KRASNODAR POLYTECHNIC INSTITUTE
(MINISTRY OF HIGHER EDUCATION, USSR)

FREEZING AND REFRIGERATION OF PERISHABLE FOOD CROPS

BY

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PREFACE

This project was undertaken at the Krasnodar Polytechnic Institute, USSR, in fulfilment of the requirements for a course of study in Refrigeration and Freezing. The project involved the storage of vegetables such as green peas and sweet pepper after blast freezing at temperatures of -18, -30 and -60 ^{0}C. This and other similar studies would hopefully help in establishing effective techniques for the quality preservation of perishable tropical vegetables during storage.

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SUMMARY

Weighed samples of green peas and sweet pepper were blast-frozen over different periods of time to attain temperatures of -18°C, -30°C and -60°C. The samples were then stored in a refrigerator at -12°C. Batches of green peas and sweet pepper of same weights were also stored at -12°C without blast freezing for comparison.

The chemical changes in the stored samples were determined at intervals of seven days, fifteen days and thirty-one days at the storage temperature of -12°C. The results showed that the samples that were blast-frozen before storage were of better quality as compared to samples that were slow-frozen.

1. INTRODUCTION

Post-harvest losses in perishable crops in developing countries is reported to be as high as 35-40% (FAO 1981). It is more economical to conserve what is produced than to produce more to compensate for subsequent losses. The losses due to spoilage and deterioration in fruits and vegetables between the time immediately after harvest and time they are sold in the retail markets may be reduced by controlling the storage environment.

The deterioration of fruits and vegetables may be due to physical, physiological, biochemical or pathological factors. Since these factors are common to all, and they vary in extent depending on the type of fruits and/or type of vegetable, the principle involved in reducing the deterioration are essentially the same regardless of the product or region of production. Fruits and vegetables are the main sources of vitamins and other essential minerals which serve the body in a balanced diet. Taking into consideration the important role fruits and vegetables play in the diet of human beings it is imperative that the production and consumption of these be increased. It is also important that attention be given in the production sector to increase production to about three seasons a year for the well being of the population.

The vital role which fruits and vegetables play in human diet makes post harvest preservation very important especially during the lean season. An even consumption of fruits and vegetable throughout the year will improve the health and well being of the population (Barkaya and Ladishancki, 1989).

Food products are complex substances of water, protein, vitamins, mineral salts and organic acids. All fruits and vegetables are very important sources of carbohydrates, mineral salts and most of all, vitamin C. The chemical composition of fruits and vegetables are varied and unequal.

Fruits and vegetables can be preserved by different methods. From literature (FAO 1960) and by works carried out by the Department of Food Technology and Preservation (Krarnodar, USSR), one of the best methods of food preservation is the use of cold storage (freezing and refrigeration) techniques.

Food products in Ghana are seasonal and therefore, there is the need to preserve enough of this for the lean seasons. As much as possible food quality substances should be retained in them. The choice of methods of food preservation depends on the end products, taking into consideration the maximum retention of food nutrients at the end of processing and storage. The purpose of this study was to determine the effect of freezing rates as a pretreatment on the quality of pepper and green peas during storage at -12°C.

2. LITERATURE REVIEW

2.1 General

"Perishable Food Crop" is a term applied to food commodities which have a relatively short shelf-life. These may include many types of fruits and vegetables including roots and tubers. Fresh fruits and vegetables in particular, require carefully controlled storage conditions if adequate shelf-life and quality standards are to be maintained. However, due to differences in the physiological and reproductive characteristics, as well as the physical structure of many fruits and vegetables, they have different sorage potentials.

There are two main types of factors that may influence deterioration in a food product. These factors are pre-harvest and post-harvest. Pre-harvest factors which may influence the keeping qualities include the cultivar of the produce used and cultural practices. Harvesting period and handling before storage are some of the post-harvest factors.

The type of deterioration depends on the characteristics of the storage environment (Burton, 1973). It is therefore necessary that the storage conditions are favourable for delaying the onset of senescence in matured produce. Also the conditions should be such that, partially matured produce can be held without deterioration so that it will mature gradually until required for consumption.

The problems of preserving plant food produce are many and it needs specialists of many disciplines such as, technologists, biochemists, microbiologists, and many others. The choice of the best method of storage for fruits and vegetables should be one that will slow down physiological processes in the matured produce to prolong the shelf-life. It is also envisaged that such a method will preserve the taste, consistency, external appearance and the produce should maintain its freshness as best as possible.

2.2 Preservation By Use Of Low Temperatures

Low temperatures are used to retard chemical reactions the action of food enzymes and to slow down or stop growth and activity of micro-organisms in food. The lower the temperature, the slower will be the chemical reactions, enzyme action, and microbial growth, and a low enough temperature will prevent the growth of micro-organisms.

Any raw plant or animal food may be assumed to contain a variety of bacteria, yeasts, and moulds which need only good conditions for growth to bring about undesirable changes in the food. Each group of micro-organisms present has an optimal, or best temperture for growth and a minimum temperature below which it cannot multiply. As the temperature drops from this optimal temperature toward the minium, the rate of growth of the organisms decreases and is slowest at the minimum temperature. Cooler temperatures will prevent growth, but slow metabolic activity may continue. Therefore, the cooling down of a food from ordinary temperatures has a different effect on the various organisms present. A drop of 10°C might stop the growth of some organisms and slow down the growth of others but to an extent that would vary with the kind of organisms. A further decrease of 10°C in temperature would stop growth of more organisms and make still slower growth of others. Low-temperature storage can therefore act as a significant environmental factor influencing the type of spoilage flora to predominate.

The growth and metabolic reactions of micro-organisms depend upon enzymes, and the rates of enzyme reactions are directly affected by temperature. The most important aspect of this temperature effect is reflected in a decrease in the rate of growth of a micro-organism when the temperature is lowered.

2.3 Chilling or "Cold Storage"

Chilling storage is carried out at temperatures not far above freezing, and usually involves cooling by ice or by mechanical refrigeration. It may be used as the main preservation method for foods or for temporary preservation until some other preservation process is applied. Most perishable foods, including eggs, dairy products, meats, seafood, vegetables and fruits, may be held in chilling storage for a limited time with little change from their original condition. Enzymatic and microbial changes in the foods are not prevented, but are slowed down considerably.

2.4 Freezing or Frozen Storage

The storage of foods in the frozen condition has been an important preservation method for a long time where outdoor freezing temperatures were available. Under the usual conditions of storage of frozen foods, microbial growth is prevented entirely and the action of food enzymes is greatly retarted.

2.5 The Use of Cold in the Preservation of Plant Food Produce

The choice of the best method of storage of fruits and vegetables implies the extension of shelf life as a whole. This involves slowing down of ripening, growth of and spoilage by microbial organisms. At the same time steps must be taken to maintain the taste, consistency, external apppearance and state of freshness on the whole. Also the choice of method of storage requires a good knowledge of environmental, biological and technical characteristics of the produce. The environmental knowledge should take into consideration the biological characteristics of the produce, like species and then the length of the shelf life are also important. Produce like potatoes after harvest must be stored in an environment that will slow down its physiological processes to the best minimum level. Produce like tomatoes, pepper, and green peas require storage conditions which are favourable for delaying the onset of senescence in the matured produce or to provide conditions in which partially matured produce can be held, without deterioration, so that it will mature gradually until required for consumption.

In storing any given crop the objective is to reduce the factors of deterioration as much as possible by controlling the most important factors. In achieving this objective however, it is often possible that the conditions imposed could have some side effects. For example, a reduction in water loss as well as storage temperature may be achieved by maintaining a high level of humidity. However, thelatter condition promotes the growth of micro-organisms which could lead to pathological deterioration. Thus in every situation a compromise in the adjustment factors is sought in order to achieve the best possible storage environment.

The tropical climate, with its features of high temperature all the year round and, in some areas, high humidity make the solution to the storage of friuts and vegetables much more difficult. For example, it has been established that the storage life of fruits and vegetables can be extended by storing them at low temperatures.

Life processes in fruits and vegetables continue during periods of storage in the fresh forms. If during growth we have mainly anabolic processes occuring in them, after harvest and during storage we have mainly catabolic processes occuring. The main physiological process during storage is respiration in fruits and vegetables.

The oxidation of one-gram of glucose releases about 2824 KJ of energy.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2 + Q$$

It could be seen from the chemical formula that the volume of oxygen needed for the oxidation and the amount of carbon dioxide released are the same, this is known as the respiration constant. In this case the value of the respiration constant is equal to one

$$\frac{6CO_2}{6O_2} K = 1$$

2.5.1 Temperature

Another important factor in the deterioration of fruits and vegetables after harvesting is temperature. The amount of carbon dioxide released during respiration depends on the ambient temperature as expressed by Gora:

$$RT = R_o^{\exp Bt}$$

where Rt - Intensity of released CO_2 at a given temperature

R_o - Intensity of released CO_2 at zero temperature 0°C.

T - Storage temperature 0°C

B - Temperature coefficient

$$q_t = q_o^{\exp bt}$$

where q_t - amount of energy released at temperature of t BT/Ka

q_o - amount of energy released at temperature of zero BT/Ka

Temperature is a very important factor in the regulation of respiration in produce. At low temperatures almost all life activities in produce come to a stand still. It could be said therefore, that the best storage temperatures would have been the lowest, close critical, or freezing points of the intercellular water in the produce.

In order to prolong the self-life and reduce losses after harvesting, life processes must be reduced to the barest minimum.

2.5.2 Biochemical Processes

The intensity of biochemical processes in fruits and vegetables is directly related to the period of storage; the higher the intensity of respiration (metabolic processes) the faster the produce ripens and deteriorates. The vitamin content reduces including acidic substances. The intensity of metabolic processes increases with an increase in temperature and at a temperature of about +30°C the activity may increase about 20 - 30 times. Biochemical reactions of breakdown and respiratory processes intensifies after the harvesting of fruits and vegetables. This, therefore requires that refrigeration or freezing of produce should be done fast and immediately after their harvesting.

The role of refrigeration is very important since it serves as the first technological process in the preservation of the produce and finally determines the quality of the end product.

The technology of refrigeration results in the lowering of the produce temperature by removing the heat energy from the produce to the surrounding. The lowest temperature allowed is that critical temperature at which water droplet start to crystalize in the cells and intercelluar spaces. At this critical temperature, microbiological and biochemical processes come to a stand still, as well as fermentative activities in the produce.

2.5.3 Cell Division

The rate of cell division in micro-organisms depends on temperature. In many micro-organisms an increase in a temperature of 2°C could effect a cell division of 1.5 - 2.0 times. In thermophylic and mesophylic micro-organisms the normal temperature for growth is between 2 - 30 °C. Life processes in these come to a standstill at a critical temperature of between -1°C to -3°C.

The rate of cell division in micro-organisms at 0°C for example is ten times less than at their maximum rate at higher temperatures. It is therefore necessary to reduce the number of micro-organisms in produce which is a factor in deterioration by reducing the temperature to the lowest possible.

2.5.4. Blast Freezing

Blast freezing or fast freezing is a modern and progressive method in food preservation. It has been observed that in blast freezing as compared to other methods of refrigeration, the produce are well preserved and have longer shelf life. A lot of produce can be blast frozen without having any mechanical damage as in other methods. The taste, colour and form are maintained as best as possible in the process of blast freezing. Blast frozen produce can be used in a variety of recipes for consumption. Blast frozen produce can also be stored for longer periods. Produce meant for blast freezing must be harvested at the biological state of maturity and be of good quality.

Freezing temperatures are chosen according to the type and nature of the produce. A freezing temperature of -30°C and lower are generally used.

3. EXPERIMENTAL PROCEDURE AND METHODOLOTY

3.1. Objective

The objective of the project was to determine the effect of blast freezing on the keeping qualities of sweet pepper and green peas. The chemical changes in the produce was determined after periods of seven days, fifteen days and thirty-one days at a storage temperature of -12°C.

3.1.1 Peppers

Peppers come from the fruit of the capsicum or chillie plant (Capsicum frutescens and capsicum annum). They are also known as Paprika, chilli, pimento, cayenne or red pepper. Pepper is used as a garnish and pungent flavouring. The hot pungent taste in red pepper is due to capsaicin. For preservation, pepper must be in the state of technical or biological ripenness, must have a smooth surface, the mesocarp at the technical ripenness should not be less than 4mm in thickness and at biological ripenness should not be less than 5mm. The produce must have its characteristic aroma, be of high dry weight and contain vitamin C. The taste must be characteristic for the chosen species. The produce must be mature green to fully red. The length of the produce must be between 70 - 90 mm and diameter 4 - 50 mm. The overall dry weight must be about 99%.

3.1.2. Green Peas

For preservation, green peas must be smooth on the surface and must have green colouration. Green peas must contain about 6% of protein, 30mg of vitamin C in 100g of the produce. The produce must contain about 7% of sugars and less carbohydrate.

3.3 Methodology

3.3.1 Sample preparation, Blast freezing, and Storage

For blast-freezing, a freezing apparatus "ILKA" GDR was used. The produce was kept in the apparatus for 30 mins. to attain a temperature of -18°C, for 60 minutes to attain a temperature of -30°C and 90 minutes to attain a temperature of -60o°C.

For slow freezing, the produce was kept in apparatus "FRESERA". The product was kept at -12°C throughout the experiment.

3.3.2 Determination of Dry Weight

Some sample of the pepper was well grinded and 50g samples were weighed into three different petri-dishes with known weight of fine sand. The samples were then placed in a moisture oven with draft at a temperature of between 120 - 130°C for 30 minutes to inactivate enzyme. The temperature was then reduced to between 100 - 105°C for 4 - 6 hrs. Until a constant dry weight was achieved. The samples before weighing were each kept in a dessicator to cool down to room temperature. The mean weight was then determined from the three samples. The amount of water loss was calculated in percentage by the undermentioned formula:

$$X = \frac{H-H_1}{100} 100$$

where X = water content in %

H = original mass of the sample in grams

H_1 = mass of sample after drying in grams.

The weighed sample was mixed well with the fine sand sample and the results calculated by the formula below:

$$X = \frac{M_2 - M}{M_1 - M} 100$$

where M = mass of dish plus sand and stirrer in grams

M_1 = M plus mass of sample before drying in grams

M_2 = M plus mass of sample after drying in grams

The differences in the weights of the three samples should not be more than 5%. The mean is then determined.

$$\text{Mean } \bar{M} = M/R,$$

$$B = (L/M)x100$$

$$M = \frac{(M - \bar{M})^2}{n - 1}$$

where M - sum of all variants

M - average

n - number of variants

3.3.3 Determination of Vitamin C

Vitamin C (D-ascorbic acid), $C_6H_8O_6$ in fruits and vegetables are of two main forms; of basic and acidic. The two forms are physiologically active. The method of determining the ascobic acid depends on its basic properties.

A weight of the material of between 10g and 30g is taken n the analytical balance. Fifty (50)ml of 4% solution of hydrochloric acid is added to dissolve the sample. The solution is then kept for between 10 - 15 minutes. The mixture is then poured into a 100ml measuring cylinder or a 100ml conical flask and the ixture is well shaken to get an even mixture. 25 ml portions of the resultant mixture is titrated fast against 2,6 dichloro - benzaldehyde. The amount of vitamin CX (in mg) of 100gm product is then calculated by the under- mentioned formula:

$$X = \frac{a.k.V_1,V_3,0,088.100}{g.\ V_2 + V_4}$$

where a = quantity of 0.001 N solution of 2,6 dichloro benzaldehyde

K = coefficient of 0.001 N of solution 2,6 dichloro benzaldehyde from table

V_1 = volume of measuring cylinder or conical flask, ml.

V_2 = volume taken for the titration: ml.

V_3 = volume of the sample taken: ml.

V_4 = volume of extract taken before addition

g = quantity of ascobic acid corresponding to 1 ml. of 0.001 N 2,6 dichloro benzaldehyde.

3.4 Determination of Reducing Sugars

The method of determining reducing sugar depends on its reducing properties. The oxidation of sugar in a basic medium in the presence of ferric salt.

$$2K_3Fe^{+3}(CN)_6 + 2KOH \longrightarrow 2K_4Fe^{+2}(CN)_6 + H_2O + O$$

In a conical flask of 100 ml volume a prepared sample is measured. Then 20 ml. of $K_3Fe^{+3}(CN)_6$ and 5 ml. NaOH solutions are added. Then 5 - 6 drops of indicator methyl blue is added. The mixture is then heated just to boiling point and then titrated hot.

Calculation of reducing sugar, X (%)

$$X = \frac{K\ (20.12 + 0.035.v)\ a}{10v}$$

where K - constant of K3Fe(CN)6 by table

V_1 - 20.12 plus 0.035 empherical coefficients. table

v_2 - volume of sample taken for the titration ml

a - factor of dilution.

3.5 Definition of Sugar (General)

From a 100 ml measuring cylinder 50 ml of the sample is taken then 5 ml concentrated hydrochloric acid added. The mixture is then allowed to stand 8-10 mins. in water bath at a temperature of between 68 - 70°C. The content of the conical flask is then cooled to 20°C and then neutralized with 20% sodium hydroxide. The flask is then filled to the mark with distilled water. The titration is carried our as with reducing sugars.

Calculation

$$X = \frac{G.\ V.\ 100}{a, v,\ 100, 1000} \quad \frac{V_2}{V_3} = \frac{G}{da}$$

$$X = \frac{G.\ V.\ 1000}{a,\ 100, 1000} = \frac{G}{4a}$$

4. RESULTS AND DISCUSSION

The results of the various physical measurements made on the freezing and storage of sweet pepper and green peas presented in the Tables that follow. The corresponding Graphs are shown in the Appendix. Figures 1-9 show the variations in Dry weight, Vitamin C, and Sugar of the produce under test over a period of days. Tables 1-10 represent the recorded results of variations over a period of days in dry weight, vitamin C and sugar.

The results obtained suggest that, in the "Slow Freezing" of green peas and sweet pepper and subsequent storage at -12°C the weight loss was manifest in the first days. The overall weight loss over the 31 days period was between 6 - 7% (Tables 1 and 2).

For the "Fast Frozen" produce which were stored at -12°C, the quality was better. This can be attributed to the formation of small crystals of water in the produce instead of bigger crystals of water in the "slow frozen" produce.

In Table 1, it was observed that for the first 7 days of storage at a temperature of -12°C the loss in water content for green peas was 25%. In Table 2 sweet pepper which was fast frozen and stored at -12°C had a weight loss of 15.6% in the first 7 days. For the rest of the 24 days of the experiment the weight loss was 10%.

The results obtained show that with green peas the loss of vitamin C content over 31 days of the experiment was 30% after the poduce has been fast frozen and stored at - 12°C. The changes in vitamin C content was pronounced in the first 10 - 15 days of the experiment after which it was fairly stable (Table 3).

Table 1. Effect of freezing temperature on the changes in the Dry weight of Green Peas during storage at -12°C.

No. of Days	Dry Weight (%)		Freezing Temperature(°C)
	Final	Initial	
7	25,2		
15	26,1		
21	25,8	20,2	-18
31	27,3		
7	28,1		
15	28,9		
21	29,3	20,2	-30
31	29,7		
7	28,1		
15	29,4		
21	29,3	20,2	-60
31	30,1		

Table 2. Effect of freezing temperature on the changes in the Dry weight of Sweet Pepper during storage at -12°C.

No. of Days	Dry Weight %		Freezing Temperature oC
	Final	Initial	
7	10,4		
15	10,9		
21	11,6	7,8	-12
31	11,9		(Slow freezing)
40	12,6		
7	9,8		
15	10,2	7,8	-18
21	10,4		
31	11,7		
40	12,3		
7	10,6		
15	11,2	7,8	-30
21	11,1		
31	12,8		
40	11,9		
7	9,2		
15	10,6		
21	9,8	7,8	-60
31	11,2		
40	12,5		

Table 3. Effect of freezing temperature on the changes in the Vitamin C content of Green peas during storage at -12°C.

No. of Days	Vitamin C (mg/100g)		Freezing Temperature (°C)
	Final	Initial	
7	24,5		
15	23,6	31,5	-18
21	20,2		
31	18,5		
7	20,3		
15	18,6		
21	18,5	29,5	-30
31	17,8		
7	20,7		
15	18,6		
21	19,7	28,8	-60
31	17,7		

With sweet pepper the loss in vitamin C content was 25% in the first 10-15 days of the experiment under the above mentioned conditions of the experiment. In considering the different temperatures of freezing before storage, -30℃ had a 16% loss in vitamin C content in the first 7 days, and 5.6% within the remaining 24 days (Table 4).

In the storage of sweet pepper at -12℃ after fast freezing at temperatures of -18℃, -30℃ and -60℃ it was observed that, at -30℃ the loss in sugar content was 13% (Table 5). In green peas the changes in the sugar content of the produce frozen at various temperatures was 16% during the first 7 days of the experiment (Table 6).

Table 4. Effect of freezing temperature on the changes in the Vitamin C content of Sweet Pepper during storage at -12°C.

No. of Days	Vitamin C mg in 100g		Freezing Temperature (°C)
	Final	Initial	
7	84		Slow freezing at -12
15	82		
21	78	125	
31	77		
40	78		
7	98,5		
15	90,6		
21	84,0	125	-18
31	85,0		
40	84,0		
7	105		
15	100		
21	100,5	125	-30
31	98		
40	99		
7	85		
15	85		
21	84	125	-60
31	80		
40	78		

Table 6. Changes in the sugar content of Sweet Pepper frozen at different temperatures and stored at - 12°C.

No. of Days	Sugar Content %		Freezing Temperature (°C)
	Final	Initial	
7	2,4		
15	1,8		
21	2,0	3,1	-12
30	1,8		(Slow freezing)
40	1,6		
7	2,6		
15	2,5		
21	2,2	3,1	-18
31	2,3		
40	2.0		
7	2,8		
15	2,7		
21	2,7	3,1	-30
31	2,6		
40			
7	2,5		
15	2,6		
21	2,5	3,1	-60
31	2,4		
40	2,3		

6. RECOMMENDATIONS FOR FURTHER WORK

This project was a preliminary work and, because of limited time available during the short farming season in the USSR, a number of important tests which were required to assess and define other parameters and produce were not done. The following should therefore be considered for further work.

1. The produce could be stored for longer periods to determine their storage life.

2. Monitoring of the parameters could be spaced out during longer periods of storage.

3. The storage temperature could be varied to determine the best storage temperature after the produce has been blast frozen.

4. Other perishable food crops like tomatoes could be experimented upon to prolong their storage life for use during the lean seasons.

5. Factors such as relative humidity, air velocity and composition of the atmosphere in the store room may also be considered.

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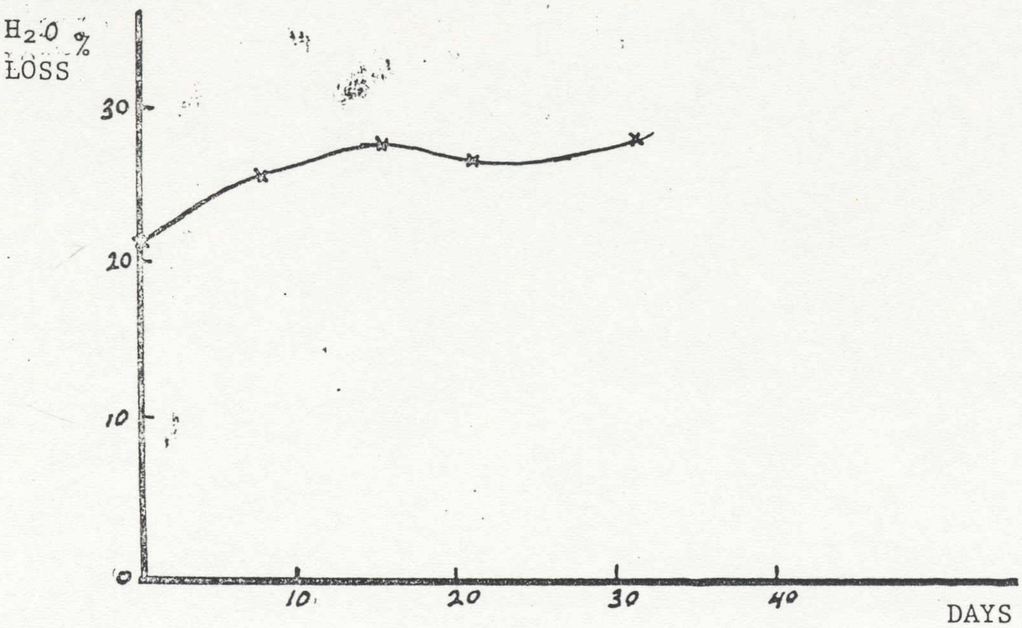
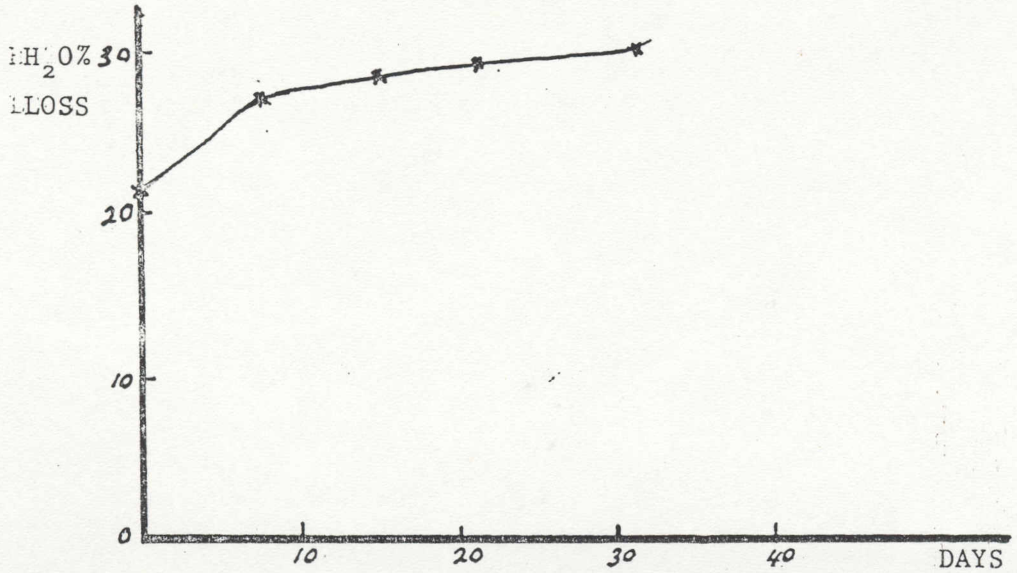
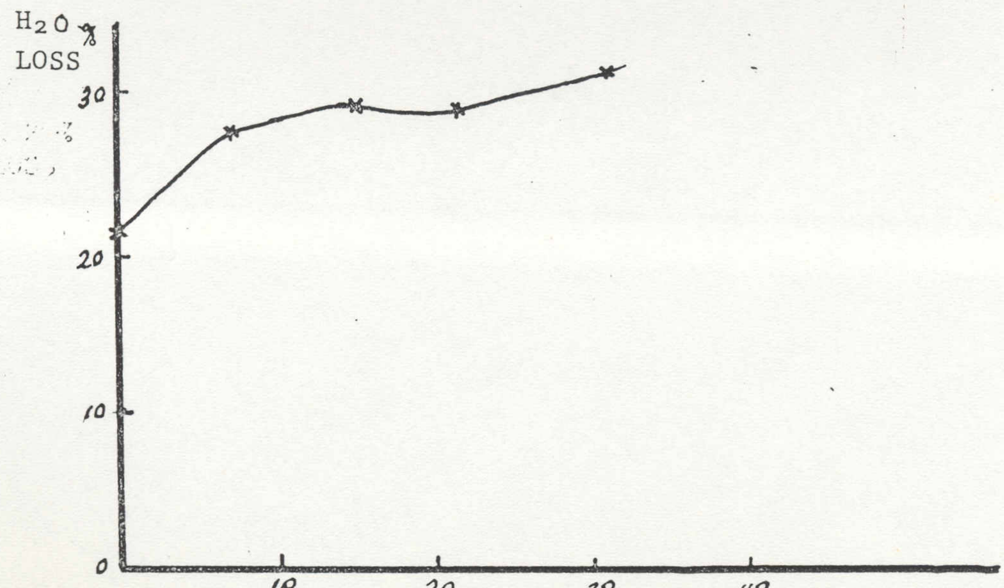
8. APPENDICES

DEFINITION OF DRY WEIGHT AFTER FREEZING AND STORAGE - GREEN PEAS

GRAPH 1

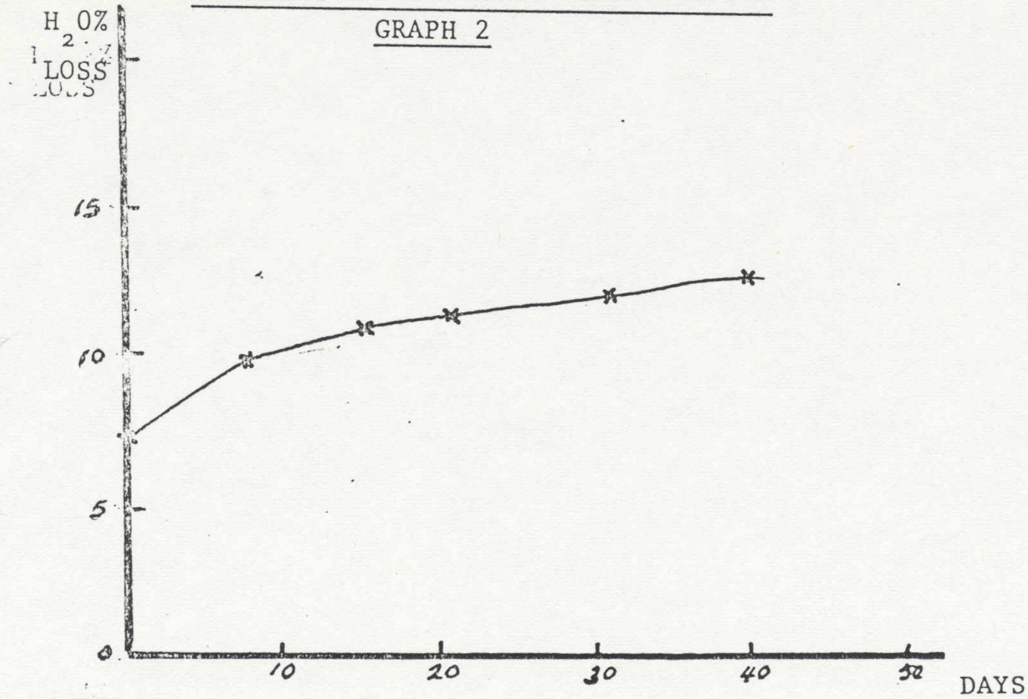


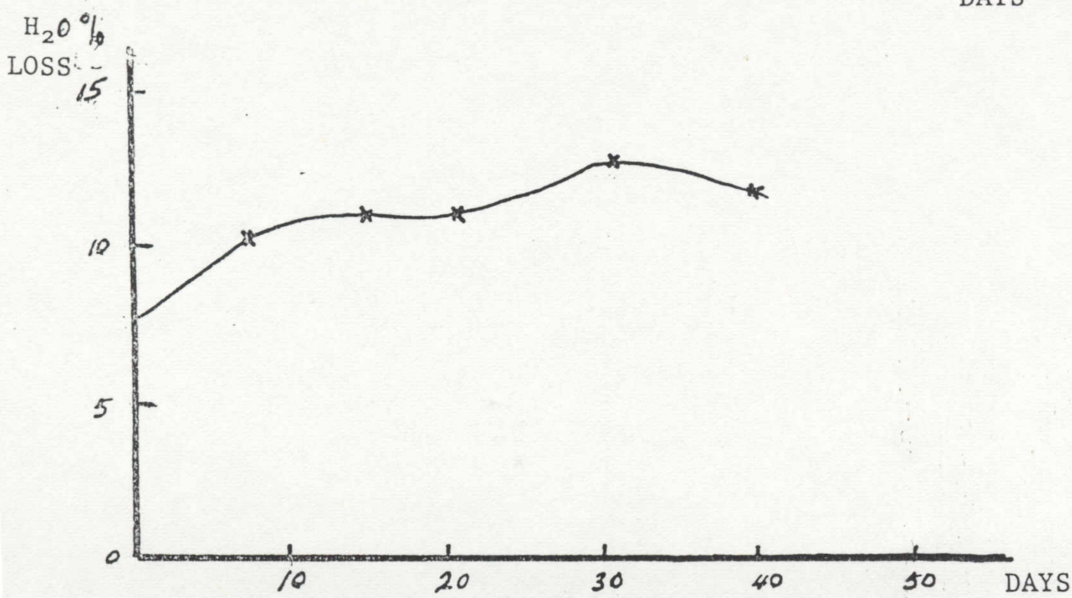


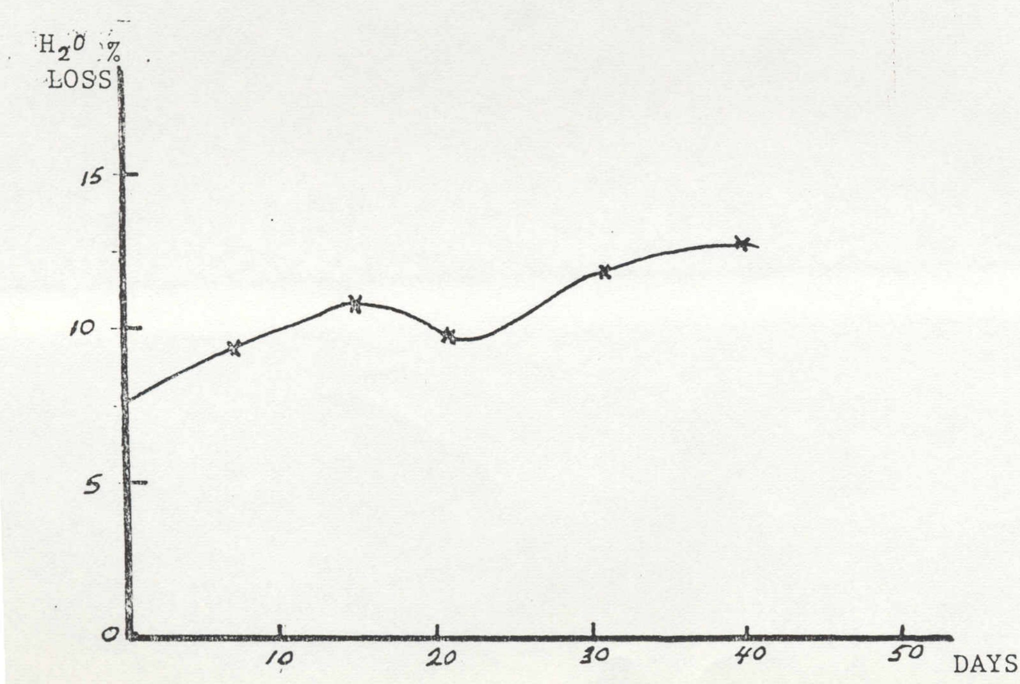


DEFINITION OF DRY WEIGHT AFTER
FREEZING AND STORAGE - SWEET PEPPER

GRAPH 2

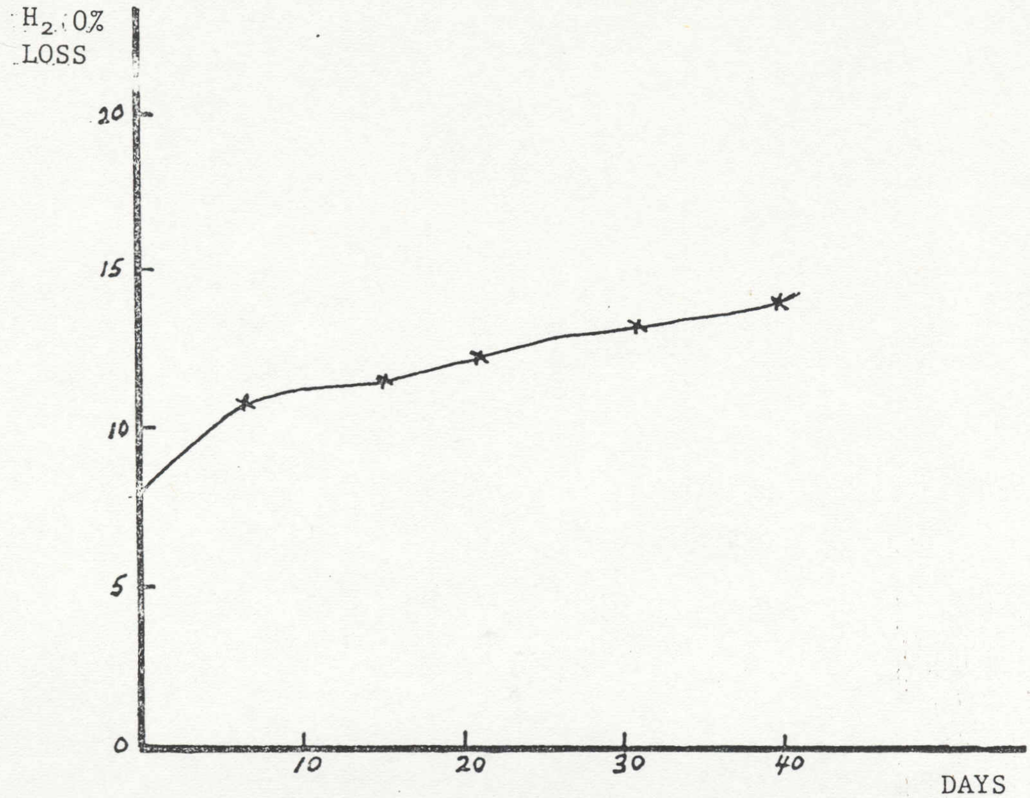






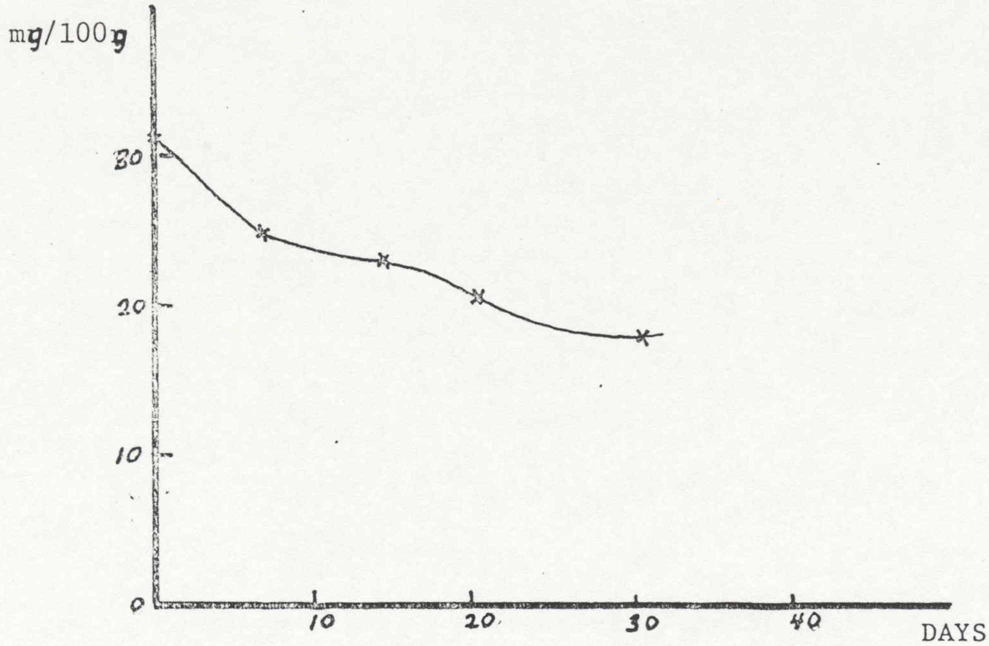
DEFINITION OF DRY WEIGHT AFTER SLOW FREEZING AND STORAGE - SWEET PEPPER

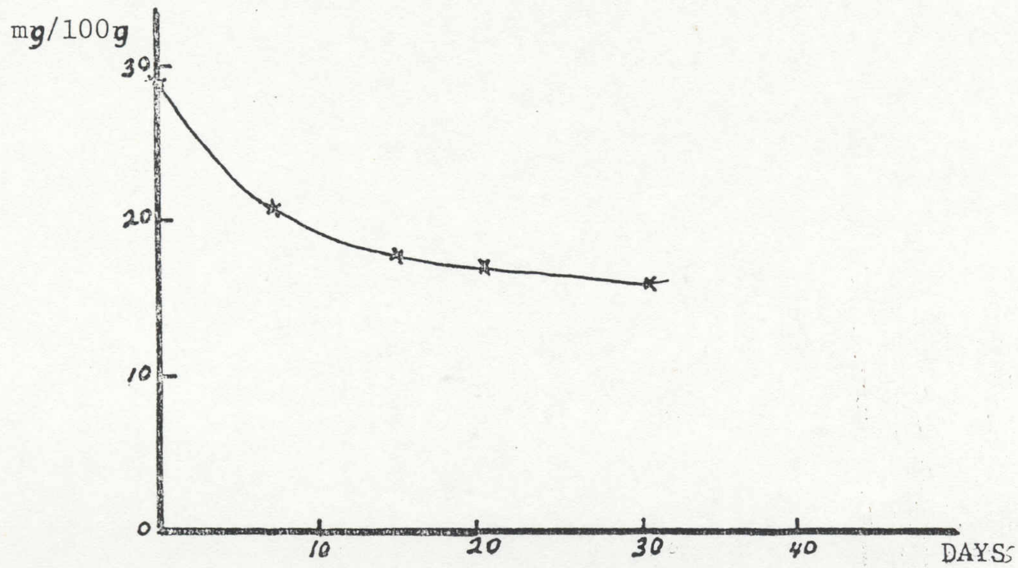
GRAPH 3

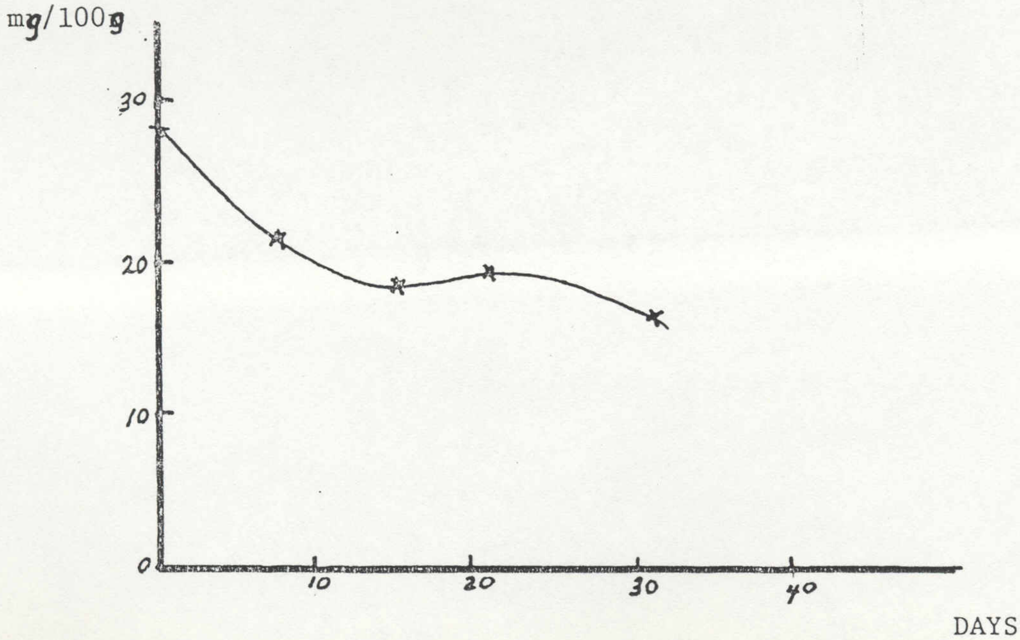


CHANGES IN VITAMIN C CONTENT AFTER
FREEZING AND STORAGE GREEN PEAS

GRAPH 4

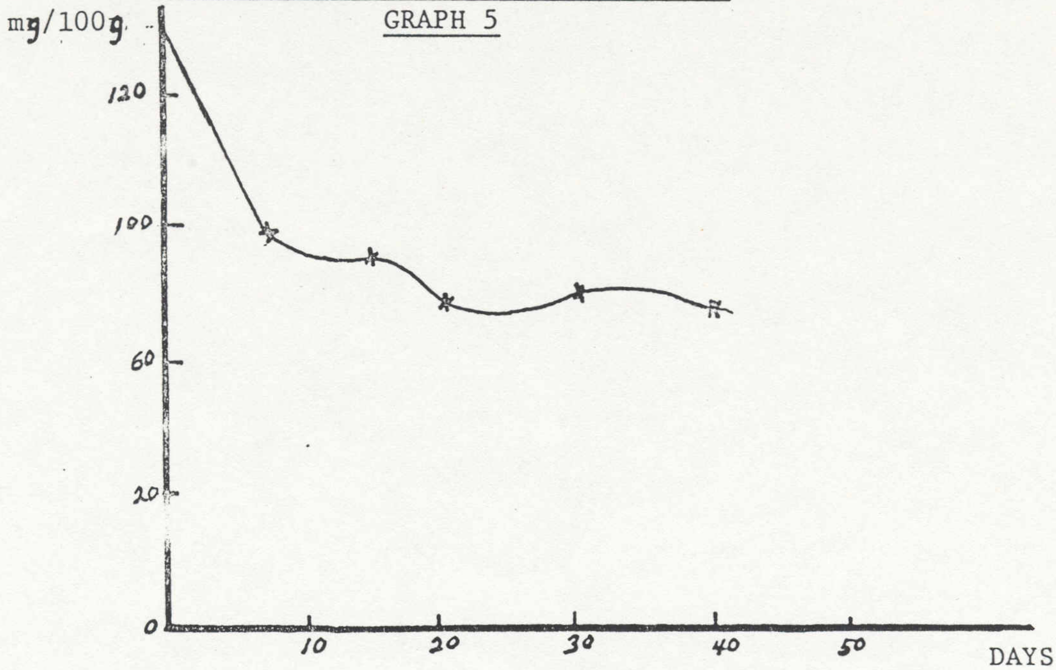


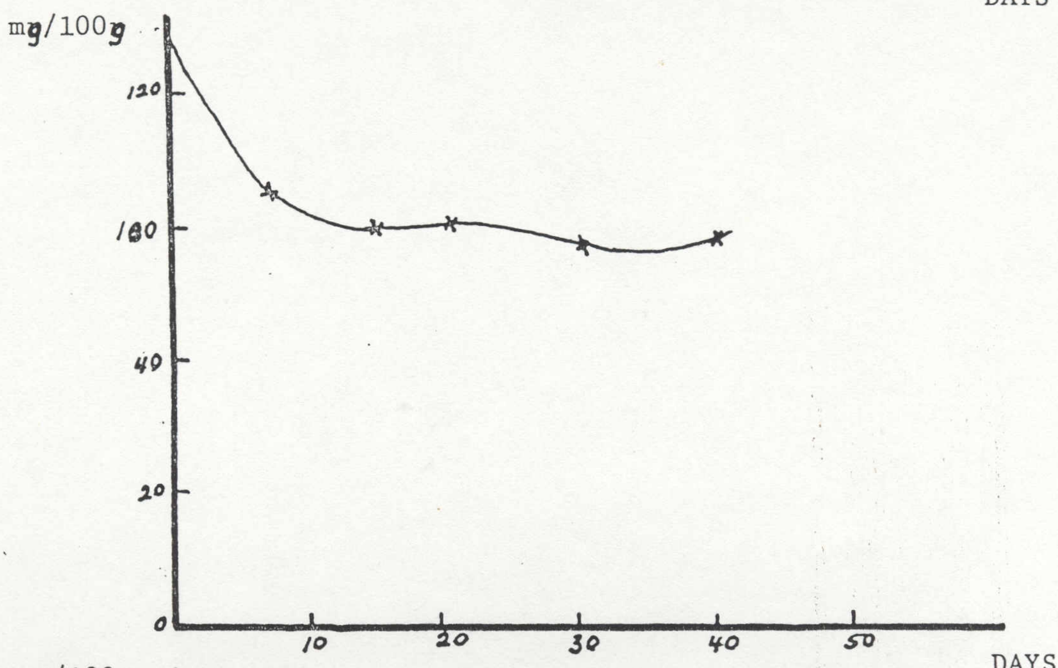


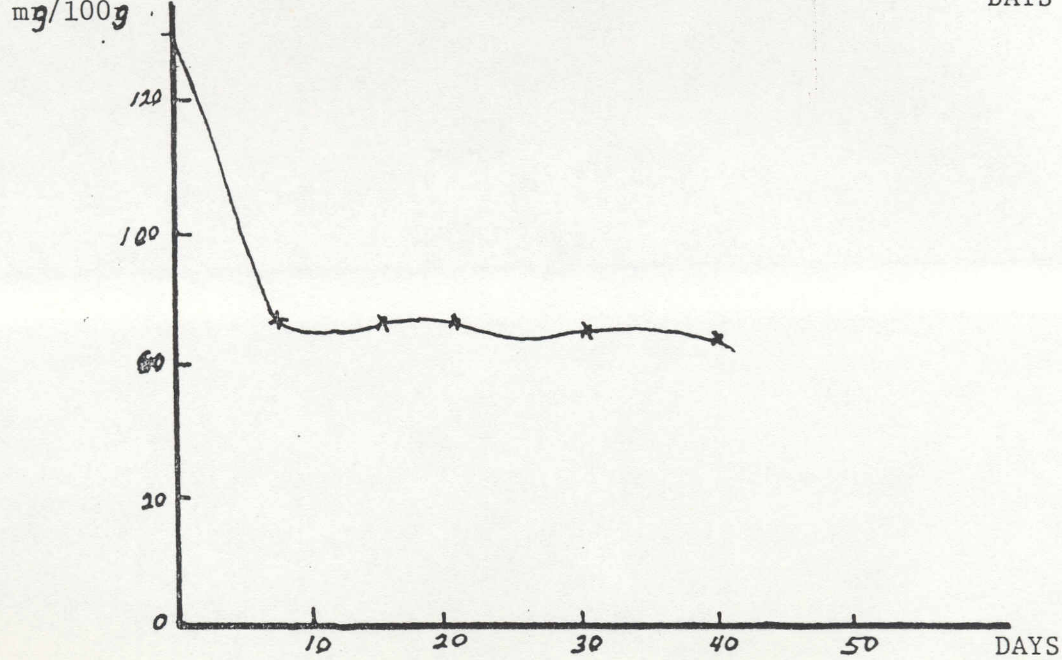


CHANGES IN VITAMIN C CONTENT AFTER FREEZING AND STORAGE - SWEET PEPPER

GRAPH 5

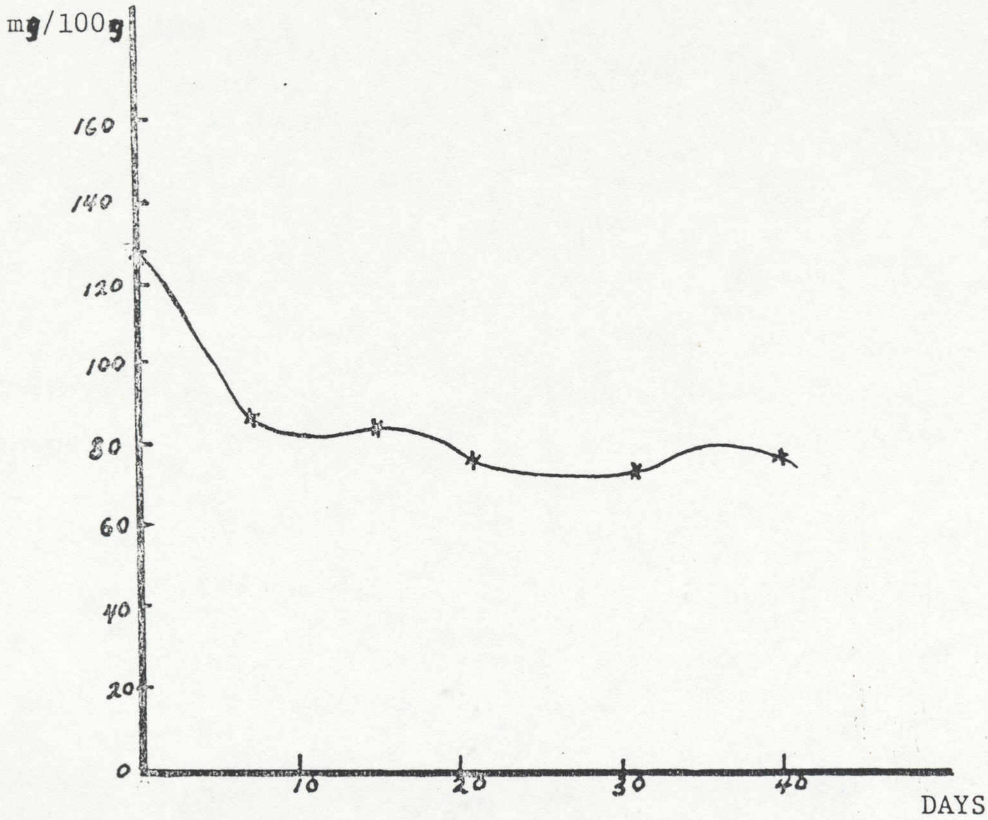






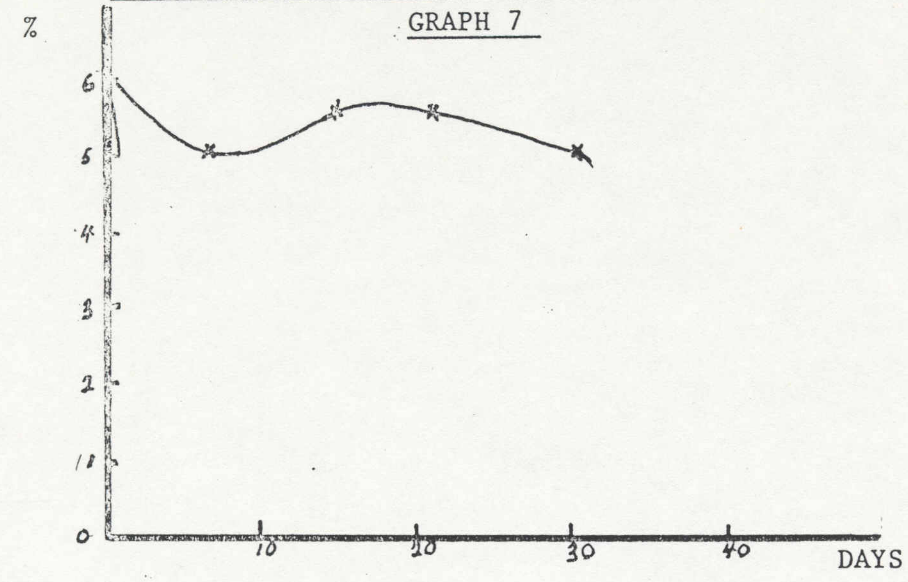
CHANGES IN VITAMIN C CONTENT AFTER SLOW FREEZING AND STORAGE - SWEET PEPPER

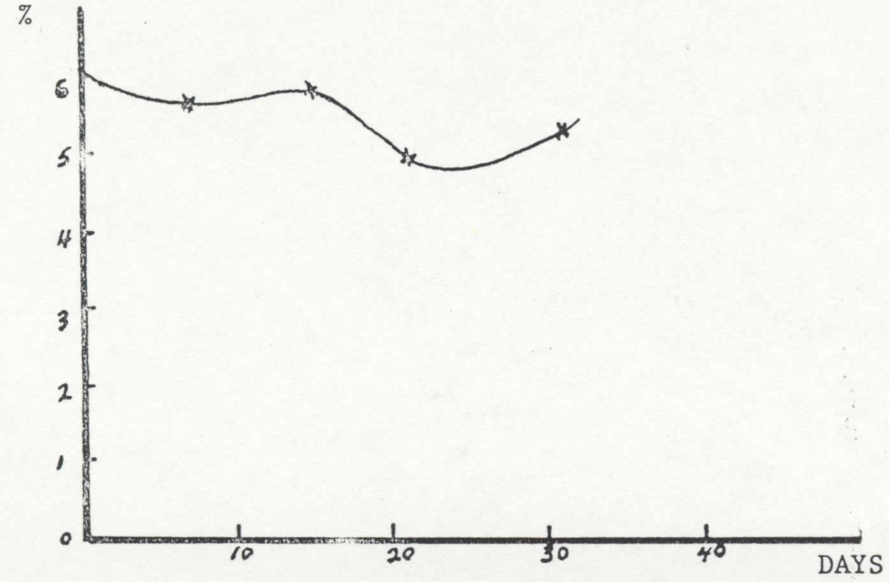
GRAPH 6

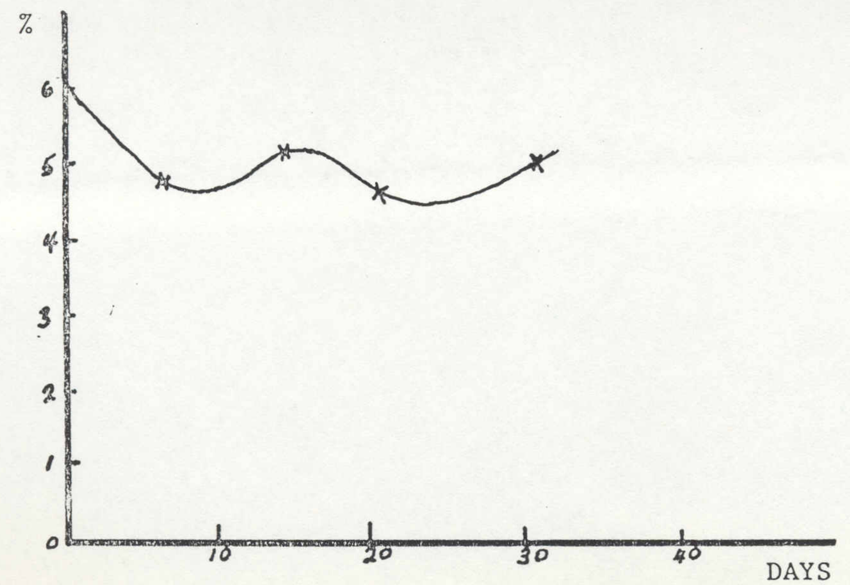


CHANGES IN SUGAR CONTENT AFTER FREEZING AND STORAGE - GREEN PEAS

GRAPH 7

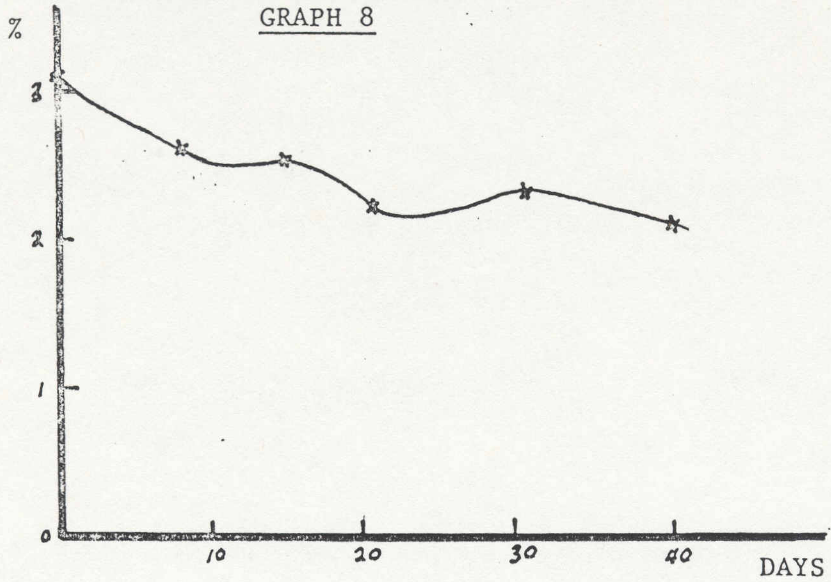


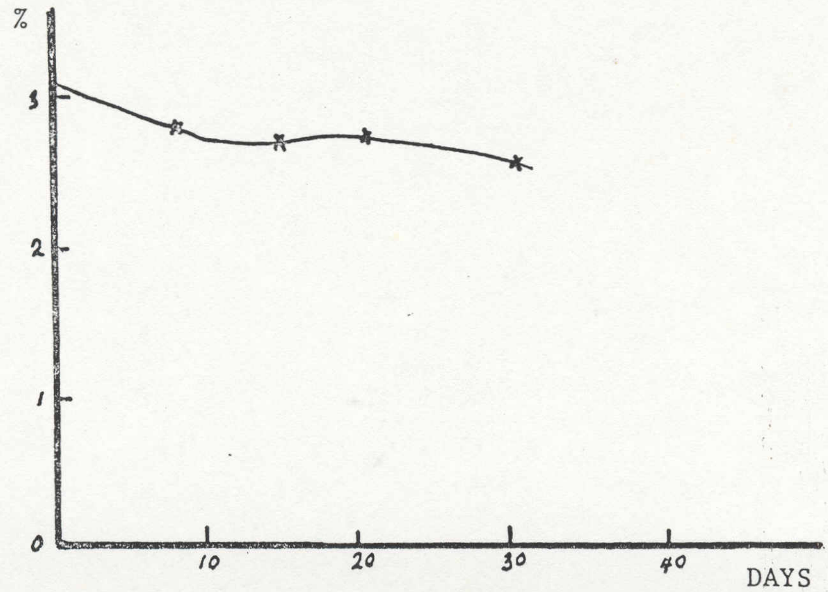


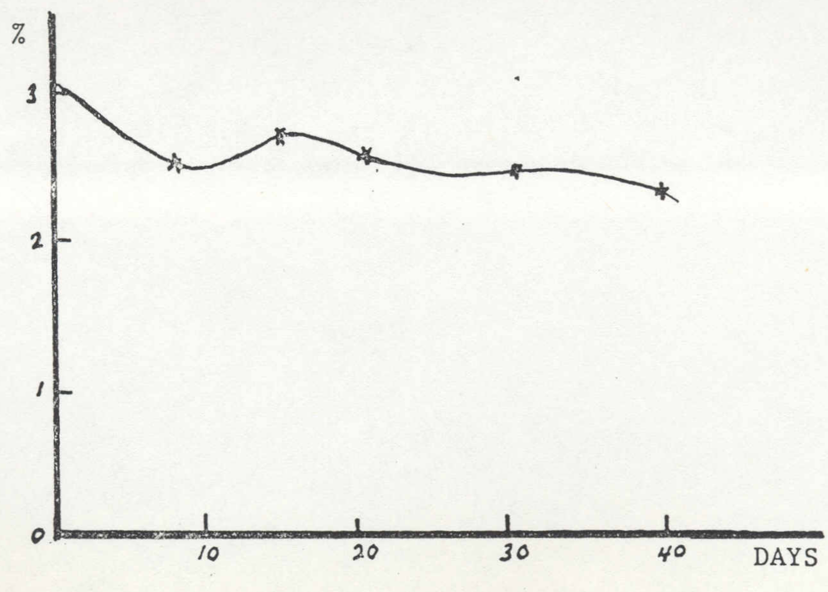


CHANGES IN SUGAR AFTER FREEZING
AND STORAGE - SWEET PEPPER

GRAPH 8







CHANGES IN SUGAR CONTENT AFTER SLOW FREEZING AND STORAGE - SWEET PEPPER

GRAPH 9