A COMPARATIVE STUDY OF THE RESPIRATORY RESPONSES IN VEGETABLES AFTER PERIODS OF COLD STORAGE.

by

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INTRODUCTION

It has been demonstrated by various workers that respiration in plants and plant parts is greatly influenced by the temperature, but there has been little work done on the effects of the alternation of temperature.

Palladin (5) believed that, besides the direct effect of temperature, there was a stimulating effect due to a sudden change of temperature. He obtained a large increase in the rate of respiration in bean seedlings exposed to 7-10° C. and 36-37° C. when they were brought to a temperature of 18-20° C. The rate was 40 to 50 per cent higher than the rate in seedlings which had remained at 18-20° C. Palladin also carried out experiments with bean seedlings fed a solution of cane sugar. His observations on the intake of cane sugar and the subsequent rate of respiration led him to conclude that no strict correlation existed between the rate of respiration and the carbohydrate supply.

Olney (4) determined the respiration rates at 20° C. in bananas which had been shipped under refrigeration conditions and under naturally ventilated conditions. He obtained a higher rate of respiration in the refrigerated fruit than in the ventilated fruit. The rate increased in the refrigerated bananas for a time and then fell off more rapidly after they had ripened than in the ventilated fruit. Olney attributed the higher respiration rate in the refrigerated bananas to the accumulation of sugars under refrigeration conditions.

Blackman and Parija (1) transferred apples from 2.5° C. to 22° C. and obtained a high initial rate of respiration which fell off after a time. They suggest three possible mechanisms which might effect this excess expiration of CO_2. First, physical processes, or the liberation of adsorbed CO_2; second, shifting of the carbohydrate equilibrium; and third, the intermediate compound effect which might by altering the velocities of the linked reactions cause an increase in the respiration rate. Finally, however, they show that no one of these mechanisms dominates the whole situation.

Appleman (Unpublished data) found that in potatoes removed from cold storage to 30° C. there was a high initial rate of respiration which fell off rapidly, while there was sometimes an increase in both reducing and total sugars at the higher temperature. Kimbrough (Unpublished data) found that there was often a parallelism between the sugar content and the rate of respiration in potatoes but no direct correlation. Kimbrough (3) also obtained a high initial rate of respiration in potatoes when they were removed from cold storage to a higher temperature.

The investigations reported in this paper were carried out to determine if there is a definite response to a change from a low to a higher temperature in a number of other vegetables and a few fruits, and also to determine if the sugar content is correlated with the respiration rate.

It was desirable to select for these studies vegetables differing as widely as possible in their biological characteristics, as well as vegetables similar in certain characteristics. As many different vegetables and fruits were included as was possible to handle in the allotted time. The vegetables and fruits included are parsnips, carrots, sweet potatoes, turnips, beets, onions, dahlia tubers, and grapefruit. These are vegetables which are generally stored for a greater or lesser part of the winter season and any information obtained from their response under the different treatments is valuable from the storage standpoint. For instance, if there occurs a very high rate of respiration immediately after a vegetable is transferred from storage to a higher temperature, as is often the case when vegetables are put on the market, it would be necessary to provide sufficient ventilation to prevent damage due to overheating. If the vegetables had to be shipped any great distance it might be necessary to ship in refrigerated cars in order to hold the respiration rate low enough to prevent excess heating, in case sufficient ventilation could not be provided in transit.

GENERAL EXPERIMENTAL PROCEDURE

SELECTION AND STORAGE: The vegetables used were selected from those generally stored for considerable periods of time. It was also desirable to have vegetables differing widely in their characteristics, and this was considered in making the selections. The vegetables were taken from lots freshly harvested where possible. In a few cases this was impossible and the vegetables were obtained in as fresh condition as possible from grocery stores.

The vegetables stored at low temperatures were all placed in an electric refrigerator at a temperature which averaged 36° F. The respiration determinations were all made at 22° C. (71°.6 F.) The temperature in the refrigerator was nearly constant at 36° F. The maximum fluctuation at any time was 5 to 6 degrees F. but these fluctuations were rare. In most cases the fluctuations were not more than 2 to 3 degrees F. and as these were fairly regular over short periods of time, the temperature of the vegetables was more nearly constant at 36 degrees due to the lag in their responses to short intervals of fluctuations in the external temperature. The temperature was recorded throughout the experiments by means of a thermograph placed in the refrigerator adjacent to the vegetable containers. All the vegetables were stored at 36° F. but some variations in the manner of storage were necessary. The exact methods of storage of each vegetable are given under experimental results.

RESPIRATION: A well insulated box fitted with a fan to stir the air was used as a constant temperature chamber for the respiration determinations. By means of electrical heating and control a constant temperature of 22° C. (71°.6 F.) was maintained in the chamber. A Hasselbring thermo-regulator was the control device used. The maximum fluctuation was only .2 - .4 degrees C. during the experiments except in a few cases in late spring when the outside temperature became so high as to cause the temperature in the chamber to increase to slightly above 23° C. These were very rare cases, however, and note was taken of each instance.

The rate of respiration was determined by measuring the amount of carbon dioxide expired. The method and apparatus were similar to those described by Gore (2).

When the material was first placed in the respiratory chambers carbon dioxide free air was drawn over it for periods of three to four hours before respiration determinations were begun. This insured the removal of all carbon dioxide from the system and allowed the vegetables to warm up to the temperature of the chamber. Determinations were usually made every 24 hours. Carbon dioxide free air was drawn over the respiring material and the expired carbon dioxide was drawn out and absorbed in a solution of sodium hydroxide. The air was drawn through the system by means of a water aspirator. Large desiccators were used as respiratory chambers and the constant temperature box was large enough to hold four of these at one time. Air was drawn through the system at a steady rate and fast enough to prevent the accumulation of carbon dioxide in the chambers but slow enough to insure complete absorption of the carbon dioxide by the sodium hydroxide solution in the Reiset absorption tubes.

The flow of air was regulated by a stopcock on each line as well as by the flow of water in the aspirator. All rubber connections were made as short as possible to prevent diffusion of carbon dioxide through the rubber. Figure 1 shows the complete path of the air through the system.

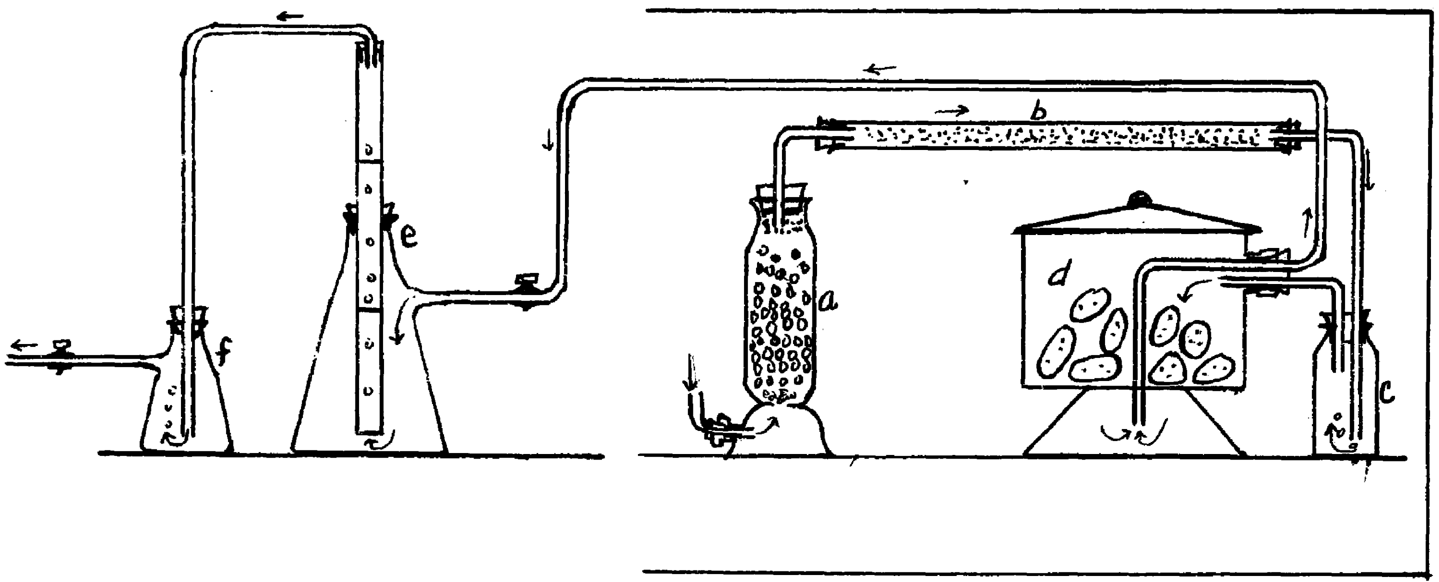


Fig. 1. Diagram of respiration apparatus showing path of air through the system. (a) Tower with $CaCl_2$ to remove moisture from air. (b) Tube with soda lime to remove CO_2 from air. (c) (f) Flask with baryta water to test for freedom of CO_2. (d) Respiratory chamber. (e) Flask with Reiset absorption tube and solution of NaOH to absorb expired CO_2.

The carbon dioxide absorbed by the sodium hydroxide was determined by the method described by Gore (2) with the modification recommended by Küster. Barium chloride was added in excess so that the carbonate was precipitated as barium carbonate. The precipitate was left in the beaker and a double titration made using phenolphthalein and methyl orange as indicators and titrating with N/1 hydrochloric acid. When the endpoint of phenolphthalein was reached the excess of sodium hydroxide was neutralized. The number of cubic centimeters of N/1 hydrochloric acid used to titrate from the endpoint of phenolphthalein to the endpoint of methyl orange was the equivalent of the carbonate present, that is, each cubic centimeter of N/1 hydrochloric acid was equivalent to 0.022 grams of carbon dioxide expired by the vegetables. Respiration rates were determined as milligrams of carbon dioxide expired per kilogram of vegetables per hour. This was obtained by multiplying the number of hours of a determination by the number of kilograms of material used in the determination and dividing the product into the total number of milligrams of carbon dioxide obtained. In making these calculations the weight of the vegetables at the time they were placed in the respiration chambers was used. The rates of respiration were also calculated to original weight and in terms of dry weight.

METHODS OF RECORDING RESPIRATION DATA

Calculationsof the rates of respiration as milligrams carbon dioxide expired per kilogram per hour based upon the weight of the materials when placed in the respiration chamber; as milligrams carbon dioxide expired per kilogram per hour based upon the original weight, that is, the weight at the beginning of the experiment; and as milligrams carbon dioxide per 100 grams dry matter per 24 hours, show great variations in the relative rates in some of the vegetables used. This is especially the case in the vegetables where a great loss of moisture occurred.

If the respiration data were used to supply information on storage problems alone, it would perhaps be better to calculate the rate on the basis of the weight of the material at the time it was placed in the respiration chamber. The main interest here would be to determine if the respiration was vigorous enough to produce sufficient heat to endanger the keeping quality of the vegetable in question. For comparing the respiration rates of different lots of the same material, however, the rate based on the original weight of the material would probably be a better basis to use, for in this way the comparison is made on the basis of the same moisture content, as well as the same content of solids. But for comparisons of the respiration rates in different materials and the responses to particular treatments, it is perhaps more accurate to use the rates based on the dry weight. We are not concerned in this case with the actual magnitude of the respiration rate but rather with the change due to a particular treatment such as cold storage.

As the main concern in the experiments reported in this paper was the determination of the respiratory response of the vegetables and fruits to a change from a low to a higher temperature, the respiration rates are presented in terms of the dry weight, except in the case of grapefruit. No dry weight determinations were made on these.

ANALYTICAL METHODS

SAMPLING: In sampling for sugar analysis and moisture determinations the vegetables which had not previously been washed were washed in running tap water, then were wiped as dry as possible with towels, and were laid on the laboratory table until the surfaces were normally dry. This required from one to two hours usually, depending upon the vegetable used. The crowns of such vegetables as the parsnips, carrots, turnips, and beets were cut off at a point so as just to remove the shoot stub, and the extreme ends of the root tips were discarded. All vegetables were split open longitudinally and either one quarter or one half of each vegetable was used in the composite sample. During the 1925-26 experiments the parsnips were ground in a small meat chopper, and further ground in a mortar. In all subsequent experiments a Nixtamal mill was used for grinding and it gave pulp so fine as to necessitate no further grinding. After being ground, the pulp was transferred to a mixing dish and kept thoroughly mixed while samples were weighed into counterpoised 200 cc. Kohlrausch flasks. The amount of pulp used for samples varied with different vegetables, and depended upon their sugar content. All samples were taken in duplicate. For parsnips, carrots, sweet potatoes, onions, and dahlia tubers 20 gram samples were used. For beets 25 gram samples were taken, and for turnips 50 gram samples were used in the first part of the experiment and 25 gram samples were used in the latter part. No sugar determinations were made on grapefruit. After weighing the samples into the flasks they were immediately covered with boiling 95 per cent alcohol and were stoppered and set aside until extractions could be made. During the 1925-26 experiments with parsnips 75 cc. of the boiling alcohol was added to each sample, but in all subsequent experiments this amount was increased to 100 cc.

MOISTURE From 3 to 6 grams of pulp were weighed in tared watch glasses and dried to constant weight at 78-80° C. in a vacuum oven at 28-30 inches of mercury. The first period of drying was about four to six hours usually. Thereafter the samples were weighed after one to three hour periods of drying. Before each weighing the covers of the watch glasses were clamped in place and the samples allowed to cool in a desiccator.

EXTRACTION OF SUGAR SAMPLES The Kohlrausch flasks containing the samples were placed on the waterbath, small funnels were placed in the mouths of the flasks to serve as condensers, and the contents of the flasks brought to a boil. In the 1925-26 experiments 50 cc. of boiling distilled water were added to each sample as soon as it began to boil, and the boiling was allowed to continue for 30 minutes. In all later experiments the samples were heated to boiling and 15 cc. of cold distilled water were added to each sample. They were then heated to boiling and allowed to boil for 30 minutes. After the 30 minutes of boiling, the flasks were made to volume with cold 95 per cent alcohol. They were then stoppered and set aside until sugar determinations could be made. This method gave an extraction concentration of about 70 per cent alcohol, and a storage concentration of about 80 per cent in experiments subsequent to the 1925-26 experiments on parsnips. In these the concentrations were somewhat lower. In the case of the parsnips stored in air where an excess of moisture was lost, sufficient water was added to give the proper alcohol concentrations.

DETERMINATION OF SUGARS   The Munson and Walker gravimetric method was used in the sugar determinations. For reducing sugars the flasks containing the extracts were made to volume with 95 per cent alcohol. The extract was filtered into a 200 cc. Erlenmeyer flask, and 125 cc. or 150 cc. were removed with carefully graduated pipettes, and placed in an evaporating dish. The dish was placed on the waterbath and the extract was allowed to evaporate until the volume was reduced to about 40 cc. The extract was then transferred to a 200 cc. volumetric flask using hot distilled water in making the transfer. A saturated solution of neutral lead acetate was added in small portions until the solution was clear. When perfectly clear, a little anhydrous sodium carbonate was added to remove any excess lead, care being taken to prevent the extract from becoming alkaline. The extract was now made to volume with distilled water and filtered. Aliquot 50 cc. portions were used for the reductions in most cases. In a few cases where large amounts of reducing sugars were present 25 cc. aliquot portions were used.

For the total sugar determinations 50 cc. of the extract were placed in 100 cc. volumetric flasks and five cc. of concentrated hydrochloric acid were added to each. The flasks were then set on top of an electric oven where they were kept warm overnight. This allowed time for complete inversion of the sucrose by the acid. When ready to make the analysis the acid extracts were neutralized with anhydrous sodium carbonate. The extracts were made up to volume with distilled water and 25 cc. or 50 cc. aliquot portions were used for the reductions.

From the cuprous oxide obtained in the reductions the sugar content was calculated on the basis of the wet weight; on the basis of the original wet weight; and on the basis of the dry weight. The wet weight was taken as the wet weight of the material at the time the samples were taken. The original wet weight was the wet weight at the time the experiment was started. The dry weight was the dry weight at the time the samples were taken. In experiment 1 on parsnips the sugars were calculated only on the wet weight basis and on the dry weight basis.

EXPERIMENTAL RESULTS

PARSNIPS

EXPERIMENT 1. (1925-26) The parsnips for this experiment were obtained from the truck farm of George Lanhardt, Hyattsville, Maryland. They were harvested November 11, 1925 and brought immediately to the laboratory. The tops were cut off about one-fourth inch above the crowns. The dirt was removed by brushing with a soft bristle brush. Ten lots of eight roots each were selected for respiration determinations and ten lots of five roots each were selected for sugar and moisture analysis. The lots for respiration averaged about 700 grams per lot while those for sugar analysis averaged about 500 grams per lot. One of the respiration lots was placed immediately in the respiration chamber. One lot was sampled for sugar and moisture analysis. The others were stored at 36° F. Four lots for respiration and four lots for sugar and moisture analysis were placed in 10-inch earthenware pots partly filled with damp soil. The roots were then covered to a depth of about one inch with the soil. The pots were set in shallow pans in which was kept constantly a little water to keep the soil damp.

The other lots were placed in small wire baskets in the refrigerator.

Duplicate lots of the soil-stored and air-stored roots were removed from the refrigerator after 21, 47, 92, and 131 days respectively, for respiration determinations and sugar and moisture analysis. The last lot of the air-stored roots was removed after 181 days storage.

The results are given in tables 1 to 6 and figures 2 and 3.

Table 1. Respiration of Parsnips at 71°.6 F. after Different Periods of Soil Storage at 36° F.

Lot No.	Days in storage at 36°F	Milligrams CO_2 per 100 grams dry matter per 24 hours																										
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day	17th day	18th day	19th day	20th day	21st day	22nd day	23rd day	24th day	25th day	26th day	27th day
1	0	1502	1080	864	756	645	632	630	---	553	497	487	504	496	520	557	501	402	399	372	452	467	449	471	539			
2	21	945	683	669	---	535	479	429	356	416	425	364	445	407	431	453	525	551	486									
3	47	1313	941	854	802	775	799	775	679	581	619	636	564	497	566	533	540	523	485	521	504	509						
4	92	1214	998	775	782	859	732	650	---	734	533	566	581	593														
5	131	1051	1363	1241	1001	950	910	---	833	826	742	756	768	792	756	816	792											

Table 2. Respiration of Parsnips at 71°.6 F. after different periods of air storage at 36° F.

Lot No.	Days in storage at 36°F	Milligrams CO_2 per 100 grams dry matter per 24 hours. 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day
1	0	1502	1080	864	756	645	632	630	---	553	497	487	504
2	21	1097	1275	1287	976	920	919	956*	1194*				
3	47	790	889	962	998*								
4	92	373	382	365	377	346	367	389*	---	373			
5	131	134	74	70	55	62	46	47	38				
6	181	28	28	31	26	33	24						

Lot No.	13th day	14th day	15th day	16th day	17th day	18th day	19th day	20th day	21st day	22nd day	23rd day	24th day
1	496	520	557	501	402	399	372	452	467	449	471	539
2												
3												
4												
5												
6												

* A little mold appeared on some of the parsnips at these points.

Table 3. Sugar Content of Parsnips After Different Periods of Soil Storage at 36° F.

Lot No.	Soil Storage at 36°F	Moisture	Total Sugars		Reducing Sugars	
			Wet Weight	Dry Weight	Wet Weight	Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	79.20	4.30	20.67	0.20	1.11
2	21	78.75	7.00	32.91	0.43	2.01
3	47	81.32	7.79	41.65	0.40	2.14
4	92	83.10	7.17	42.50	0.79	4.68
5	131	83.47	8.20	49.65	0.65	3.95

Table 4. Sugar Content of Soil-Stored Parsnips After the Respiration Tests.

Lot No.	Soil Storage at 36°F	Respiration tests at 71°.6F	Moisture	Total Sugars		Reducing Sugars	
				Wet Weight	Dry Weight	Wet Weight	Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
2	21	18	80.49	7.28	37.26	0.47	2.44
3	47	21	78.69	7.94	37.30	3.71	17.47
4	92	13	82.05	7.12	39.70	0.59	3.31
5	131	16	82.50	6.40	36.55	0.69	3.96

Table 5. Sugar Content of Parsnips after Different Periods of Air Storage at 36° F.

Lot No.	Air Storage at 36°F	Moisture	Total Sugars Wet Weight	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	79.20	4.30	20.67	0.20	1.11
2	21	74.75	12.89	51.71	1.78	7.10
3	47	57.45	20.50	48.35	2.49	5.88
4	92	39.88	28.01	46.65	1.65	2.75
5	131	31.65	30.03	44.05	1.63	2.40
6	181	20.46	33.27	41.87	1.98	2.48

Table 6. Sugar Content of Air-Stored Parsnips After the Respiration Tests.

Lot No.	Air Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars Wet Weight	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
2	21	8	74.88	11.68	48.80	4.54	19.03
3	47	4	61.71	18.12	47.46	3.58	9.40
4	92	9	39.60	28.27	46.80	----	----
6	181	6	19.74	35.14	43.90	2.75	3.49

Figure 2. Respiration and Sugar Content af Parsnips After Different Periods of Soil Storage at 36° F. Respiration at 71°.6 F.

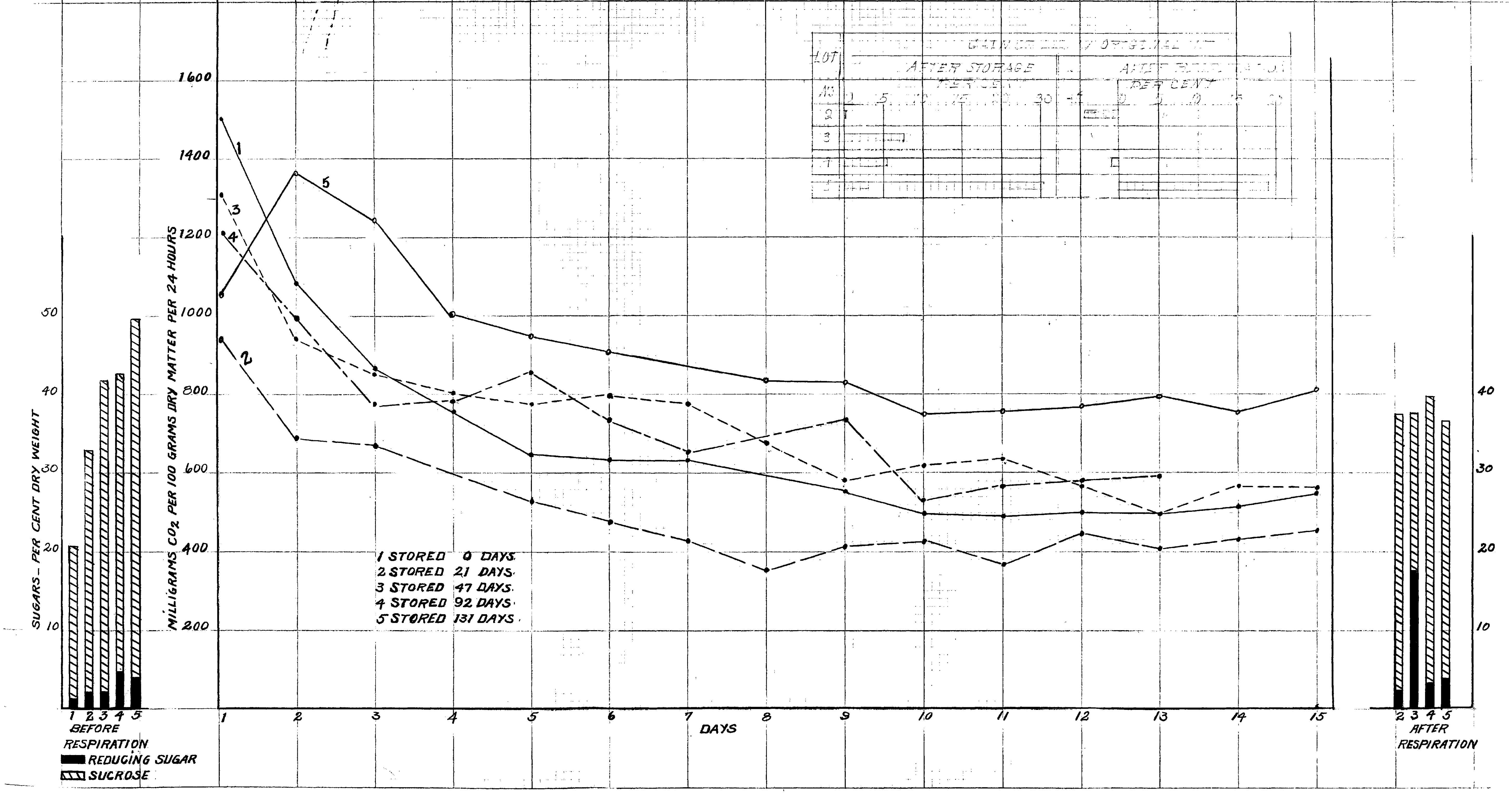
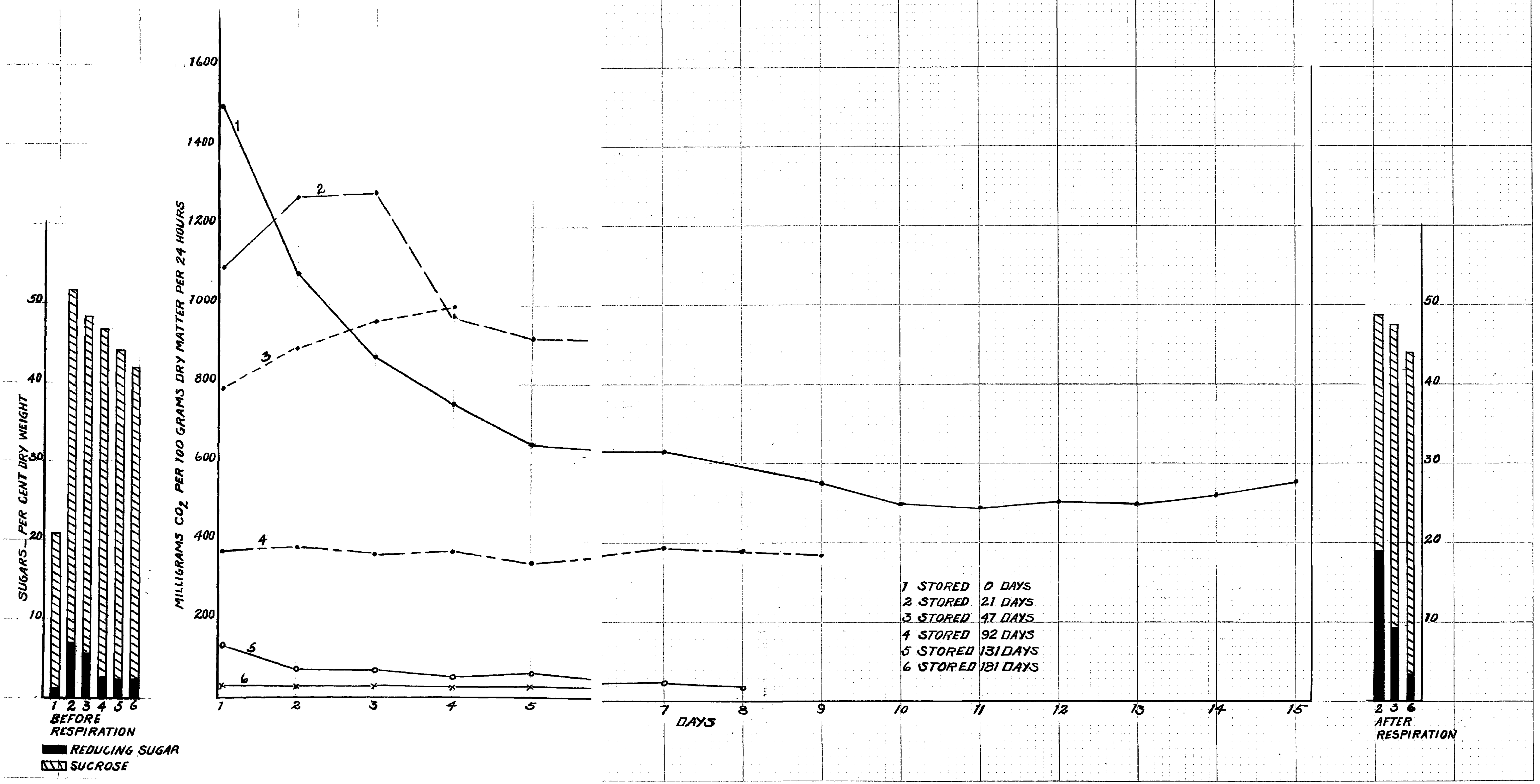

SUGARS_ PER CENT DRY WEIGHT
10
20
30
40
50
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
200
400
600
800
1000
1200
1400
1600
1 2 3 4 5
BEFORE RESPIRATION
REDUCING SUGAR
SUCROSE
1 STORED 0 DAYS.
2 STORED 21 DAYS.
3 STORED 47 DAYS.
4 STORED 92 DAYS.
5 STORED 131 DAYS.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
DAYS
2 3 4 5
AFTER RESPIRATION

Figure 3. Respiration and Sugar Content of Parsnips After Different Periods of Air Storage at 36° F. Respiration at 71°.6 F.


SUGARS _ PER CENT DRY WEIGHT
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20
30
40
50
1 2 3 4 5 6
BEFORE RESPIRATION
REDUCING SUGAR
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200
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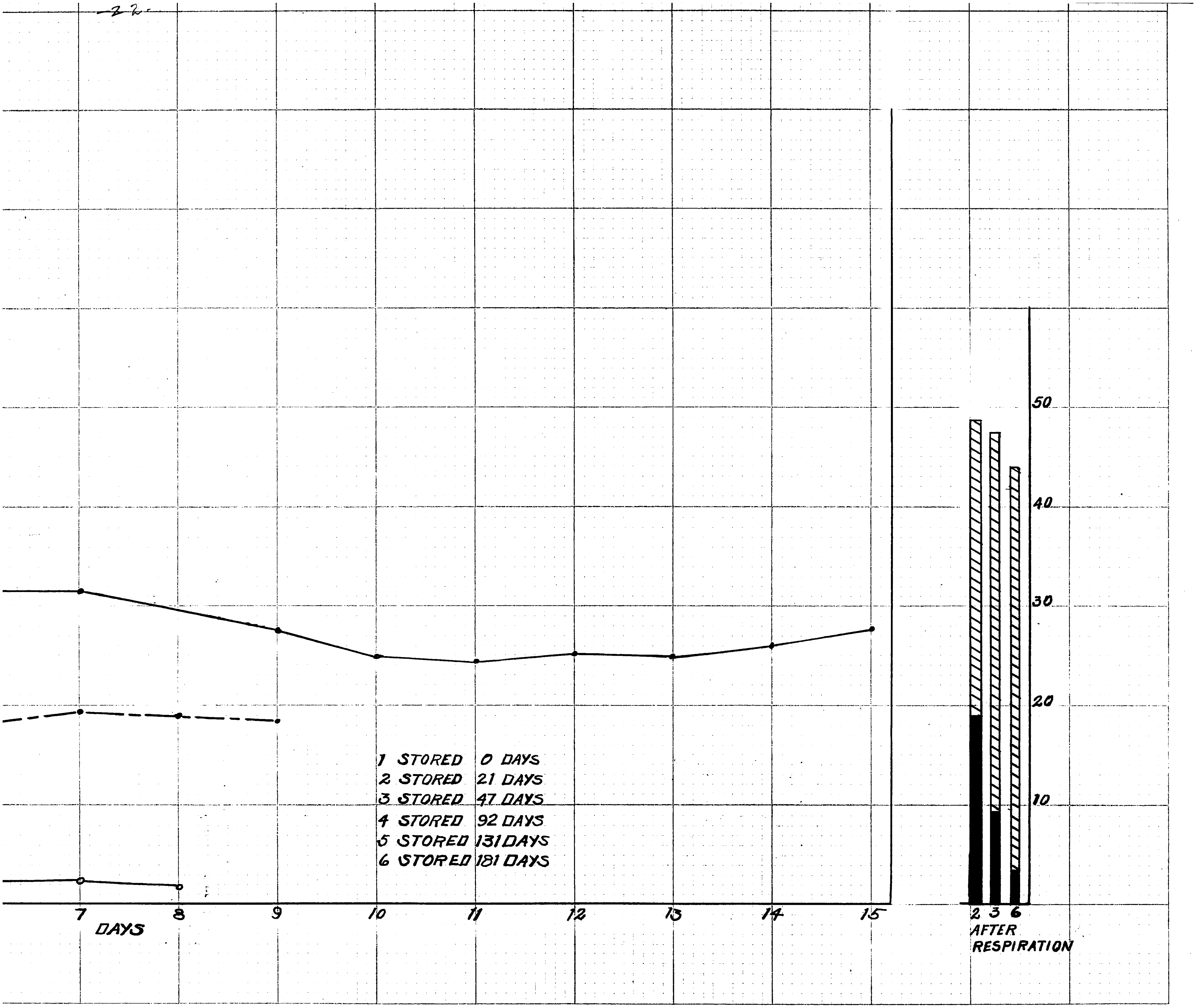
AFTER RESPIRATION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AFTER
RESPIRATION

DISCUSSION OF RESULTS

It will be noted that there was a period of high respiration in the parsnips immediately after harvesting which became practically constant after about ten days and remained practically constant for the remainder of the respiration period. Small shoots developed on some of the parsnips on the 17th day but caused no apparent increase in the respiration rate. It was thought that the field temperature previous to harvesting might have had some effect on the initial rate of respiration in this lot. The mean daily temperature for a period of three weeks prior to harvesting the roots is given in table 7. It is noted that the average temperature for the period was much lower than the temperature at which respiration determinations were made, but was higher than the temperature of the refrigerator.

Table 7. Daily Mean Temperature at College Park from October 21 to November 11, 1925.

Date	Temperature	Date	Temperature
October 21	43.5	November 1	39.0
October 22	41.5	November 2	41.5
October 23	43.0	November 3	48.0
October 24	42.0	November 4	43.0
October 25	60.0	November 5	49.0
October 26	46.5	November 6	52.5
October 27	42.5	November 7	47.0
October 28	43.5	November 8	56.0
October 29	42.5	November 9	42.5
October 30	37.0	November 10	37.5
October 31	34.0	November 11	41.0

There was a high initial rate of respiration in all of the soil-stored parsnips, but the initial rate in the original unstored lot was higher than in any soil-stored lot. In the lot stored for 131 days, however, the rate reached on the second day was higher than the initial rate in the unstored lot. The air-stored parsnips gave a high initial rate of respiration after 21 and 131 days storage, while the other air-stored lots had as high respiration rates at the ends of the respiration periods as at the beginning.

The respiration rates in the soil-stored parsnips were higher than in the air-stored roots, except in the lots after 21 days storage. Here there was a higher rate manifested by the air-stored roots. The air-stored parsnips lost moisture at a rapid rate in storage, while there were slight gains in the percentages of moisture in the soil-stored roots.

The respiration rates fluctuated more in the stored parsnips than in the original ones direct from the field. The points at which a nearly constant rate of respiration was attained in the soil-stored roots were in most cases higher than in the fresh roots. The rate in the lot after 131 days soil-storage was considerably higher than in the others after the first forty-eight hours.

The reducing sugar content increased in all soil-stored parsnips up to the ninety-second day of storage. The lot stored for 131 days had slightly less reducing sugars than the lot stored for ninety-two days. The total sugar content increased gradually throughout the storage period, there being more than twice as much in the roots stored for 131 days as in the roots at the time of harvest.

The reducing sugar content increased slightly during the respiration period in the roots after twenty-one days soil-storage, and greatly in those after forty-seven days soil-storage. In the latter there was an increase during the respiration period from 2.14 per cent to 17.47 per cent dry weight. At the same time there was a decrease in the total sugar from 41.65 per cent to 37.30 per cent dry weight. The parsnips stored in soil for ninety-two days showed a decrease in reducing sugars during the respiration period from 4.68 per cent to 3.31 per cent dry weight, and a decrease in total sugar from 42.50 per cent to 39.70 per cent dry weight. In the roots stored for 131 days in soil there was no change in the reducing sugar content, but there was a decrease in the total sugar from 49.65 per cent to 36.55 per cent dry weight during the sixteen days of respiration.

It is interesting to note that after the different periods of respiration at 71°.6 F. the total sugar content of the soil-stored roots is nearly the same. The greatest difference between any two lots is only 3.15 per cent dry weight, and no lot varies more than 2.00 per cent from the average of the four lots. This phenomenon would seem to indicate that there is a balance or range of equilibrium between the polysaccharide reserves and the sugars in the parsnips, and that there is a shifting of the equilibrium when the roots are transferred from the 36° F. temperature to 71°.6 F. It will be remembered that there was an increase in the total sugar content during the respiration periods in the roots which had a lower total sugar content, and a decrease in the total sugar in the roots which had a higher total sugar content than the average reached by the parsnips during the respiration periods.

In the air-stored roots there was a rapid accumulation of total sugar in storage. The maximum of both total and reducing sugars was found in the lot stored for 21 days when calculated to dry weight. The total sugar content at this time was higher than that reached at any time in the soil-stored roots. It amounted to 51.71 per cent as compared with 49.65 per cent attained by the soil-stored roots after 131 days storage. This would seem to indicate that the conditions brought about by the rapid loss of moisture or by the exposure to the air accelerates the formation of sugars from the polysaccharides in the parsnips.

There was a gradual falling off in the total sugar content of the lots stored in air longer than twenty-one days. The reducing sugar content also decreased from the twenty-first day to the forty-seventh day, after which time it remained practically constant. The total sugar content after respiration determinations in the air-stored lots varies from 43.90 per cent to 48.80 per cent dry weight. This is a somewhat greater variation than in the soil-stored lots and the total sugar content is also higher, but it may be assumed that the range of the equilibrium level is somewhat wider under the conditions of air storage as compared with soil storage, and that the level is somewhat higher also.

There was no direct correlation between the sugar content and the rate of respiration. As was previously pointed out there was a high initial rate of respiration in all the soil-stored lots and in two of the air-stored lots. It was also pointed out that the initial rate in the unstored lot was higher than for any other and the sugar content, both reducing sugars and total sugar were lower than in any other lot. The lot stored in soil for twenty-one days had about twice as much reducing sugar and more than a third more total sugar than the original fresh lot at the beginning of the respiration period. There was also an increase in both reducing sugars and total sugar during the respiration period, yet the initial rate of respiration was considerably lower than in the fresh roots, and the rate remained lower until the fifteenth day when the rates were about the same.

The lot stored for 47 days in soil contained about twice as much reducing sugar and about twice as much total sugar as the original fresh roots at the beginning of the respiration period. There was an increase in reducing sugars from 2.14 per cent to 17.47 per cent dry weight, and a decrease in total sugar from 41.65 per cent to 37.30 per cent during the respiration period. The initial rate of respiration was lower than that of the fresh roots until the third day when they were about the same. From the third day to the ninth day the rate in this lot was considerably higher than in the fresh roots, but after the ninth day the rates remained about the same. The lot stored for 92 days in soil had a higher sugar content than the lot stored for 47 days. There was a decrease in both reducing sugars and total sugar during the respiration period in this lot. The respiration rate was a little lower at the start than in the lot stored for 47 days, but subsequently it was about the same. The lot stored for 131 days in soil had the highest total sugar content of any soil-stored lot, and nearly as high reducing sugar content at the beginning of the respiration period. The total sugar increased during the respiration period while the reducing sugar content did not change appreciably. The initial rate of respiration was lower than in any other lot, except one, but increased after the first day to a point considerably higher than any of the others and remained consistently higher, reaching a level of equilibrium after about ten days, as was the tendency in all lots.

The lot stored in air for 21 days had the highest sugar content of any air-stored lot. The initial rate of respiration was also the highest. This initial rate was not, however, as high as the initial rate in the fresh roots, while the total sugar content was about two and a half times as great and the reducing sugar content was more than six times as great at the beginning of the respiration period. There was an increase in the reducing sugar content in this lot during the respiration period from 7.10 per cent to 19.03 per cent dry weight, and a decrease in the total sugar content from 51.71 per cent to 48.80 per cent. Only four respiration determinations were made on the roots stored for 47 days in air due to the fact that molds appeared on some of them. The rates of respiration in the other air-stored lots are much lower, the rates decreasing with increase in length of the storage periods. This was probably due to the fact that they lost moisture so rapidly that after a few weeks they were subnormal in activity due to the extreme desiccation.

PARSNIPS

EXPERIMENT 2. 1926-27. The parsnips used in this experiment were obtained from George Lanhardt's truck farm. They were harvested December 11, 1926 and brought at once to the laboratory. The roots were handled in essentially the same manner as those in Experiment 1. A few exceptions were necessary. Duplicate lots stored in the soil pots were placed in one layer as shown in Figure 4. Those stored exposed to air were placed on mesh wire fitted as covers for the soil pots, and the roots of duplicate lots were placed alternately in the same manner as those stored in the soil. This insured strict uniformity of storage conditions in duplicate lots.

Eleven lots of six roots each were selected, each lot averaging about 875 grams in weight. Two lots were placed immediately in the respiration chamber and respiration determinations started. One lot was sampled for sugars and moistures. The other lots were stored at 36° F. Duplicate lots from both soil-storage and air-storage were removed for respiration determinations and sugar and moisture analysis after 31 and 94 days respectively.

The results of the experiments are given in tables 8 to 13 and figures 5 and 6. The daily mean temperature for a period of three weeks prior to the harvesting date of the parsnips is also given in table 14.

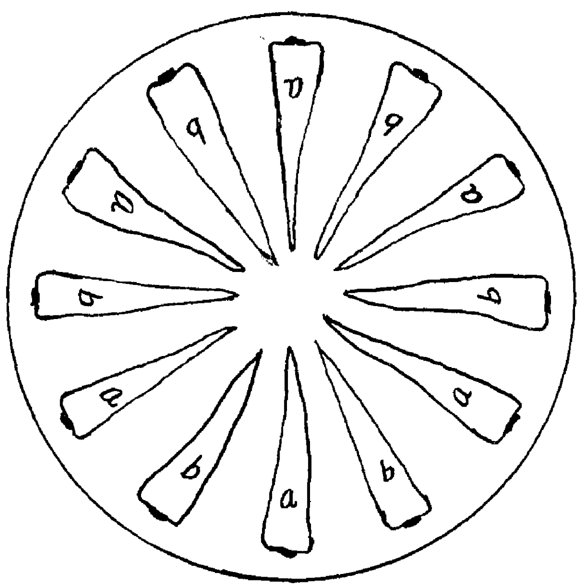


Fig. 4. The arrangement of parsnips in storage in soil pots and exposed to air. Duplicate lots of roots are marked (a) and (b) respectively.

Table 8. Respiration of Parsnips at 71°.6 F after Different Periods of Soil Storage at 36° F.

Lot No.	Days in storage at 36° F	Milligrams CO_2 per 100 grams dry matter per 24 hour periods												
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day
1	0	1387	1084	687	584	522	551	498	539	546	467	482		
2	31	1288	1077	1093*	1013	840	1009	1119	1048	840	843	825	818	784
3	94	1233*	1391*	1181*	1165	984	899	1030	988	743	802			

*Temperature went to 73°.4 F - 75°.2 F due to outside high temperature.

Table 9. Respiration of Parsnips at 71°.6 F after Different Periods of Air Storage at 36° F.

Lot No.	Days in storage at 36°F	Milligrams CO_2 per 100 grams Dry matter per 24 hours.												
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day
1	0	1387	1084	687	584	522	551	498	539	546	467	482		
2	31	1025	941	1132*	855									
3	94	552*	691*	672*	779*	740	607	550	600					

*Temperature went to 73°.4 - 75°.2 F due to outside high temperature.

Table 10. Sugar Content of Parsnips After Different Periods of Soil Storage at 36° F.

Lot No.	Soil storage at 36°F	Moisture	Total Sugars			Reducing Sugars		
			Wet Weight	Original Wet Wt.	Dry Weight	Wet Weight	Original Wet Wt.	Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	81.80	6.43	6.43	35.36	0.34	0.34	1.89
2	31	83.94	6.73	7.12	41.91	1.56	1.65	9.77
3	94	84.84	6.42	7.13	42.36	1.25	1.38	8.25

Table 11. Sugar Content of Soil-Stored Parsnips After the Respiration Tests.

Lot No.	Air Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars			Reducing Sugars		
				Wet Weight	Original Wet wt.	Dry Weight	Wet Weight	Original Wet Wt.	Dry Weig
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PERC
1	0	11	80.89	7.35	7.02	38.50	0.66	0.63	3.5
2	31	13	83.58	6.40	6.27	39.00	1.45	1.42	8.8
3	94	10	85.40	5.76	6.25	39.51	0.83	0.90	5.6

Table 12. Sugar Content of Parsnips After Different Periods of Air Storage at 36° F.

Lot No.	Air Storage at 36°F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	81.80	6.43	6.43	35.36	0.34	0.34	1.89
2	31	67.95	14.72	8.71	45.90	1.16	0.68	3.62
3	94	45.24	23.34	7.00	42.63	0.90	0.27	1.63

Table 13. Sugar Content of Air-Stored Parsnips After the Respiration Tests.

Lot No.	Air Storage at 36°F	Respiration tests at 71°.6F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	11	80.89	7.35	7.02	38.50	0.66	0.63	3.50
2	31	4	70.94	13.00	7.36	44.90	4.79	2.71	16.48
3	94	8	49.40	18.39	5.05	36.36	1.45	0.40	2.87

Table 14. Daily Mean Temperature at College Park, Maryland from November 20th to December 11, 1926.

Date	Temperature	Date	Temperature
November 20	33.5	December 1	39.0
November 21	33.5	December 2	36.0
November 22	33.0	December 3	25.5
November 23	39.5	December 4	39.0
November 24	38.0	December 5	29.0
November 25	39.5	December 6	25.5
November 26	43.5	December 7	22.5
November 27	44.5	December 8	37.0
November 28	30.0	December 9	39.5
November 29	40.5	December 10	37.5
November 30	47.5	December 11	36.5

Figure 5. Respiration and Sugar Content of Parsnips After Different Periods of Soil Storage at 36^{0} F. Respiration at $71^{o}.6$ F.

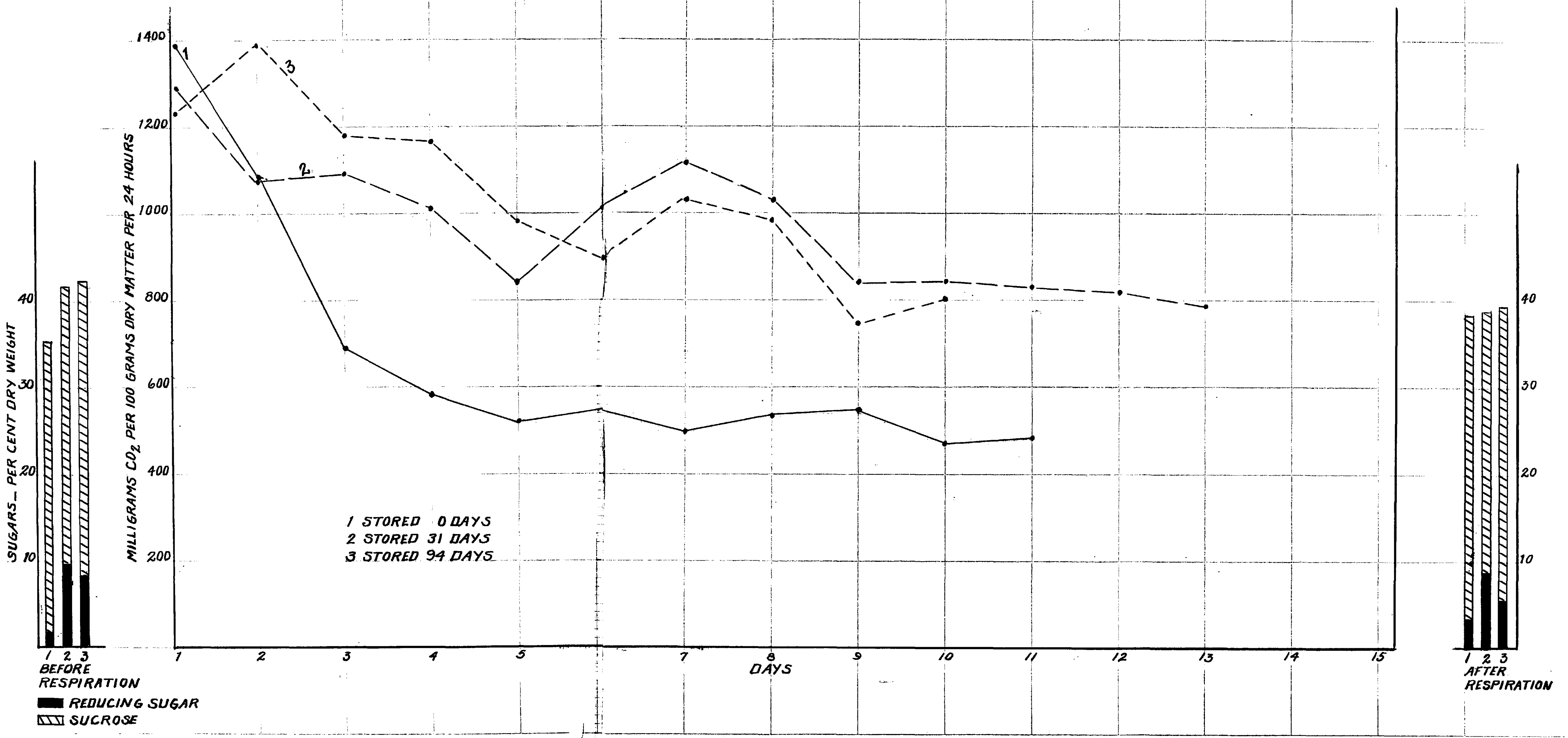
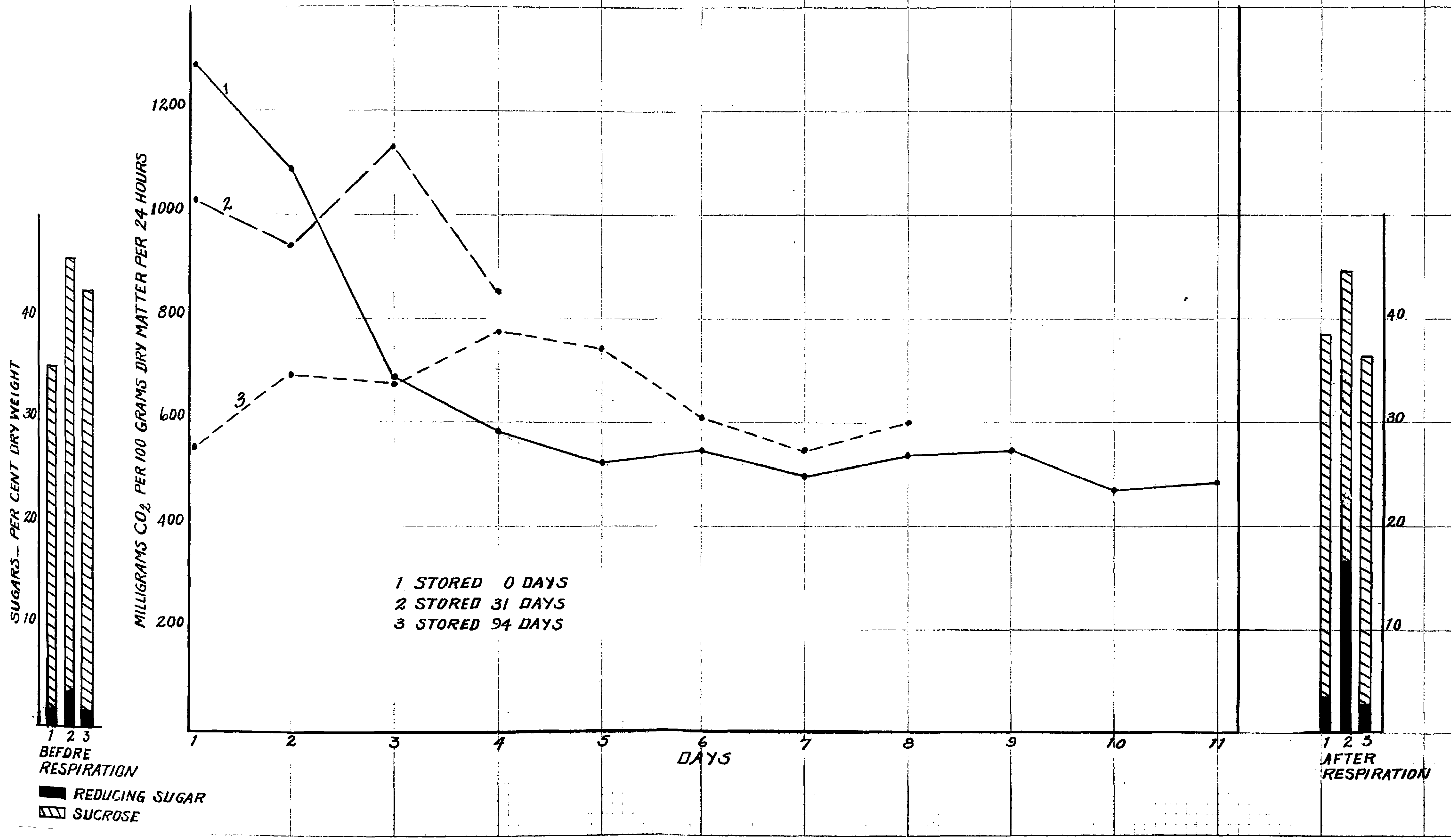

SUGARS_ PER CENT DRY WEIGHT
10
20
30
40
1 2 3
BEFORE
RESPIRATION
REDUCING SUGAR
SUCROSE
MILLIGRAMS CO2 PER 100 GRAMS DRY MATTER PER 24 HOURS
200
400
600
800
1000
1200
1400
1 STORED 0 DAYS
2 STORED 31 DAYS
3 STORED 94 DAYS
1
2
3
1 2 3 4 5 7 8 9 10 11 12 13 14 15
DAYS
1 2 3
AFTER
RESPIRATION

Figure 6. Respiration and Sugar Content of Parsnips After Different Periods of Air Storage at 36° F. Respiration at 71°.6 F.


SUGARS – PER CENT DRY WEIGHT
10
20
30
40
1 2 3
BEFORE RESPIRATION
REDUCING SUGAR
SUCROSE
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
200
400
600
800
1000
1200
1 STORED 0 DAYS
2 STORED 31 DAYS
3 STORED 94 DAYS
1 2 3 4 5 6 7 8 9 10 11
DAYS
1 2 3
AFTER RESPIRATION

DISCUSSION OF RESULTS

The respiration rate in fresh parsnips was higher than that in any other lot, as was true in experiment 1. The rates in the soil-stored parsnips were higher than in the air-stored roots for equal periods of storage.

As was the case in experiment 1, there was a greater fluctuation in the respiration rates after periods of storage than in the fresh parsnips.

The soil-stored lots respired at a higher rate after one or two days than the fresh roots. This tendency was the same in the soil-stored roots of the previous experiment but it was less marked in those and occurred after three or four days as compared to one or two days in this case. There was also a greater difference in the rates at the end of the respiration tests than in experiment 1, the final rates being higher in each case than the final rates in the fresh parsnips. The respiration periods were longer in experiment 1 and this might account in part for the greater divergence, yet there is a greater difference when compared on corresponding days. It will be noted that there is a pronounced secondary rise in the respiration rate after the fifth and sixth days of the two stored lots. This rise reaches a maximum in two days after which there is a decrease during the next two days to a point about the same level as when the rise started. The explanation of this secondary rise is not known.

It is to be noted that there is a high initial rate of respiration in each lot except the one stored in air for 94 days. Due to the excess loss of moisture in this lot it is probable that these were subnormal in their response. The respiration rates of the air-stored parsnips show the same general results as in experiment 1. The initial rates were lower with longer periods of storage, and the tendency was for the respiration rates in these stored lots to decrease more slowly than the rates in the fresh parsnips.

The results of this experiment show no correlation between the sugar content and the rate of respiration. There was an increase in sugar content during storage in all lots. The lots stored in air for 31 days had the highest sugar content. These lots accumulated more total sugar in the 31-day period than the soil-stored lots accumulated in 94 days. But the roots stored for 31 days and for 94 days in soil had more reducing sugars. The original unstored lot had the lowest sugar content, both reducing sugars and total sugar, than any other lot, and the initial rate of respiration was higher than in any other lot. These roots accumulated sugar during the respiration period while the respiration rate decreased to a nearly constant rate after the fifth day. In the soil-stored lots there was a decrease in both reducing and total sugars during the respiration periods, all lots having about the same total sugar content at the end of the periods; yet the respiration rates of the two stored lots at equilibrium were higher than the equilibrium rate in the fresh lot.

The lot stored for 31 days in air increased markedly in reducing sugar content and decreased slightly in total sugar during the respiration period. It contained a much higher percentage of both total and reducing sugars at the beginning of respiration tests than the fresh roots. The rate of respiration was lower at the start, but higher after the second day than in the fresh roots. In the lot stored for 94 days in air there was a decrease in total sugar and an increase in reducing sugars during the respiration period. The total sugar content at the end was a little less than that in the fresh roots, while the rate of respiration was a little higher.

These results show again that there was a tendency for the total sugar content to reach an equilibrium at $71^{o}.6$ F. The total sugar content of the fresh roots and those stored for different periods in soil reached about the same level after periods in the respiration chamber, as was true in experiment 1. The equilibrium values for the total sugar content in experiment 1 was about 37 per cent and in this experiment about 38 per cent based on dry weight. There was a greater difference in the sugar content in the air stored lots of the two experiments, these reaching equilibrium at about 45 per cent total sugar in experiment 1, and at about 37 per cent in this experiment. The difference in the rates of respiration of the air-stored lots may be in some way associated with the rapid loss of water in storage, as was suggested in experiment 1.

CARROTS

EXPERIMENT 1. (1926-27) The carrots used in this experiment were secured from the truck farm of George Lanhardt of Hyattsville. They were harvested October 23, 1926 and brought to the laboratory. The tops were cut off about one-fourth inch above the crowns. The roots were carefully washed in running tap water, wiped as dry as possible with towels, and spread upon the laboratory table for two hours. Four lots of eight roots each were selected. Each lot was as uniform in size and weight as possible. The average weight per lot was about 765 grams.

One lot was placed immediately in the respiratory chamber and respiration determinations started. One lot was sampled for sugars and moisture. The remaining lots were stored at 36° F. The carrots were placed in moisture dishes and the lids were so adjusted as to allow sufficient ventilation, but were closed sufficiently to prevent excessive loss of moisture by evaporation. The roots were removed from the refrigerator after 28 days and respiration determinations started on one lot, and sugar and moisture samples taken from the other. The results are given in tables 15 to 17 and figure 7 inclusive. The daily mean temperature for 3 weeks prior to the date of harvest of the carrots is given in table 18.

Table 15. Respiration of Carrots at 71°.6 F. After Different Periods of Storage at 36° F.

Lot No.	Days in Storage at 36°F	Milligrams CO_2 per 100 grams dry matter per 24 hours. 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day
1	0	1529	1393	1157	1143	968	1062	1088							
2	28	1476	1382	1337	1172	1115	1085	----	921						
2'	28 32	934	1034	973	978	1017									

2' This is Lot 2 after 28 da. at 36° F; 9 da. at 22° C; and 32 da. at 36° F.

Table 16. Sugar Content of Carrots After Different Periods of Storage at 36° F.

Lot No.	Storage at 36°F	Moisture	Total Sugars			Reducing Sugars		
			Wet Weight	Original Wet Wt.	Dry Weight	Wet Weight	Original Wet Wt.	Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	88.01	5.10	5.10	42.60	2.40	2.40	20.02
2	28	89.50	4.15	4.02	39.55	3.12	3.02	29.80

Table 17. Sugar Content of Carrots After the Respiration Tests.

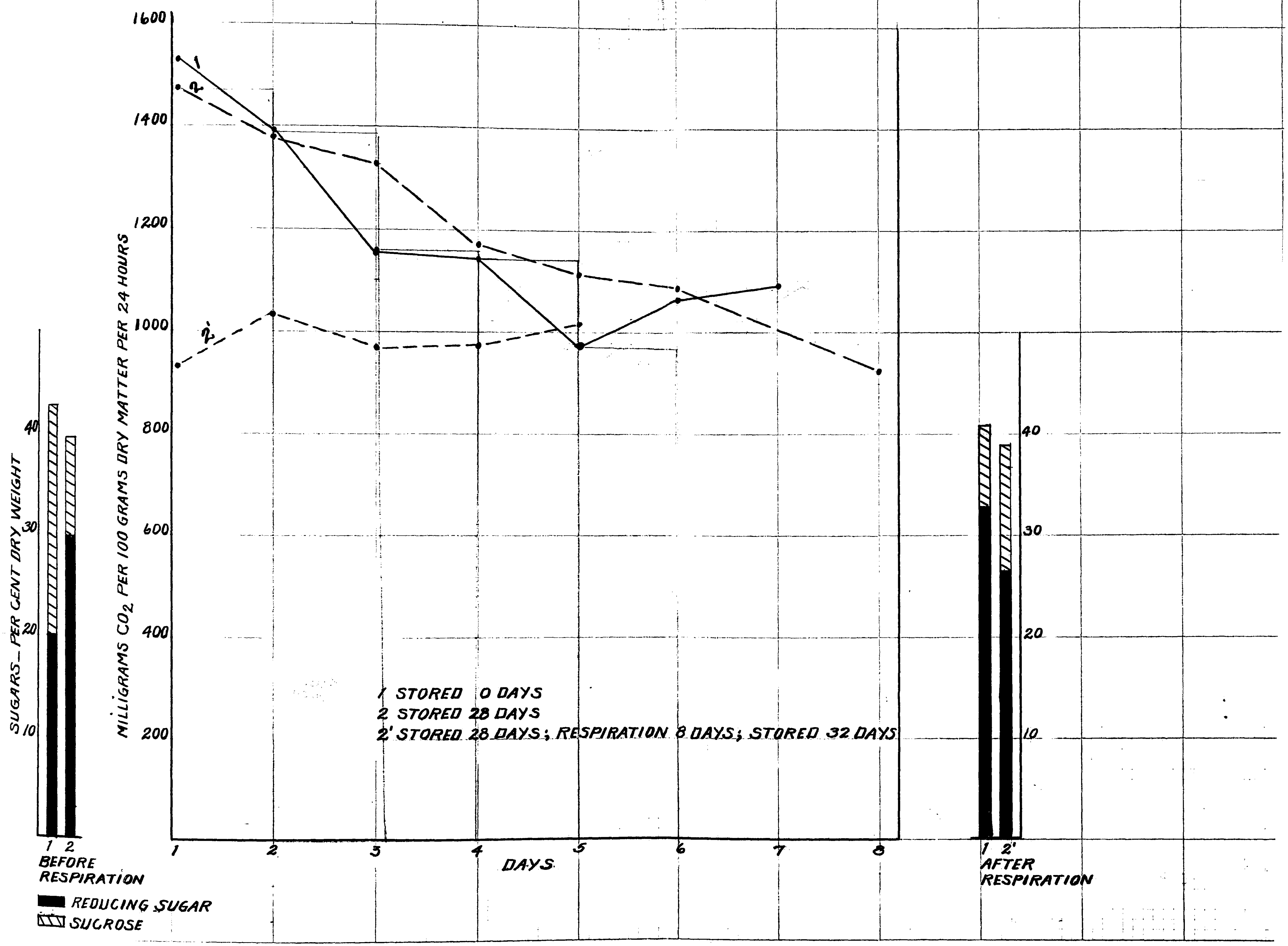
Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars			Reducing Sugars		
				Wet Weight	Original Wet Wt.	Dry Weight	Wet Weight	Original Wet Wt.	Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	7	90.62	3.83	3.75	40.91	3.06	2.99	32.67
2'	28* 32	9* 6	88.92	4.30	3.67	38.85	2.93	2.50	26.54

*Stored 28 days at 36° F. ; Respiration 9 days; stored 32 days at 36° F.; and respiration 6 days.

Table 18. Daily Mean Temperature at College Park from October 1, 1926 to October 23, 1926.

Date	Temperature	Date	Temperature
October 1	65	October 13	69
October 2	69	October 14	62
October 3	74	October 15	55
October 4	76	October 16	50
October 5	77	October 17	57
October 6	70	October 18	45
October 7	55	October 19	51
October 8	49	October 20	47
October 9	46	October 21	46
October10	54	October 22	45
October11	63	October 23	47
October12	62		

Figure 7. Respiration and Sugar Content of Carrots After Different Periods of Storage at 36° F. Respiration at 71°.6 F.


SUGARS _ PER CENT DRY WEIGHT
10
20
30
40
1 2
BEFORE RESPIRATION
REDUCING SUGAR
SUCROSE
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
200
400
600
800
1000
1200
1400
1600
1
2
2'
DAYS
1
2
3
4
5
6
7
8
1 STORED 0 DAYS
2 STORED 28 DAYS
2' STORED 28 DAYS; RESPIRATION 8 DAYS; STORED 32 DAYS
1 2'
AFTER RESPIRATION

DISCUSSION OF RESULTS

The initial rate of respiration was higher in the fresh carrots than in those after periods of storage. There was a rather rapid decrease in the rate in fresh carrots during the first five days after which there was an increase. This increase may have been due to a slight decay in the tips of some of the roots as they were affected slightly with molds when removed from the respiration chamber.

The initial rate of respiration in the carrots stored for twenty-eight days was lower than the initial rate in fresh carrots, but after the second day the rate was higher until near the end of the respiration period, when it was again lower. It will be remembered, however, that there was an increase in the respiration rate in fresh carrots at this point and this probably accounts for the rate being higher than in the stored lot. There was a nearly constant decrease in the respiration rate in the stored lot throughout the respiration period. At the end of eight days this lot was stored again at 36° F. for 32 days, after which respiration determinations were again made. The respiration rate was much lower at the start than the rate during the first test, and increased gradually from the beginning to the end of the period.

The total sugar content was higher in the fresh carrots than in those after storage. The total sugar decreased during the storage period while there was an increase in the reducing sugars.

There was a decrease in the total sugar during the respiration period in fresh carrots from 42.60 per cent to 40.91 per cent dry weight. The reducing sugars increased during the same period from 20.02 per cent to 32.67 per cent dry weight. As previously stated, the respiration rate decreased during this period.

The carrots stored for 28 days had a higher reducing sugar content and a lower total sugar content at the beginning of the respiration period than the fresh carrots. The respiration rate at the beginning was lower than the initial rate in the fresh roots, but later it was higher for most of the period. No sugar determinations were made at the end of the first respiration period. The carrots were stored at 36° F after the first respiration period for 32 days. After this storage period the respiration rate was much lower than in the previous test, and gradually increased from the start. The rate at the beginning of this second test was as low as the final rate in the previous tests. The sugar content at the end of the test was considerably lower than at the end of the 28 days of storage. The reducing sugar content, however, was considerably higher than that of the fresh carrots at the beginning of the respiration test.

The results show an initial high rate of respiration for fresh carrots and for those after 28 days storage at 36° F., but there is not shown any correlation between the sugar content and the rate of respiration.

It will be noted that there is not a great deal of difference in the total sugar content of the two lots after the respiration tests. Unfortunately no sugar determinations were made on Lot 2 after the first respiration test, so that the sugar content at that time is not known, but due to the fact that there is such slight difference in the total sugar content of the two lots at the end of their respective respiration periods, it seems as though there must be a range of equilibrium for a given temperature between the total sugar and reserve polysaccharides. This is made more evident when it is considered that the Lot 2' carrots were subjected to two periods of storage and to two periods of respiration, and at the end of the second respiration period the total sugar content was nearly the same as in Lot 1 which was subjected only to the respiration temperature.

CARROTS

EXPERIMENT 2 (1927-28). Carrots for this experiment were grown on the Experiment Station Farm at College Park. They were dug November 15, 1927 and were handled and stored in the same manner as those in Experiment 1. Four lots of eight roots each were used. Those stored were left in the refrigerator for 104 days. The results are given in tables 19 to 21 and figure 8 and the mean daily temperature for three weeks prior to the date of harvest is given in table 22.

Table 19. Respiration of Carrots at 71°.6 F. after a Period of Storage at 36° F.

Experiment 2 (1927-28)

Lot No.	Days in Storage at 36° F.	Milligrams CO_2 per 100 grams Dry matter per 24 hours. 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day	17th day	18th day	19th day	20th day	21st day
1	0	943	1055	828	801	749	693	---	642	665	660	626	647	624	638	565	587	708	715	652	548	---
2	104	1349	1234	1423	1228	1209	983															

Table 20. Sugar Content of Carrots After a Period of Storage at 36° F.

Lot No.	Storage at 36°F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	87.30	6.48	6.48	51.17	0.70	0.70	5.54
2	104	82.90	8.23	5.22	48.18	4.04	2.56	23.65

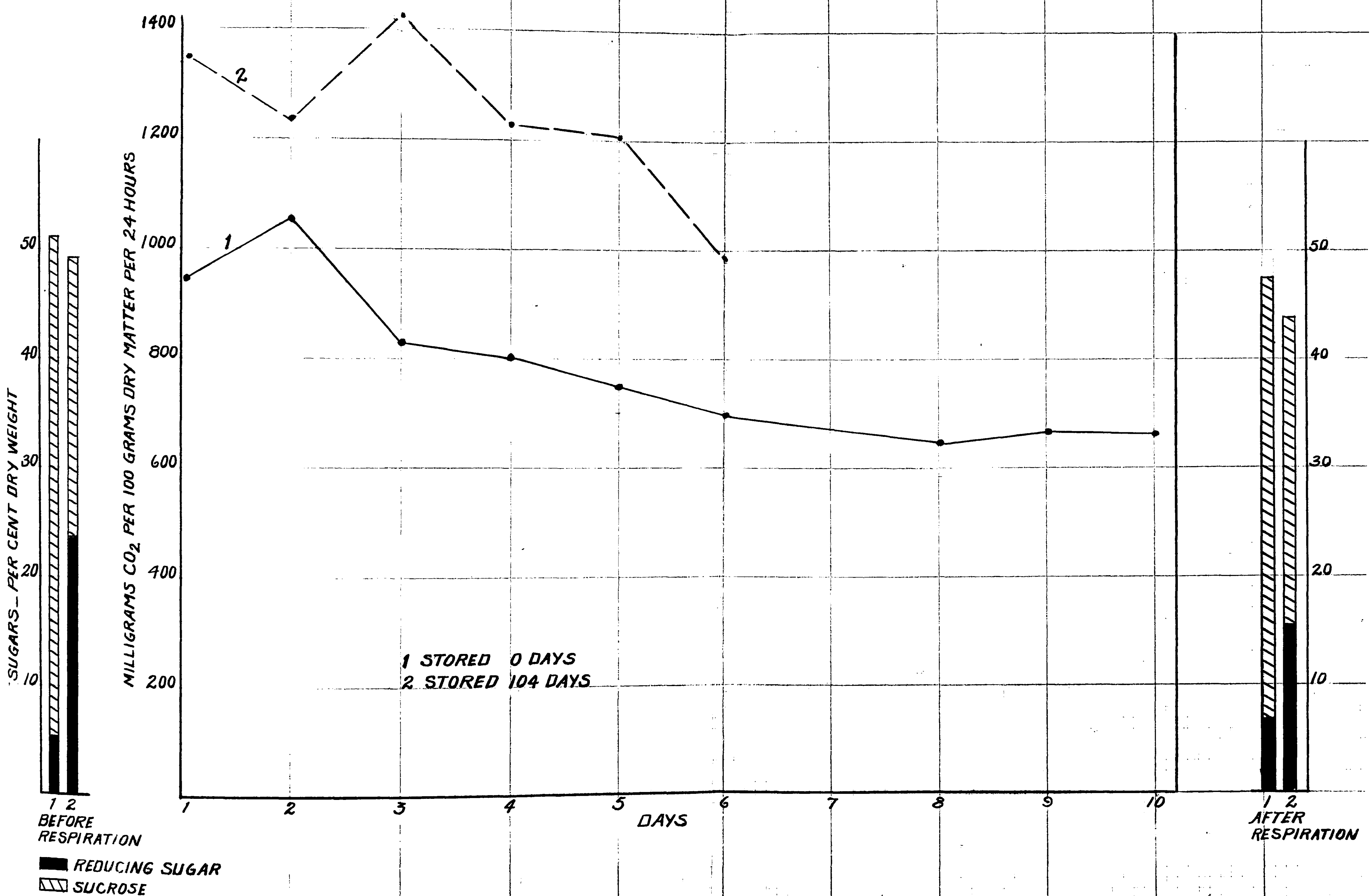
Table 21. Sugar Content of Carrots After the Respiration Tests.

Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	21	87.11	6.14	5.51	47.66	0.89	0.80	6.94
2	104	6	81.32	8.21	4.41	43.97	2.87	1.54	15.37

Table 22. Daily Mean Temperature at College Park, from October 26, 1927 to November 15, 1927.

Date	Temperature	Date	Temperature
October 26	52	November 7	35
October 27	56	November 8	35
October 28	59	November 9	44
October 29	61	November 10	38
October 30	61	November 11	55
October 31	55	November 12	58
November 1	58	November 13	41
November 2	59	November 14	43
November 3	58	November 15	61
November 4	46		
November 5	41		
November 6	40		

Figure 8. Respiration and Sugar Content of Carrots After Different Periods of Storage at 36° F. Respiration at $71^{\circ}.6$ F.


SUGARS_ PER CENT DRY WEIGHT
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
1400
1200
1000
800
600
400
200
50
40
30
20
10
1
2
1 STORED 0 DAYS
2 STORED 104 DAYS
1 2 3 4 5 6 7 8 9 10
DAYS
1 2
BEFORE RESPIRATION
1 2
AFTER RESPIRATION
REDUCING SUGAR
SUCROSE

DISCUSSION OF RESULTS

The freshly harvested carrots gave a high initial rate of respiration which reached its peak the second day and then gradually decreased to a nearly constant level about the sixth day. The respiration of the lot after 104 days storage showed a high initial rate which reached its peak after three days and then rapidly decreased to the end of the test. The rate in this lot was much higher than the rate in the fresh carrots throughout the entire period.

The percentage total sugars in the fresh roots decreased during the respiration period from 51.17 per cent to 47.66 per cent dry weight. The reducing sugars increased during the same period from 5.54 per cent to 6.94 per cent dry weight. As was stated previously, the respiration rate decreased during this period.

The percentage total sugar decreased in the carrots during the 104 days storage from 51.17 per cent to 48.18 per cent dry weight, while the reducing sugars increased from 5.54 per cent to 23.65 per cent dry weight. Following this period of storage there was a decrease in the total sugar from 48.18 per cent to 43.97 per cent dry weight during the six-day respiration period, and a decrease of reducing sugars from 23.65 per cent to 15.37 per cent dry weight. The rate of respiration decreased during this period.

The tendency of the shift in the sugar content in the carrots in this experiment was very similar to that in the carrots of experiment 1. There was a loss in the percentage of total sugar during the respiration periods, and also during storage in both experiments. At the same time there was an increase in reducing sugars in the carrots in both experiments during storage. After storage there was a loss during the respiration periods in both reducing and total sugars in the carrots in both experiments.

The respiration rate in the carrots after 104 days storage was much higher than the rate in the fresh carrots, but in experiment 1 the rate in the roots after twenty-eight days storage was not very different from the rate in the fresh roots.

There was a wide difference in the total sugar content in the two lots after the respiration tests as well as a great difference in the reducing sugar content. There was also a great difference in the final rates of respiration in the two lots, but there was no definite correlation between the sugar content and the rate of respiration.

CARROTS

EXPERIMENT 3 (1928) Carrots for this experiment were grown by Henry Stello, Beltsville, Maryland. They were harvested October 16th and brought to the laboratory where they were stored in crates in a cool cellar until October 17th. Nine lots of fifteen carrots each were used. They were handled in the same manner as in experiments 1 and 2 except that duplicate lots were used for respiration determinations. Triplicate lots stored in the refrigerator were removed at the end of 26 days and 36 days respectively. The experimental results are given in tables 23 to 25 and figure 9. The averages of the respiration rates of duplicate lots are given in the tables and plotted in figure 9. The daily mean temperature for three weeks prior to the date of harvest is given in table 26.

Table 23. Respiration of Carrots at 71°.6 F. after Different Periods of Storage at 36° F.

Experiment 3 (1928)

Lot No.	Days in Storage at 36°F	Milligrams CO_2 per 100 grams dry matter per 24 hours.															
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day
1	0	1295	1067	1151	880	779	---	709	806	749	711	---	488	---	545		
2	26	1177	1166	938	912	1075	---	838									
3	36	1064	1205	873	---	---	715										

Table 24. Sugar Content of Carrots After Different Periods of Storage at 36° F.

Lot No.	Storage at 36°F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	88.60	5.07	5.07	44.55	3.48	3.48	30.62
2	26	88.95	5.02	4.53	45.51	4.02	3.62	36.48
3	36	87.85	5.58	4.93	46.06	4.11	3.63	33.92

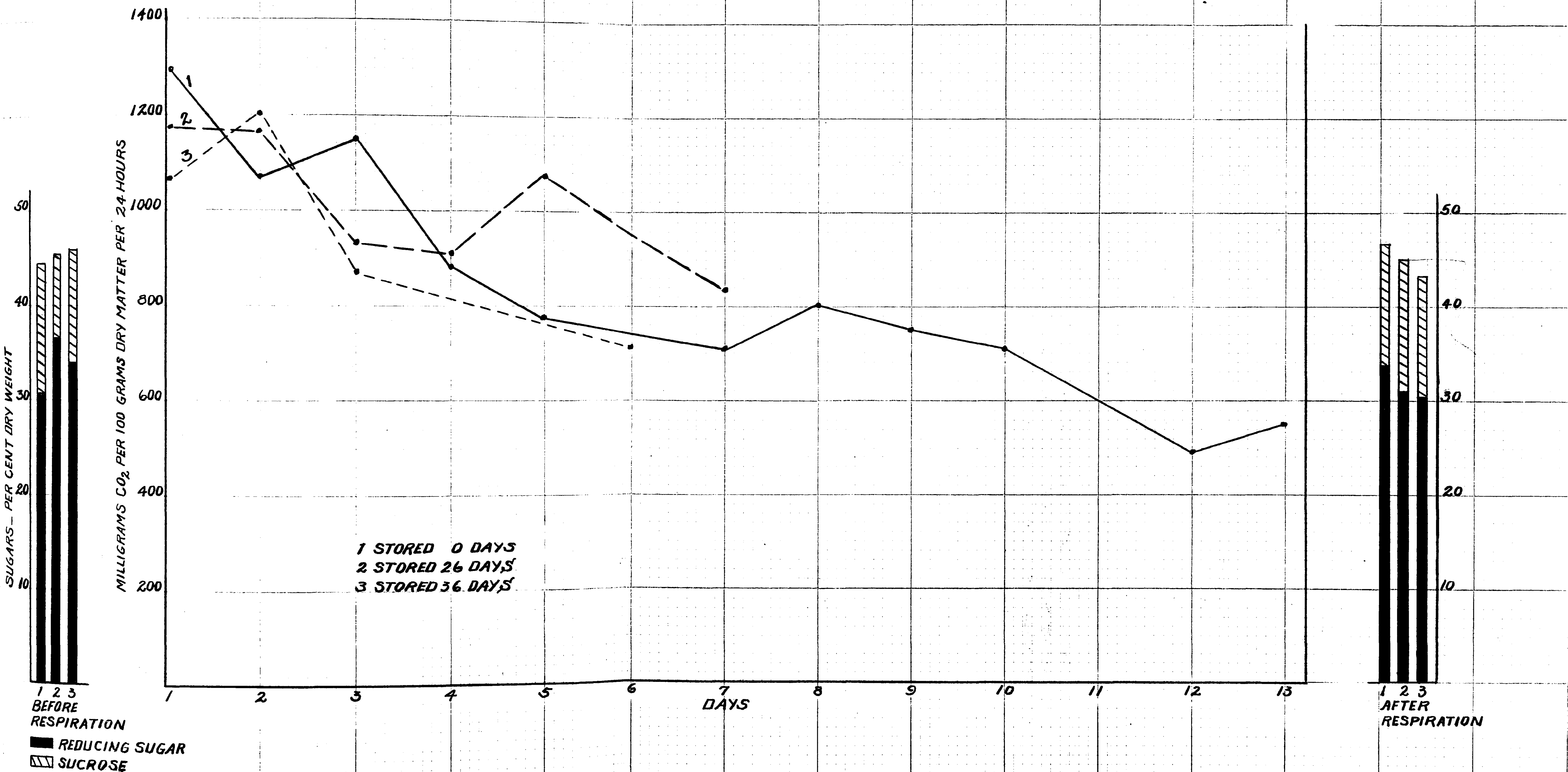
Table 25. Sugar Content of Carrots After the Respiration Tests.

Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CEN
1	0	16	88.75	5.26	4.94	46.78	3.77	3.54	33.62
2	26	7	87.80	5.50	4.63	45.15	3.78	3.18	31.03
3	36	5	87.81	5.25	4.48	43.18	3.69	3.15	30.38

Table 26. Daily Mean Temperature at College Park from September 25, 1928 to October 16, 1928.

Date	Temperature	Date	Temperature
September 25	47	October 6	64
September 26	50	October 7	57
September 27	51	October 8	56
September 28	53	October 9	70
September 29	56	October 10	61
September 30	52	October 11	59
October 1	51	October 12	64
October 2	57	October 13	71
October 3	59	October 14	69
October 4	60	October 15	52
October 5	67	October 16	69

Figure 9. Respiration and Sugar Content of Carrots After Different Periods of Storage at 36° F. Respiration at 71°.6 F.


SUGARS _ PER CENT DRY WEIGHT
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
1400
1200
1000
800
600
400
200
50
40
30
20
10
1 2 3
BEFORE RESPIRATION
AFTER RESPIRATION
DAYS
1 2 3 4 5 6 7 8 9 10 11 12 13
1 STORED 0 DAYS
2 STORED 26 DAYS
3 STORED 36 DAYS
REDUCING SUGAR
SUCROSE

DISCUSSION OF RESULTS

The results of this experiment show a high initial rate of respiration in the fresh carrots, and also a high initial rate in those after periods of storage. The rate in the fresh carrots was higher during the first day than in any of the stored lots. During the second day the rate declined rapidly but during the third day there was a marked increase. This increase was followed by a rather rapid decrease in the rate until the seventh day when there followed another rather abrupt increase for a day, and then a gradual decrease in the rate to the end of the experiment. Despite the fluctuations in the rate in this lot, however, the rate at the end of the experiment was not quite half as high as at the beginning.

The initial respiration rate in the carrots after 26 days storage was lower than the initial rate in the fresh carrots. The rate decreased during the first four days but on the fifth day there occurred an abrupt increase which fell off rapidly to the end of the respiration period.

The rate at the end of the test was considerably higher than the final rate in the fresh carrots.

The respiration rate in the carrots after 36 days of storage was somewhat lower during the first day than the rate in the fresh carrots or the rate in those after 26 days of storage. But there was a marked increase during the second day and due to this increase the rate was considerably higher than in any of the other lots at a corresponding time. There was a rapid falling off in the respiration rate during the third day, and the rate remained somewhat below that of the other lots from the third day to the end of the test.

The total sugar content, based on percentage of the dry weight, gradually increased in carrots during storage. The reducing sugars increased during the 26-day storage period, but there was a rather marked decrease from the twenty-sixth to the thirty-sixth day. However, the reducing sugar content in the carrots stored for 36 days was considerably higher than that in the fresh carrots.

During the respiration period there was an increase in the total sugar in fresh carrots from 44.55 per cent to 46.78 per cent dry weight. The reducing sugars increased during the same period from 30.62 per cent to 33.62 per cent dry weight. As was previously stated, the respiration rate decreased during this time.

There was a slight decrease in the total sugar during the respiration period in carrots after 26 days of storage, and a decrease in reducing sugars from 36.48 per cent to 31.03 per cent dry weight. The respiration rate decreased during this period.

After 36 days of storage there was a decrease in the total sugar during the respiration period from 46.06 per cent to 43.18 per cent dry weight, and a decrease in the reducing sugars from 33.92 per cent to 30.38 per cent dry weight.

The sugar content of fresh carrots was lower at the beginning of the respiration test than in any of the stored lots. The respiration rate decreased during the respiration period while both reducing and total sugars increased. In the carrots stored for 26 days there was a slight decrease during the respiration period in the total sugar content and a considerable decrease in the reducing sugar contant. The respiration rate also decreased during this time. In the lot after 36 days of storage there was a considerable decrease in both the reducing and the total sugar content during the respiration period, and there was also a decrease in the respiration rate. The sugar content in fresh carrots at the end of the respiration test was higher than in any other lot but the respiration rate was lower than in any other. Thus there is no evidence that there is any direct correlation between the sugar content and the rate of respiration in the carrots in this experiment.

It will be noted that the total sugar content after the different respiration tests varies to some extent, but the variation in the percentage total sugars based on dry weight is only slightly more than three per cent. If the average for the three values is taken, no one lot would vary from the average by as much as three per cent. It seems probable from this that there is an equilibrium range for a given set of conditions between the sugar content and the reserve polysaccharides in carrots.

BEETS

EXPERIMENT 1 (1926-27). The beets for this experiment were grown by George Lanhardt, at Hyattsville. They were harvested October 23, 1926 and brought immediately to the laboratory. Two varieties were used, one variety of red beets, and one variety of green-top beets. The red beets were assorted into lots as uniform as possible and experiments started on October 23. The green-top beets were stored in a crate in a cool cellar until October 25th when experiments were started on them.

The tops were cut off the beets about one-fourth inch above the crownsand the roots were washed in running tap water. They were then wiped as dry as possible with towels and laid on the laboratory table for two hours.

Four lots of each variety were used, each lot containing ten beets. The average weight per lot was about 950 grams for the red beets and about 830 grams for the green-top variety.

Respiration determinations were started on one lot of each variety and one lot of each was sampled for moisture and sugars. The other lots were placed in ventilated moisture dishes and were stored at 36° F. for 26 and 28 days. One lot of each variety was then placed in the respiration chambers and one lot of each was sampled for sugars and moisture. After nine days of respiration the two lots were stored at 36° F. for a second period of 32 days, after which respiration determinations were again made.

The experimental results are given in tables 27 to 32 and figures

10 and 11, inclusive. The daily mean temperature for a period of three weeks prior to the harvesting date is given in table 18.

Table 27. Respiration of Red Beets at 71°.6 F After Storage at 36° F.

Lot No.	Days in Storage at 36° F	Milligrams of CO_2 per 100 grams dry matter per 24 hours. 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day
1	0	1218.2	726.7	615.5	615.5	534.3	551.4	500.1		
2	28	895.5	737.3	619.0	609.0	607.0	586.9	548.9	---	496.8
2'	28* 32	828.7	767.8	697.3	656.8	717.6				

* Stored 28 days at 36° F; 9 days at 22° C; then 32 days at 36° F.

Table 28. Respiration of Green Top Beets at 71°.6 F after Storage at 36° F.

Lot No.	Days in Storage at 36°F	Milligrams of CO_2 per 100 grams dry matter per 24 hours 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day
1	0	1005.7	898.0	668.0	564.0	576.7							
2	26	830.3	643.8	637.2	571.1	551.3	521.6	566.2	---	505.1			
2'	26* 32	1215.1	960.4	960.4									

*Stored 26 days at 36° F., 9 days respiration at 22° C.; and then stored 32 days at 36° F.

Table 29. Sugar Content of Red Beets after a Period of Storage at 36° F.

Lot No.	Storage at 36°F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	88.77	5.56	5.56	49.54	0.08	0.08	0.68
2	28	88.02	5.56	5.37	46.51	0.10	0.09	0.82

Table 30. Sugar Content of Red Beets After the Respiration Tests.

Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0		88.56	5.68	5.59	49.68	0.10	0.10	0.90
2'	28* 32	9* 6	88.16	4.91	4.60	41.49	0.21	0.19	1.78

*Stored 28 da. at 36° F.; Respiration 9 da.; Stored 32 da. at 36° F.; Respiration 6 da.

Table 31. Sugar Content of Green-top Beets After a Period of Storage at 36° F.

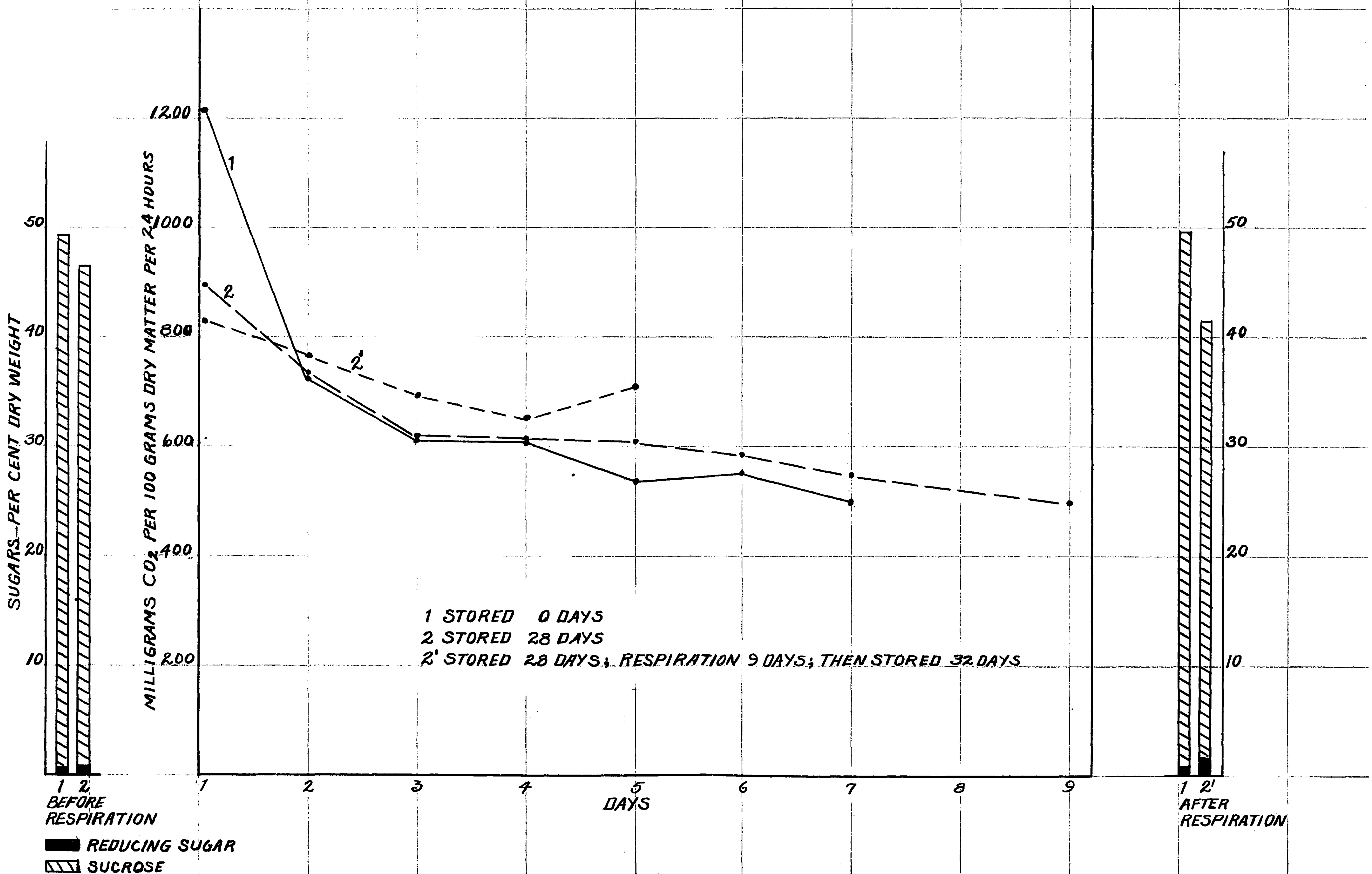
Lot No.	Storage at 36°F.	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	86.85	6.65	6.65	50.64	0.09	0.09	0.75
2	26	85.46	6.68	5.69	45.89	0.11	0.09	0.81

Table 32. Sugar Content of Green-top Beets After the Respiration Tests.

Lot No.	Storage at 36°F.	Respiration tests at 71.6 F.	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	5	87.04	6.03	5.93	46.60	0.08	0.08	0.62
2'	26* 32	9* 3	88.07	4.96	4.50	41.60	0.12	0.11	1.03

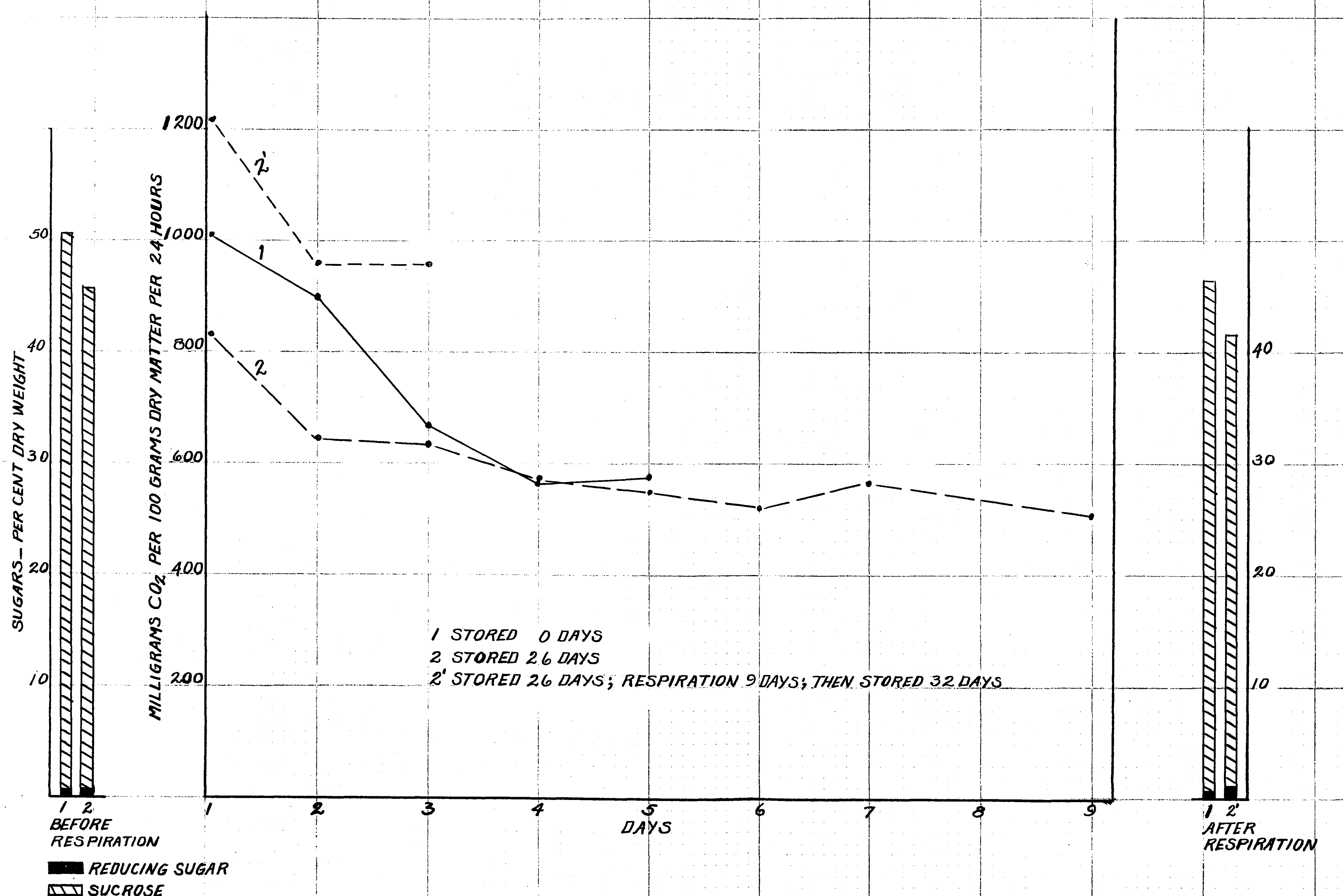
*Stored 26 da. at 36° F.; 5 da. respiration; stored 32 da. at 36° F.; respiration 3 da.

Figure 10. Respiration and Sugar Content of Red Beets After Different Periods of Storage at 36° F. Respiration at 71°.6 F.



SUGARS—PER CENT DRY WEIGHT
10
20
30
40
50
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
200
400
600
800
1000
1200
1
2
2'
1 STORED 0 DAYS
2 STORED 28 DAYS
2' STORED 28 DAYS; RESPIRATION 9 DAYS; THEN STORED 32 DAYS
1 2 3 4 5 6 7 8 9
DAYS
1 2
BEFORE RESPIRATION
1 2'
AFTER RESPIRATION
REDUCING SUGAR
SUCROSE

Figure 11. Respiration and Sugar Content of Green-Top Beets After Different Periods of Storage at 36° F. Respiration at 71°.6 F.


SUGARS – PER CENT DRY WEIGHT
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
1 STORED 0 DAYS
2 STORED 26 DAYS
2' STORED 26 DAYS; RESPIRATION 9 DAYS; THEN STORED 32 DAYS
DAYS
BEFORE RESPIRATION
AFTER RESPIRATION
REDUCING SUGAR
SUCROSE

DISCUSSION OF RESULTS

The initial rate of respiration of freshly harvested beets was high. The rate decreased rapidly during the first three or four days and then less rapidly for the remainder of the period. The initial respiration rates in the beets after 26 and 28 days storage was much lower than the initial rates in the fresh beets, and the final rates were about the same as the final rates in the fresh beets. The respiration rate after a second period of storage was lower in red beets at the beginning of the respiration tests, but after the second day it remained higher than the rate in fresh beets or the rate after the first period of storage. The rate of respiration in green-top beets after a second period of storage was much higher than in any other lot.

There was a slight increase in both reducing sugars and total sugar in the fresh red beets during the respiration period, while in the green-top beets there was a slight decrease in the reducing sugars and a considerable decrease in the total sugar.

There was a slight increase in the reducing sugars during storage in both varieties of beets, and a considerable decrease in the total sugar in both. The reducing sugars in red beets increased from 0.68 per cent to 0.82 per cent dry weight, and the total sugar decreased from 49.54 per cent to 46.51 per cent dry weight during the 28 days of storage. The reducing sugars in green-top beets increased from 0.75 per cent to 0.81 per cent dry weight, and the total sugar decreased from 50.64 per cent to 45.89 per cent dry weight during the 26 days of storage. During the respiration periods of these lots the reducing sugars increased considerably while there was a considerable decrease in the total sugar. It will be remembered that these lots were subjected to two periods of storage and to two periods of respiration. See tables 29 - 32. No sugar analysis was made at the end of the first respiration tests or immediately after the second period of storage.

There is exhibited no correlation between the sugar content and the rate of respiration in beets. In the case of fresh red beets there was a decrease in the rate of respiration simultaneously with an increase in both the reducing and the total sugar content, while in the fresh green-top beets there was a decrease in the respiration rate simultaneously with a decrease in both the reducing and the total sugar content. After the periods of storage the respiration rates in both varieties of beets decreased from the beginning of the tests while there was an increase in the reducing sugars and a decrease in the total sugar.

The sugar content of the beets at the end of the respiration tests varied rather markedly, but there is a rather close agreement in the sugar content of the lots of the two varieties which had the same treatments. Comparing Lot 2' of each variety it is noted that the total sugar content in the case of red beets was 41.49 per cent and in green-top beets was 41.60 per cent dry weight.

The total sugar content of freshly harvested red beets after the respiration tests was 49.68 per cent dry weight, and for similar green-top beets was 46.60 per cent dry weight. Thus it is possible that under a given treatment the total sugar content of beets tends to reach a range of equilibrium.

TURNIPS

EXPERIMENT 1. (1926-1927). The turnips for this experiment were grown by George Lanhardt, at Hyattsville. They were harvested October 23, 1926 and brought immediately to the laboratory. The tops were cut off about one-fourth inch above the crowns and the roots were washed in running tap water. They were then wiped as dry as possible with towels and laid on the laboratory table for two hours. Four lots were selected, two lots with ten roots each, and two lots with eight roots each. Respiration determinations were started on one lot and one lot was sampled for analysis. The remaining two lots were placed in ventilated moisture dishes and stored at 36° F for twenty-eight days. One of the stored lots was then sampled for analysis and respiration determinations made on the other lot for a period of nine days. This lot was stored again at 36° F. for 32 days, and then respiration determinations made for six days.

The experimental results are given in tables 33 to 35 and figure 12. The mean daily temperature for a period of three weeks prior to the harvesting data is given in table 18.

Table 33. Respiration of Turnips at 71°.6 F. After Different Periods of Storage at 36° F.

Lot No.	Days in storage at 36° F.	Milligrams CO_2 per 100 grams dry matter per 24 hours. 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day
1	0	1734.0	1118.3	1055.8	1002.3	904.2	862.5	841.6									
2	28	1051.0	1245.8	1237.0	1036.2	962.4	956.5	885.7	--	749.8							
2'	28* 32	1142.2	1189.3	1419.9	1288.0	1109.0											

*Stored 28 days at 36° F.; 9 days at 22° C. (71°.6 F.); then stored 32 days at 36° F.

Table 34. Sugar Content of Turnips After a Period of Storage at 36° F.

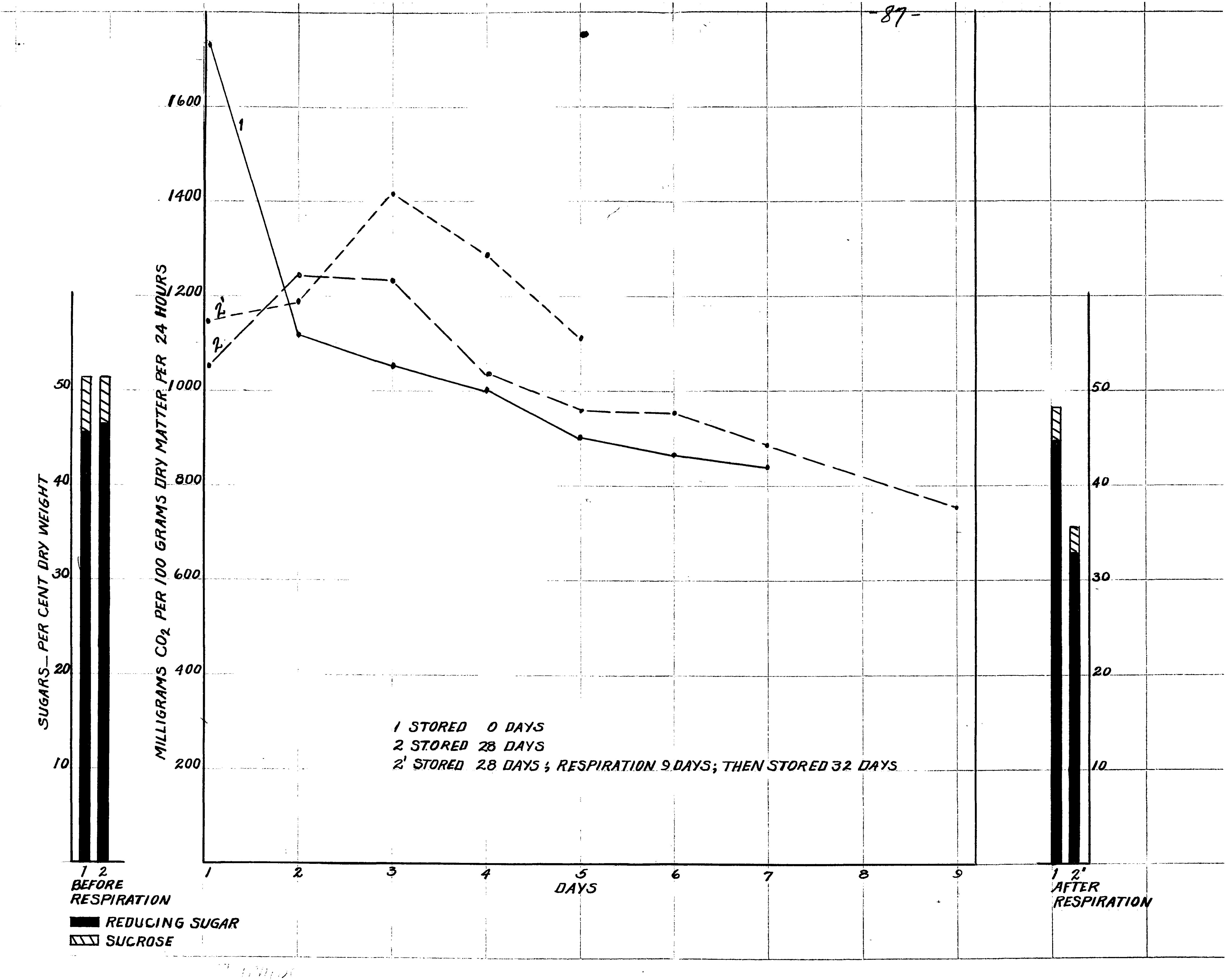
Lot No.	Storage at 36°F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	91.93	4.14	4.14	51.34	3.67	3.67	45.58
2	28	91.87	4.17	4.05	51.30	3.77	3.66	46.49

Table 35. Sugar Content of Turnips After the Respiration Tests.

Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	7	92.30	3.73	3.67	48.44	3.46	3.41	44.85
2'	28* 32	9* 6	92.36	2.71	2.39	35.54	2.49	2.20	32.64

*Stored 28 da. at 36° F.; Respiration 9 da.; stored 32 da. at 36°F.; and respiration 6 da.

Figure 12. Respiration and Sugar Content of Turnips After Different Periods of Storage at 36° F. Respiration at 71°.6 F.


SUGARS_ PER CENT DRY WEIGHT
MILLIGRAMS CO2 PER 100 GRAMS DRY MATTER PER 24 HOURS
1600
1400
1200
1000
800
600
400
200
50
40
30
20
10
1
2
2'
1 STORED 0 DAYS
2 STORED 28 DAYS
2' STORED 28 DAYS; RESPIRATION 9 DAYS; THEN STORED 32 DAYS
1 2 3 4 5 6 7 8 9
DAYS
BEFORE RESPIRATION
AFTER RESPIRATION
REDUCING SUGAR
SUCROSE

DISCUSSION OF RESULTS

The freshly harvested turnips gave a high initial rate of respiration which decreased rapidly from the beginning through the second day, and then rather slowly to the end of the respiration period.

In the turnips after 28 days of storage the initial rate of respiration was nearly as low as the final rate in the freshly harvested roots, but there was a rather rapid rise in the rate during the first three days. This rise was followed by a decrease and the final rate was considerably lower than the final rate in the fresh turnips. The respiration tests on this lot were suspended at the end of nine days and the turnips were again stored at 36° F. for 32 days. Respiration tests were then made for five days. The rate after this second period of storage was higher than the rate after the first period but the rate curve was very similar in shape to that of the previous test.

The reducing sugar content in turnips was high at the beginning of the respiration tests and the sucrose content was relatively low. There was a slight increase in the reducing sugars, but no appreciable change in the total sugar during the 28 days of storage.

During the respiration period the reducing sugars decreased in fresh turnips from 45.58 per cent to 44.85 per cent dry weight, while the total sugar decreased from 51.34 per cent to 48.44 per cent dry weight. After 28 days of storage the Lot 2 turnips were subjected to nine days of respiration, 32 days of storage, and a final six-day period of respiration. There was a decrease in reducing sugars during this forty-seven-day period from 46.49 per cent to 32.64 per cent dry weight, and a decrease in total sugar from 51.30 per cent to 35.54 per cent dry weight. No sugar determinations were made at the end of the first respiration test, or at the end of the second storage period.

The sugar content, both reducing sugars and total sugar, was much higher at the end of the respiration tests in fresh turnips than in those after storage, while the final respiration rate was much lower. Thus there is exhibited no direct correlation between the rate of respiration and the sugar content.

There seemed to be no tendency for the total sugar content to reach an equilibrium range during the respiration tests in turnips. Their behaviour in this respect was unlike that of most of the other vegetables used in these experiments.

ONIONS

EXPERIMENT 1 (1927-28). Onions for this experiment were purchased from the Sanitary Grocery Company at Hyattsville on October 17th, 1927. They were brought to the laboratory and stored overnight. On October 18th, six lots of ten onions each were selected. The average weight per lot was about one kilogram. One lot was sampled for analysis, and respiration determinations were started on one lot. The other lots were stored in paper bags at 36°F. The bags were perforated in a few places so as to insure plenty of ventilation. Duplicate lots were removed from storage at the end of 23 days and 49 days, respectively, for analysis and respiration determinations. The experimental results are given in tables 36 to 38 and figure 13.

Table 36. Respiration of Onions at 71°.6 F After Different Periods of Storage at 36° F.

Lot No.	Days in storage at 36°F	Milligrams of CO_2 per 100 grams dry matter per 24 hours. 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day
1	0	448.9	438.3	397.4	366.8	343.6	338.0	328.5	297.6	281.7	271.3	318.7	294.0
2	23	429.8	479.4	396.7	--	281.0	264.4	291.1	292.3	277.4	267.0	250.8	293.1
3	49	468.9	527.2	408.1	409.4	355.1	298.5	389.5	316.5	291.4	315.5	294.8	305.8

Lot No.	Days in storage at 36°F	13th day	14th day	15th day	16th day	17th day	18th day	19th day	20th day	21st day	22nd day	23rd day	24th day
1	0	297.1	325.1	323.4	338.2	369.3	321.3	349.9	357.7	321.3	350.9	317.8	341.5
2	23												
3	49	258.6	274.1	254.1	298.5	285.9	274.9	253.1	251.0	242.9	270.6	279.4	

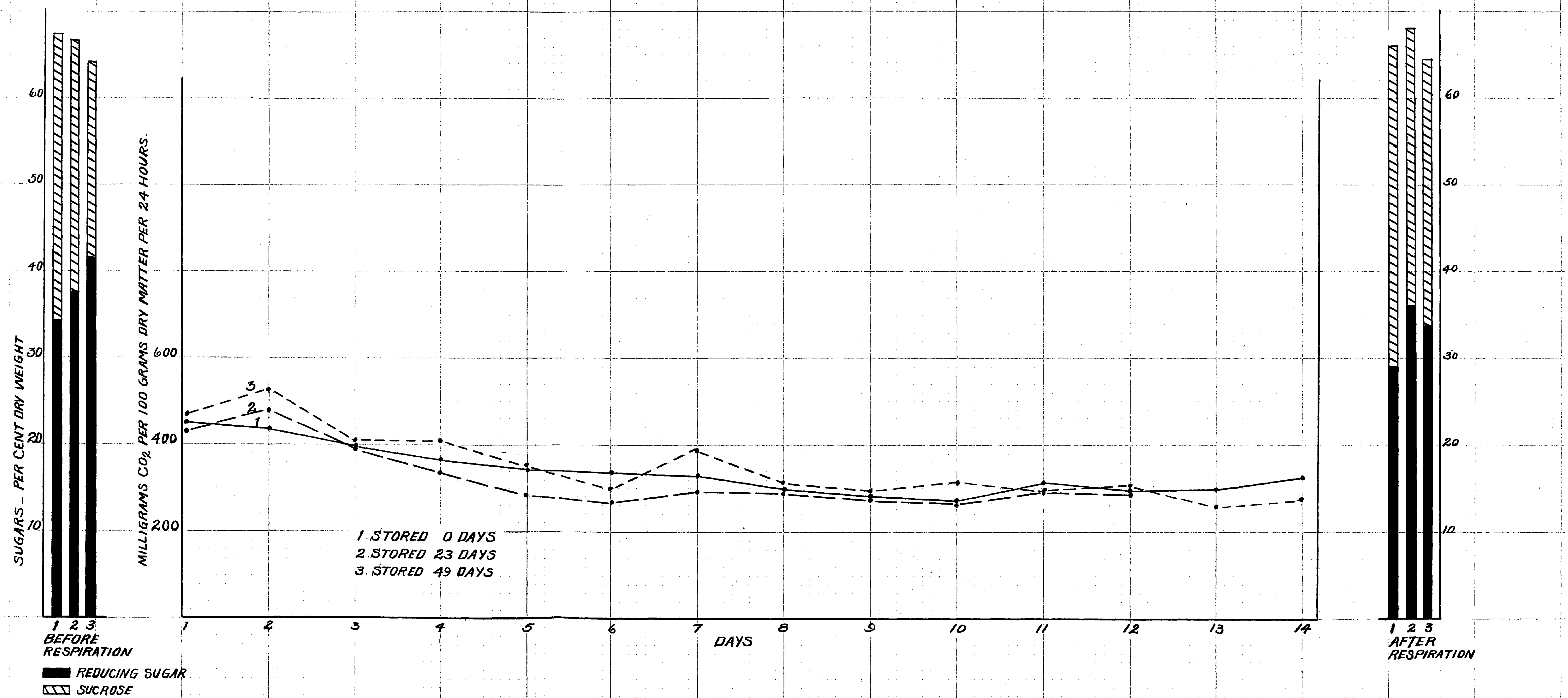
Table 37. Sugar Content of Onions After Different Periods of Storage at 36° F.

Lot No.	Storage at 36° F	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	90.50	6.42	6.42	67.57	3.26	3.26	34.32
2	23	90.44	6.40	6.30	66.91	3.61	3.55	37.79
3	49	90.85	5.87	5.66	64.22	3.79	3.85	41.43

Table 38. Sugar Content of Onions After the Respiration Tests.

Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	24	90.27	6.43	6.16	66.14	2.82	2.70	29.02
2	23	12	90.47	6.49	6.32	68.11	3.44	3.35	36.14
3	49	23	90.55	6.09	5.76	64.46	3.19	3.02	33.86

Figure 13. Respiration and Sugar Content of Onions After Different Periods of Storage at 36° F. Respiration at 71°.6 F.


SUGARS _ PER CENT DRY WEIGHT
10
20
30
40
50
60
1 2 3
BEFORE RESPIRATION
REDUCING SUGAR
SUCROSE
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS.
200
400
600
1. STORED 0 DAYS
2. STORED 23 DAYS
3. STORED 49 DAYS
1 2 3 4 5 6 7 8 9 10 11 12 13 14
DAYS
1 2 3
AFTER RESPIRATION

DISCUSSION OF RESULTS

The respiration rates of onions were relatively low in all cases, but the initial rates in the fresh onions and in those after periods of storage were much higher than the final rates attained in the tests. The initial rates after storage were higher for the first two days than the initial rate in fresh onions, but the final rates were lower than the final rate of the fresh onions.

The sugar content of onions was relatively high. The reducing sugars gradually increased during storage while the total sugar gradually decreased. A considerable decrease in reducing sugars occurred during the respiration tests in all cases. There was also a decrease in the respiration rates during these periods. There was a slight decrease in the total sugar during the respiration test in fresh onions, but the total sugar increased slightly during the respiration periods in the onions after periods of storage. The reducing sugar content of fresh onions was lower at the beginning of the respiration test than that of any of the stored lots. The reducing sugar decreased during the respiration period, and at the end was much lower than the final reducing sugar content of the stored lots after respiration tests. The final respiration rate, however, was much higher than the final rates of the stored lots. The total sugar content at the end of the respective respiration periods was lower in fresh onions than in the lot which had been stored for 23 days, but was higher than in the lot which had been stored for 49 days. Thus it appears from the data that there was no correlation between the sugar content and the rate of respiration in the onions.

The total sugar content of the different lots of onions after respiration tests varied between 64.46 per cent and 68.11 per cent dry weight. The average for the three lots was 66.23 per cent, and the maximum variation of any lot from this average was only 1.88 per cent. Thus it seems that the total sugar content of onions tends to reach an equilibrium range under a constant set of conditions.

SWEET POTATOES

EXPERIMENT 1 (1927-28). Sweet potatoes of the Big Stem Jersey variety grown on the Experiment Station farm at College Park were dug October 25th, 1927 and brought to the laboratory. The roots were dug by hand with a shovel and handled very carefully to prevent bruising. Nine lots of six roots each were selected, each lot averaging about 1450 grams in weight. The dirt was brushed off the roots with a soft brush. One lot was sampled for moisture and sugar analysis, and one lot was placed immediately in the respiratory chamber and respiration determinations started. Four lots were stored in open pans at 36° F. Three lots were stored in an electrically controlled oven at a constant temperature of 85° F. This constituted the curing process. Two of the lots from the refrigerator were removed at the end of twenty-four days for respiration tests and for sugar and moisture analysis. The other two lots from the refrigerator were removed after forty-two days of storage, but they were found to be rotting and were discarded.

The three lots stored at 85° F. were removed after twenty-eight days; one lot was sampled for analysis, and one lot was placed in the respiratory chamber for respiration determinations. The third lot was stored in an open pan at 36° F. where it remained for twenty-three days. At the end of this period the lot was removed and three of the roots were sampled for analysis, and respiration determinations were made on the other three.

The lot which was transferred from the 85° F. storage to the respiration chamber was removed after 22 days. Three of the roots were sampled for analysis, and the other three were placed in storage at 36° F. The three roots sampled were split into halves longitudinally and the halves not used were wrapped with oiled paper and stored in a moisture dish at 36° F. These were used for sugar and moisture analysis when the three roots were removed for respiration tests after twenty-three days storage.

The results of this experiment are presented in tables 39 to 44 and figure 14. The daily mean temperature for three weeks prior to the harvesting date is given in table 45.

Table 39. Respiration of Uncured Sweet Potatoes at 71°.6 F after different periods of storage at 36° F.

Lot No.	Days in storage at 36°F	Milligrams CO_2 per 100 grams dry matter per 24 hours: 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day
1	0	418.9	249.6	244.2	282.6	217.8	201.8	196.1	194.2	184.8	188.0	177.5
2	24	536.2	667.2	587.2	965.5	—	794.9	949.4	703.9	734.7	652.9	—

Lot No.	Days in storage at 36°F	12th day	13th day	14th day	15th day	16th day	17th day	18th day	19th day	20th day	21st day	22nd day
1	0	148.3	157.7	158.7	142.0	175.4	138.9					
2	24	663.0	679.7									

Table 40. Respiration of Cured Sweet Potatoes at 71°.6 F. After Different Periods of Storage at 36° F.

Lot No.	Days in Storage at 36 F	Milligrams CO_2 per 100 grams dry matter per 24 hours										
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day
5	0	234.9	206.2	197.3	185.5	187.5	--	289.1	186.5	203.3	169.7	165.8
4	23	744.7	509.1	411.7	343.6	372.0	--	297.2	301.9	--	--	353.0
5	23*	603.5	638.1	461.7	437.9	414.2	386.4	355.7	375.5	376.5	--	277.4

Lot No.	Days in Storage at 36 F	12th day	13th day	14th day	15th day	16th day	17th day	18th day	19th day	20th day	21st day	22nd day
5	0	154.9	166.7	186.5	178.6	175.6	162.8	166.7	151.9	185.5	165.8	170.7
4	23	--	247.9	269.7	264.0	238.5	209.1	204.4				
5	23*	267.5	287.3	250.7	204.1	201.1	--	253.5	--	276.4		

* 28 days at 85° F.
23 days at 22° C.
23 days at 36° F.

Table 41. Sugar Content of Uncured Sweet Potatoes After a Period of Storage at 36° F.

Lot No.	Storage at 36°F	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	77.02	3.26	3.26	14.18	0.33	0.33	1.45
2	24	74.82	5.92	5.16	23.52	0.61	0.53	2.44

Table 42. Sugar Content of Uncured Sweet Potatoes After the Respiration Tests.

Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	17	77.38	3.95	3.79	17.43	1.06	1.02	4.70
2	24	13	74.39	11.48	9.53	44.85	0.76	0.63	2.97

Table 43. Sugar Content of Cured Sweet Potatoes After Different Periods of Storage at 36° F.

Lot No.	Storage at 36°F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
3	0	75.68	6.23	5.24	25.62	0.81	0.68	3.29
4	23	74.64	6.32	5.31	24.95	0.81	0.68	3.21
5	23*	75.78	5.77	4.70	23.87	0.34	0.27	1.42

*Respiration was run on these for 23 days and then they were stored for 23 days at 36° F.

Table 44. Sugar Content of Cured Sweet Potatoes After the Respiration Tests.

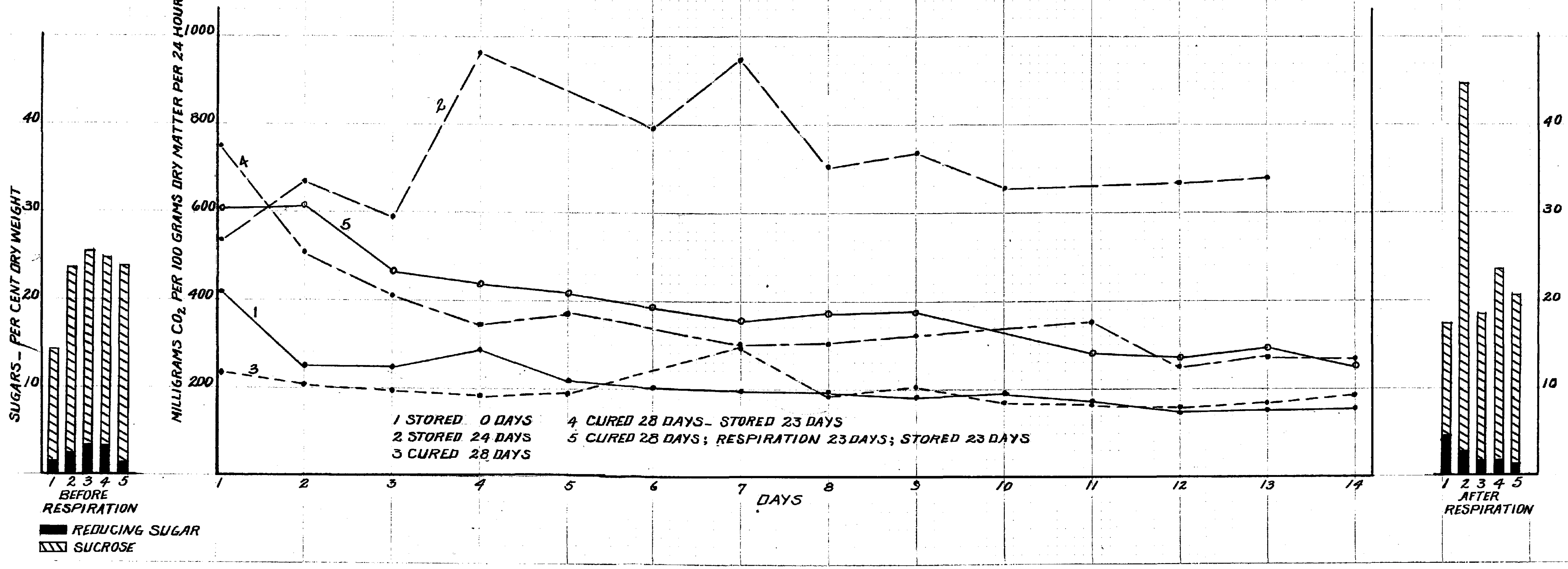
Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars: Wet Weight	Total Sugars: Original Wet Wt.	Total Sugars: Dry Weight	Reducing Sugars: Wet Weight	Reducing Sugars: Original Wet Wt.	Reducing Sugars: Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
3	0	23	75.90	4.46	3.69	18.54	0.37	0.30	1.51
4	23	18	75.72	5.72	4.61	23.53	0.44	0.35	1.80
5	23	23* 20	75.31	5.11	3.88	20.70	0.27	0.20	1.26

*Respiration tests for 23 days; stored 23 days at 36° F.; and respiration tests for 20 days.

Table 45. Daily Mean Temperature at College Park from October 4, 1927 to October 25, 1927.

Date	Temperature	Date	Temperature
October 4	72	October 15	50
October 5	60	October 16	51
October 6	63	October 17	54
October 7	67	October 18	51
October 8	68	October 19	48
October 9	55	October 20	56
October 10	53	October 21	57
October 11	60	October 22	52
October 12	64	October 23	57
October 13	55	October 24	57
October 14	47	October 25	53

Figure 14. Respiration and Sugar Content of Uncured and Cured Sweet Potatoes after Different Periods of Storage at 36° F. Respiration at 71°.6 F.


SUGARS – PER CENT DRY WEIGHT
10
20
30
40
1 2 3 4 5
BEFORE RESPIRATION
REDUCING SUGAR
SUCROSE
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
200
400
600
800
1000
1 STORED 0 DAYS
2 STORED 24 DAYS
3 CURED 28 DAYS
4 CURED 28 DAYS – STORED 23 DAYS
5 CURED 28 DAYS; RESPIRATION 23 DAYS; STORED 23 DAYS
1 2 3 4 5 6 7 8 9 10 11 12 13 14
DAYS
1 2 3 4 5
AFTER RESPIRATION

DISCUSSION OF RESULTS

The freshly harvested sweet potatoes gave a high initial rate of respiration which rapidly decreased to a nearly constant level after six or seven days. The rate in the roots after twenty-four days storage at 36° F. was abnormally high after the first day. The roots were probably damaged by the low temperature, and the respiration rate was not regarded as that of normal roots. The roots, when examined at the conclusion of the respiration period showed dark discolorations on the inside and the pulp changed to a dark, almost black, color immediately upon being ground. The total sugar content was extremely high at the end of the respiration tests. The uncured roots left in storage for forty-two days were badly rotted.

The sweet potatoes which were cured for twenty-eight days at 85° F. gave a low rate of respiration at 71°.6 F., the rate being almost identical with the constant rate reached by the fresh roots. After twenty-three days of storage at 36° F. the cured roots gave a high initial rate of respiration. The rate decreased rather rapidly, reaching a nearly constant rate after about six days. This constant rate, however, was considerably higher than the constant rate attained by the fresh roots.

Respiration was determined on one lot of cured roots for twenty-two days and then part of the roots were stored at 36° F. for twenty-three days. They were then removed and the respiration rate again determined. These gave a high initial rate of respiration which followed closely that of the other cured lot after storage at 36° F. The constant rate level reached after the period of storage was considerably higher than the level reached before.

The fresh sweet potatoes contained less total sugar than any other lot, and less reducing sugars, with one exception, at the beginning of the respiration test. During the respiration period the total sugar increased from 14.18 per cent to 17.43 per cent dry weight, and the reducing sugars increased from 1.45 per cent to 4.70 per cent dry weight. The respiration rate decreased during this period.

Both reducing sugars and total sugar increased in the uncured sweet potatoes during storage. The reducing sugars increased from 1.45 per cent to 2.44 per cent dry weight, and the total sugar increased from 14.18 per cent to 23.52 per cent dry weight during the 23 days at 36° F.

There was also an increase in the reducing sugars and the total sugar in sweet potatoes during the curing period at 85° F. The reducing sugars increased from 1.45 per cent to 3.29 per cent and the total sugar increased from 14.18 per cent to 25.62 per cent dry weight during the 28-day curing period. It will be noted that there was a greater increase in the sugars during this period than during the 24-day period at 36° F. The respiration rate of the cured sweet potatoes was low and remained practically constant during the respiration period but the sugar content decreased greatly. The reducing sugar content decreased from 3.29 per cent to 1.51 per cent dry weight, and the total sugar content decreased from 25.62 per cent to 18.54 per cent dry weight. The respiration rate of these roots was about the same as the constant rate attained by the fresh roots. There was a slight decrease in both the total sugar and the reducing sugars in cured sweet potatoes during the 23 days of storage. The respiration rate after this period, however, was very much higher than in similar roots not subjected to the 36° F. storage. The rate rapidly decreased during the first three or four days and then less rapidly to a nearly constant rate. There was a decrease in total sugars during the 18-day respiration period from 24.95 per cent to 23.53 per cent dry weight, and a decrease in reducing sugars from 3.21 per cent to 1.80 per cent dry weight.

In the cured sweet potatoes subjected to respiration tests for 22 days and then to storage at 36° F. there was an increase in total sugars from 18.54 per cent to 23.87 per cent dry weight and a decrease in reducing sugars from 1.51 per cent to 1.42 per cent dry weight, during the 23 days at the low temperature. Both the reducing sugars and the total sugar decreased in this lot during the respiration period following the storage at 36° F. The respiration rate also decreased during this period. The reducing sugar content at the end of the respiration period was a little lower than the reducing sugar content of fresh roots at the end of the respiration test, but the total sugar content was higher. The final respiration rate was also higher than the final rate in the fresh sweet potatoes.

The sugar content in the sweet potatoes at the end of the respiration periods differed quite considerably. The total sugar content varied as much as 5 per cent in different lots, but the variation of any one lot from the average was far less than this. Lot 2 which represents uncured roots after storage and respiration determinations is not considered in the average as it is believed its sugar content is abnormal on account of injury at the low temperature. On the basis of results presented it might be considered that there is a range of equilibrium between reserve polysaccharides and the total sugar which tends to be attained under a given set of conditions. There seems to be no correlation between the sugar content and the rate of respiration in sweet potatoes.

DAHLIA TUBERS

EXPERIMENT 1 (1928). The dahlia tubers used in this experiment were grown on the Experiment Station farm at College Park during the 1927 season. They were stored in a cellar room next to the greenhouse until February 29, 1928. The tubers were then brought to the laboratory and cut from the stalks. They were carefully washed in running tap water, wiped with towels and allowed to dry on the laboratory table for two and one-half hours. The tubers were taken from four varieties. The tubers from each variety were divided into four lots of equal numbers and as nearly uniform in size as possible. Then one lot from each variety was combined into a composite lot for the experiment. This gave four lots for the experiment, each lot containing eleven tubers. The average weight per lot was about 760 grams. Respiration determinations were started immediately on one lot, and one lot was sampled for analysis. The other two lots were placed in ventilated moisture dishes and stored at 36° F. for 23 days. At the end of this period they were removed and respiration determinations made on one lot and the other lot sampled for analysis. The lot used for the respiration test was removed at the end of eight days and again stored at 36° F. for 21 days, after which respiration determinations were made for fifteen days.

The experimental results are given in tables 46 to 48 and figure 15.

Table 46. Respiration of Dahlia Tubers at 71°.6 F. After Different Periods of Storage at 36° F.

Lot No.	Days in storage at 36°F	Milligrams of CO_2 per 100 grams dry matter per 24 hours. 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day	17th day	18th day	19th day	20th day	21st day	22nd day	23rd day
1	0	226.7	246.8	167.7	132.8	150.1	122.0	123.4	126.1	93.9	93.9	79.1	71.1	80.5	77.8	72.4	63.0	--	68.4	--	63.0	--	61.7	71.1
2	23	459.0	446.2	303.0	240.4	182.8	195.6	153.4	140.6															
2'	23* 21	300.1	357.3	306.1	233.4	183.4	297.2	--	165.5	--	136.9	--	133.4	--	119.1	135.8								

*Stored 23 days at 36° F.; 8 days at 71°.6 F.; then 21 days at 36° F.

Table 47. Sugar Content of Dahlia Tubers After a Period of Storage at 36° F.

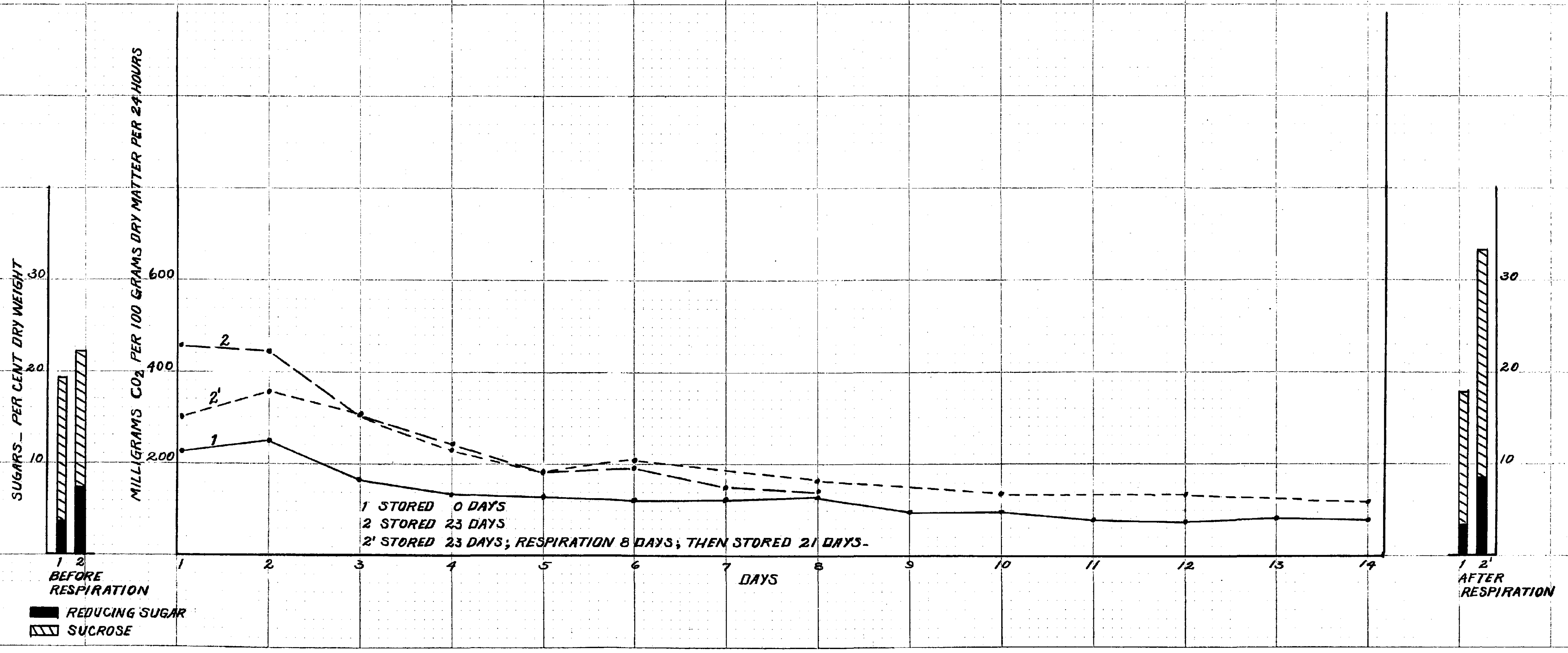
Lot No.	Storage at 36°F	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	82.11	3.47	3.47	19.40	0.67	0.67	3.75
2	23	81.23	4.16	3.80	22.20	1.39	1.27	7.40

Table 48. Sugar Content of Dahlia Tubers After the Respiration Tests.

Lot No.	Storage at 36°F	Respiration tests at 71°.6 F	Moisture	Total Sugars Wet Weight	Total Sugars Original Wet Wt.	Total Sugars Dry Weight	Reducing Sugars Wet Weight	Reducing Sugars Original Wet Wt.	Reducing Sugars Dry Weight
	DAYS	DAYS	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
1	0	23	81.48	3.32	3.17	17.95	0.62	0.59	3.33
2'	23* 20	8* 15	79.85	6.72	5.82	33.37	1.72	1.49	8.58

*Stored 23 da. at 36° F.; Respiration 8 da.; Stored 20 da. at 36° F.; Respiration 15 da.

Figure 15. Respiration and Sugar Content of Dahlia Tubers After Different Periods of Storage at 36° F. Respiration at 71°.6 F.


SUGARS_ PER CENT DRY WEIGHT
10
20
30
1 2
BEFORE RESPIRATION
REDUCING SUGAR
SUCROSE
MILLIGRAMS CO_2 PER 100 GRAMS DRY MATTER PER 24 HOURS
200
400
600
1
2
2'
1 STORED 0 DAYS
2 STORED 23 DAYS
2' STORED 23 DAYS; RESPIRATION 8 DAYS; THEN STORED 21 DAYS.
1 2 3 4 5 6 7 8 9 10 11 12 13 14
DAYS
1 2'
AFTER RESPIRATION
10
20
30

DISCUSSION OF RESULTS

The respiration rates of the dahlia tubers were relatively low in all cases. There were however high initial rates in both the fresh tubers and in those after periods of storage. The high initial rates decreased rapidly during the first four or five days, and then less rapidly until the rates were nearly constant at the end of five to eight days. The initial rates of respiration in the lots after storage were much higher than the initial rate in the fresh tubers, and the final rates were somewhat higher than the final rate in fresh tubers.

Both the total sugar and reducing sugar content increased during storage. There was a slight decrease in both the reducing sugars and the total sugar in fresh dahlia tubers during the respiration period. The reducing sugars decreased from 3.75 per cent to 3.33 per cent dry weight and the total sugar decreased from 19.40 per cent to 17.95 per cent dry weight during this period.

Both the reducing sugars and the total sugar increased during the respiration periods in the tubers after periods of storage. The reducing sugars in these tubers increased from 7.40 per cent to 8.58 per cent dry weight, and the total sugar increased from 22.20 per cent to 33.37 per cent dry weight during the periods of storage and respiration subsequent to the first period of storage. It is noted that these tubers were subjected to two periods of storage and to two periods of respiration. No sugar analysis was made at the end of the first respiration test or immediately after the second period of storage. At the end of the respiration tests the reducing sugar content of the tubers which had been stored was more than twice as great as that of the fresh tubers. The total sugar content was nearly twice as great also, but the respiration rate was only slightly higher. Thus it appears that there was no correlation between the sugar content and the rate of respiration in the dahlia tubers.

The sugar content varied widely in the two lots at the end of the respiration tests. Unlike most of the other materials used in these experiments, there seemed to be no tendency for the total sugar to reach a range of equilibrium at the respiration temperature.

GRAPEFRUIT

EXPERIMENT 1 (1928). The Florida grapefruit used in this experiment were purchased from E. T. Harrison & Company on March 8, 1928 and brought to the laboratory. Six lots of two fruits each were used. Respiration determinations were started immediately on duplicate lots. The other four lots were wrapped in the oiled paper wrappers in which they were shipped, and stored at 36° F. A few small holes were made in each wrapper to furnish ventilation.

Duplicate lots were removed for respiration determinations after 16 and 25 days respectively. After eight days of respiration determinations the lots which had been stored for 16 days were again stored at 36° F. for 20 days. At the end of this period respiration determinations were made.

No moisture or sugar analyses were made on grapefruit.

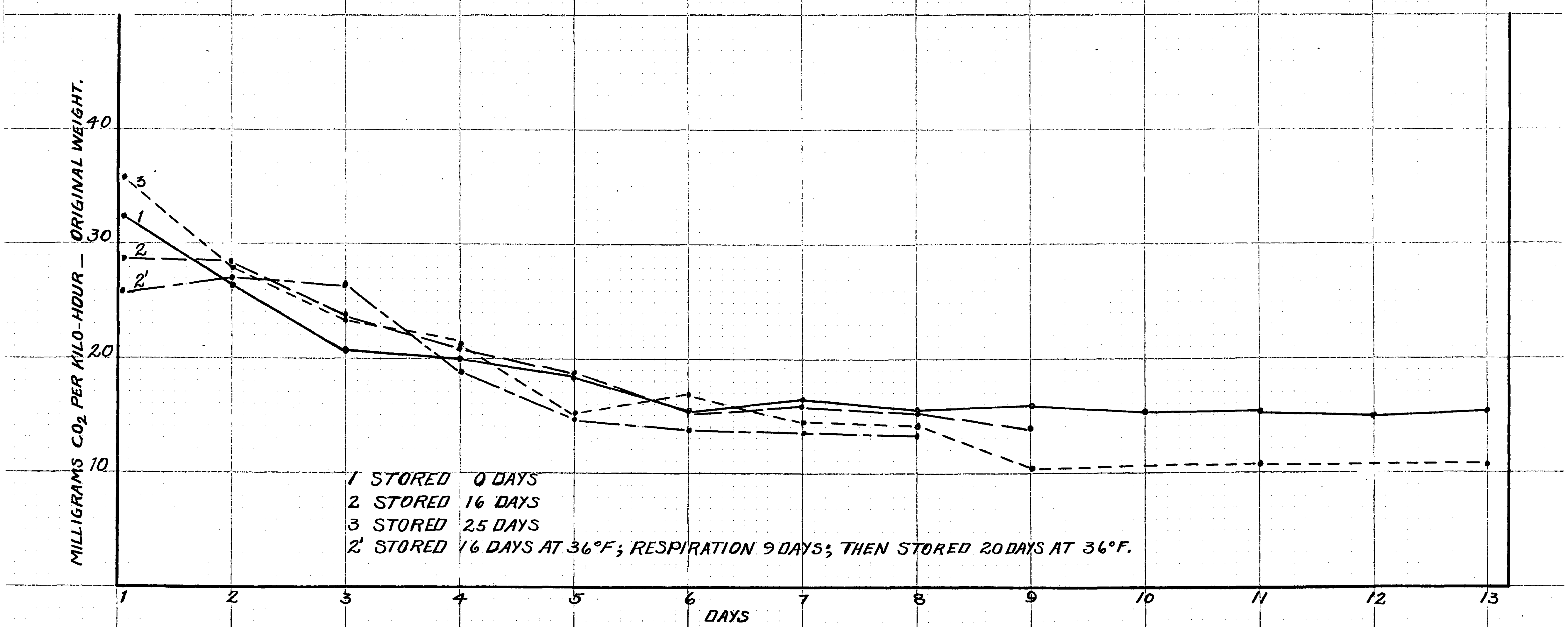
The experimental results are given in table 49 and figure 16. The respiration rates were calculated as milligrams carbon dioxide expired per hour per kilogram of the original weight of the fruit and the averages of duplicate lots are given in the table and graph.

Table 49. Respiration of Florida Grapefruit at 71°.6 F After Different Periods of Storage at 36° F.

Lot No.	Days in storage at 36°F	Milligrams CO_2 Per Kilo Per Hour Calculated to Original Weight															
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day
1	0	32.4	26.8	20.8	20.0	18.4	15.2	16.4	15.4	15.9	15.3	15.4	14.8	15.2	15.6	--	14.3
2	16	28.9	28.5	23.8	20.9	18.9	15.2	16.0	15.3	14.0							
3	25	35.8	28.1	23.9	21.1	15.1	16.7	14.4	14.0	10.4	--	10.6	--	10.5	10.0	--	9.8
2'	16* 20	26.0	27.0	26.5	19.0	14.6	13.9	--	13.2								

*Stored 16 days at 36° F.; Respiration 9 days; then stored 20 days at 36° F.

Figure 16. Respiration of Florida Grapefruit at $71^{o}.6$ F. After Different Periods of Storage at 36^{o} F.


MILLIGRAMS CO_2 PER KILO-HOUR — ORIGINAL WEIGHT.
10
20
30
40
1
2
3
2'
1 STORED 0 DAYS
2 STORED 16 DAYS
3 STORED 25 DAYS
2' STORED 16 DAYS AT 36°F; RESPIRATION 9 DAYS; THEN STORED 20 DAYS AT 36°F.
1
2
3
4
5
6
7
8
9
10
11
12
13
DAYS

Grape [illegible]

DISCUSSION OF RESULTS

The respiration rates of the grapefruits were relatively low both in the fresh fruits and in those after periods of storage. However, the initial rates were much higher than the final rates in every case. It is interesting to note that no great differences occur in the rates of the lots with different treatments. The lot stored for 25 days gave a little higher initial rate of respiration than any other lot, and also the lowest final rate. The initial rates and the final rates in the other lots were in close agreement except the initial rate in Lot 2* after the second period of storage. The initial respiration rate after this period was below the average of the other lots.

The temperature that this fruit was subjected to prior to the beginning of the experiment is not known but it is assumed that the average was considerably below the temperature at which respiration tests were made, (71°.6 F.); and it was probably higher than the 36° F. storage temperature.

GENERAL DISCUSSION

A comparison of the results obtained with the different plant materials in these experiments reveals some interesting facts. Vegetables and fruits of very different character and composition were included in the number of materials used. It might be expected that the respiratory responses of these plant organs would be as different under a given set of conditions as the organs are different in character and composition. A study of the results, however, shows that there is a great similarity in the general respiratory response at 71°.6 F after periods of storage at 36° F. in all the materials used, as well as a similarity in the behaviour of the freshly harvested vegetables. The response of the freshly harvested vegetables is perhaps, partly at least, a temperature response. It is noted that in every case where the daily mean temperatures are given for periods previous to the harvest of the vegetables, the mean temperature was considerably lower than the temperature at which respiration tests were made while at the same time it was considerably higher than the temperature at which the vegetables were stored.

The initial rates of respiration of the fresh materials in every case were much higher than the rates attained after a few days at the respiration temperature. A nearly constant rate was reached within the first few days in most of the vegetables and fruits used.

There was a great difference in the actual rates of respiration in the different materials, but there is a marked similarity in the respiratory response of all the materials relative to their normal respiration rates. The respiration rates of the vegetables and fruits before storage are taken as the normal rates.

The highest initial rate of respiration was obtained with turnips. Fresh parsnips gave nearly as high initial respiration, while the initial rates in carrots were about the same as in parsnips. But the actual rates of respiration are not to be compared in order to obtain the responses after low temperature storage. The deviation of the respiration rates from the normal rates is better to use for this comparison.

When such comparison is made it is noted that the greatest responses were obtained in dahlia tubers and sweet potatoes after periods of storage at 36° F. The initial rates in these, after the periods of storage, were much higher than the initial rates of the fresh materials and decreased to nearly constant levels considerably above the constant levels reached by the fresh materials. The least response after storage at the low temperature occurred in turnips and beets. In these the initial respiration rates after storage were much lower than the initial respiration rates of the fresh roots, but the decrease in the rates during the respiration period was not so great.

Dahlia tubers and sweet potatoes gave the highest percentage increase in the initial rates of respiration after periods of storage as compared to the normal initial rates. The other materials used ranked in the descending order as follows:

carrots (experiment 2); onions; soil-stored parsnips (experiment 2); carrots (experiments 1 and 3); soil-stored parsnips (experiment 1); beets and turnips. The dahlia tubers, sweet potatoes, and the carrots of experiment 2 gave initial respiration rates after storage higher than the initial rates in the fresh materials. In one lot of stored onions the initial respiration rate was higher than the initial rate of the fresh onions. The initial rates in the others were somewhat lower than the initial rates in the fresh materials. It is noted, however, that in these latter cases the initial respiration rates after periods of storage are higher than the final rates attained at the constant respiration temperature. Thus it seems safe to assume that there is a definite temperature response in all the vegetables used even though the degree of the response is very different for different vegetables.

Grapefruits also gave high initial rates of respiration after periods of storage at 36° F. These were not included in the above comparisons because the respiration rates were not calculated on the dry weight basis. The air-stored parsnips were not included for reasons previously stated.

It will be seen from the data that the carrots in experiment 1 which were subjected to a second period of storage did not give the usual temperature response. The same thing was true of the turnips which were subjected to a second storage period. The cause of this departure from the usual behaviour is not known. It may be possible that some decomposition organisms were at work on the materials and caused the respiration rates to increase from the start, but there was no noticeable effect of any such organisms at the end of the respiration tests. It must be that the explanation lies elsewhere than with any bacterial or fungus organisms.

There was no temperature response in the parsnips which were subjected to long periods of air-storage. The water loss from these was so great that very probably they did not give the normal responses because of the extreme desiccation. The respiration rates in these parsnips were lower than the rates in soil-stored parsnips also, and this is another indication that they were subnormal in activity. It is also noted that the longer the storage period in air the lower was the respiration rate.

It is not known by what mechanism the high initial rates of respiration are brought about when a sudden rise in the temperature of the material occurs. Some workers have attributed the increased respiration to the sugars which accumulate during cold storage, but in these experiments there was no definite correlation between the sugar content and the rates of respiration. It is noted particularly that in sweet potatoes an accumulation of sugars occurs at both the high and the low temperatures. Yet the initial respiration rate following the storage at the higher temperature was much lower than the initial rate in those after storage at the low temperature, while the sugar content was not very different. It is further noted that in several instances there is an actual increase in the sugar content during the respiration period at 71°.6 F. while the respiration rate always decreased to an almost constant rate after a few days at the same temperature. It is evident from the data presented that some mechanism other than the carbohydrate equilibrium dominates the acceleration of the respiration rate at a higher temperature after a period of storage at a low temperature.

Palladin (5) attributed the high initial rates of respiration to the stimulus of a sudden change of temperature. He obtained an initial increase in the rate of respiration in bean seedlings when they were transferred from a lower to a higher temperature and also when they were transferred from a higher to a lower temperature.

Of interest in this connection is an experiment carried out by the writer. Two lots of similar potatoes were selected and one lot was stored at 36° F. The other lot was placed at 84°.5 F. and respiration determinations made on it. Both lots were kept at the respective temperatures for 3 weeks, and then both lots were brought to 71°.6 F. and their respiration rates determined. The respiration rate in the lot which had been exposed to the 84°.5 F. temperature was lower from the beginning than it had been at the higher temperature, while the lot from storage at 36° F. gave the usual initial high rate. Thus it would seem that potatoes respond only to a change from a lower to a higher temperature in giving an accelerated rate of respiration, and not to change from a higher to a lower temperature.

SUMMARY

1. The respiration rate was high in all the vegetables and fruits used in these experiments immediately after they were harvested and placed at 22° C (71°.6 F.), but decreased to a nearly constant rate within a few days.

2. There was also a high initial rate of respiration in all the vegetables and fruits used after different periods of storage at 36° F. when they were transferred to 22° C.(71°.6 F.) The rate decreased to a nearly constant level within a few days at the higher temperature but the final rate was usually somewhat higher than the final rate reached in the vegetables and fruits not subjected to the low temperature.

3. The respiratory responses were very similar in all the plant organs used in these experiments, but the actual magnitude of the responses was different for most of them.

4. The total sugar content in most of the vegetables used tended to reach equilibrium values at 71°.6 F.

5. There was no direct correlation between the sugar content and the rates of respiration in the vegetables used.

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