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To the Graduate Council:

I am submitting to you a thesis written by Joe W. White entitled "Dry Weight Changes in Porto Rico Sweet Potatoes Under Actual Storage Conditions in Tennessee." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Horticulture.

B. H. [illegible]

Major Professor

We have read this thesis and recommend its acceptance:

Homer D. Swingle

L N Skold

Accepted for the Council:

Dale Wantling

Dean of the Graduate School

DRY WEIGHT CHANGES IN PORTO RICO SWEET POTATOES UNDER ACTUAL STORAGE CONDITIONS IN TENNESSEE

A THESIS

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Joe W. White

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CHAPTER I

INTRODUCTION

Respiration is a necessary process common to all forms of living matter. Since the sweet potato root is living tissue, it too must respire in order to remain alive.

Basically, the respiratory process involves the oxidation of sugars or sugar derivatives to carbon dioxide and water by the living cell (3). Since after harvest the sweet potato has no new source of food materials, it must rely upon the stored carbohydrates it accumulated during the time it was growing. This sugar consumption by respiration results in a dry matter reduction, which coupled with a decrease in moisture, brings about an economically serious weight loss of the stored crop.

Accelerated rates of respiration are responsible for a more rapid loss of substrate. Thus high temperatures, which are often the cause of increased respiratory rates (3), result in increased weight losses. Cold storage of the crop is not satisfactory, however, because sweet potatoes exhibit chilling injury even when stored at temperatures of fifty degrees Fahrenheit for prolonged periods. Generally, recommendations suggest that the crop be stored at temperatures ranging from fifty to sixty degrees Fahrenheit following the short curing period immediately after harvest.

Environmental conditions under which the sweet potato crop is grown and harvested differ from state to state. Varieties differ in response to storage conditions as well. In consideration of these points, the purpose of the experiment here reported was to investigate the metabolic activity of the Porto Rico sweet potato under the influence of actual storage conditions in Tennessee.

CHAPTER II

REVIEW OF LITERATURE

Respiration trials with sweet potatoes have been far less common than with many other fruits and vegetables; however, some few experiments are reported in the literature. Methods of curing and storing, weight losses after harvest, and other aspects of handling the crop have seemingly been studied to a greater extent and are mentioned more frequently.

Hasselbring and Hawkins (6) found that starch, the principal component of growing sweet potato roots, was rapidly transformed into sucrose and reducing sugars at harvest. Both of these initially accumulate in excess of respirational requirements, even at thirty degrees centigrade. Later respirational activity diminishes the amount of reducing sugar, however. Hasselbring and Hawkins (9) discovered that the sucrose present in the stored root was synthesized from the reducing sugars, which were the product of the starch conversion. They suggested also that the rates of starch hydrolysis and sugar synthesis conformed in a general way to Van't Hoff's temperature rule for rates of chemical reactions. By putting two to three kilograms of Jersey Big Stem sweet potatoes in a special incubator and passing forty to fifty liters of carbon dioxide-free air through the vessel each hour of the trial, Hasselbring and Hawkins (7) found that the sweet potato's rate of respiration varied from 24.9 to 41.7 milligrams of carbon dioxide per kilogram of tissue per hour. In another phase of the same experiment, sweet potatoes cured in the normal manner and placed in cold storage at six to seven degrees centigrade developed not only a high sugar content, but also a very high respiration rate which dropped rapidly toward the end of the test. Later, Hasselbring and Hawkins (8) concluded that the quantity of material consumed in anaerobic respiration was considerably larger than that used in normal respiration and further, that there was a greater output of carbon dioxide under anaerobic conditions.

Whiteman and Schomer (16) obtained results in a trial which indicated that wounding sweet potato roots increased their apparent respiration. They believed that this increase probably was due to the escape of some of the internal carbon dioxide. As a result of this observation they stated that to obtain a true value in measuring the respiratory rate of any plant organ or tissue, the apparent rate had to be corrected to include any change between the initial and the final internal content of carbon dioxide.

At the beginning of storage the respirational rate for each variety of sweet potato being tested was lower at fifty degrees Fahrenheit than at fifty-nine degrees Fahrenheit, according to some recent work by Lewis and Morris (11). However, they discovered that the rate at fifty degrees increased rapidly and soon exceeded the rate of those stored at fifty-nine degrees. In all cases they observed the increase in rate of respiration at fifty degrees long before any visible symptoms of chilling injury appeared on the roots. Differences in respirational response occurred later and were smaller for the Porto Rico variety than for any other variety in the study.

In an Alabama experiment Price (14) accurately weighed a particular lot of Triumph sweet potatoes at regular intervals from the time they were dug on November 10, until they were removed from storage on March 13 of the following year, and found that their loss in weight amounted to 24.92 per cent of the original weight. Webb, et. al. (15) noted that weight loss was rapid during curing and gradual during the storage period for several varieties with which they were experimenting. Lutz (12) commented that curing for four days at eighty-four degrees Fahrenheit was ample and that the longer periods usually recommended were not only unnecessary, but also wasteful of heat and conducive to sprouting.

Dry weight, as a per cent of fresh weight at the time of sampling, showed little change from the time of harvest to the end of the storage period since water and dry matter were lost roughly in proportion to the amounts originally present, according to a recent report by Morris and Mann (13). Dry matter content may, however, be expressed as per cent of the initial dry matter content of the samples. In this case the Porto Rico variety was found to lose two per cent during curing and an additional eight per cent by the end of the first one and one half months of the storage period. These values are an average of five different tests using different curing methods. Anderson (1) studied the changes in weight, dry matter, and carotene content during curing and storage of three varieties of sweet potatoes at Mississippi State College for four years. The changes in weight were determined by weighing individual crates at the beginning and ending of each of the curing and storage periods. Using the values obtained from the four different crops per cent dry matter for the Porto Rico variety averaged 31.56 per cent before curing, 31.50 per cent after curing, and 31.01 per cent after storage. However, these values varied considerably from year to year.

CHAPTER III

EQUIPMENT, MATERIAL AND METHODS

The 1956 sweet potato crop of the University of Tennessee was harvested on October 25, and a dry weight study initiated at once. Accurate records of temperature and relative humidity in the storage room were kept throughout curing and for the first ten days of storage. Late in the storage season another temperature record was made. Undamaged sweet potatoes of U. S. grade one and the small size of grade two were removed each day from the storage room throughout the curing period and for the first ten days of storage. Thereafter sweet potatoes were removed infrequently for sampling. Samples were composed of one hundred grams of small cubes cut from these sweet potatoes and were oven-dried for four days at seventy degrees centigrade. At the end of a three day period, a constant weight usually had been reached, but another weighing was performed on the fourth day for verification. These values were the dry weight as per cent of fresh weight at the time of sampling. Since dry matter changes in this variety of sweet potatoes was the subject of study, this information formed an important segment of the experimental data. In another aspect of the dry matter study, carefully selected sweet potatoes were divided at harvest into four groups and placed in respirometer jars, with the sweet potatoes in each group being of a particular U. S. grade. Each potato in these groups was tagged, and weighed on a small laboratory balance at harvest, after curing, and after ten days of storage. The weights were converted to per cent of the original fresh weight at harvest.

In the early spring of 1957 the necessary equipment for conducting the respiration trial became available. The equipment used in this portion of the experiment consisted of a vacuum pump, various-sized glass tubing, rubber tubing, Erlenmyer flasks, ringstands, adjustable clamps, four one-gallon jars, and fritted-glass filters.

To collect a carbon dioxide sample for analysis, the sweet potatoes in the respirometer jars, which were located within the storage room, were removed carefully and weighed. While the weighing operation was proceeding, the jars were inverted so that any accumulation of carbon dioxide might escape. The sweet potatoes were then returned to their respective jars which were sealed. After checking the dessicant bottles in the system to see that the tubes leading from them were not obstructed with calcium chloride particles, three hundred milliliters of approximately 0.1 normal sodium hydroxide solution was poured into each of the five towers. The

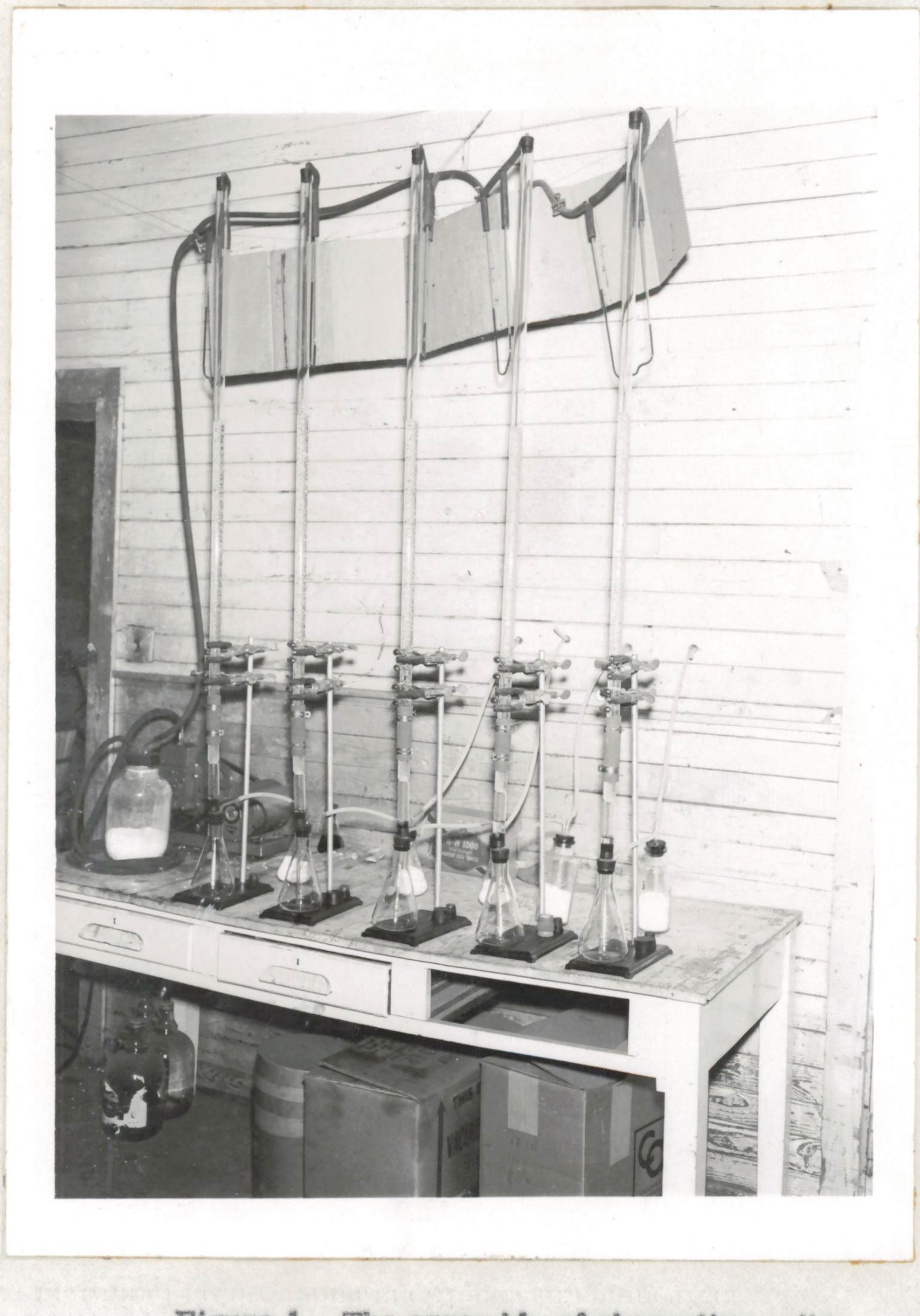

Figure 1. The assembly of absorption units used in the respiration study.

vacuum pump was started and the clamps adjusted so that the same volume of air would flow through each tower. As the first bubbles of air were seen rising through the collecting solution, the time was noted and the air flow allowed to continue for one hour. At the end of this period, the motor was shut off and the vacuum released slowly to prevent the contents of the flowmeters from being pulled back into the towers and contaminating the sodium hydroxide solutions. Each tower was then emptied and rinsed twice with distilled water, the whole volume used amounting to one hundred milliliters.

In the chemical analysis thirty milliliters of barium chloride solution were added to the sodium hydroxide solution of each tower to precipitate the carbonates. These volumes were subsequently diluted to five hundred milliliters. From the clear supernatant liquid fifty milliliter aliquots were drawn and titrated with 0.1 normal hydrochloric acid. Phenolphthalein indicator solution was used in the titrations.

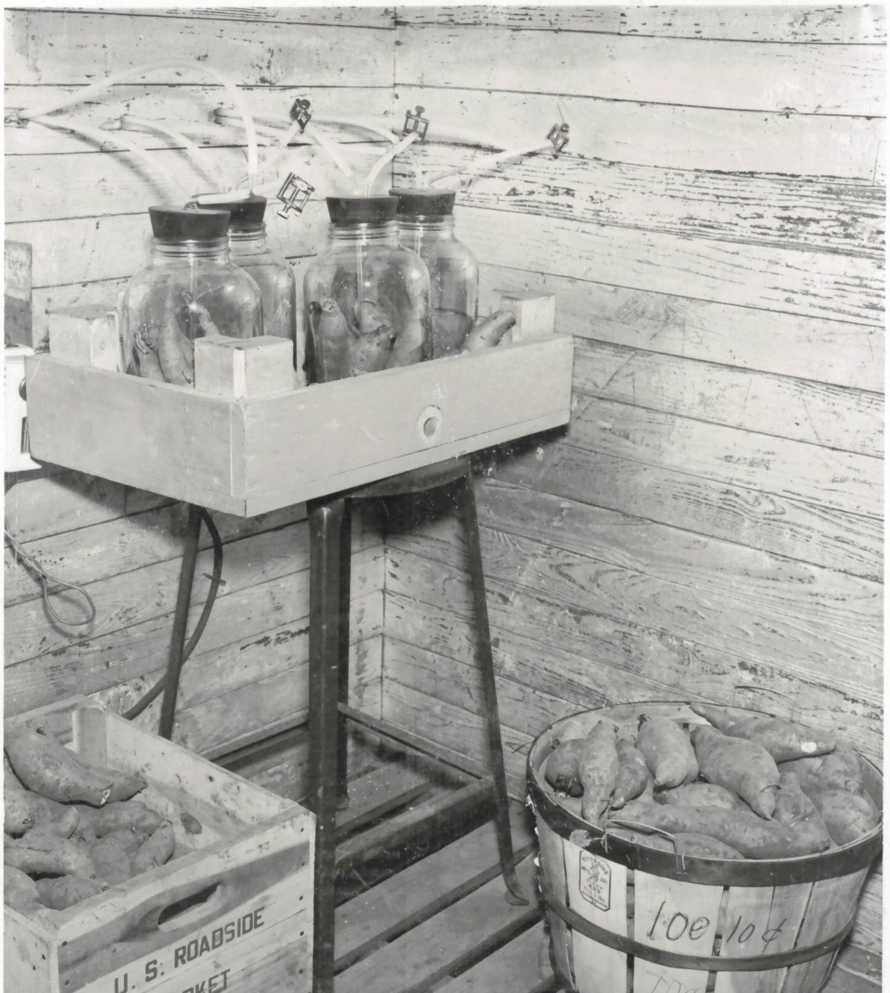

Figure 2. A view inside the storage room showing the respirometers and two common types of storage containers.

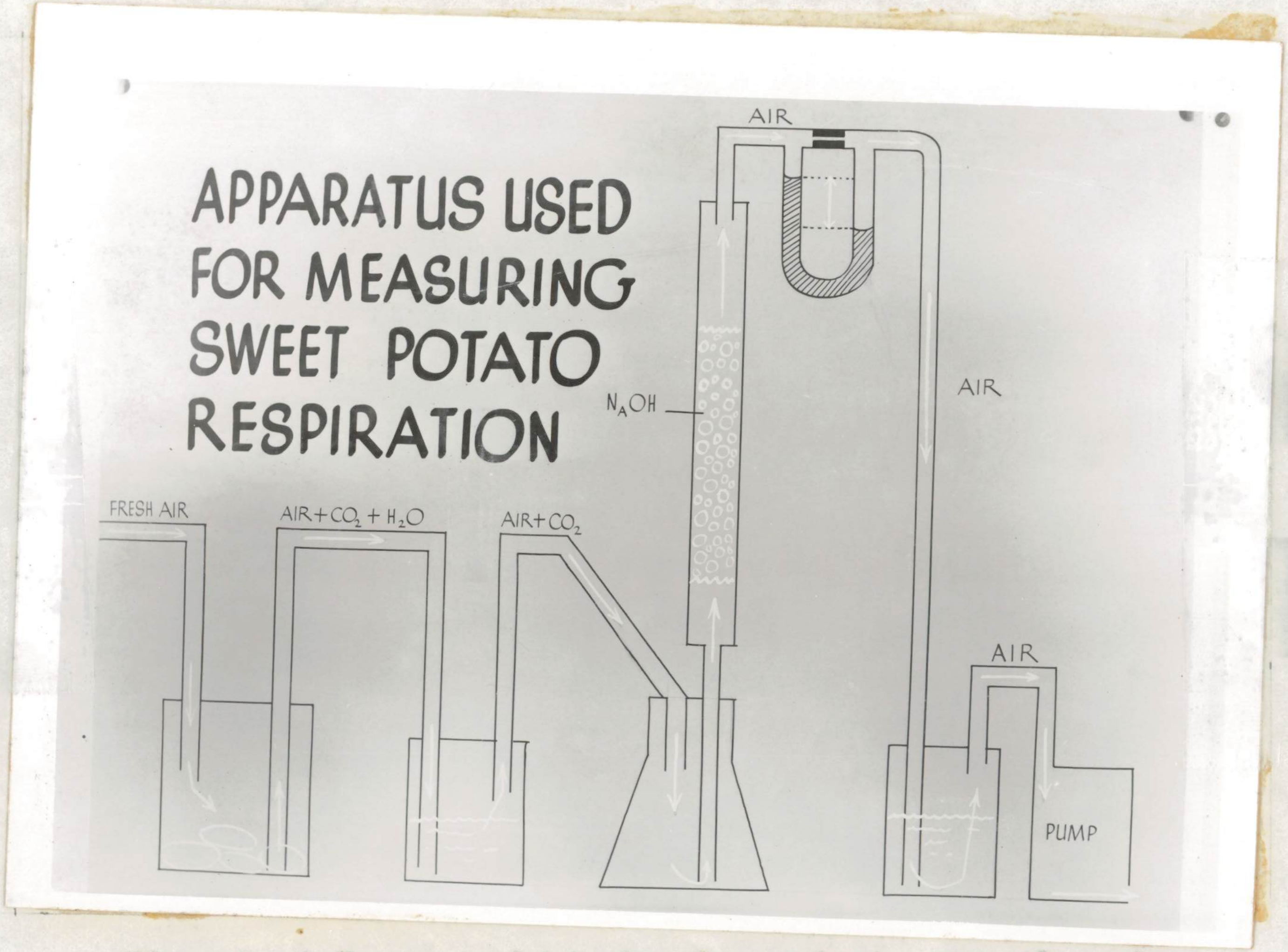

Figure 3. A diagram explaining how the respiration assembly works.

CHAPTER IV

EXPERIMENTAL RESULTS AND DISCUSSION

It is generally recognized that the successful storage of sweet potato roots is difficult unless careful handling and proper curing are employed. Proper curing, as we now think of it, involves the use of reasonably high temperatures and relative humidities near saturation for a short period immediately after harvest. Following this process, storage room conditions usually are allowed to fluctuate; however, artificial heat is provided to maintain a temperature not lower than fifty degrees Fahrenheit. During the curing process the temperature ranged from eighty to ninety degrees Fahrenheit, with few readings falling below eighty-five degrees. The relative humidity fluctuated between eighty and ninety-five per cent. During early storage the temperature varied from sixty to seventy-eight degrees Fahrenheit while the relative humidity stayed within the range of forty-eight to seventy per cent. Late in the storage period (May) daily temperatures rarely exceeded eighty degrees Fahrenheit and night temperatures seldom fell below seventy degrees. Most certainly the crops handled in this manner lose considerable weight over long storage periods.

Since carbon dioxide production by a living tissue gives an index to its rate of respiration, it was decided that this would be one satisfactory means for following the decline of dry matter of the crop through the curing and storage periods. In addition, it was decided that an actual dry weight study would be desirable. The dry weight determinations were started the day of harvest, while the respiration equipment did not become available until the latter part of the storage period.

The data collected during curing and storage are presented in Tables I, II, III, and IV. Tables I and II show that dry matter as per cent of fresh weight at the time of sampling fluctuated in a relatively narrow range from the time of harvest until the end of storage. This agrees with a report by Morris and Mann (13). The data presented in Table III show that a measurable quantity of dry matter was used up during curing, but that the dry matter loss in early storage was masked by the loss of water. This is not surprising because the high temperatures associated with curing would certainly be conducive to a rapid metabolic rate while the high relative humidity at this time would tend to suppress the loss of moisture. On the other hand, the drop in relative humidity at the end of the curing period would be quite favorable to an accelerated water loss and the

TABLE I

PER CENT DRY MATTER IN PORTO RICO SWEET POTATOES DURING THE CURING PERIOD

Date	Lower Grade No. 2	Grade 1 and Grade 2	Grade 1	Average of All Potatoes
10/25/56	34.1	31.7	32.2	32.7
10/26/56	35.2	34.1	35.3	34.9
10/27/56	30.0	36.9	33.9	33.6
10/28/56	32.7	32.4	32.7	32.6
10/29/56	31.4	36.5	33.4	33.8
10/30/56	34.9	30.6	30.8	32.1
10/31/56	36.1	32.4	31.6	33.4
11/1 /56	35.1	33.6	32.7	33.8
11/2 /56	31.9	32.5	32.8	32.4
11/3 /56	31.1	34.2	32.6	32.6
11/4 /56	34.1	32.5	31.3	32.6

TABLE II

PER CENT DRY MATTER IN PORTO RICO SWEET POTATOES DURING THE STORAGE PERIOD

Date	Lower Grade No. 2	Grade 1 and Grade 2	Grade 1	Average of All Potatoes
11/5 /56	33.7	33.6	32.1	33.1
11/6 /56	33.6	35.4	33.7	34.2
11/7 /56	31.6	36.0	34.9	34.2
11/8 /56	36.2	36.2	34.1	35.5
11/9 /56	36.5	34.9	33.7	35.0
11/10/56	33.6	33.8	33.3	33.6
11/11/56	36.4	35.6	32.6	34.9
11/12/56	31.1	35.5	31.8	32.8
11/13/56	39.8	36.4	32.6	36.3
11/14/56	35.9	34.9	35.7	35.5
12/10/56	36.1	33.0	29.5	32.9
6/6 /57	33.5	----	31.3	32.4
6/12/57	35.6	----	32.7	34.2

TABLE III

DRY MATTER IN PORTO RICO SWEET POTATOES
(PER CENT)

Grade	Harvest	After* Curing	After Ten Days* of Storage
No. 2	34.10	32.71	32.07
No. 1	32.20	30.15	32.92
No. 1	32.20	30.05	32.42
No. 1	32.20	30.12	33.07

*Dry weight based on fresh weight at the time of harvest.

reduced temperature would slow the loss of dry matter. It is noted with interest that the small U. S. No. 2 sweet potatoes lost a larger percentage of fresh weight than U. S. No. 1 roots, both in early and late storage. This is indicated in Table IV. Tables III and V show that there was also a greater dry matter loss among No. 2 roots. Perhaps the larger surface area for a given fresh weight of these smaller roots accounts for the observed differences. Regardless of grade, however, a consistent loss of dry weight was recorded.

The respiration trials were performed during the months of March, April, and May. From the titration data was calculated the milligrams of carbon dioxide evolved per kilogram of tissue and per square centimeter of surface area. These data are presented in Tables VI and VII. Although some of the readings of Table VI closely agreed with those reported in the literature (11), many varied widely. It was subsequently found that little correlation existed between the dry weight loss records and the values obtained with the respirometers. Since close correlation between these sets of values would be expected, the data contained in Tables VI and VII are not considered valid. It is believed that improper functioning of the apparatus resulted in the erroneous readings because good checks were obtained in titrating the absorption fluids. The rate of air flow was thought most likely to be

TABLE IV

COMPARISON OF DAILY LOSS OF FRESH WEIGHT DURING CURING, EARLY STORAGE AND LATE STORAGE OF U.S. GRADE NO. I AND U.S. NO. 2 PORTO RICO SWEET POTATOES (PER CENT)

Period	No. 2	No. 1
Curing (Oct. 25 - Nov. 4)	.215	.187
Early Storage (Nov. 4 - Nov. 14)	.312	.221
Late Storage (Mar. 15 - May 23)	.173	.145

TABLE V

ACCUMULATIVE DRY MATTER LOSSES IN PORTO RICO SWEET POTATOES DURING THE LATE STORAGE PERIOD (PER CENT)

Date	Grade			
	No. 2	No. 1	No. 1	No. 1
3/15/57	0.00	0.00	0.00	0.00
4/2 /57	0.97	0.97	----	0.33
4/20/57	1.88	1.59	0.66	0.97
4/27/57	2.18	1.88	0.31	1.06
4/30/57	2.47	1.88	0.97	1.19
5/13/57	3.03	2.18	1.28	1.56
5/20/57	3.30	2.47	1.88	1.77
5/23/57	3.57	2.75	2.18	1.88

TABLE VI

RESPIRATION OF THE PORTO RICO SWEET POTATO EXPRESSED IN MILLIGRAMS OF CARBON DIOXIDE PER KILOGRAM PER HOUR

Date	Tower 2	Tower 3	Tower 4
3/15/57	20.14	42.17	22.39
3/19/57	28.10	37.84	16.53
4/20/57	17.67	33.89	13.69
4/27/57	19.45	31.38	19.39
4/30/57	22.29	33.58	10.52
5/13/57	15.78	25.38	9.06
5/20/57	23.30	42.63	10.19
5/23/57	21.91	69.20	21.43

TABLE VII

RESPIRATION OF THE PORTO RICO SWEET POTATO EXPRESSED IN MILLIGRAMS OF CARBON DIOXIDE PER SQUARE CENTIMETER PER HOUR

Date	Tower 2	Tower 3	Tower 4
3/15/57	.025	.032	.022
3/19/57	.035	.023	.016
4/20/57	.021	.026	.013
4/27/57	.023	.024	.019
4/30/57	.026	.025	.010
5/13/57	.013	.019	.009
5/20/57	.027	.031	.010
5/23/57	.025	.050	.021

the source of the difficulty. An average value of 0.5 milligram of carbon dioxide per liter of air was used in the calculation for determining air volume. In that the carbon dioxide content of the air varies considerably from time to time, the use of such a value could result in a large error. On the basis of the calculations made, the rate of air flow was generally around twenty liters per hour. This volume is substantially less than the volume employed by other investigators in similar work and may well have been inadequate (5). The method of regulating the volume of air passing through each tower was also a likely source of error. Open-end manometers, closed-end manometers, and barometer-type devices were found to be completely unsatisfactory for regulating the flow of air. A type of flow meter consisting of a glass U-tube partly-filled with water and a capillary tube which had an opening of one millimeter diameter was the instrument found to be the most successful of those available. (Ideally, a wet-test meter would have been used.) It was discovered at the end of the experiment, however, that very minor changes in flow meter readings were reflected in large differences of air volumes passing through the towers. This offers a plausable explanation for the great variations observed in the readings from the various absorption towers, for the flow meters were suspended from flexible vacuum lines which made extremely accurate regulation of air flow virtually impossible. A much better system would have been to mount all the flow meters on a single inflexible frame.

There also occurred a temperature drop within the respirometer chambers during each collection period. Although this may not be of consequence, it should certainly be considered in future investigations.

At best this experiment has only resulted in indications about the metabolism of Porto Rico sweet potatoes under actual storage conditions. However it has produced, with certain modifications, a workable technique for use in future endeavors dealing with metabolism of sweet potatoes. It is hoped that it will serve in this capacity.

CHAPTER V

SUMMARY

A study of the metabolic activity of Porto Rico sweet potatoes under actual storage conditions was made during the 1956-57 storage period. Dry weight records were kept during curing, early storage, and late storage. Atmospheric conditions within the storage room were also recorded during the curing process and in early storage. Dry matter losses were measurable during curing, but were masked by moisture loss in early storage. A consistent weight loss was common to all grades from the time of harvest, but the small size U. S. No. 2 grade roots lost a greater percentage of fresh weight and of dry weight than the U. S. No. 1 sweet potatoes. Dry matter as per cent of fresh weight at the time of sampling varied little from harvest until the end of storage.

Respiration trials were carried out in the latter part of the storage season. Since there were such wide deviations in the readings, and no correlation with the dry weight studies could be found, the results were not considered valid.

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