



LIBRARY
Michigan State
University

This is to certify that the

thesis entitled

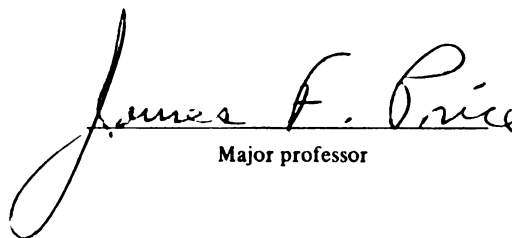
**Studies of Temperature, Cultivars and Biochemical
Control and Their Effect on Reducing Sugar Content
of Michigan Grown Potatoes**

presented by

Kevin Halfmann

has been accepted towards fulfillment
of the requirements for

Master of Science degree in **Food Science**


Major professor

Date April 24, 1997

**PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.**

DATE DUE	DATE DUE	DATE DUE
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

**STUDIES OF TEMPERATURE, CULTIVARS AND
BIOCHEMICAL CONTROL AND THEIR EFFECT ON
REDUCING SUGAR CONTENT OF MICHIGAN GROWN POTATOES**

By

Kevin S. Halfmann

A THESIS

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

MASTER OF SCIENCE

Department of Food Science and Human Nutrition

1997

ABSTRACT

STUDIES OF TEMPERATURE, CULTIVARS AND BIOCHEMICAL CONTROL AND THEIR EFFECT ON REDUCING SUGAR CONTENT OF MICHIGAN GROWN POTATOES

BY

KEVIN S. HALFMANN

Proper storage temperature is critical in helping to control reducing sugar accumulation in potato tubers. This study involved conducting variety and temperature comparison studies to understand storage performances of certain tuber selections at specified temperatures. There was also an attempt to determine if Sucrose-6-Phosphate Synthetase (SPS) had a role in regulating sugar metabolism of specific tuber selections.

The selections which maintained acceptable reducing sugar contents (<.02%) were NDO1496-1, ND2676-10, NY102 and NDA2031-2.

In the temperature comparison, 45 °F storage resulted in tubers with the highest reducing sugar content. Storage at 50 °F resulted in tubers with the lowest reducing sugar content.

SPS activity was slightly higher in reconditioned tubers vs. nonreconditioned tubers.

The storage period from week 11 through week 19 contained the most significant rise in reducing sugar during the study.

The Norchip variety had a correlation between current glucose levels and sucrose levels 4 weeks previous.

ACKNOWLEDGEMENTS

I would like to thank Dr. James Price who provided many hours of time and support. I would also like to thank the members of my committee, Drs. Gale Strasburg and Mark Uebersax. I would like to give special thanks to Dr. Roger Brook also a member of my committee and coordinator of this project for his time, support, suggestions and contributions.

This research was funded by a special USDA grant. Thanks also to Bishop Farms, and Sackett Potatoes.

I would also like to thank my family for their help and support and especially my wife Stephanie for helping to guide me to the completion of this work.

TABLE OF CONTENTS

	Page
List of Tables	vi
List of Figures	viii
INTRODUCTION	1
OBJECTIVES	3
LITERATURE REVIEW	4
Storage Practice for Potatoes used in Processing	4
Correlation of Reducing Sugar Content and Chip Color	4
Studies of Reducing Sugars in Potatoes	5
Factors Affecting Reducing Sugars in Potatoes	5
Temperature Comparisons of Stored Potatoes	6
Effect of Reconditioning	7
Low Temperature Storage	7
High Temperature Storage	8
Variety Comparisons	8
Storage Performance History of the Snowden Variety	9
Effect of Gluconeogenesis on Reducing Sugar Content	9
Carbon Partitioning in Potatoes	11
Effect of Senescence on Reducing Sugar Content	11
Effect of Sucrose on Reducing Sugar Content	12
Carbohydrate Metabolism During Sprouting	12
Regulation Effect of Enzymes on Reducing Sugar Content	12
Starch/Sugar Interconversion in Stored Potatoes	13
Biochemical Control of Starch Breakdown in Stored Tubers	14
Key Regulatory Enzymes	14
Sucrose-6-Phosphate Synthetase	15
Effect of Temperature and pH on SPS Activity	16
SPS Effect on Gluconeogenesis	17
Difficulties in Previous Enzyme Assays on Potato Tubers	17
MATERIALS AND METHODS	18
Potato Harvesting and Collection	18
Potato Storage	18
Suberization Period	19
Variety Comparison Study	19
Temperature Comparison Study	20
Reconditioning Period	21
Sugar Analysis Samples	21
Chip Samples	23
Extraction and Assay for SPS Enzyme	23
Tubers used in Enzyme Assay	23
Extraction	25
Assay	25
Statistical Analysis	26

RESULTS AND DISCUSSION	27
Storage Temperature Study Comparison of Glucose	
Content in Selections	27
Effect of Late Season Storage on Temperature	
Comparison Tuber Varieties	30
Glucose Levels in the Variety Trial	32
Critical Storage Time in Reducing Sugar Accumulation	36
Reducing Sugar Levels and Chip Color Scores of	
Standard Chipping Potatoes	38
Discussion of Color Scores in Variety Trial	40
Effect of Reconditioning	43
Utilizing Sucrose as an Indicator of Future Glucose	
Levels Within the Tuber	45
Results of Sucrose-6-Phosphate Synthetase Enzyme Assay	50
CONCLUSIONS	52
SUGGESTIONS FOR FUTURE WORK	53
REFERENCES	55
APPENDICES	62
APPENDIX A Sugar Analysis Data	62
APPENDIX B Color Score Data	70
APPENDIX C Statistical Analyses	72
APPENDIX D SPS Analysis Data	78

LIST OF TABLES		Page
TABLE 1	1994-1995 Variety and Temperature Comparison Study; Tuber Selections and Originations	19
TABLE 2	Procedure for Juicing Stored Tubers	22
TABLE 3	Procedure for Chipping Stored Tubers	24
TABLE A1	Glucose Percentage of Tubers in Variety and Temperature Study	62
TABLE A2	Sucrose Percentage of Tubers in Variety and Temperature Study	65
TABLE A3	Average Reducing Sugar Content of Tubers in Variety Trial	68
TABLE A4	Effect of Reconditioning on Stored Tubers	69
TABLE B1	Color Scores (Agtron) for Chips	70
TABLE B2	Rankings for Chip Color Scores vs. Ranking of Tuber Reducing Sugar Content in Variety Trial (Lowest to Highest)	71
TABLE C1	Statistical Analysis of Variety Trial	72
TABLE C2	Correlation Coefficients of Previous Sucrose Percentage and Current Glucose Percentage of Selections in Variety Comparison	75

**TABLE C3 Correlation Coefficients of Previous Sucrose Percentage
and Current Glucose Percentage of all Selections
Combined in Variety Comparison 77**

**TABLE D1 Sucrose Phosphate Synthetase (SPS) Content in
Selected Reconditioned and Non Reconditioned
Tubers 78**

LIST OF FIGURES		Page
FIGURE 1	Gluconeogenesis Pathway	10
FIGURE 2a	Storage Temperature Comparison for Snowden selection	28
FIGURE 2b	Storage Temperature Comparison for E5535 selection	28
FIGURE 2c	Storage Temperature Comparison for W870 selection	29
FIGURE 2d	Storage Temperature Comparison for W870II selection	29
FIGURE 3	Average weekly reducing sugar content in tubers in Storage Temperature Comparison	31
FIGURE 4a	Monthly glucose percentage average for NY-102, ND-2676-10, NDO-1496-1 and NDA-2417-6 selections in the Variety Comparison	33
FIGURE 4b	Monthly glucose percentage average for BO-178-34, NDA-2031-2, Sun crisp and AF-875-15 selections in the Variety Comparison	34
FIGURE 4c	Monthly glucose percentage average for Atlantic, NY-95, NDA-2471-8 and Norchip selections in the Variety Comparison	35
FIGURE 5	Glucose content in tuber selections Atlantic, NY-102, and AF-875-15 during critical storage time	37

FIGURE 6	Weekly average glucose content of tubers in Variety Comparison	39
FIGURE 7a	Chip color score vs. glucose content in selections from Variety Comparison	41
FIGURE 7b	Chip color score vs. glucose content in selections from Variety Comparison	42
FIGURE 8	Effect of reconditioning on three potato selections after 26 weeks of storage at 45 deg. F	44
FIGURE 9a	Average sucrose values in Variety Comparison 1 week prior to average glucose values	46
FIGURE 9b	Average sucrose values in Variety Comparison 2 weeks prior to average glucose values	46
FIGURE 9c	Average sucrose values in Variety Comparison 3 weeks prior to average glucose values	47
FIGURE 9d	Average sucrose values in Variety Comparison 4 weeks prior to average glucose values	47
FIGURE 10	Sucrose percentage in Norchip selection 1 week prior to glucose percentage	49

INTRODUCTION

Proper long term storage of potatoes to be used in processing is of great concern to growers and processors because tubers may sprout, rot and/or accumulate undesirable levels of reducing sugars if proper storage conditions are not maintained. Growers would like to store tubers at temperatures as low as possible to conserve heat energy, decrease incidence of sprouting and maintain weight by decreasing respiration. However, the low temperature conditions which benefit tubers in many ways may be detrimental to processing quality because because reducing sugar accumulation is enhanced by low temperature storage for many reasons.

For these economic reasons, a variety comparison is necessary to know the storage performances of certain tuber cultivars at specified temperatures.

During the variety comparison, the emphasis was on the reducing sugar content in the tuber. One particular variety, Snowden, has emerged as top processing potato in Michigan. Snowden has also shown promise to be a variety that will produce acceptable chips at cold storage temperatures.

Studies also focus upon optimal long term storage temperatures of the tubers.

It is also important to understand the biochemical control of starch breakdown. It is likely that there will be significant

breakthroughs in fruit and vegetable biotechnology in the near future. The alteration of genes can make fruits and vegetables more disease resistant and increase their postharvest quality. In altering the genetic structure of the potato, it is necessary to know which constituents are important to enhance storage and processing quality of the tubers.

Because the enzyme, sucrose-6-phosphate synthetase is thought to play an important role in starch/sugar interconversion, it has been studied in an attempt to understand regulation in the metabolism process. The enzyme analysis was done during late season tuber storage at the reconditioning phase. During reconditioning, reducing sugar levels are known to have a higher magnitude of change than during normal storage. Consequently, the enzyme's importance during starch/sugar interconversion may be magnified during this stage.

OBJECTIVES

To compare storage performance as a function of reducing sugar content for selections of Michigan grown potato tubers.

To optimize long term storage temperature for selections of Michigan grown potato tubers.

To observe any correlations between potato tuber reducing sugar content and previous sucrose content in an attempt to utilize sucrose as a predictor for future reducing sugar content trends in tubers.

To understand the significance of the enzyme sucrose-6-phosphate synthetase in biochemical pathways of the potato tuber.

LITERATURE REVIEW

Storage Practice for Potatoes used in Processing

The general tuber storage practice is to undergo an initial suberization period at 55°-60°F for 2-3 weeks (Chase, 1981). This allows the acceleration of healing bruised and damaged areas of the tuber. Potatoes to be used in processing are then held at a temperature of 50°-52°F at a constant humidity level of 95%. The storage period may last from 3-8 months depending on the needs of the processing industry but the typical storage time is 6-8 months. Near the end of the storage period, the temperature is usually raised to 55°-60°F to increase respiration and metabolize excess sugars that have accumulated during storage. This "reconditioning" phase may not be necessary with some selections but it is generally utilized with most processing tubers.

Correlation of Reducing Sugar Content and Chip Color

One of the most critical processing factors in the potato chipping industry is the color of the chip. In previous work involving the measurement of reducing sugars in potatoes, a correlation was evident between reducing sugar level in stored potatoes and the color of the fried chip (Shallenberger et al., 1959; Pritchard and Adam, 1994). Reducing sugar molecules are able to be a reducing agent because they have a free hydrogen atom on them. The terms 'reducing sugar' and glucose are used synonymously in potato tuber research articles as glucose is the predominant reducing sugar in tubers. A high reducing sugar level in a tuber yields a darker colored chip due to the Maillard reaction (Shallenberger et al., 1959).

The Maillard reaction is non-enzymatic browning of a food product and requires a reducing sugar, amino group and heat for the reaction to be carried out.

Fuller and Hughes (1984), noted that tuber glucose content was closely related to chip color. This observation was made after analyzing fructose, glucose, sucrose and total sugar content of tubers stored for 8-9 months at 45°F. Glucose content in tubers should be no higher than .035% to produce chips which have acceptable color in the industry (Sowokinos and Preston, 1988).

Studies of Reducing Sugars in Potatoes

There has been considerable research done regarding the optimal tuber variety and storage temperature needed to attain a reducing sugar content feasible for producing marketable chips (Rastovski and van Es, 1981).

More recent studies have focused on the mechanism associated with sugar accumulation among certain varieties at cold storage temperatures ($\geq 45^{\circ}\text{F}$). It has been established that various cultivars accumulate unacceptably high reducing sugar levels at different rates particularly during low temperature storage (Burton, 1965; Coffin et al., 1987). Sugar accumulation also occurs during late season storage. This phenomenon is known as senescent sweetening and is irreversible unlike cold storage sweetening.

Factors Affecting Reducing Sugar Content During Storage

There are many factors which have proven to affect reducing sugar content of potato tubers during storage and many more that have been hypothesized to have an influence. Sugar is a key in the metabolic process of plants (Rastovski and van Es, 1981). Therefore,

everything that affects metabolism is also likely to affect the reducing sugar content.

The physical parameters which can affect reducing sugar content of tubers in storage have been reported to be storage temperature, humidity level and O₂ content (Burton, 1965). Less than optimum levels of these factors increase the stress level of the stored tubers which leads to an increase in reducing sugar content.

Many studies (Sowokinos, 1987; Pollock and ap Rees, 1975) have focused upon enzymatic control of reducing sugar content. The most widely studied enzyme within the metabolic process of potato tubers has been invertase (Dixon and ap Rees, 1980). Invertase causes the breakdown of the non-reducing sugar sucrose into the reducing sugars glucose and fructose.

Temperature Comparisons of Stored Potatoes

Temperature plays a key role in the rate of respiration in all fruits and vegetables. Because cold temperature storage slows respiration, glucose is slow to be converted into the final products, water and CO₂. This creates an excess of reducing sugars in potatoes stored at temperatures in the range of 40°-45°F.

Storage temperature may also play a significant role in starch breakdown, the source of reducing sugars. Cottrell et al., (1993) have determined that the activity of starch hydrolytic enzymes in tubers is higher during the first few weeks of storage at 37°F than during storage at 50°F.

There have been many studies in determining the optimum storage temperatures of tubers for seed, whole tubers for

consumption and tubers for processing. Linnemann et al. (1985) measured the reducing sugars glucose and fructose as well as the non-reducing sugar, sucrose over a 12 week period. It was determined that all three sugars were temperature dependent over this time. Sucrose content rose from .2 g/100 g fresh weight to .8 g/100g fresh weight during this period at 28°C. Glucose and fructose decreased from .2g/100g fresh weight to .05g/100g fresh weight at the same time and temperature.

Effect of Reconditioning

Reducing sugar may accumulate at 45°-55°F storage and cause unacceptable color development in processed products.

Reconditioning at 55°-60°F has been shown to lower reducing sugars to an acceptable level. Kim and Lee (1993) reported that after normal storage at 41°F for 1 month, potatoes which were reconditioned at 60°F slowly decreased in reducing sugar content. This decrease continued constantly at reconditioning temperatures.

Low Temperature Storage

When storing potato tubers at 55°F and below, a major concern is the activity of the enzyme invertase. The activity of invertase can increase glucose levels of many tuber selections to ranges that are unacceptable for chipping (Rastovski and van Es, 1981).

Storage at temperatures of 45°F or below may induce chilling stress on tubers and increase reducing sugar content. The mechanism of this increase is thought to be hormone induced (Isherwood, 1976). Sweetening can then result from certain hormones which alter enzyme activity.

Guy (1990) and Thomashow (1990) reported that chilling alters the lipid composition of cell membranes, particularly the amyloplast membrane integrity. This increases the enzymatic activity at specific steps in metabolic pathways of carbohydrate metabolism which could account for an increase in reducing sugar accumulation.

High Temperature Storage

At storage temperatures in excess of 50°F, the reducing sugar content in potato tubers normally remains at an acceptable level for processing. One of the main reasons for this is the reduction of invertase activity by an invertase inhibitor which is active at these temperatures (Rastovski and van Es, 1981). However, there are disadvantages of storage at high temperatures. The incidence of sprouting is increased at high temperature storage. The rate of respiration is also increased thus accelerating the onset of senescence. There is also an economic concern because high temperatures require substantial heat energy into potato stores in cold climate areas. Mehta and Kaul (1988) studied the feasibility of storing potatoes at high temperatures in a tropical region. They found that although the reducing sugar level was acceptable, the level of sprouting was increased.

Variety Comparisons

Potato varieties have been compared with respect to parameters such as disease resistance, yield and specific gravity for many years. Tuber storage performances with regard to reducing sugars have not been compared until recent years. Sinha et al. (1992) evaluated variety performances for specific gravity, yield, chip color, glucose and sucrose based upon growing conditions and

harvest date. Barichello et al. (1990) studied biochemical differences between 2 potato cultivars (Norchip and ND 860-2) at low temperature (45°F) storage. It was determined that although post harvest storage significantly reduced respiration rate for both cultivars, the ND 860-2 tuber exhibited a higher respiration rate than the Norchip variety.

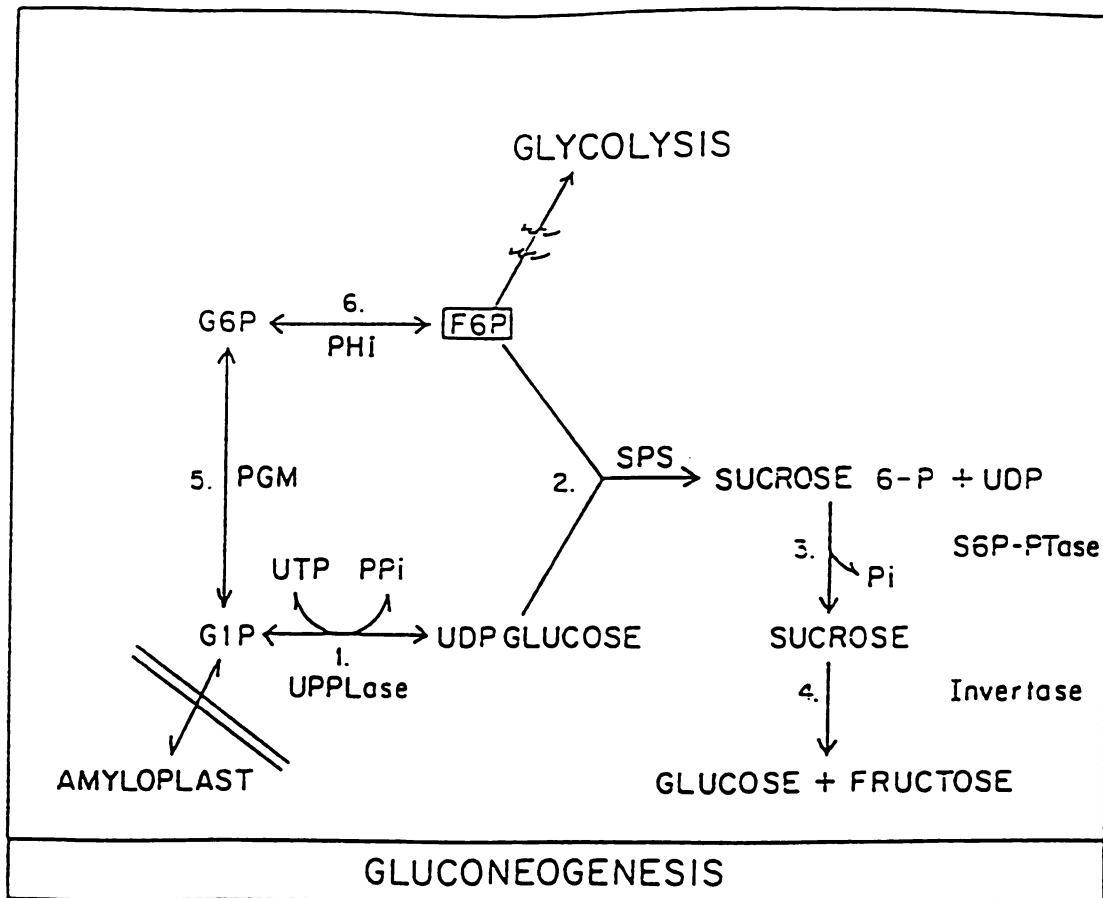
The cold chipping ND 860-2 selection has been the subject of other studies to determine the physiological trait which is associated with accumulation of lower levels of reducing sugar. Schwobe and Parkin (1990) concluded that the ND 860-2 variety had a lower reducing sugar content because it had a lower Glucose Forming Potential (GFP). GFP is defined by Sowokinos (1987) as the ability of a potato clone to convert sucrose into glucose.

Storage Performance History of the Snowden Variety

One characteristic that has been found in only a very few potato selections is the ability to produce acceptable colored chips directly out of cold temperature storage. This phenomenon is known as "cold temperature processability" (CTP) (Coffin et al., 1987). Snowden is a new Michigan grown cultivar which seems to have the ability to develop an acceptable reducing sugar content and CTP. Sinha et al. (1992) compared many selections of potatoes grown in Michigan. In a two year study, it was found that Snowden had one of the lowest levels of reducing sugar among the selections and consequently produced light colored chips.

Effect of Gluconeogenesis on Reducing Sugar Content

Figure 1 shows the gluconeogenic pathway in stored tubers and the important enzymes involved. During storage at low temperatures



Enzymes represented are (1) UDPglucose pyrophosphorylase, (2) sucrose 6-P synthase, (3) sucrose 6-P phosphatase, (4) acid invertase, (5) phosphoglucomutase and (6) phosphohexose isomerase.

Figure 1. Gluconeogenesis Pathway

From Sowokinos (1990)

(< 50°F), glycolysis is inhibited and gluconeogenesis with glucose as the end product is favored (Burton, 1965). There is also an increase of sucrose in most tuber selections at temperatures where gluconeogenesis is favored.

Carbon Partitioning in Potatoes

The history of sugar and starch availability during tuber growth is important in determining reducing sugar performances during storage. One of the main factors affecting the quantity of reducing sugar content in potato tubers is the supply of sucrose and the method of tuber storage. Carbon partitioning in plants have been the subject of many reviews. This process is initiated by carbon fixation during photosynthesis (Dwelle, 1990). Following fixation the carbon is then partitioned between sugar and starch and stored in the plant leaf. During tuber growth, this storage pool is available to the tuber (Oparka et al., 1986). Most of the storage energy is taken up in the form of sucrose. The storage uptake by the growing tuber is driven by mass flow. The rate of storage uptake is variety dependent. When the sucrose has been translocated to the tuber, it is then partitioned between starch (50-70%), structural polysaccharides (5-10%) and storage sucrose (remainder) (Mares and Marschner, 1980).

Effect of Senescence on Reducing Sugar Content

Sowokinos (1990) summarized the factors which lead to increased reducing sugar levels during senescence. These factors include:

- A) hormones
- B) membrane structure and function

C) compartmentalization and concentration of key ions, substrates, enzymes and other effectors

D) enzyme synthesis and/or activity

Sowokinos et al. (1987) found that during senescence, electron micrographs showed that bi-layers of the amyloplast membrane were beginning to separate.

If the physical condition of the tuber is changed during senescence, membrane structure could become damaged leading to a change in concentration of important enzymes in carbohydrate metabolism.

Effect of Sucrose on Reducing Sugar Content

Current sucrose content in the stored potato tuber may be used as an indicator for an upcoming increase in glucose level. Sucrose is a 12 carbon non-reducing sugar that occupies a critical position in tuber development (Sowokinos and Preston, 1988). In carbohydrate metabolism, sucrose is broken down by invertase into glucose and fructose. Sucrose is also used as a measure of the chemical maturity of the tuber.

Carbohydrate Metabolism During Sprouting

The incidence of tuber sprouting is higher as storage temperature is increased. There have been studies to determine if quantities of sucrose, the main transport sugar, increase during sprouting. Davies and Ross, (1987) found that sucrose quantity did not significantly increase in sprouting tubers.

Regulation Effect of Enzymes on Reducing Sugar Content

Cold induced sweetening of stored potatoes is related to the sensitivity of key metabolic enzymes at low temperatures. This sensitivity slows the glycolytic rate in tubers resulting in high glucose accumulation. Phosphofructokinase (PFK) and pyruvate kinase are two important enzymes in glycolysis which have shown particular sensitivity to cold storage temperatures (Dixon and ap Rees, 1980). These enzymes have different equilibriums when exposed to cold storage than during storage at optimal temperatures. PFK catalyzes the conversion of fructose-6-phosphate to fructose 1,6 bisphosphate in the first step of glycolysis. Pyruvate kinase is suggested to play a role in determining the level of intermediates in the glycolytic and oxidative pentose pathway and indirectly influence PFK (Dixon and ap Rees, 1980).

Starch/Sugar Interconversion in Stored Potatoes

Glucose accumulates in stored potatoes by the metabolic transformation of starch into sugars. Sucrose is the predominant sugar in stored tubers and may remain as such, be converted back to starch or hydrolyzed into fructose and glucose.

The sucrose level in tubers just prior to harvest is normally low (around .25%). However, after the stolon connection to the plant has been severed, the starch/sugar interconversion rate changes. The intensity of this change depends on the tuber variety and the temperature at which it is stored. In many cases, starch/sugar interconversion rate change results in the accumulation of undesired reducing sugars (Fuller and Hughes, 1984).

The effect of temperature on the metabolism of stored tubers was shown by Dixon and ap Rees (1980) when labeled [^{14}C] glucose was introduced into the tuber by boring a well into the flesh and placing the [^{14}C] glucose dilution into the wells at flesh temperatures of 34° and 77°F. The majority of the labeled glucose was found in CO_2 at 77°F. However at 34°F, the labeled glucose was diverted from respiratory pathways to the production of sucrose.

Biochemical Control of Starch Breakdown in Stored Tubers

It has been proposed that biochemical control of reducing sugar accumulation in cold stored tubers is a result of enzymes in the glycolytic pathway which are cold labile (Pollock and ap Rees 1975; Dixon and ap Rees, 1980). However, the mechanisms controlling enzyme activity *in planta* are still not very well understood.

There has been a recent attempt to depict a global picture of the metabolism of tubers in storage. The difficulty in this is that biochemical changes depend not only on the storage conditions but also the preharvest conditions of the tubers. Muller-Rober et al. (1992) studied the consequences of the inhibition of ADP-glucose phosphorylase (ADPase) in tubers as an attempt to use this as a global parameter of metabolism. They determined that ADPase inhibition causes a decrease in starch biosynthesis and an increase of the major sucrose synthesizing enzyme, sucrose phosphate synthase.

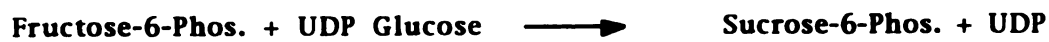
Key Regulatory Enzymes

Many of the important enzymes involved in starch/sugar interconversion are believed to be those within the glycolytic pathway. Phosphofructokinase and pyruvate kinase are two enzymes which have been extensively studied. There are other enzymes

which have not been studied as much but have been hypothesized to play an important role in starch/sugar interconversion such as sucrose phosphate synthase and sucrose-6-phosphate synthetase.

Sucrose-6-Phosphate Synthetase

One enzyme which has not been extensively studied but may play a vital role in regulating sucrose synthesis in potato tubers is sucrose-6-phosphate synthetase (SPS). SPS catalyzes the following reaction:



Pressey (1969) studied SPS activity in tubers at different maturities and found that its activity was lower in less mature tubers than in older potatoes. Dwelle (1990) found the activity of SPS to be influenced by genetics of the potato, photoperiod, CO₂ concentration and water stress. Sowokinos (1990) assayed the activity of SPS in tubers susceptible to cold sweetening and found that the enzyme was more active at cold storage temperatures (38°F) than at 48°F.

One theory concerning SPS activity is that it may regulate source-sink manipulations. Source-sink manipulations are rate changes in the carbon partitioning of starch as a function of demand for sucrose. For example, when sucrose demand was decreased by excision of pod from the soybean plant, Ciha and Brun (1978) observed that while photosynthesis rates decreased, starch accumulation within the plant increased. Mendicino (1960) concluded that the only metabolic function of SPS is its involvement in sucrose biosynthesis. Rufty and Huber (1983) followed the

changes in activity of SPS within soybean plants as it responded to source-sink alterations and found that its activity confirmed the following previously demonstrated characteristics of a regulatory enzyme:

- 1) Exhibited sigmoidal enzyme kinetics characteristic of a regulatory enzyme.
- 2) Source-sink alterations had a negative correlation with SPS activity and the partitioning of carbon into starch.
- 3) At its highest rate of activity, during sucrose formation, SPS activity was low compared to other enzymes involved in sucrose formation which means that any changes in activity may significantly alter sucrose formation .

It is believed that SPS regulation involves both fine metabolic control and coarse metabolic control (Sowokinos, 1990). Coarse metabolic control by plants involves maintaining a certain level of enzyme synthesis whereas fine metabolic control involves the variation of preexisting enzyme activity.

Effect of Temperature and pH on SPS Activity

Pressey (1969) studied SPS activities of stored tubers, and found that enzyme activity increased gradually after harvest but a greater increase was noted in cold stored tubers. Sowokinos (1990) found that tubers which are susceptible to cold storage sweetening and stored at low temperatures, tend to have higher SPS activity.

Partially purified SPS has a reported broad pH range from 6-8 with optimum pH at 6.9 (Harbron et al, 1981). This range falls within the pH of potato tubers. Therefore, SPS will be close to its highest activity within the potato tuber.

SPS activity may also be indirectly affected by low temperature storage. Sowokinos et al, (1985) assayed particular enzymes when the amyloplast membrane was altered due to cold storage. The activities of UDP-glucose pyrophosphorylase, invertase and α -amylase were not affected by this phenomenon. However, the activities of phosphorylase and SPS were significantly elevated.

SPS Effect on Gluconeogenesis

SPS is considered to be an important factor in regulating gluconeogenesis. Figure 1 shows the role of SPS within the gluconeogenic pathway. Sowokinos (1990) stated that UDP glucose pyrophosphorylase, invertase and SPS are the most critical enzymes in regulating gluconeogenesis.

Difficulties in Previous Enzyme Assays of Potato Tubers

Previous studies of various metabolic pathways and measurement of enzymatic activities in potato tubers have encountered numerous problems (Kruger, 1995). These problems can be caused from interferences within enzymatic interactions and the formation of phenolic compounds formed during preparation of extracts. Another source of error in tuber enzyme activity measurement has been the excessive activity of phosphatases.

METHODS AND MATERIALS

Potato Harvesting and Collection

The potatoes used in the variety comparison were grown in a sandy loam soil plot with optimum management production techniques at the Montcalm Research Farm; Michigan State University Agricultural Experiment Station in Montcalm County. A complete listing of the tuber types used in the variety study is in Table 1. They were harvested October, 1994 and dug with a plot harvester. The tubers were then manually picked up and placed into mesh bags and transported to storage cubicles at Michigan State University.

Potato Storage

The potato tubers used in this study were stored in temperature controlled stainless steel cubicles (1.7m long, 1.3m wide, 2.4m high). Tubers were separated by variety into 46cmx61cm standard potato lugs. These lugs were periodically rotated with each other to assure sufficient air flow to all tubers in the cubical. Controlled 95% humidity conditions were achieved with an Emerson Model #850 humidifier.

The air flow was controlled by electric fans located at the top of the cubicles. These fans ran whenever cooling was needed except when the door was opened. There was no exchange of air outside of the cubicles.

SFA Variety Trial Selections**Harvest Site**

NDA 2417-6	Montcalm Research Site, Montcalm County, MI
NDA 2031-2	
NDO 1496-1	
NDA 2471-8	
BO 178-34	
AF875-15	
Norchip	
NY102	
ND2676-10	
NY95	
Suncrisp	
Atlantic	

Temperature Comparison Varieties

E5535	Bishop Farms, Pinconning, MI
Snowden	
W8701	Sackett Potatoes Mecosta, MI
W87011	

Table 1. 1994-1995 Variety and Temperature Comparison Study; Tuber Selections and Originations.

During the storage period, tubers were periodically inspected for disease and/or rotting. If rotting was detected, the affected tuber was removed to prevent spreading to other tubers.

Suberization Period

Following the harvest, tubers were initially stored at a temperature of 55°F for 2 weeks to facilitate wound healing. After this period, the tubers were subjected to changes in temperature of 1°F/2 days until the desired storage temperature was reached.

Variety Comparison Study

The tubers in the variety comparison study were all stored in the same cubicle at a temperature of 45°F with a humidity level of 95%. There was approximately 90 pounds of tubers for each of the 12 selections in the variety comparison for a total of about 1100 pounds in the cubicle.

Temperature Comparison Study

The temperature comparison study involved four different types of tubers. There were three different varieties: Snowden, W-870 and E-5535. The W-870 variety had two entries which were grown at different farms.

The varieties were separated into subsets so that they could all be stored at four different temperature treatments:

- 1) Storage at 45°F for the duration of the study.
- 2) Storage at 50°F for the duration of the study.
- 3) Storage at 65°F for 1 month initially then at 50°F for the remainder of the study.
- 4) Storage at 65°F for 2 months initially then at 50°F for the remainder of the study.

Reconditioning Period

Near the end of the storage period, three tuber selections that were part of the variety comparison (NDA-2417-6, Norchip and BO-178-34) were split into two groups. The first group remained at the storage temperature of 45°F. The second group was exposed to a temperature increase of 1°F/2 days until a final reconditioning temperature of 55°F was reached. The second group remained in the reconditioning phase until the end of the experiment. The reconditioning phase lasted for 3 weeks.

Sugar Analysis Samples

Samples of eight tubers from both the variety comparison and the temperature comparison were taken weekly for sugar analysis.

The sugar analysis followed the procedure of Sowokinos and Preston (1988)(Table 2).

After thawing the frozen samples to room temperature, a Yellow Springs Instrument (YSI) model 2700 sugar analyzer

- Sample size of 8 tubers from each selection/treatment.
- Cut samples to obtain total of 200 g potato centers.
- Blend in Acme Juicerator to obtain potato juice.
- Dilute potato juice with distilled water to a total volume of 430 ml.
- Chill dilution at 38°F for 1 hour.
- Freeze dilution until time of sugar analysis.
- Thaw dilution at time of sugar analysis and determine sucrose concentration using YSI 2700 analyzer.

Table 2. Procedure for Juicing Stored Tubers

was used to determine the glucose and sucrose concentrations. The analyzer was located at Techmark Inc., Lansing, MI.

The YSI analyzer measured reducing sugar in grams of free glucose/liter of solution. The following calculation was made to obtain % glucose:

$$(x)\text{g/l} \times 430\text{ml}/200\text{g} = (x_2)(.00215) = \% \text{ glucose}$$

Chip Samples

Chip samples were produced each month during the study (Table 3).

The rinsed slices were placed in canola oil at 360°F (182°C) in a Hotpoint™ chip frier. The fry time was for 115 seconds (recommended by Gould (1989)) or until the water had cooked out of the chip.

The chip samples were visually scored based upon color by four individuals with previous experience in color scoring. The visual scoring was based on the use of the Snackfood Association's 1 to 5 color chart using 0.5 increment steps (Snackfood Association; Alexandria, VA, undated).

Extraction and Assay for SPS Enzyme

Tubers Used in the Enzyme Assay

Tubers from the variety comparison (Norchip, NDA2417-6 and BO178-34) were used in the enzyme assay. The tuber samples were split into two groups; Group 1 had no reconditioning and Group 2 were reconditioned at 55°F. A total of 18 assays were performed. A sample of tubers from each

- Sample size of 8 tubers from each selection/treatment.
- Cut tuber in half through stem.
- Cut 5-6 slices per tuber, approximately .020" thickness.
- Rinse slices in distilled water.
- Fry slices in 350°F canola oil for 115 seconds.

Table 3. Procedure for Chipping Stored Tubers

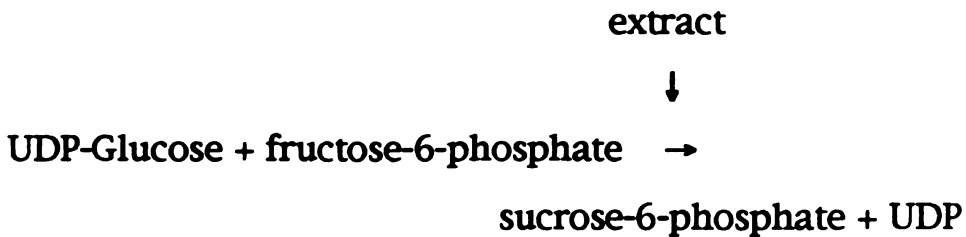
variety in Group 1 were assayed in duplicate before reconditioning. After 10 days of reconditioning, a sample of tubers from each variety in both Group 1 and Group 2 was assayed. The sample size for the assays was 6 tubers.

Extraction

Crude extract for enzyme assays was prepared according to a modified method of Harbron et al. (1980) for spinach leaf. Fifty grams of potato obtained from center cuts of 6 uniform sized potato tubers were mixed in a Waring blender for 1.5 minutes with 100 ml of extraction medium containing 0.02 mM Tris HCl buffer (pH 7.6) containing 5 mM 2-mercaptoethanol. The homogenate was squeezed through two layers of cheesecloth and then centrifuged for 20 minutes at 40,000 g in a refrigerated centrifuge (Sorvall RC 2-B, Dupont Instruments, Newtown, CT). The supernatant was fractionated by addition of solid ammonium sulphate; protein which precipitated between 35 and 50% salt saturation was collected by centrifugation and dissolved in 2.5 ml of 0.01 M ADA-NaOH buffer (pH 6.5) containing 10 mM MgCl_2 and 0.1 M NaCl.

Assay

The enzyme assay was based on a method used by Harbron et al. (1980) for spinach leaf. Enzyme activity was measured by the following:



Changes in SPS activity was determined by measuring the amount of sucrose-6-phosphate end product in assays. The extracts were taken to Techmark Inc. for analysis on a YSI model 2700 glucose/sucrose analyzer.

Statistical Analysis

Statistical analysis was performed using the SAS and Minitab programs for Microsoft Windows.

RESULTS AND DISCUSSION

Storage Temperature Study Comparison of Glucose Content in Selections

Storage temperature did not have a significant effect on glucose content in the Snowden variety. This variety has maintained a low glucose content throughout storage for the previous 2 years of this study. Because of the previous history of low reducing sugar levels in this and other studies, it is hypothesized that the Snowden variety cannot produce enough glucose to show any significant influence that storage temperature may have on it. Figure 2a shows the consistently low glucose levels in Snowden after 6 weeks of storage regardless of temperature.

Another variety, E5535 has had increasing glucose levels in this study as storage progressed for the past 2 seasons. In this study, storage temperature did show an effect on glucose content in E5535. Figure 2b shows that tubers stored at 45°F experienced the highest average glucose content. E5535 stored at 65°F for 2 months had a high late season glucose level and may have been affected by senescence near the end of storage.

Figure 2a and 2b shows the glucose levels in W870 and W870II. Storage at 50° was the optimum of the four temperature treatments in maintaining glucose at a minimum level for this variety.

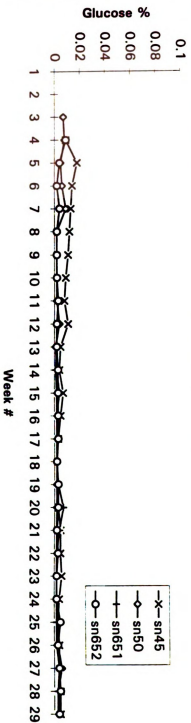


Figure 2.A

Storage temperature comparison for Snowden selection.

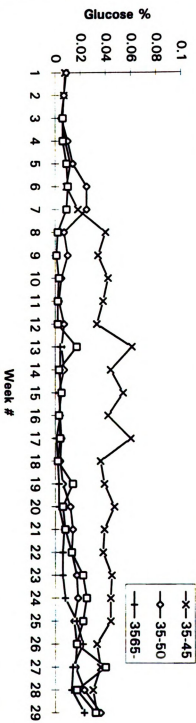


Figure 2.B

Storage temperature comparison for ES535 selection.

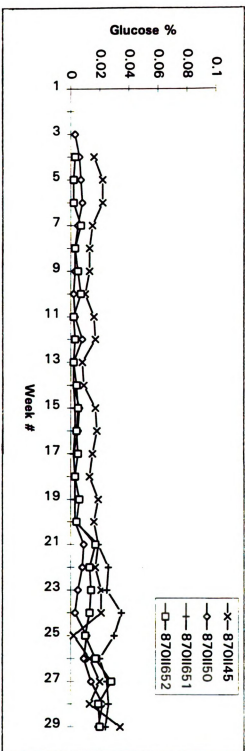
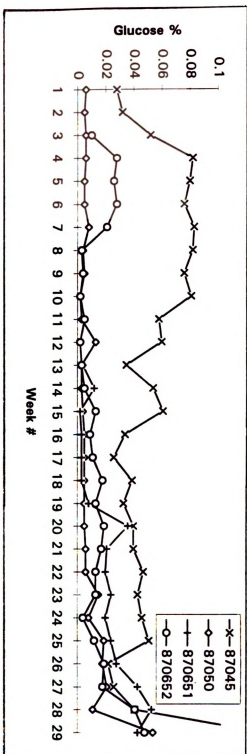


Figure 3 shows the average glucose content of the 4 tuber selections; E5535, Snowden, W870 and W870II stored at 45°F was .030 %, at 50° was .008 % at 65° for 1 month was .013 % and stored at 65° for 2 months was .011 %.

The most significant difference in the average glucose content among subgroups in the temperature comparison was the low glucose level for tubers stored at 50°F compared to the other temperature treatments. This indicates that regardless of the selection, the optimum temperature for maintaining a low glucose level was 50°F.

There was not a significant difference in average glucose level between those stored at 65°F for 1 month or for 2 months. A possible reason for this is that the tubers were exposed to the 65°F treatment at the beginning of storage. If the treatment of high temperature for differing times was applied at the end of storage, there may have been a more significant variance in glucose levels due to senescent sweetening.

Effect of Late Season Storage on Temperature Comparison Tuber Varieties

The physical state of all of the tubers from the temperature comparison during late March and early April was of lower quality than what they were earlier in storage. The most prominent attributes were a high degree of sprouting and water loss which may have affected membrane structure and

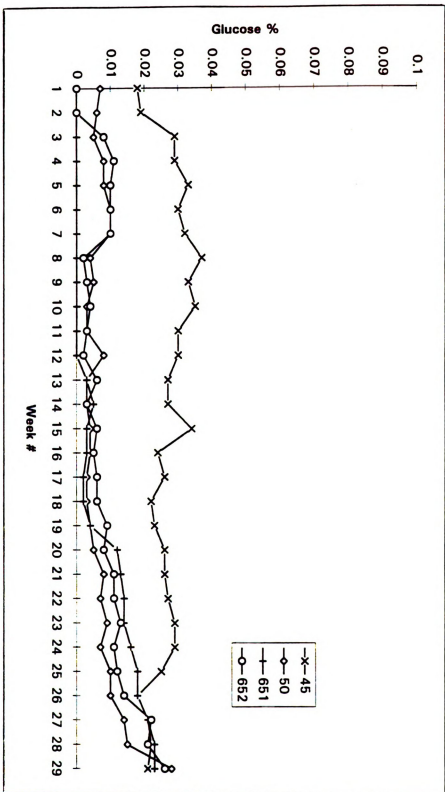


Figure 3.

Average weekly reducing sugar content in tubers in Storage Temperature comparison.

function leading to senescent sweetening. Of the four temperature comparison varieties, W870 exhibited the highest degree of what seemed to be senescent sweetening with end of storage reducing sugar readings of .13% at 45°, .05% at 50°, .04% at 65° for 1 month and .05% at 65° for 2 months. This is in contrast to acceptable (<.02%) reducing sugar levels for W870 throughout the rest of the storage period.

Glucose Levels in the Variety Trial

Table A1 in the appendix shows the average glucose content for all tuber selections during storage. The tuber selection with the lowest average glucose level throughout the variety trial was NDO1496-1 with an average level of .008 % glucose (figure 4a). Conversely, the selection with the highest glucose content was Norchip (figure 4b) with an average level of .092 % glucose, over 10 times higher than NDO 1496-1 stored at the same temperature.

It is possible that the respiration rate of NDO 1496-1 was fast enough to maintain a low level of glucose during the variety trial storage temperature while the Norchip variety could not convert the accumulated glucose to CO₂ and water quickly enough. Another possibility is that NDO1496-1 respiration was not as inhibited due to temperature as in the other selections with a higher average reducing sugar content which may have allowed it to metabolize more glucose.

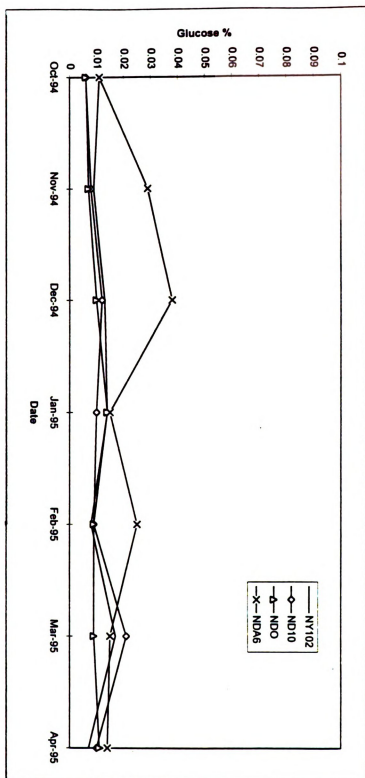


Figure 4a. Monthly glucose % average for NY-102, ND-2676-10, NDO-1496-1 and NDA-2417-6 selections in the variety trial.

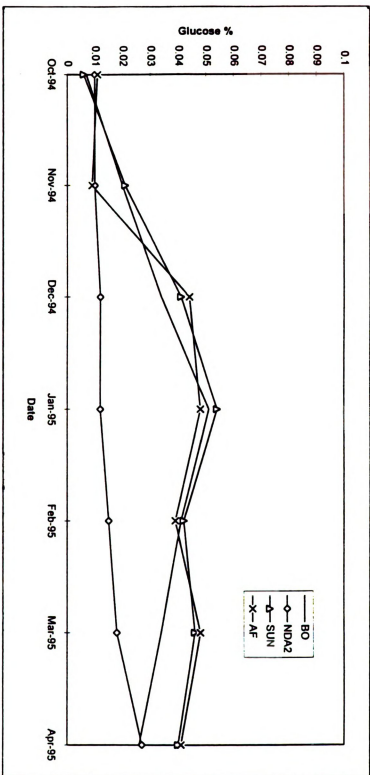


Figure 4b. Monthly glucose % average for BO-178-34, NDA-2031-2, Suncrisp and AF-875-15 selections in the variety trial.

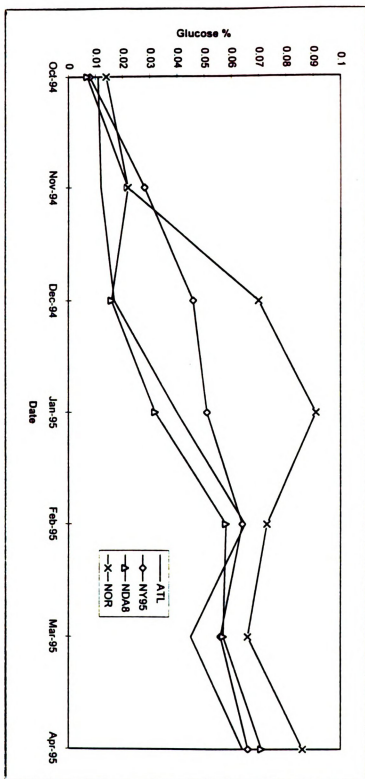


Figure 4c. Monthly glucose % average for Atlantic, NY-95, NDA-2471-8 and Norchip selections in the variety trial.

Other selections in the variety trial which maintained an acceptable average glucose content ($< .02\%$) included ND 2676-10 (.009 %) (figure 4a), NY 102 (.009 %) (figure 4a) and NDA 2031-2 (.015 %) (figure 4b) .

The selection BO178-34 started with an acceptable glucose content for the initial 9 storage weeks (figure 6b), but then experienced a dramatic rise from week 10 through week 13. The increase in glucose subsided after week 14 and even decreased in many of the subsequent weeks. However, this decrease was not enough to bring BO178-34 into the acceptable reducing sugar range for the remainder of the storage period.

Many selections in the variety trial also experienced an increase of glucose during the latter part of storage particularly from storage week 25 until the end of the study. NDA2031-2, NY-95 and Atlantic selections were the most evident of this increase with glucose readings at least 75% higher at the end of storage than storage week 24. These results indicate late season sweetening.

Critical Storage Time in Reducing Sugar Accumulation

During this study, an important timeframe for reducing sugar accumulation in stored tubers was storage week 11 through week 19. Figure 5 shows reducing sugar content of the selections Atlantic, AF-875-15 and NY-102 from storage week 13 through week 17.

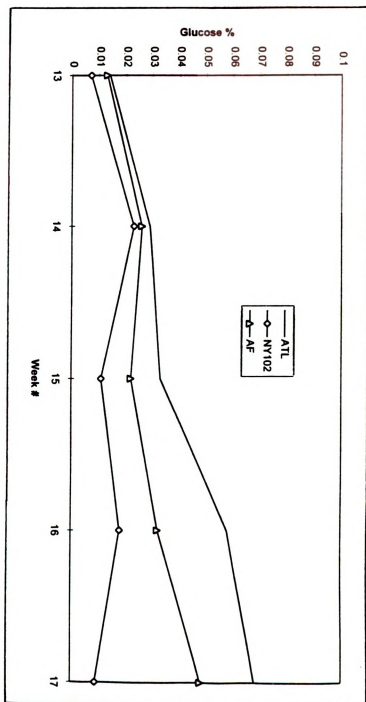


Figure 5. Glucose content in tuber selections Atlantic, NY-102 and AF-875-15 during critical storage time.

Atlantic and AF175-15 experienced sharp rises in glucose content during this period. There was probably no change in respiration rate of these selections at this time. There may have been a change in the activity of one or more enzymes in the carbohydrate metabolic pathway for the conversion of glucose to the final products; CO₂ and water. These selections also had a significantly high glucose level at the end of storage.

Conversely, the selection NDO1496-1 did not have a great change in reducing sugar content. This selection had a low level of glucose present at the end of storage.

Figure 6 shows the weekly average glucose content of tubers within the variety comparison. A dramatic rise is noted at storage week 11 as the average glucose content is .04 % . The average then drops steadily until week 16 as the trend reverses to a weekly increase until week 20.

It is possible that these dramatic reducing sugar increases could have been lessened with a slight temperature increase during this critical storage period. The increased temperature may have heightened respiration levels in the tubers to allow for metabolism of the reducing sugars.

Based upon these and previous potato selection storage experimental results, it may be possible in some cases to predict the range of glucose within tubers based upon the magnitude of reducing sugar increases during the 12th through 18th weeks of tuber storage.

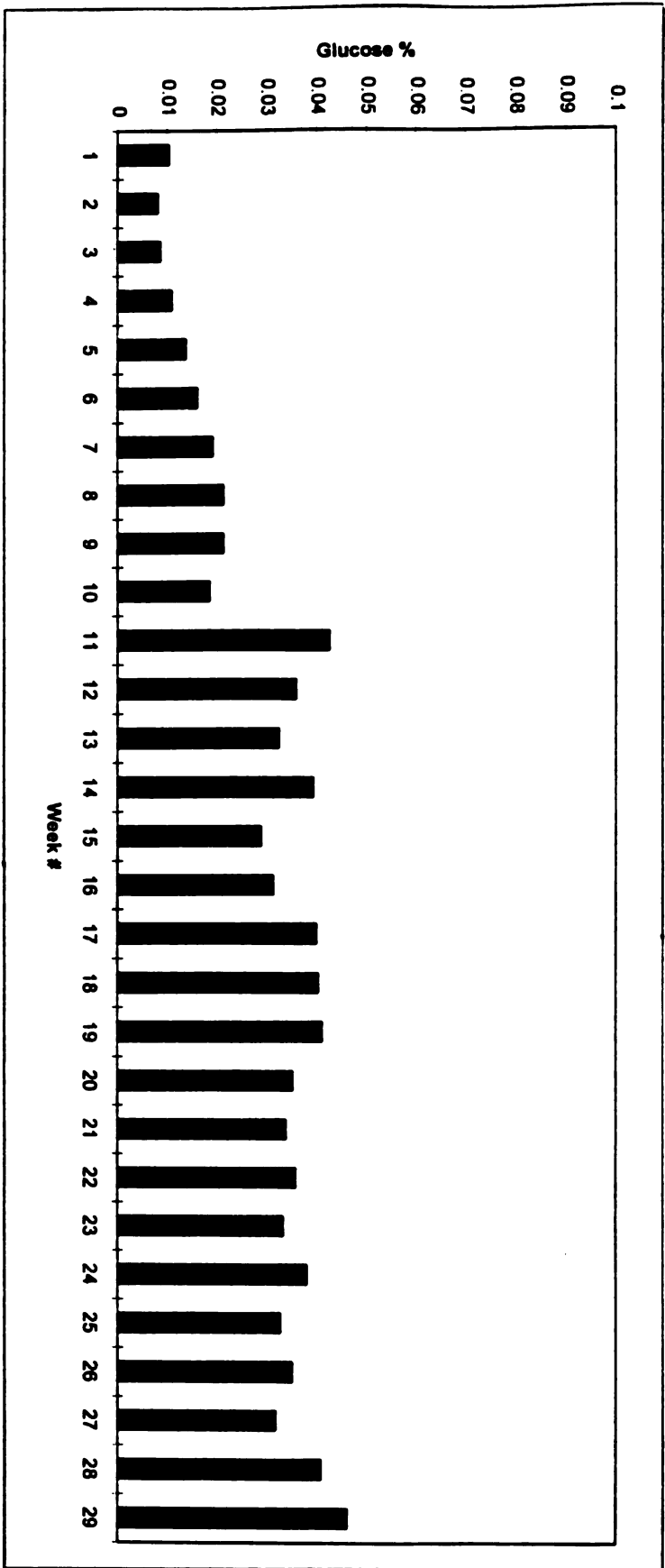


Figure 6. Weekly average glucose content of tubers in variety comparison.

Reducing Sugar Levels of Standard Chipping Potatoes

Standard chipping varieties Norchip and Atlantic had unacceptably high glucose sugar levels throughout the variety trial storage period with averages of .092% and .037%. Norchip in particular was significantly higher in average reducing sugar content than all other varieties in the variety storage trial ($\alpha=.05$) (table C1a in the appendix).

Normal storage temperatures for these standard chipping potatoes is around 52°F which is considerably warmer than the 45°F storage temperature during this study. It is possible that the respiration rate could be affected adversely enough to not be able to break down the glucose as fast as it is produced.

Discussion of Color Scores in Variety Trial

A complete list of the color scores is in appendix table B1. The selection which had the best average color score in the variety trials was NDO 1496-1 with a 2.4 average Agtron reading. NDO 1496-1 also had the lowest average glucose level in the trial.

Figures 7a and 7b shows a comparison of the level of glucose vs. the chip color scores for selections in the variety trial. A distinct linearity can be seen in the graph due to the positive correlation between chip color and glucose % in the Norchip variety. However, this linearity is not as evident in most other selections.

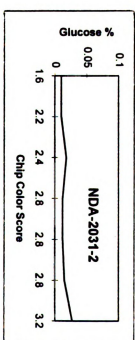
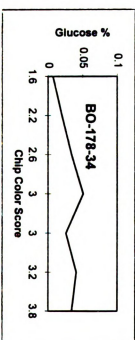
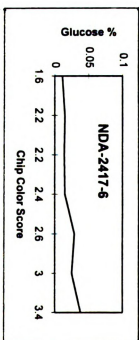
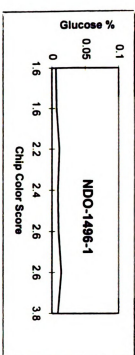
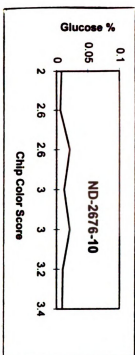
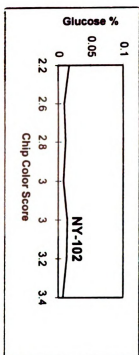


Figure 7a.

Chip color score vs. glucose content in selections from variety trial

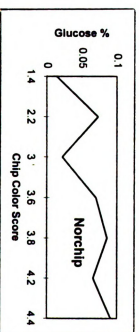
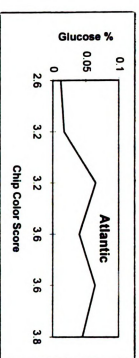
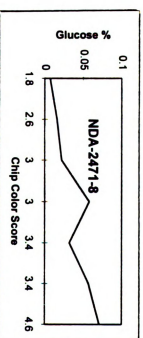
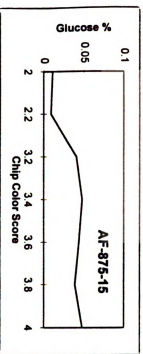
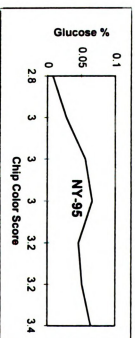
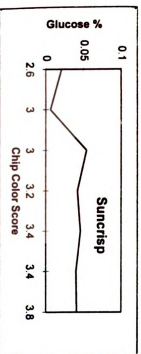


Figure 7b.

Chip color score vs. glucose content in selections from variety trial

Table B2 in the appendix shows the rankings of chip color scores and tuber glucose levels. All tubers selections with average glucose levels at $<0.02\%$ had chip color scores of 2.9 or lower. This further confirms what has already been published the importance of acceptable reducing sugar levels to achieve chip colors acceptable to the standards of industry.

Effect of Reconditioning

Near the end of the storage experiment, three tuber selections (Norchip, BO 178-34 and NDA2417-6) were selected to be analyzed at both reconditioning temperature and at the normal storage temperature. Figure 8 shows that all three selections had a slightly lower glucose level at the reconditioned temperatures than those stored at normal storage temperatures.

Table A4 in the appendix shows the glucose level at reconditioned storage conditions and regular storage conditions. The probable reason for this is that larger amounts of glucose were converted to CO_2 and water because of a higher respiration rate in the reconditioned potatoes. The respiration rate in each of the reconditioned selections was increased due to the higher storage temperatures.

BO178-34 was the only selection that had a significantly lower glucose level after reconditioning with a drop of $.023\%$. The reason for the more significant glucose drop during reconditioning in BO178-34 than in the other tuber selections

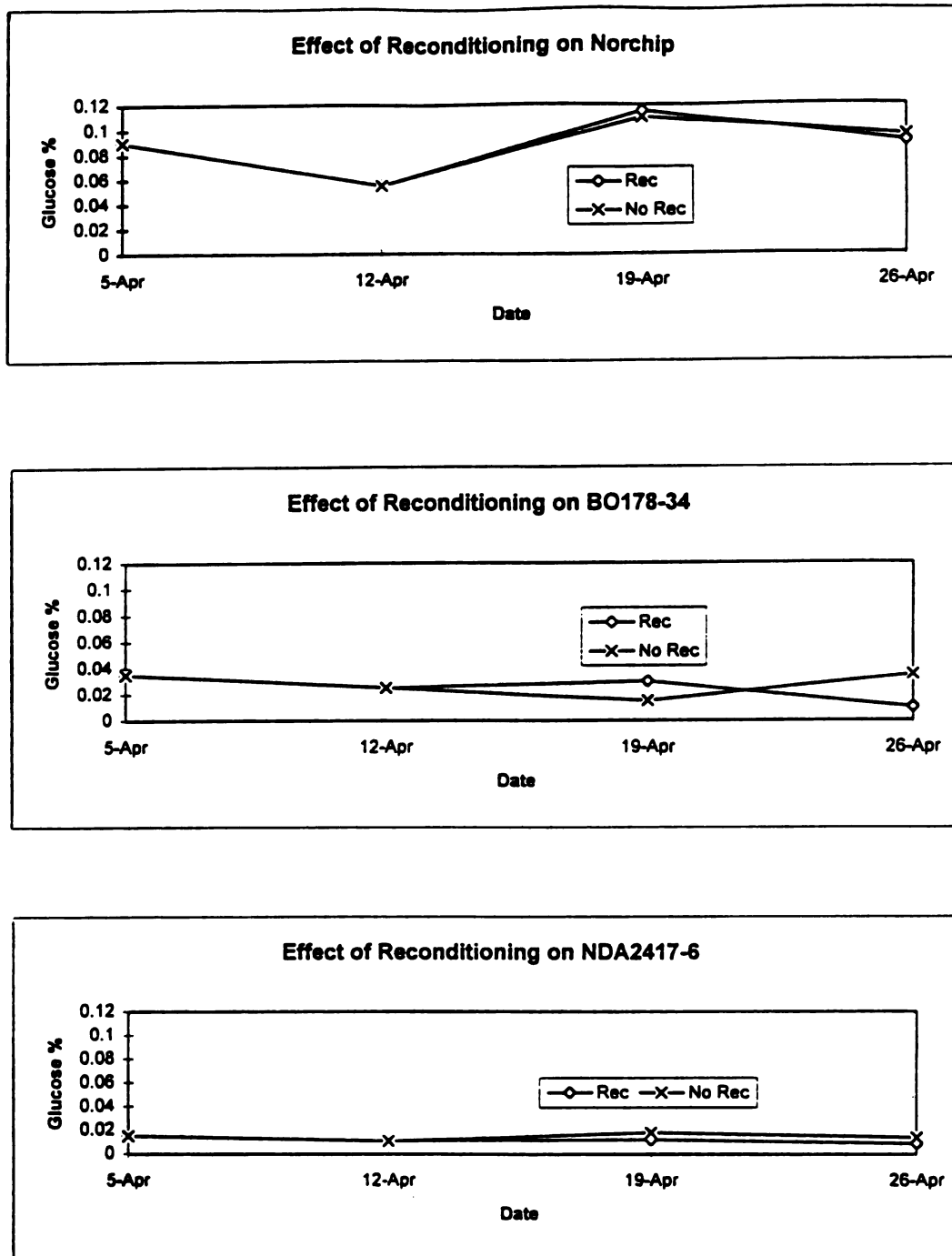


Figure 8. Effect of reconditioning on three selected potato varieties after 26 weeks of storage at 45 deg. F.

may be due to the varying rates of respiration. BO178-34 may have a lower 'respiration burst' than the other selections which would cause it to respire more slowly during the reconditioning period. Respiration burst has been defined as a sudden change in respiration due to fluctuating storage temperatures (Rastovski and van Es, 1981).

Utilizing Sucrose as an Indicator of Future Glucose Levels Within the Tuber

In addition to monitoring weekly glucose levels, the non reducing sugar, sucrose was analyzed in all tubers in the study. The data for weekly sucrose readings is in table A2 in the appendix. Sucrose has been hypothesized to provide a possible signal to the magnitude of future glucose levels in the tuber. If current sucrose content in stored tubers can be used as a predictor of future glucose levels, the storage conditions can be manipulated to change the potato respiration rate, thus enabling a more desirable glucose level.

Glucose percentage data from this study was compared to sucrose percentage data from 1, 2, 3 and 4 weeks previous to determine if there was a correlation between them. Figures 9a-9d track glucose percentage in all selections in the variety comparison with sucrose percentage from 1-4 weeks previous. Table C3 in the appendix shows the correlation data for this analysis.

There was not a high correlation in sucrose percentage vs. glucose percentage in all selections collectively regardless of

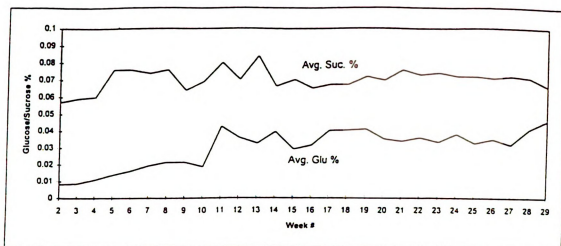


Figure 9a. Average sucrose values in Variety Comparison 1 week prior to average glucose values.

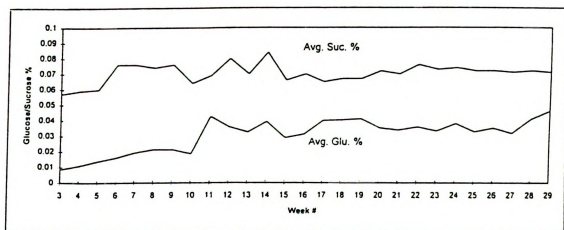


Figure 9b. Average sucrose values in Variety Comparison 2 weeks prior to average glucose values.

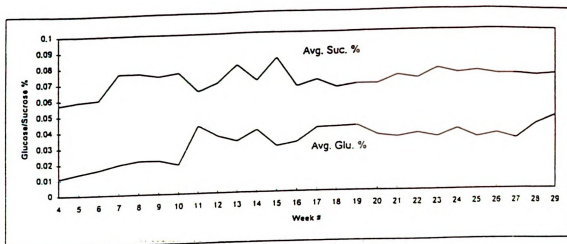


Figure 9c. Average sucrose values in Variety Comparison 3 weeks prior to average glucose values.

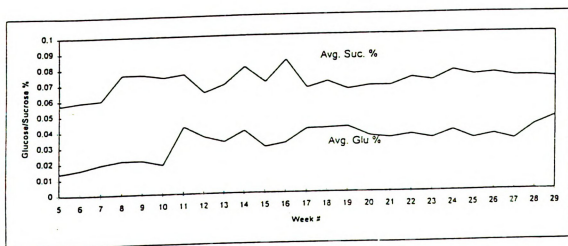


Figure 9d. Average sucrose values in Variety Comparison 4 weeks prior to average glucose values.

the number of weeks previous. The highest correlation was sucrose percentage 2 weeks previous with .40 correlation coefficient.

In addition to analyzing all selections from the variety trial, individual selections were analyzed for correlation between current glucose percentage vs. sucrose levels 1, 2, 3 and 4 weeks previous. Table C2a and C2b in the appendix has the correlation data for this analysis.

Data from selections such as AF-875-15 and Norchip which had higher amounts of glucose than other selections in the study, also had the strongest correlation of previous sucrose content vs. current glucose levels. However, even these selections did not indicate a strong correlation between previous sucrose levels and current glucose levels. The correlation may appear more evident in these selections than in other selections because there is much more glucose in these tubers.

There is evidence of a strong correlation between current glucose levels and sucrose percentage 1 week previous in the Norchip variety from weeks 8-19 (figure 10). This influence is not as evident after week 19. The lesser correlation after week 19 may have to do with other factors influencing Norchip glucose levels such as late storage season respiration rate changes.

The differing levels of strength of correlation between prior sucrose levels and current glucose levels within tubers

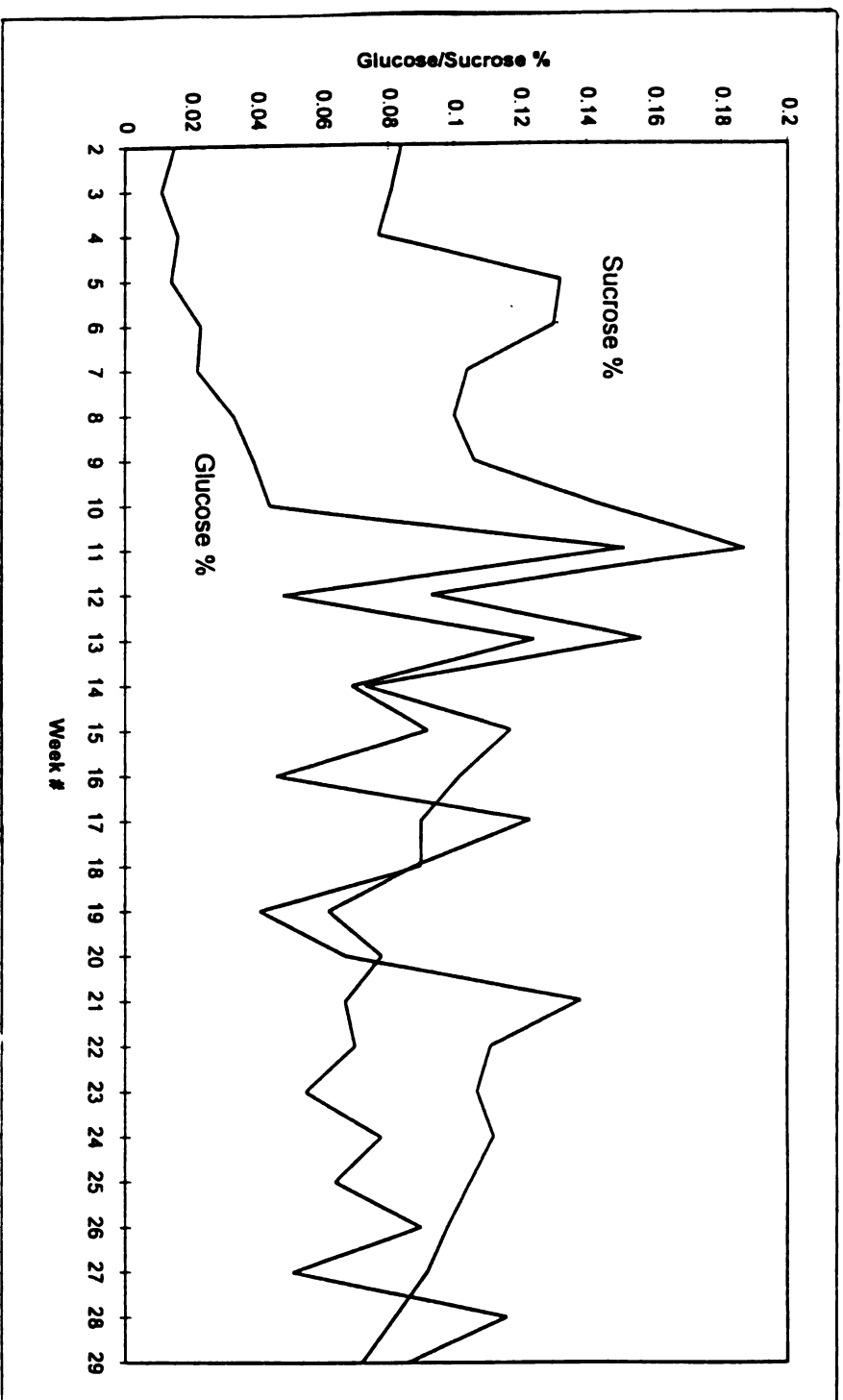


Figure 10. Sucrose percentage in Norchip selection 1 week prior to glucose percentage.

may be because of the higher degree of reducing/nonreducing sugar contained in selections such as Norchip over selections with lesser amounts. Another possible reason for the differing correlations may be due to differences in metabolism among the selections. It may require a longer period of time in the pathways of other selections to metabolize sucrose into glucose. Therefore, consideration should be given to determine for any tuber selection the time required to metabolize 1 unit of sucrose into the subsequent amount of glucose.

Results of Sucrose-6-Phosphate Synthetase Enzyme Assay

A key enzyme in the pathway of metabolizing glucose Sucrose-6-Phosphate Synthetase was assayed during the reconditioning study of BO178-34, Norchip and NDA 2417-6. The completed data from the study can be found in table D1 in the appendix.

There was little variance in the SPS activity among the varieties. However, there was some variance in SPS content of tubers that had been reconditioned versus those that had not been reconditioned. In theory, the SPS activity should be higher in tubers undergoing reconditioning than tubers held at normal storage conditions. This is because reconditioning temperatures are closer to the optimum SPS temperature for its activity.

As SPS activity increases, it is able to decrease activation energy required in the reaction of Glucose-6-Phosphate +

Fructose-6-Phosphate → Sucrose-6-Phosphate during gluconeogenesis. This would have caused the reaction to be more favorable in the direction of Sucrose-6-Phosphate formation which would lead to a higher amount of sucrose formed and possibly an increase in reducing sugar.

A possible reason for the lack of variance may have been the method of measuring SPS activity. SPS activity was measured by the sucrose end product formed in the reaction that it facilitated. It may be more accurate to directly measure SPS activity spectrophotometrically than to indirectly measure activity based upon end product formed. It is known that SPS activity level is very low compared to other enzymes studied in potato tuber metabolism. Therefore, it is important to utilize the most sensitive method of measurement available in determining SPS activity.

CONCLUSIONS

The best performing tuber selection in the variety comparison in regarding low reducing sugar content was NDO-1496-1. This selection had a glucose content of no higher than .021 % throughout the study. Established varieties in the chipping industry such as Norchip and Atlantic maintained a consistently high glucose content during the study.

The temperature study revealed that of the four temperature treatments, 50°F was the optimum for keeping reducing sugar levels at a minimum. Storage temperature had little impact on reducing sugar levels on the Snowden variety which has a history of having a consistently low glucose content.

The correlation between glucose content of all selections of tubers in the variety comparison and previous sucrose content was low. The correlation was low regardless of the number of weeks previous that sucrose was analyzed. A few individual selections such as ND-2676-10 and AF-875-15 that were analyzed revealed a slight correlation. Therefore, it may be possible to predict future glucose levels in some tuber selections based upon current sucrose values.

There was little variance detected in SPS activity among selections in the reconditioning study. This lack of detection may be due to lack of sensitivity in the indirect method of analysis. Because of the lack of variance, it was not possible to determine biochemical significance of SPS in this study.

SUGGESTIONS FOR FUTURE WORK

The cubicles in which the tubers for this experiment were stored in were lacking in proper airflow capacity. This may have allowed an improper ratio of CO₂ and O₂ gasses in the air which may have hindered proper respiration in the tubers. In addition to improper airflow conditions, the temperature control of the cubicles was less than optimal for the temperature comparison portion of the study. The fluctuation of temperature was +/- 2°F. The fluctuation for the temperature comparison of the tubers should be less than +/- 1° F. In future studies of tuber storage at MSU, the current cubicles should have an airflow system implemented in them that can be controlled by the researcher. New thermostats should also be installed so that the temperature conditions may be controlled more precisely.

A critical storage time for tubers was determined in this experiment in which reducing sugar content increased more during this period than any other time during storage. Future tuber storage experiments may include a comprehensive analysis of this critical storage time. For example, at storage week 11 at normal 50° F storage, divide tuber selection into 2 subgroups: 1 group stays at the 50° storage and the other group has it's temperature increased to 55°F until the end of the critical storage period. Weekly reducing sugar analysis could

determine if there was a difference in reducing sugar level between the 2 subgroups.

There was a possible correlation between the sucrose content of some tubers and reducing sugar content 1 week following. Further studies into this topic may include an attempt to determine the period of time it takes to hydrolyze 1 mole of sucrose into glucose and fructose at a certain temperature for a particular potato variety.

In future studies of SPS in potato tubers, a different assay should be investigated to analyze activity. It is possible that the YSI analysis was not sensitive enough in determining the amount of sucrose produced when the enzyme was added. It is possible that a spectrophotometric assay may be more accurate in determining SPS activity than measuring the sucrose end product.

Continuing to identify significant enzymes in the pathway of formation of reducing sugar will be an important area of study for potato researchers. It is becoming more feasible for biogenetic engineers to manipulate genes in plants for a desired effect. Researchers in the potato field must be able to effectively interface with bioengineers in developing more resistance to disease, decrease tuber respiration problems and generation of a tuber variety that can maintain a low reducing sugar level during cold storage.

REFERENCES

REFERENCES

Barichello, V., Yada, R.Y., Coffin, R.H. and Stanley, D.W.
1990. Respiratory enzyme activity in low temperature
sweetening of susceptible and resistant potatoes. J. Food Sci.
55:1060.

Burton, W.G. 1965. The sugar balance in some British
potato varieties during storage: The effects of tuber age,
previous storage temperature and intermittent refrigeration
upon low temperature sweetening. Eur. Potato J. 12:81.

Burton, W.G. 1966. The Potato. H. Veenman & Zonen,
Wageningen.

Chase, R.W. 1981. Potatoes. Michigan State University
Cooperative Extension Service. Michigan State University, East
Lansing, MI. Extension Bulletin E-1526.

Ciha, A.J. and Brun, W.A. 1978. Effect of pod removal on
nonstructural carbohydrate concentration in leaf tissue. Crop Sci. 18:
773.

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

Cottrell, J.E., Duffus, C.M., Paterson, L., Mackay, G.R., Allison, M.J. and Bain, H. 1993. The effect of storage temperature on reducing sugar concentration and the activities of three amylolytic enzymes in tubers of the cultivated potato, *Solanum tuberosum* L. Potato Res. 36:107.

Davies, H.V. and Ross, H.A. 1987. Hydrolytic and phosphorolytic enzyme activity and reserve mobilization in sprouting tubers of potato (*Solanum Tuberosum* L.) : The effect of water stress. J. Plant Physiol. 126: 387.

Dixon, W.L. and Ap Rees, T. 1980. Identification of the regulatory steps in glycolysis in potato tubers. Phytochem. 19:1297.

Dwelle, R.B. 1990. Source/sink relationships during tuber growth. Am. Potato J. 67:829.

Fuller, T.J. and Hughes, J.C. 1984. Factors influencing the relationship between the reducing sugars and fry colour of potato tubers of cv. Record. J. Food Tech. 19:455.

Gould, W.A. 1989. Factors affecting the oil content of potato chips. In: Chipping Potato Handbook. Snackfood Association, Alexandria, VA. USA.

Guy, C.L. 1990. Cold acclimation and freezing stress tolerance: role of protein metabolism. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 41:187.

Harbron, H., Foyer, C. and Walker, D. 1981. The purification and properties of sucrose-phosphate synthetase from spinach leaves: the involvement of this enzyme and fructose biphosphatase in the regulation of sucrose biosynthesis. *Arch. of Biochem. and Biophy.* 212:237.

Harbron, S., Woodrow, I.E., Kelly, G.J., Robinson, S.P., Latzko, E. and Walker, D.A. 1980. A Continuous Spectrophotometric Assay for Sucrose Phosphate Synthetase. *Anal. Biochem.* 107:56.

Isherwood, F.A. 1976. Mechanism of starch/sugar interconversion in *Solanum Tuberosum*. *Phytochem.* 15:33.

Kim, H.O. and Lee, S.K. 1993. Effects of curing and storage conditions on processing quality in potatoes. *ACTA Hort.* 343:73.

Kruger, N.J. 1995. Errors and Artifacts in Coupled Spectrophotometric Assays of Enzyme Activity. *Phytochem.* 38:1065.

Linnemann, A.R., Van Es, A. and Hartmans, K.J. 1985. Changes in the content of L-ascorbic acid, glucose, fructose, sucrose and total glycoalkaloids in potatoes (cv. Bintje) stored at 7, 16 and 28° C. *Potato Res.* 28:271.

Mares, D.J. and Marschner, H. 1980. Assimilate conversion in potatoes in relation to starch deposition and cell growth. *Ber. Deutsch Bot Ges.* 93:299.

Mehta, A. and Kaul, H.N. 1988. High temperature storage of potato (*Solanum Tuberosum* L.) for processing - a feasibility study. *Plant Foods for Hum. Nut.* 38:263.

Mendicino, J. 1960. Sucrose phosphate synthesis in wheat germ and green leaves. *J. Biol. Chem.* 235: 3347.

Muller-Rober, B., Sonnewald, U and Willmitzer, L. 1992. Inhibition of the ADP-glucose pyrophosphorylase in transgenic potatoes leads to sugar storing tubers and influences tuber formation and expression of tuber storage protein genes. *EMBO J.* 11: 1229.

Oparka, K.J., Marshall, B. and Mackerron, D.K.L. 1986. Carbon partitioning in a potato crop in response to applied nitrogen. In: *Phloem Transport*, Alan R. Liss, Inc. pp 577.

Pollock, C.J. and ap Rees, T. 1975. Activities of enzymes of sugar metabolism in cold-stored tubers of *Solanum Tuberosum*. *Phytochem.* 14:613.

Pressey, R. 1969. Potato sucrose synthetase: purification, properties and changes in activity associated with maturation. *Plant Physiol.* 44:759.

Pritchard, M.K. and Adam, L.R. 1994. Relationships between fry color and sugar concentration in stored Russet Burbank and Shepody potatoes. *Am. Potato J.* 71:59.

Rastovski, A. and van Es, A. 1981. Storage of Potatoes: Post Harvest Behavior, Store Design, Storage Practice, Handling. Centre for Agricultural Publishing and Documentation, Wageningen.

Rufty, T.W. and Huber, S.C. 1983. Changes in starch formation and activities of sucrose phosphate synthase and cytoplasmic fructose-1-6-bisphosphatase in response to source sink alterations. *Plant Physiol.* 72: 474.

Schwobe, M.A. and Parkin, K.L. 1990. Effect of low temperature and modified atmosphere storage on sugar accumulation in potatoes. *J Food Proc. Pres.* 14:241.

Shallenberger, R.S., Smith, O. and Treadway, R.H. 1959. Role of Sugars in the Browning Reaction of Potato Chips. Agric. and Food Chem. 7:274.

Sinha, N.K., Cash, J.N. and Chase, R.W. 1992. Differences in sugars, chip color, specific gravity and yield of selected potato cultivars grown in Michigan. Am. Potato J. 69:385.

Snackfood Association Color Chart. Purchased by writing: SFA, 1711 King Street, Suite 1 Alexandria, VA 22314.

Sowokinos, J. 1990. Effect of stress and senescence on carbon partitioning in stored potatoes. Am. Potato J. 67: 849.

Sowokinos, J.R. and Preston, D. 1988. Maintenance of potato processing quality by chemical maturity monitoring (CMM). Minnesota Agricultural Experiment Station. University of Minnesota, St. Paul, MN. Station Bulletin 586:1.

Sowokinos, J.R., Orr, P.H., Knoper, J.A. and Varns, J.L. 1987. Influence of potato storage and handling on sugars, chip quality and integrity of the starch (amyloplast) membrane. Am. Potato J. 64:213.

Sowokinos, J.R. 1987. Variations in glucose forming potential (GFP) between various potato clones. Am. Potato J. 64:459.

Sowokinos, J.R., Lulai, E.C. and Knoper, J.A. 1985. Translucent tissue Defects in *Solanum tuberosum* L. Plant Physiol. 78:489.

Thomashow, M.F. 1990. Molecular genetics of cold acclimation in higher plants. Adv. Genet. 28:99.

APPENDICES

APPENDIX A

Data from Sugar Analyses

Glucose Percentage

SEL/TRT	Week 1 10/11/94	Week 2 10/18/94	Week 3 10/25/94	Week 4 11/1/94	Week 5 11/8/94	Week 6 11/15/94	Week 7 11/22/94	Week 8 11/29/94	Week 9 12/6/94	Week 10 12/13/94
NDA-2031-2	0.013	0.012	0.005	0.008	0.007	0.01	0.013	0.014	0.016	0.004
NDA-2417-6	0.007	0.007	0.019	0.019	0.014	0.018	0.051	0.044	0.046	0.033
BO-178-34	0.007	0.004	0.01	0.012	0.021	0.021	0.022	0.022	0.021	0.018
Norchip	0.016	0.015	0.011	0.016	0.014	0.023	0.022	0.033	0.039	0.044
Suncrisp	0.004	0.005	0.01	0.017	0.015	0.022	0.018	0.031	0.03	0.022
AF-875-15	0.013	0.013	0.009	0.007	0.008	0.009	0.008	0.012	0.01	0.012
NY-102	0.014	0.013	0.007	0.008	0.007	0.009	0.008	0.012	0.01	0.012
NDA-2471-8	0.005	0.006	0.011	0.006	0.024	0.029	0.031	0.021	0.019	0.015
NY-95	0.009	0.007	0.008	0.015	0.026	0.024	0.03	0.043	0.04	0.033
Atlantic	0.017	0.008	0.008	0.013	0.012	0.011	0.012	0.011	0.01	0.016
NDO-1496-1	0.01	0.004	0.003	0.005	0.006	0.007	0.009	0.006	0.005	0.006
ND-2676-10	0.01	0.004	0.003	0.005	0.011	0.01	0.007	0.007	0.01	0.008
E5535-45	0.008	0.007	0.006	0.008	0.012	0.009	0.018	0.04	0.034	0.042
E5535-50	0.009	0.007	0.005	0.01	0.014	0.025	0.025	0.007	0.01	0.005
E5535-65-1										
E5535-65-2			0.006	0.006	0.009	0.01	0.009	0.002	0.001	0.003
W-870-45	0.028	0.032	0.052	0.082	0.08	0.076	0.083	0.082	0.076	0.081
W-870-50	0.006	0.005	0.006	0.006	0.005	0.005	0.008	0.004	0.005	0.002
W-870-65-1										
W-870-65-2			0.01	0.028	0.026	0.028	0.021	0.003	0.004	0.002
Snowden-45				0.009	0.018	0.014	0.013	0.012	0.011	0.009
Snowden-50			0.007	0.008	0.005	0.006	0.009	0.002	0.002	0.002
Snowden-65-1										
Snowden-65-2				0.009	0.004	0.002	0.004	0.002	0.002	0.002
W870-II-45				0.016	0.022	0.022	0.015	0.013	0.013	0.01
W870-II-50			0.003	0.006	0.007	0.008	0.005	0.003	0.003	0.002
W-870II-65-1										
W-870II-65-2				0.003	0.002	0.002	0.007	0.003	0.005	0.007

W-870 and W-870II were grown at different farms.

65-1 indicates storage at this temperature for 1 month before stepping down to 50 deg.

65-2 indicates storage at this temperature for 2 months before stepping down to 50 deg.

Table A1a.

Glucose Data From Tubers in Variety Comparison.

Glucose Percentage

SEL/TRT	Week 11 12/20/94	Week 12 12/27/94	Week 13 1/3/95	Week 14 1/10/95	Week 15 1/17/95	Week 16 1/24/95	Week 17 1/31/95	Week 18 2/7/95	Week 19 2/14/95	Week 20 2/21/95
NDA-2031-2	0.016	0.012	0.016	0.01	0.009	0.01	0.017	0.012	0.017	0.016
NDA-2417-6	0.059	0.017	0.009	0.037	0.013	0.008	0.007	0.031	0.037	0.012
BO-178-34	0.04	0.057	0.057	0.078	0.044	0.044	0.031	0.046	0.05	0.041
Norchip	0.151	0.048	0.124	0.069	0.092	0.046	0.123	0.088	0.062	0.078
Suncrisp	0.031	0.08	0.031	0.09	0.036	0.06	0.055	0.053	0.046	0.021
AF-875-15	0.084	0.068	0.013	0.026	0.022	0.032	0.048	0.043	0.036	0.038
NY-102	0.018	0.015	0.007	0.023	0.011	0.018	0.009	0.007	0.008	0.009
NDA-2471-8	0.012	0.019	0.03	0.027	0.026	0.051	0.028	0.055	0.086	0.041
NY-95	0.058	0.054	0.051	0.049	0.037	0.037	0.082	0.065	0.078	0.071
Atlantic	0.028	0.017	0.014	0.029	0.033	0.058	0.068	0.068	0.055	0.073
NDO-1496-1	0.007	0.022	0.029	0.017	0.012	0.006	0.006	0.008	0.009	0.011
ND-2676-10	0.007	0.022	0.009	0.017	0.012	0.006	0.006	0.008	0.009	0.011
E5535-45	0.038	0.033	0.061	0.044	0.054	0.042	0.06	0.036	0.039	0.047
E5535-50	0.003	0.007	0.005	0.007	0.003	0.004	0.005	0.004	0.006	0.012
E5535-65-1	0.002	0.002	0.017	0.003	0.005	0.003	0.004	0.002	0.003	0.003
E5535-65-2	0.058	0.06	0.035	0.054	0.061	0.034	0.026	0.039	0.033	0.04
W-870-45	0.003	0.013	0.003	0.003	0.004	0.005	0.005	0.005	0.005	0.005
W-870-50	0.005	0.002	0.003	0.012	0.002	0.003	0.003	0.003	0.008	0.036
W-870-65-1	0.005	0.002	0.003	0.005	0.013	0.009	0.011	0.018	0.013	0.019
W-870-65-2	0.008	0.011	0.005	0.004	0.007	0.005	0.003	0.002	0.003	0.003
Snowden-45	0.002	0.004	0.001	0.002	0.004	0.002	0.002	0.002	0.002	0.002
Snowden-50	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.003	0.003
Snowden-65-1	0.016	0.017	0.008	0.009	0.017	0.018	0.015	0.013	0.019	0.016
Snowden-65-2	0.003	0.008	0.002	0.002	0.006	0.005	0.002	0.003	0.003	0.003
W870-11-45	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.003	0.003	0.003
W870-11-50	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.003	0.003	0.003
W-87011-65-1	0.002	0.003	0.002	0.004	0.005	0.004	0.005	0.003	0.006	0.004
W-87011-65-2	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

W-870 and W-87011 were grown at different farms.

65-1 indicates storage at this temperature for 1 month before stepping down to 50 deg.

65-2 indicates storage at this temperature for 2 months before stepping down to 50 deg.

Table A1b.

Glucose Data From Tubers in Variety Comparison.

Glucose Percentage

SEL/TRT	Week 21 2/28/95	Week 22 3/7/95	Week 23 3/14/95	Week 24 3/21/95	Week 25 3/28/95	Week 26 4/4/95	Week 27 4/11/95	Week 28 4/18/95	Week 29 4/25/95
NDA-2031-2	0.016	0.015	0.017	0.019	0.022	0.021	0.02	0.03	0.035
NDA-2417-6	0.018	0.017	0.015	0.012	0.014	0.014	0.012	0.018	0.013
BO-178-34	0.038	0.049	0.036	0.018	0.033	0.032	0.024	0.015	0.031
Norchip	0.067	0.07	0.055	0.078	0.064	0.09	0.051	0.116	0.086
Suncrisp	0.046	0.058	0.054	0.039	0.031	0.029	0.025	0.059	0.043
AF-875-15	0.037	0.047	0.053	0.048	0.044	0.035	0.037	0.04	0.051
NY-102	0.006	0.006	0.005	0.049	0.008	0.01	0.003	0.007	0.009
NDA-2471-8	0.052	0.053	0.051	0.056	0.066	0.067	0.093	0.058	0.068
NY-95	0.043	0.043	0.047	0.041	0.046	0.056	0.06	0.053	0.095
Atlantic	0.067	0.052	0.045	0.04	0.043	0.043	0.033	0.079	0.1
NDO-1496-1	0.007	0.008	0.01	0.01	0.007	0.012	0.007	0.01	0.015
ND-2676-10	0.009	0.012	0.011	0.046	0.014	0.011	0.016	0.005	0.007
E5535-45	0.039	0.038	0.045	0.044	0.044	0.033	0.036	0.03	0.033
E5535-50	0.014	0.013	0.017	0.018	0.015	0.017	0.016	0.023	0.036
E5535-65-1	0.007	0.006	0.006	0.008	0.017	0.022	0.014	0.013	0.023
E5535-65-2	0.008	0.013	0.022	0.025	0.022	0.017	0.04	0.017	0.032
W-870-45	0.04	0.047	0.043	0.046	0.051	0.022	0.026	0.041	0.135
W-870-50	0.008	0.008	0.015	0.008	0.019	0.018	0.021	0.011	0.054
W-870-65-1	0.021	0.02	0.024	0.02	0.024	0.028	0.043	0.053	0.043
W-870-65-2	0.017	0.013	0.013	0.004	0.012	0.019	0.018	0.041	0.048
Snowden-45	0.005	0.005	0.006	0.004	0.003	0.004	0.004	0.005	0.005
Snowden-50	0.002	0.002	0.002	0.002	0.002	0.003	0.006	0.003	0.004
Snowden-65-1	0.004	0.002	0.002	0.002	0.002	0.002	0.004	0.003	0.003
Snowden-65-2	0.002	0.003	0.002	0.002	0.005	0.003	0.004	0.005	0.004
W870-11-45	0.019	0.017	0.021	0.021	0.002	0.013	0.02	0.013	0.034
W870-11-50	0.009	0.008	0.005	0.003	0.011	0.009	0.014	0.022	0.019
W-87011-65-1	0.019	0.026	0.025	0.035	0.03	0.02	0.025	0.026	0.024
W-87011-65-2	0.017	0.013	0.014	0.013	0.01	0.017	0.028	0.019	0.02

W-870 and W-87011 were grown at different farms.

65-1 indicates storage at this temperature for 1 month before stepping down to 50 deg.

65-2 indicates storage at this temperature for 2 months before stepping down to 50 deg.

Table A1c.

Glucose Data From Tubers in Variety Comparison.

Sucrose Percentage

SEL/TRT	Week 1 10/11/94	Week 2 10/18/94	Week 3 10/25/94	Week 4 11/1/94	Week 5 11/8/94	Week 6 11/15/94	Week 7 11/22/94	Week 8 11/29/94	Week 9 12/6/94	Week 10 12/13/94
NDA-2031-2	0.032	0.031	0.031	0.043	0.031	0.036	0.016	0.018	0.025	0.03
NDA-2417-6	0.051	0.05	0.046	0.051	0.047	0.018	0.016	0.047	0.033	0.041
BO-178-34	0.058	0.062	0.064	0.098	0.086	0.089	0.097	0.092	0.088	0.095
Norchip	0.084	0.081	0.077	0.132	0.13	0.104	0.1	0.106	0.143	0.187
Suncisp	0.04	0.049	0.063	0.072	0.09	0.074	0.075	0.079	0.067	0.07
AF-875-15	0.067	0.064	0.085	0.096	0.092	0.107	0.115	0.118	0.11	0.127
NY-102	0.073	0.066	0.088	0.076	0.068	0.064	0.056	0.043	0.057	0.051
NDA-2471-8	0.057	0.067	0.078	0.073	0.108	0.177	0.249	0.051	0.05	0.073
NY-95	0.057	0.063	0.067	0.069	0.079	0.065	0.046	0.05	0.054	0.061
Atlantic	0.052	0.063	0.054	0.072	0.055	0.073	0.071	0.076	0.078	0.085
NDO-1496-1	0.046	0.055	0.045	0.051	0.045	0.04	0.032	0.041	0.05	0.047
ND-2676-10	0.063	0.062	0.05	0.08	0.085	0.042	0.035	0.05	0.072	0.092
EE535-45	0.086	0.084	0.126	0.159	0.138	0.11	0.106	0.119	0.129	0.127
EE535-50	0.108	0.1	0.106	0.073	0.09	0.087	0.082	0.084	0.078	0.057
EE535-65-1			0.109	0.081	0.075	0.064	0.04	0.03	0.039	0.032
EE535-65-2			0.128	0.132	0.144	0.117	0.107	0.108	0.132	0.124
W-870-45	0.078	0.083	0.079	0.08	0.13	0.105	0.118	0.086	0.076	0.046
W-870-50										
W-870-65-1			0.099	0.067	0.075	0.067	0.064	0.057	0.061	0.064
W-870-65-2				0.101	0.095	0.098	0.09	0.098	0.085	0.094
Snowden-45			0.099	0.067	0.075	0.067	0.064	0.057	0.061	0.064
Snowden-50										
Snowden-65-1				0.104	0.07	0.067	0.06	0.054	0.046	0.041
Snowden-65-2				0.108	0.124	0.107	0.089	0.063	0.05	0.062
W870-II-45				0.106	0.114	0.099	0.117	0.069	0.07	0.075
W870-II-50										
W-870II-65-1				0.11	0.076	0.078	0.071	0.057	0.04	0.043
W-870II-65-2										

W-870 and W-870II were grown at different farms.

65-1 indicates storage at this temperature for 1 month before stepping down to 50 deg.

65-2 indicates storage at this temperature for 2 months before stepping down to 50 deg.

Table A2a.

Sucrose Data From Tubers in Variety Comparison.

Sucrose Percentage

SEL/TRT	Week 11 12/20/94	Week 12 12/27/94	Week 13 1/3/95	Week 14 1/10/95	Week 15 1/17/95	Week 16 1/24/95	Week 17 1/31/95	Week 18 2/7/95	Week 19 2/14/95	Week 20 2/21/95
NDA-2031-2	0.035	0.035	0.038	0.039	0.041	0.054	0.054	0.048	0.041	0.041
NDA-2417-6	0.116	0.232	0.045	0.047	0.045	0.039	0.039	0.061	0.05	0.041
BO-178-34	0.103	0.086	0.084	0.067	0.052	0.051	0.051	0.058	0.051	0.06
Norchip	0.093	0.156	0.073	0.117	0.102	0.09	0.09	0.041	0.067	0.138
Suncrisp	0.061	0.075	0.073	0.06	0.06	0.053	0.053	0.051	0.052	0.06
AF-875-15	0.068	0.042	0.112	0.123	0.112	0.111	0.111	0.146	0.101	0.108
NY-102	0.05	0.052	0.048	0.052	0.059	0.064	0.064	0.071	0.071	0.078
NDA-2471-8	0.058	0.075	0.062	0.083	0.062	0.04	0.095	0.074	0.102	0.117
NY-95	0.081	0.05	0.049	0.063	0.073	0.071	0.071	0.079	0.069	0.067
Atlantic	0.073	0.057	0.053	0.058	0.049	0.095	0.04	0.104	0.109	0.076
NDO-1496-1	0.04	0.056	0.075	0.049	0.048	0.048	0.048	0.049	0.045	0.041
ND-2676-10	0.067	0.092	0.075	0.076	0.079	0.082	0.082	0.077	0.079	0.081
E5535-45	0.136	0.232	0.15	0.167	0.185	0.203	0.203	0.145	0.185	0.234
E5535-50	0.04	0.077	0.072	0.064	0.05	0.045	0.045	0.051	0.059	0.038
E5535-65-1	0.021	0.024	0.027	0.028	0.032	0.048	0.036	0.044	0.039	0.046
E5535-65-2	0.029	0.034	0.031	0.042	0.045	0.059	0.068	0.094	0.151	0.204
W-870-45	0.043	0.078	0.07	0.075	0.073	0.077	0.107	0.075	0.058	0.063
W-870-50	0.049	0.048	0.043	0.051	0.056	0.056	0.059	0.099	0.104	0.058
W-870-65-1	0.02	0.026	0.028	0.047	0.061	0.074	0.041	0.075	0.089	0.119
W-870-65-2	0.073	0.026	0.048	0.078	0.071	0.074	0.135	0.084	0.11	0.141
Snowden-45	0.087	0.077	0.064	0.069	0.07	0.073	0.069	0.075	0.051	0.059
Snowden-50	0.043	0.068	0.048	0.05	0.052	0.063	0.039	0.075	0.078	0.066
Snowden-65-1	0.038	0.032	0.035	0.038	0.041	0.05	0.068	0.065	0.078	0.095
Snowden-65-2	0.046	0.041	0.056	0.067	0.07	0.089	0.091	0.094	0.096	0.088
W870-II-45	0.071	0.077	0.07	0.074	0.091	0.122	0.082	0.064	0.106	0.112
W870-II-50	0.067	0.066	0.043	0.058	0.051	0.06	0.062	0.074	0.079	0.088
W-870II-65-1	0.025	0.047	0.044	0.067	0.064	0.059	0.068	0.078	0.069	0.082
W-870II-65-2	0.058	0.051	0.074	0.086	0.084	0.113	0.12	0.083	0.101	0.134

W-870 and W-870II were grown at different farms.

65-1 indicates storage at this temperature for 1 month before stepping down to 50 deg.

65-2 indicates storage at this temperature for 2 months before stepping down to 50 deg.

Table A2b.

Sucrose Data From Tubers in Variety Comparison.

Sucrose Percentage

SEL/TRT	Week 21 2/28/95	Week 22 3/7/95	Week 23 3/14/95	Week 24 3/21/95	Week 25 3/28/95	Week 26 4/4/95	Week 27 4/11/95	Week 28 4/18/95	Week 29 4/25/95
NDA-2031-2	0.037	0.037	0.039	0.049	0.046	0.044	0.048	0.033	0.01
NDA-2417-6	0.042	0.04	0.035	0.043	0.036	0.033	0.031	0.033	0.046
BO-178-34	0.079	0.081	0.074	0.056	0.069	0.076	0.084	0.06	0.097
Norchip	0.111	0.107	0.112	0.105	0.098	0.092	0.082	0.072	0.088
Sunchisp	0.054	0.061	0.059	0.062	0.07	0.076	0.096	0.052	0.051
AF-875-15	0.1	0.105	0.101	0.095	0.096	0.097	0.093	0.114	0.105
NY-102	0.072	0.071	0.072	0.069	0.07	0.071	0.068	0.05	0.058
NDA-2471-8	0.101	0.103	0.102	0.106	0.108	0.111	0.115	0.132	0.169
NY-95	0.043	0.044	0.048	0.052	0.05	0.046	0.041	0.032	0.047
Atlantic	0.067	0.067	0.065	0.069	0.068	0.071	0.073	0.065	0.057
NDO-1496-1	0.099	0.092	0.088	0.081	0.07	0.066	0.048	0.084	0.031
ND-2676-10	0.075	0.076	0.074	0.079	0.075	0.076	0.073	0.064	0.057
E5535-45	0.09	0.096	0.105	0.12	0.144	0.156	0.151	0.112	0.095
E5535-50	0.052	0.059	0.049	0.051	0.056	0.054	0.061	0.109	0.209
E5535-65-1	0.056	0.065	0.081	0.093	0.099	0.12	0.117	0.331	0.232
E5535-65-2	0.078	0.112	0.13	0.138	0.21	0.318	0.462	0.102	0.325
W-870-45	0.058	0.071	0.088	0.13	0.141	0.128	0.108	0.054	0.076
W-870-50	0.097	0.112	0.108	0.105	0.116	0.114	0.132	0.16	0.245
W-870-65-1	0.155	0.212	0.218	0.16	0.209	0.265	0.374	0.412	0.379
W-870-65-2	0.292	0.265	0.232	0.205	0.188	0.19	0.121	0.165	0.311
Snowden-45	0.062	0.065	0.071	0.084	0.081	0.079	0.083	0.066	0.068
Snowden-50	0.061	0.074	0.073	0.098	0.099	0.118	0.167	0.185	0.122
Snowden-65-1	0.035	0.283	0.276	0.251	0.264	0.19	0.155	0.166	0.186
Snowden-65-2	0.138	0.152	0.168	0.201	0.209	0.198	0.247	0.193	0.214
W870-II-45	0.07	0.081	0.092	0.1	0.093	0.071	0.068	0.076	0.092
W870-II-50	0.117	0.121	0.119	0.113	0.136	0.157	0.186	0.201	0.19
W-870II-65-1	0.11	0.156	0.168	0.154	0.261	0.031	0.382	0.412	0.39
W-870II-65-2	0.17	0.195	0.25	0.218	0.269	0.285	0.325	0.346	0.109

W-870 and W-870II were grown at different farms.

65-1 indicates storage at this temperature for 1 month before stepping down to 50 deg.

65-2 indicates storage at this temperature for 2 months before stepping down to 50 deg.

Table A2c.

Sucrose Data From Tubers in Variety Comparison.

Average Reducing Sugar Content of Tubers in Variety Trial

<u>Week</u>	<u>Glucose %</u>
1	0.010
2	0.009
3	0.007
4	0.011
5	0.014
6	0.016
7	0.019
8	0.022
9	0.022
10	0.019
11	0.042
12	0.035
13	0.032
14	0.038
15	0.029
16	0.032
17	0.040
18	0.040
19	0.041
20	0.034
21	0.034
22	0.036
23	0.033
24	0.032
25	0.033
26	0.035
27	0.032
28	0.041
29	0.046

Table A3. Reducing Sugar Data from Tubers in Variety Trial

Effect of Reconditioning on Stored Tubers

	<u>Reconditioned (glu %)</u>	<u>Not Reconditioned (glu %)</u>
Norchip		
Apr. 5	.090	.090
Apr. 12	.055	.055
Apr. 19	.116	.118
Apr 26	.099	.096
BO-178-34		
Apr. 5	.038	.038
Apr. 12	.030	.030
Apr. 19	.038	.019
Apr 26	.010	.042
NDA-2417-6		
Apr. 5	.019	.019
Apr. 12	.016	.016
Apr. 19	.015	.021
Apr 26	.014	.019

Table A4. Reducing Sugar Data from Reconditioned Tubers.

APPENDIX B

Color Score Data

Color Scores (Agtron) for Chips

Selection (Treatment)	Chipping Month							
	<u>10/94</u>	<u>11/94</u>	<u>12/94</u>	<u>1/95</u>	<u>2/95</u>	<u>3/95</u>	<u>4/95</u>	<u>AVG</u>
NDA 2417-6	1.6	2.6	3.4	2.2	3	2.4	2.2	2.5
NDA 2417-6 (rec)							2.2	2.2
NDA 2031-2	1.6	2.2	2.8	2.8	2.8	2.4	3.2	2.5
NDO 1496-1	1.6	1.6	2.6	2.6	3.8	2.4	2.2	2.4
NDA 2471-8	1.8	3	2.6	3.4	3	3.4	4.6	3.1
BO 178-34	1.6	2.2	3.8	3	3.2	2.6	3	2.8
BO 178-34							2.2	2.2
AF 875-15	2	2.2	3.6	3.4	3.8	4	3.2	3.2
Norchip	1.4	3	3.6	4.4	2.2	4.2	3.8	3.1
Norchip (rec)							3.8	3.8
NY 102	2.8	2.6	3.2	3	3	2.2	3.4	2.9
ND 2676-10	2.6	2	3	3.2	3.4	3	2.6	2.8
NY 95	2.8	3	3.2	3.2	3.4	3	3	3.1
Suncrisp	3	2.6	3.8	3	3.2	3.4	3.4	3.2
Atlantic		2.6	3.2	3.6	3.2	3.8	3.6	3.3
E5535 45°F		2.8	3	4	3.2	2	2.8	3.0
W870 45°F		3.4	3.6	3.4	3	3	3.2	3.3
Snowden 45°F		2	2.2	1.6	1.8	2	2	1.9
W870II 45°F		2.4	2.8	3	2.4	3	2.8	2.7
E5535 50°F	2.6	3.4	2.6	3	2.2	3	3.2	2.9
W870 50°F	2.8	2.4	2.2	2.8	2.2	3	3.8	2.7
Snowden 50°F	2.2	1.8	2.2	2.8	1.2	2.4	3.6	2.3
W870II 50°F	2.2	2.6	1.4	2.4	1.8	2.2	3	2.2
E5535 65°F (1 month)		2.4	1.8	2.6	2.4	2	2.6	2.3
W870 65°F (1 month)		2.8	1.8	2.6	1.6	3	4	2.6
Snowden 65°F (1 month)		2.6	2.6	2.8	1.2	2.6	3.2	2.3
W870II 65°F (1 month)		2.2	2.2	2.8	2.4	3.2	3.4	2.7
E5535 65°F (2 months)			2	2.8	2.4	2	3.2	2.5
W870 65°F (2 months)			2.2	3.2	2.6	3	3.8	3.0
Snowden 65° (2 months)			2	3.2	1.4	2	3	2.3
W870II 65° (2months)			2.2	3.2	2.4	2.8	3	2.7

Table B1. Color Score Data

Rankings for Chip Color Scores vs. Ranking of Tuber Reducing Sugar Content in Variety Trial (Lowest to Highest)

<u>Selection</u>	<u>Avg. Red. Sugar Level (g/L)</u>	<u>Rank</u>	<u>Avg. Color Score</u>	<u>Rank</u>
NDO 1496-1	.008	1	2.4	1
ND 2976-10	.010	2	2.8	4
NY 102	.010	2	2.9	6
NDA 2031-2	.014	4	2.5	2
NDA 4217-6	.021	5	2.5	2
BO 178-34	.031	6	2.8	4
AF 875-15	.032	7	3.2	10
Suncrisp	.036	8	3.2	10
Atlantic	.036	8	3.3	12
NDA 2421-8	.038	10	3.1	7
NY 95	.044	11	3.1	7
Norchip	.061	12	3.1	7

Table B2. Color Score Rankings

APPENDIX C

Statistical Analyses Data

General Linear Models Procedure

Tukey's Studentized Range (HSD) Test for variable: RESPONSE

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 Confidence= 0.95 df= 307 MSE= 0.000274
Critical Value of Studentized Range= 4.658

Comparisons significant at the 0.05 level are indicated by '***'.

		Simultaneous		Simultaneous		
		Lower	Difference	Upper		
		Confidence	Between	Confidence		
		Limit	Means	Limit		
VAR						
Comparison						
Norchip	4 - 9	0.002328	0.016655	0.030983	***	
	4 - 8	0.009017	0.023345	0.037672	***	
	4 - 10	0.010569	0.024897	0.039224	***	
	4 - 5	0.010638	0.024966	0.039293	***	
	4 - 3	0.014775	0.029230	0.043685	***	
	4 - 6	0.015121	0.029448	0.043776	***	
	4 - 2	0.026121	0.040448	0.054776	***	
	4 - 1	0.032328	0.046655	0.060983	***	
	4 - 7	0.037362	0.051690	0.066017	***	
	4 - 12	0.037604	0.051931	0.066259	***	
	4 - 11	0.038810	0.053138	0.067465	***	
NY 95	9 - 4	-0.030983	-0.016655	-0.002328	***	
	9 - 8	-0.007638	0.006690	0.021017		
	9 - 10	-0.006086	0.008241	0.022569		
	9 - 5	-0.006017	0.008310	0.022638		
	9 - 3	-0.001880	0.012575	0.027030		
	9 - 6	-0.001534	0.012793	0.027121		
	9 - 2	0.009466	0.023793	0.038121	***	
	9 - 1	0.015672	0.030000	0.044328	***	
	9 - 7	0.020707	0.035034	0.049362	***	
	9 - 12	0.020948	0.035276	0.049603	***	
	9 - 11	0.022155	0.036483	0.050810	***	
NDA 2421-8	8 - 4	-0.037672	-0.023345	-0.009017	***	
	8 - 9	-0.021017	-0.006690	0.007638		
	8 - 10	-0.012776	0.001552	0.015879		
	8 - 5	-0.012707	0.001621	0.015948		
	8 - 3	-0.008569	0.005885	0.020340		
	8 - 6	-0.008224	0.006103	0.020431		
	8 - 2	0.002776	0.017103	0.031431	***	
	8 - 1	0.008983	0.023310	0.037638	***	
	8 - 7	0.014017	0.028345	0.042672	***	
	8 - 12	0.014259	0.028586	0.042914	***	
	8 - 11	0.015466	0.029793	0.044121	***	
Atlantic	10 - 4	-0.039224	-0.024897	-0.010569	***	
	10 - 9	-0.022569	-0.008241	0.006086		
	10 - 8	-0.015879	-0.001552	0.012776		
	10 - 5	-0.014259	0.000069	0.014396		
	10 - 3	-0.010121	0.004334	0.018789		
	10 - 6	-0.009776	0.004552	0.018879		
	10 - 2	0.001224	0.015552	0.029879	***	
	10 - 1	0.007431	0.021759	0.036086	***	
	10 - 7	0.012466	0.026793	0.041121	***	
	10 - 12	0.012707	0.027034	0.041362	***	
	10 - 11	0.013914	0.028241	0.042569	***	

Table C1a. Comparisons of Reducing Sugar Content Among Tubers in Variety Comparison.

General Linear Models Procedure

Tukey's Studentized Range (HSD) Test for variable: RESPONSE

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 Confidence= 0.95 df= 307 MSE= 0.000274

Critical Value of Studentized Range= 4.658

Comparisons significant at the 0.05 level are indicated by '***'

		VAR	Simultaneous	Difference	Simultaneous	
		Comparison	Lower	Between	Upper	
			Confidence	Means	Confidence	
			Limit		Limit	
NDA 2031-2	1	- 4	-0.060983	-0.046655	-0.032328	***
	1	- 9	-0.044328	-0.030000	-0.015672	***
	1	- 8	-0.037638	-0.023310	-0.008983	***
	1	- 10	-0.036086	-0.021759	-0.007431	***
	1	- 5	-0.036017	-0.021690	-0.007362	***
	1	- 3	-0.031880	-0.017425	-0.002970	***
	1	- 6	-0.031534	-0.017207	-0.002879	***
	1	- 2	-0.020534	-0.006207	0.008121	
	1	- 7	-0.009293	0.005034	0.019362	
	1	- 12	-0.009052	0.005276	0.019603	
	1	- 11	-0.007845	0.006483	0.020810	
NY 102	7	- 4	-0.066017	-0.051690	-0.037362	***
	7	- 9	-0.049362	-0.035034	-0.020707	***
	7	- 8	-0.042672	-0.028345	-0.014017	***
	7	- 10	-0.041121	-0.026793	-0.012466	***
	7	- 5	-0.041052	-0.026724	-0.012397	***
	7	- 3	-0.036914	-0.022459	-0.008004	***
	7	- 6	-0.036569	-0.022241	-0.007914	***
	7	- 2	-0.025569	-0.011241	0.003086	
	7	- 1	-0.019362	-0.005034	0.009293	
	7	- 12	-0.014086	0.000241	0.014569	
	7	- 11	-0.012879	0.001448	0.015776	
ND 2676-10	12	- 4	-0.066259	-0.051931	-0.037604	***
	12	- 9	-0.049603	-0.035276	-0.020948	***
	12	- 8	-0.042914	-0.028586	-0.014259	***
	12	- 10	-0.041362	-0.027034	-0.012707	***
	12	- 5	-0.041293	-0.026966	-0.012638	***
	12	- 3	-0.037156	-0.022701	-0.008246	***
	12	- 6	-0.036810	-0.022483	-0.008155	***
	12	- 2	-0.025810	-0.011483	0.002845	
	12	- 1	-0.019603	-0.005276	0.009052	
	12	- 7	-0.014569	-0.000241	0.014086	
	12	- 11	-0.013121	0.001207	0.015534	
NDO 1496-1	11	- 4	-0.067465	-0.053138	-0.038810	***
	11	- 9	-0.050810	-0.036483	-0.022155	***
	11	- 8	-0.044121	-0.029793	-0.015466	***
	11	- 10	-0.042569	-0.028241	-0.013914	***
	11	- 5	-0.042500	-0.028172	-0.013845	***
	11	- 3	-0.038363	-0.023908	-0.009453	***
	11	- 6	-0.038017	-0.023690	-0.009362	***
	11	- 2	-0.027017	-0.012690	0.001638	
	11	- 1	-0.020810	-0.006483	0.007845	
	11	- 7	-0.015776	-0.001448	0.012879	
	11	- 12	-0.015534	-0.001207	0.013121	

Table C1b. Comparisons of Reducing Sugar Content Among Tubers in Variety Comparison.

General Linear Models Procedure

Tukey's Studentized Range (HSD) Test for variable: RESPONSE

NOTE: This test controls the type I experimentwise error rate.

Alpha= 0.05 Confidence= 0.95 df= 307 MSE= 0.000274
Critical Value of Studentized Range= 4.658

Comparisons significant at the 0.05 level are indicated by '***'.

		Simultaneous	Difference	Simultaneous	
		Lower	Between	Upper	
		Confidence	Means	Confidence	
		Limit		Limit	
VAR					
Comparison					
Suncrisp	5 - 4	-0.039293	-0.024966	-0.010638	***
	5 - 9	-0.022638	-0.008310	0.006017	
	5 - 8	-0.015948	-0.001621	0.012707	
	5 - 10	-0.014396	-0.000069	0.014259	
	5 - 3	-0.010190	0.004265	0.018720	
	5 - 6	-0.009845	0.004483	0.018810	
	5 - 2	0.001155	0.015483	0.029810	***
	5 - 1	0.007362	0.021690	0.036017	***
	5 - 7	0.012397	0.026724	0.041052	***
	5 - 12	0.012638	0.026966	0.041293	***
	5 - 11	0.013845	0.028172	0.042500	***
BO 178-34	3 - 4	-0.043685	-0.029230	-0.014775	***
	3 - 9	-0.027030	-0.012575	0.001880	
	3 - 8	-0.020340	-0.005885	0.008569	
	3 - 10	-0.018789	-0.004334	0.010121	
	3 - 5	-0.018720	-0.004265	0.010190	
	3 - 6	-0.014237	0.000218	0.014673	
	3 - 2	-0.003237	0.011218	0.025673	***
	3 - 1	0.002970	0.017425	0.031880	***
	3 - 7	0.008004	0.022459	0.036914	***
	3 - 12	0.008246	0.022701	0.037156	***
	3 - 11	0.009453	0.023908	0.038363	***
AF 875-15	6 - 4	-0.043776	-0.029448	-0.015121	***
	6 - 9	-0.027121	-0.012793	0.001534	
	6 - 8	-0.020431	-0.006103	0.008224	
	6 - 10	-0.018879	-0.004552	0.009776	
	6 - 5	-0.018810	-0.004483	0.009845	
	6 - 3	-0.014673	-0.000218	0.014237	
	6 - 2	-0.003328	0.011000	0.025328	***
	6 - 1	0.002812	0.022241	0.035589	***
	6 - 7	0.008155	0.022483	0.036810	***
	6 - 12	0.009362	0.023690	0.038017	***
	6 - 11				
NDA 4217-6	2 - 4	-0.054776	-0.040448	-0.026121	***
	2 - 9	-0.038121	-0.023793	-0.009466	***
	2 - 8	-0.031431	-0.017103	-0.002776	***
	2 - 10	-0.029879	-0.015552	-0.001224	***
	2 - 5	-0.029810	-0.015483	-0.001155	***
	2 - 3	-0.025673	-0.011218	0.003237	
	2 - 6	-0.025328	-0.011000	0.003328	
	2 - 1	-0.008121	0.006207	0.020534	
	2 - 7	-0.003086	0.011241	0.025569	
	2 - 12	-0.002845	0.011483	0.025810	
	2 - 11	-0.001638	0.012690	0.027017	

Table C1c. Comparisons of Reducing Sugar Content Among Tubers in Variety Comparison.

<u>NDA-2031-2</u>		<u>NY-102</u>	
Sucrose 1 week previous:	.279	Sucrose 1 week previous:	(-).144
Sucrose 2 weeks previous:	.457	Sucrose 2 weeks previous:	(-).178
Sucrose 3 weeks previous:	.488	Sucrose 3 weeks previous:	(-).185
Sucrose 4 weeks previous:	.390	Sucrose 4 weeks previous:	.016

<u>NDA-2417-6</u>		<u>NDA-2471-8</u>	
Sucrose 1 week previous:	(-).251	Sucrose 1 week previous:	.227
Sucrose 2 weeks previous:	.014	Sucrose 2 weeks previous:	.140
Sucrose 3 weeks previous:	(-).078	Sucrose 3 weeks previous:	(-).072
Sucrose 4 weeks previous:	(-).289	Sucrose 4 weeks previous:	(-).118

<u>BO-178-34</u>		<u>NY-95</u>	
Sucrose 1 week previous:	.012	Sucrose 1 week previous:	(-).142
Sucrose 2 weeks previous:	.040	Sucrose 2 weeks previous:	(-).008
Sucrose 3 weeks previous:	.155	Sucrose 3 weeks previous:	(-).018
Sucrose 4 weeks previous:	.248	Sucrose 4 weeks previous:	(-).291

Table C2a. Correlation Coefficients of Previous Sucrose Percentage and Glucose Percentage of Selections in Variety Comparison.

<u>Norchip</u>		<u>Atlantic</u>	
Sucrose 1 week previous:	.265	Sucrose 1 week previous:	.240
Sucrose 2 weeks previous:	(-).013	Sucrose 2 weeks previous:	.276
Sucrose 3 weeks previous:	.273	Sucrose 3 weeks previous:	.034
Sucrose 4 weeks previous:	.041	Sucrose 4 weeks previous:	.006

<u>Suncrisp</u>		<u>NDO-1496-1</u>	
Sucrose 1 week previous:	.059	Sucrose 1 week previous:	.163
Sucrose 2 weeks previous:	.128	Sucrose 2 weeks previous:	.015
Sucrose 3 weeks previous:	.052	Sucrose 3 weeks previous:	(-).023
Sucrose 4 weeks previous:	.310	Sucrose 4 weeks previous:	(-).095

<u>AF-875-15</u>		<u>ND2676-10</u>	
Sucrose 1 week previous:	.250	Sucrose 1 week previous:	.133
Sucrose 2 weeks previous:	.398	Sucrose 2 weeks previous:	.230
Sucrose 3 weeks previous:	.400	Sucrose 3 weeks previous:	.073
Sucrose 4 weeks previous:	.460	Sucrose 4 weeks previous:	.102

Table C2b. Correlation Coefficients of Previous Sucrose Percentage and Glucose Percentage of Selections in Variety Comparison.

Correlation Coefficients of Previous Sucrose Percentage and Glucose Percentage of all Selections Combined in Variety Comparison

Sucrose Percentage 1 Week Previous as Indicator:	0.347
Sucrose Percentage 2 Weeks Previous as Indicator:	0.400
Sucrose Percentage 3 Weeks Previous as Indicator:	0.193
Sucrose Percentage 4 Weeks Previous as Indicator:	0.328

Table C3. Correlation Coefficients of Previous Sucrose Percentage and Glucose Percentage of all Selections Collectively in Variety Comparison.

APPENDIX D

SPS Analysis Data

Sucrose Phosphate Synthetase (SPS) Content in Selected Reconditioned and Non Reconditioned Tubers

<u>Selection</u>	<u>SPS Content (grams /liter)</u>	
	<u>Replication 1</u>	<u>Replication 2</u>
Norchip Reconditioned	.125	.057
Norchip Not Reconditioned	.082	.099
BO178-34 Reconditioned	.090	.064
BO178-34 Not Reconditioned	.056	.076
NDA2417-6 Reconditioned	.066	.074
NDA2417-6 Not Reconditioned	.078	.054
Standard 1 Unit	.081	.072
Standard 2 Units	.094	.084

Table D1. Data from SPS Analysis.

MICHIGAN STATE UNIV. LIBRARIES



31293015812237