly than nor-mal diploid varieties tested at the same time. The average values for three years showed the polyploids respired only about 84.3 percent as rapidly as variety SL 824 tested at the same time. The average respiration rate of the four polyploids tested in 1953 was only 68.5 percent of the average rate of the two inbred diploid varieties tested under similar conditions. It seems probable that an increased cell size of the polyploids may be responsible and that the increase in cell size is greater than the increase in respiration rate per cell.

A respiration test was run comparing the respiration rates, quality and spoilage losses, of two 4*n* and two 2*n* varieties. The tetraploid of SL 824 was about 2 percent lower in sugar percentage than the SL 824 diploid. The tetraploid, however, had a significantly lower respiration rate and the total losses from respiration and spoilage were lower in the tetraploid. The tetraploid of US 22/2 was even lower in respiration rate. Previous comparisons between SL 824 and US 22/3 showed US 22/3 (a curly-top selection from US 22/2) was lower in respiration rate than SL 824. US 56/2 showed a higher respiration rate than SL 824. The data in Table 1 involved eight 44-pound analytical samples in four respiration drums for each variety. Statistical analysis showed differences as small as only 0.73 milligrams of CO_2 per kilogram per hour were significant.

Another test run in 1953 involved the curly-top resistant CT9, its male-sterile equivalent, SL 798 4*n* (selected from US 22/2) , two selections from SL 798 4*n* (SL 241 4*n* and SL 241A 4*n)* , and a 3*n* hybrid between selected stock from SL 798 and selected stock from a male-sterile CT9 hybrid SL 9090H4.

The female parent of the 3n hybrid, SL 241H14, was the CT9 MS hybrid SL 9090H4. SL 9090H4 combined high quality with a very high degree of resistance to inversion or spoilage during previous tests. The 3*n* hybrid SL 241HI4 proved to be a very vigorous, fair-quality beet with a low respiration rate. No acre-yield rates were determined but the average weight of the 3*n* hybrid was about 300 grams heavier than that of SL 798. Small beets of the 3*n* hybrid SL 241H14, therefore, had to be selected for the samples reported in Table 2, in order to keep the size distribution of all varieties constant. This was also true of SL 241 4*n.*

The increase in reducing sugar of all polyploid beets was rather dis-appointing. In previous tests, a rise in the apparent respiration rate toward

Table 1.—Comparison of Quality, Respiration, and Spoilage Losses of 2*n* and 4*n* Varieties During 54 Days at 70° F., 1952

Variety	Dry sub.	Direct pol.	Purity	Amino N	Na	Invert Sugar	Resp. Rate O_2/kg/hr	Resp. Rate % of ave. 2n	Calculated losses, 52 days at 70° F. Sugar per ton per day Resp.	Spoilage	Total[1]	By Anal.
	%	%	%	%	p.p.m.	%	mg.	%	Lbs.	Lbs.	Lbs.	Lbs.
MS of CT9 2*n*	17.70	15.51	87.58	0.240	304	0.053	10.03	96.2				
Loss	—1.43	—1.26	+0.01	+0.020	+70	+0.162			0.420	0.062	0.482	0.485
CT9 2*n*	18.87	15.98	87.64	0.230	246	0.057	10.83	103.8				
Loss	—2.48	—2.70	—4.10	+0.090	+153	+0.427			0.453	0.164	0.617	1.039
241H14 3*n*	17.16	15.15	88.34	0.206	342	0.058	7.71	73.8				
Loss	—1.04	—1.68	—4.98	+0.080	+50	+0.362			0.329	0.216	0.545	0.647
798 4*n*	17.03	15.00	88.17	0.202	336	0.052	6.90	66.0				
Loss	—0.58	—0.94	—2.73	+0.080	+49	+0.447			0.295	0.172	0.467	0.361
241 4*n*	17.94	15.46	86.13	0.156	327	0.056	7.42	71.0				
Loss	—2.02	—2.20	—2.80	+0.130	+117	+0.756			0.317	0.291	0.608	0.847
241A 4*n*	18.66	15.75	84.46	0.245	261	0.067	6.61	63.2				
Loss	—1.14	—1.97	—0.09	+0.120	+76	+0.648			0.282	0.249	0.531	0.758

[1] Sum of respiration and spoilage losses.

Table 2.—Comparison of Quality, Respiration, and Spoilage Losses of 4*n*, 4*n* Selections and 3*n* Hybrids During 52 Days at 70° F. 1953.

the end of the test, and obvious spoilage when the drums are opened, were well correlated with the increased reducing sugar in the stored beets. This was not the case in the present test. The average late increase in apparent respiration rate of the polyploids was smaller and obvious spoilage appeared to be less than in the diploid varieties in nearly all samples. Samples of polyploid beets that appeared to be in almost perfect condition had fairly large increases in invert sugar. Although 4*n* varieties have been included *in* several similar tests previously without any indication of unusual in-creases in invert sugar, the fact that practically all 4*n* or 3*n* samples in this test indicated fairly large increases warrants further study. The male-sterile equivalent (E_5) of CT9 (obtained after five successive backcrosses) appears to have higher sugar percentage, more vigor, a lower respiration rate, and greater resistance to spoilage than the CT9 itself.

Summary

Carbon dioxide in the atmosphere in which sugar beets are stored causes the beets to retain some CO_2 in the tissues. The beets give off the CO_2 rapidly when moved to a storage atmosphere containing less CO_2. Increased amounts of CO_2 in the tissues lower the respiration rate.

There is apparently a linear relationship between the respiration rate of beets and the oxygen concentration of the storage atmosphere between about 5 and 35 percent O_2. Below about 4 or 5 percent O_2, some anaerobic aerobic respiration occurs.

Large sugar beets or pieces of tissue have a lower respiration rate than smaller beets or smaller pieces of tissue. The rate is apparently correlated with surface area per unit of weight.

Polyploid sugar beets respire more slowly than normal diploid varieties. Inversion losses in polyploid varieties tested in 1953 were unusually high without apparent spoilage. This observation should be checked using the same and other polyploids.

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