DETERMINATION

OF

FREEZING RANGE TEMPERATURES

OF

STRAWBERRIES, GRAPEFRUIT, AND APPLES

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A THESIS SUBMITTED FOR THE DEGREE

OF

BACHELOR OF SCIENCE

MECHANICAL ENGINEERING COURSE

THE UNIVERSITY OF TENNESSEE

1931

ACKNOWLEDGEMENT

I wish to express my appreciation and indebtedness to Professor W. R. Woolrich and Mr. Paul Scates for their assistance and cooperation in the preparation of the material contained in this thesis.

CONTENTS

ILLUSTRATIONS

BIBLIOGRAPHY

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INTRODUCTION

For a number of years, in fact, until recently it was thought that there was little or no use for data explaining whether a fruit or vegetable had a freezing point or if it had a range of freezing that required the lowest point on the range to be reached before being completely frozen. Since it was known that fruits were composed of a number of different elements or compounds and each of these had a different effect upon the depression of the freezing point of the other, it was reasonable for one to assume that the elements composing these different compounds would freeze only when the temperature was lowered to a point below the freezing point of any of the elements composing it. Then if this were the case, the portion of the fruit frozen at a certain temperature would depend on the amount of elements that went to make up the fruit whose freezing point was above that temperature. Therefore, at different temperatures below the point that the fruit or vegetable began to freeze, a portion of it was frozen only until the lower point on the freezing range was reached.

The problem of the quick freezing of foods is the reason for this investigation. The different cells which compose the fruit contain water plus certain salts, sugars, and starches. These materials do not have latent heats of fusion at normal (room) temperature. With these facts in mind, the following theories are the basis of this investigation.

The cell growth theory assumes that ice crystals grow larger the longer the period of freezing. Short freezing periods produce small crystals. Long freezing periods produce large crystals. If the crystals grow large, they pierce the cell wall, thus letting the juices flow from within the cell.

The osmosic theory assumes that one cell freezes before its adjacent cell. The liquid that freezes in the cell first is water, thus leaving a more concentrated solution for freezing at a lower temperature. Now if one cell has some of its water frozen out and a second cell has not, and both cells originally had cell liquids of equal concentration then after the first cell has some of its water frozen, we have two cells side by side with different concentrations of unfrozen liquid.

By the law of equilibrium of solution the two cell concentrations will try to equalize. Water from the weaker solution will pass into the second. If time is permitted, a larger amount of solution will exist in the first than in the second and together with the expansion occurring at freezing, the cell capacity will be exceeded and the cell will rupture.

However, if the food is rapidly frozen or what is known as "quick-frozen" by freezing rapidly and quickly, the cells of the food do not have time to rupture as when frozen slowly. Then, if these cells are not ruptured in the process of freezing, the defects that occurred before will not be present. The fruits treated by the "quick-frozen" process then will have all of the characteristics of fresh fruit as has been shown by experiment.

In order to obtain the "quick-frozen" condition, it must be known to what extent the freezing of the food takes place. This fact is because it is quite necessary that it be known when the food is completely frozen, otherwise it would not be of any value since the portion unfrozen would contaminate the remainder. Then, it can be seen, the object of this experiment is to ascertain the range of freezing of these fruits and the point at which the fruit is completely frozen.

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LATENT HEAT METHOD OF FREEZING RANGE DETERMINATION

In obtaining freezing ranges of fruits, a number of methods have been tried, but it has been found that the most satisfactory method is the latent heat method.

When heat is applied to a crystalline solid and heat is slowly transferred to this substance, the temperature will steadily increse until a certain point is reached. At this point, the addition of a greater amount of heat does not raise the temperature, but it is found that the solid begins to melt. This temperature is found to remain constant until the solid is completely melted and then begins to rise again. Thus, it is obvious that since the melting and freezing takes time to complete, that heat is entering the substance during liquefaction and leaving it during solidification. The heat energy supplied during the process of melting has no effect on the temperature, but it is used up in altering the physical state of the substance. This is known as the latent heat of the substance. Briefly, the latent heat of fusion of a substance is the quantity of heat which must be imparted at constant temperature, to unit mass of the substance in the solid state in order to effect the change of state from the solid to liquid. In other words, latent heat is the heat change in any substance due to the internal physical change of state of the substance itself.

It is found that it will require 143.4 B. T. U. of heat to change one pound of ice from ice at 32°F. to water at 32°F. In order to obtain the approximate latent heat of a substance that is not wholly water, the percent of water times the 143.4 will give a close figure. The equivalent of this figure in the metric system is 79.7.

The heats contained in the frozen solids are the heat of the liquid, latent heat, and small amount of heat of the solid. It can be understood that the heat of the liquid is a definite quantity as is the heat of the solid. This being the case, the only variable quantity is the latent heat. This latent heat is variable since the amount of the substance frozen is variable if different temperatures are considered.

Level

Freezing Begins

X

Initial Temperature

This diagram shows, briefly, the method used in obtaining the variation of latent heat at the different temperatures from which the freezing range is found.

The line marked level is the temperature of the water in the calorimeter or the highest temperature used. The second level, as shown, is the beginning of the freezing range or the freezing point as given by the government bulletin. The third level is the end of the freezing range. The last level is the lowest temperature used or the temperature of the food.

In order to obtain the unavoidable latent heat the following procedure is used:

The heat that should be set free is in four parts:

(Lower temperature - x) heat of solid = (1)

$$(\text{Freezing point} - x) \times \frac{Sp1 + Sp_2}{2} = (2)$$

(Upper level - freezing point) sp. heat of liquid = (3)

Latent heat (computed) = (4)

The sum of (1) + (2) + (3) + (4) = heat that should be set free.

<u>The calorimeter shows the actual amount of heat that is set free.</u>

The difference in these two quantities is the latent heat that has not been found before, that is:

$$\left[(1) + (2) + (3) + (4) \right] = \text{latent heat not able to find}$$

This procedure of finding the latent heat that was failed to be found is gone through with at various temperatures, starting at the frrezing point and going down the scale of the thermometer at intervals of approximately every five degrees until a constant difference of latent heat is found. Then, by plotting the temperature as abscissa against the latent heat not able to be found at these temperatures the freezing range of the food is obtained. This is true because it is known that there is no latent heat heat involved except while the food is in the process of being frozen. This will explain the fact that the graph is a straight perpendicular line until it reaches the lowest point on the freezing range and then curves according to its latent heat until it reaches the upper point on the freezing range; at this point it again has a vertical trend.

METHOD OF DETERMINING LATENT HEATS

In obtaining the latent heats of the fruits that were quickly frozen, the following procedure was followed:

The general method by which the heat of a reaction is measured is to determine the elevation or depression of temperature produced in a known mass of substance, generally water, of a known specific heat.

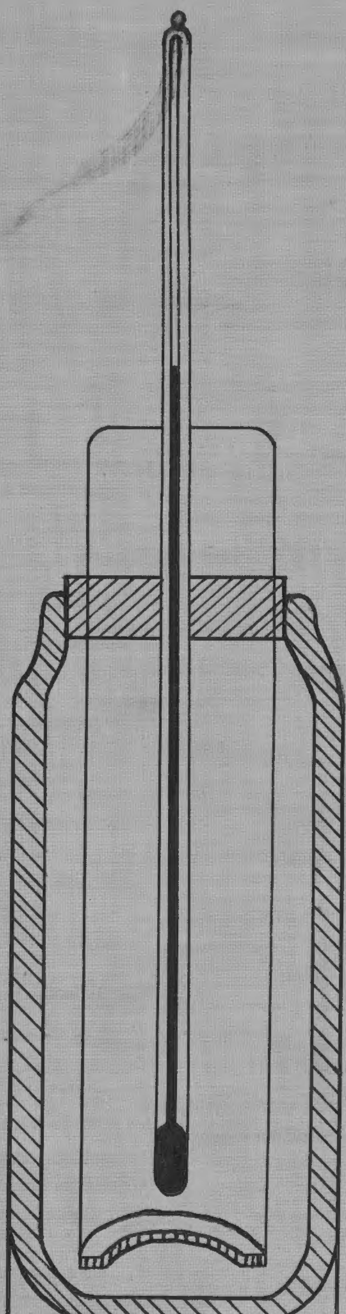
A double walled vacuum bottle was used in order to reduce the amount of heat radiation loss or gain to a minimum. This bottle contained a weighed amount of water. By observing the change in temperature of the water accompaning the change of state, and from experiment finding the heat capacity of the calorimeter and its accesories, it is possible to calculate the amount of heat change.

First, a weighed amount of water was placed in the calorimeter and the temperature taken. Weighed samples of the fruits used were frozen for at least forty-eight hours and then tempered up to the desired temperature. These were then added to the calorimeter and the temperature drop noted. By means of the formula given in the foregoing section, the latent heat can be computed.

CALIBRATION OF CALORIMETER

Some heat is obtained from the atmosphere and surroundings and is taken up by the walls of the calorimeter. It is necessary to estimate the amount of heat gained in this way.

In determining this amount of heat, a number of experiments were made on determining the latent heat of ice. Since the latent heat of ice is a definite known value (143.4 B. T. U.) and a certain definite amount of water was used in the calorimeter, the water value of the calorimeter can be obtained for the various temperatures. The curve, Fig. , was developed showing the relation between heat losses and temperature changes.



CALORIMETER

DETERMINATION OF SPECIFIC HEAT

Specific heat is known as the ratio of heat required to raise the temperature of one pound of any material one degree Fahreneit to that necessary to raise the temperature of one pound of water at room temperature one degree.

The specific heat of water is known to be one. Then, the specific heat of any substance would readily be seen to be a function of the moisture content.

Since this investigation is based on the fundamental of heat absorption, it is necessary to know the specific heats at the changes of state. The changes of state as, above freezing, below freezing, and during freezing, cause a variation of specific heats.

The specific heat of fruits above freezing is usually taken as 0.90 and below at 0.48. For fruits and vegetables having less than 90% water content these values are somewhat high. An emperical formula giving the approximate specific heat above freezing is

$$5 = 0.40 + .60\ P$$

Where S is specific heat expressed as a decimal, 0.40 is a constant applicable to fruits and vegetables.

P is the percentage of water in the fruit or vegetable expressed as a decimal.

The specific heat below freezing, since better data is not obtainable, is approximately determined by multiplying the specific heat above freezing by 0.54.

Problem:

A sample of strawberries contains 91.95% moisture. Then the specific heat above freezing would be:

$$S = .4 + .6(.9195)$$

$$S = .9517$$

For below freezing the specific heat would be:

$$S = .9517 \times .54$$

$$S = .5.4$$

The specific heat while freezing or for the freezing range is assumed to be the average of the specific heats above and below freezing.

From the preceding example:

$$S = \frac{.952 + .514}{2}$$

$$S = 0.733$$

DETERMINATION OF MOISTURE CONTENT

It is known that all foods of the same variety do not have the same percentage of moisture content. That is, all varieties of apples do not contain the same percentage of water. From the preceding discussion, it can be seen that the water content in the food has a marked effect on this investigation. Because of this fact, some method is required for accurately determining the amount of moisture in the foods used in these experiments.

The method used was simple in the procedure. First, an empty porcelain crucible was weighed. This weight was recorded. Then a portion of the fruit that was being tested for latent heat was placed in the crucible. The crucible was again weighed. The subtraction of this figure and the first one recorded gives the weight of food plus the moisture content.

This crucible containing the food was then placed in the inner compartment of a double boiler whose lower compartment was filled with oil. A flame was adjusted beneath this boiler until a constant temperature of from 105°F. to 110°F. was maintained. This crucible was allowed to stand in this boiler for twenty-four hours. At the end of that time it was removed and weighed. After repeating and reweighing until a constant weight is obtained, the constant weight is recorded. The difference in this weight and the weight of the crucible plus the fruit before heating gives the moisture content in grams. The ratio of the grams of moisture to grams of fruit is the ratio of the percent of moisture.

Example:

Before cooking:

Weight of crucible + strawberries	=	51.6
Weight of crucible	=	42.9
Weight of strawberries before cooking	=	8.7

After cooking:

Weight of crucible + strawberries (before)	=	51.6
Weight of crucible + strawberries (after)	=	43.6
Weight of moisture in strawberries	=	8.0

$$\text{Percentage of moisture} = \frac{8.0}{8.7} \times 100 = 91.95\%$$

COMPLETE COMPUTATIONS FOR THE OBTAINING

OF THE CURVE

SHOWING THE FREEZING RANGE OF STRAWBERRIES

I

To obtain the latent heat lacking when food is frozen to 6°F.

1. To obtain heat that should have been liberated in the change of lowest temperature of strawberries to lower point on freezing range (assumed to be -6.5°C.).

7.9 x .51 x 14.8 =	59.63

2. To obtain heat that should have been liberated from lower point on freezing range (-6.5°C.) to upper point on freezing range (-1.0°C.)

5.5 x 0.71 x 14.8 =	57.81

3. To obtain heat that should be liberated from upper point on freezing range (-1.0°C.) to the highest temperature (21.0°C.)

2. x 0.94 x 14.8 =	291.9

4. To obtain latent heat that is known

.895 x 79.7 x 14.8 =	1058.2
A. Heat that should be set free in calories	1517.54
B. Heat actually liberated	
352 x 4 =	1408.00
C. Total heat short in calories	109.54

D. Heat short per gram in calories

$$\frac{109.54}{14.8} = 7.40 \text{ calories per gram}$$

E. Heat per gram short in B. T. U.

$$7.4 \times 1.8 = 13.32 \text{ B. T. U. low}$$

II

1.	4.7 x 0.51 x 20.6 =	49.4
2.	4.5 x 0.73 x 20.6 =	67.67
3.	20.2 x 0.95 x 20.6 =	395.41
4.	.918 x 79.7 x 20.6 =	1507.92
A.	Heat that should be liberated =	2020.40
B.	Heat actually liberated	
	352 x 5.3 =	1865.60
C.	Total heat short in calories	154.80

D. Heat per gram short =

$$\frac{154.8}{20.6} = 7.51$$

E. Latent heat in B. T. U. low =

7.51 x 1.8 = 13.52 B. T. U.

III

1.	1.5 x 0.52 x 16 =	12.48
2.	5.5 x 0.74 x 16 =	65.12
3.	20.1 x .96 x 16 =	308.80
4.	20.1 x 79.7 x 16 =	1183.36
A.	Heat that should be liberated	1569.66
B.	Heat actually liberated	
	353 x 3.7 =	1306.10
C.	Heat unaccounted for in calories ;	263.56

D. Heat per gram unaccounted for =

$$\frac{263.56}{16.0} = 16.47$$

E. Latent heat in B. T. U. unaccounted for =

16.47 x 1.8 = 29.7 B. T. U.

IV

1. There is no heat liberated here as the temperature of 25°F. is above that of 20°F. which was assumed as the freezing point.

2. 2.8 x .73 x 21.2 =	43.34
3. 19.05 x .95 x 21.2 =	383.67
4. 0.92 x 79.7 x 21.2 =	1554.50
A. Heat that should be liberated =	1981.51
B. Heat actually liberated =	
352 x 4.25 =	1496.00
C. Heat unaccounted for in calories =	485.51

D. Heat per gram unacoounted for =

$$\frac{485.51}{21.2} = 22.89$$

E. Latent heat in B. T. U. unaccounted for =

22.89 x 1.8 = 41.2 B. T. U.

V

1. No heat liberated as the temperature is above that of freezing for this point.

2. No heat liberated here as the temperature is still above that of the upper point on the freezing range.

3. $20.4 \times .96 \times 17.7 =$	346.8 calories
4. $0.936 \times 79.7 \times 17.7 =$	1320.42 calories
A. Heat that should be liberated =	1667.22
B. Heat actually liberated =	
$352 \times 1.55 =$	545.6
C. Heat unaccounted for =	1121.62

D. Heat per gram unaccounted for =

$$\frac{1121.62}{17.7} = 63.4$$

E. Latent heat in B. T. U. unaccounted for =

$63.4 \times 1.8 = 114.1$ B. T. U.

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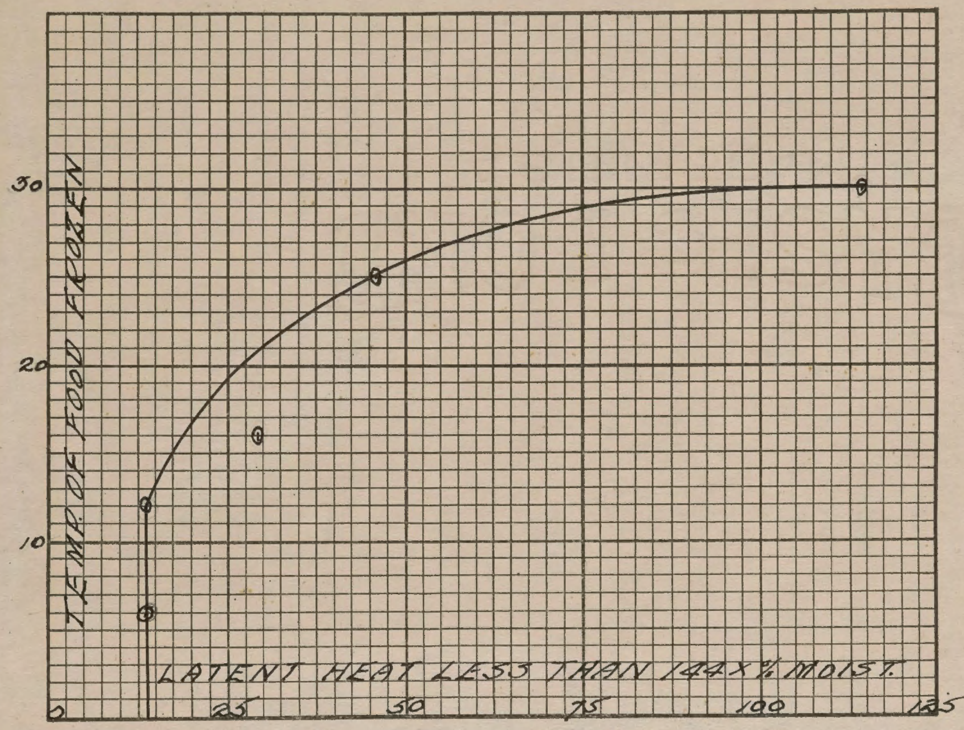

FIG. NO.

TITLE:- FREEZING RANGE OF STRAWBERRIES

INTERPRETATION OF CURVES

STRAWBERRIES

Temperature of Food	6°F.
Temperature of Water in Calorimeter	24.0°C.
Temperature of Frozen Strawberries in Centigrade	- 14.4°C.
Final Weight of Calorimeter + Food + Water	763.4
Initial Weight or Weight of Calorimeter + Water	748.6
Weight of Strawberries	14.8
Final temperature of Mixture in Calorimeter	20.0°C
Temperature Drop in Calorimeter	4°C.
Percent of Water in Strawberries	89.5%
Specific Heat - Above Freezing	0.94
Specific Heat - Below Freezing	0.51
Specific Heat - Freezing Range	0.72
Weight of Water Used in Calorimeter	353
Latent Heat in B. T. U. Lacking Per Gram	13.32

Upper point on freezing range is -1.0°C (29.93°F.)

STRAWBERRIES

Temperature of Food	12°F.
Temperature of Water in Calorimeter	23.5°C.
Temperature of Frozen Strawberries in Centigrade	-11.2°C.
Final Weight of Calorimter + Food + Water	752.5
Initial Weight or Weight of Calorimeter + Water	731.9
Weight of Strawberries	20.6
Final Temperature of Mixture in Calorimeter	18.2°C.
Temperature Drop in Calorimeter	5.3°C.
Percent of Water in Strawberries	91.8%
Specific Heat - Above Freezing	0.95
Specific Heat - Below Freezing	0.51
Specific Heat - Freezing Range	0.73
Weight of Water Used in Calorimeter	352
Latent Heat in B. T. U. Lacking Per Gram	13.52

Upper point on freezing range is -1.0°C. (29.93°F.)

STRAWBERRIES

Temperature of Food	18°F.
Temperature of Water in Calorimeter	22.8°C.
Temperature of Frozen Strawberries in Centigrade	-8°C.
Final Weight of Calorimeter + Food + Water	761.8
Initial Weight or Weight of Calorimeter + Water	745.8
Weight of Strawberries	16.0
Final Temperature of Mixture in Calorimeter	19.1°C.
Temperature Drop in Calorimeter	3.7°C.
Percent of Water in Strawberries	92.85%
Specific Heat - Above Freezing	0.96
Specific Heat - Below Freezing	0.52
Specific Heat - Freezing Range	0.74
Weight of Water Used in Calorimeter	353
Latent Heat in B. T. U. Lacking Per Gram	29.7

Upper point on freezing range is -1.0°C. (29.93°F.)

STRAWBERRIES

Temperature of Food	25°F.
Temperature of Water in Calorimeter	22.3°C.
Temperature of Frozen Strawberries in Centigrade	-3.8°C.
Final Weight of Calorimeter + Food + Water	774.5
Initial Weight or Weight of Calorimeter + Water	753.3
Weight of Strawberries	21.2
Final Temperature of Mixture in Calorimeter	18.05°C.
Temperature Drop in Calorimeter	4.25°C.
Percent of Water in Strawberries	91.9%
Specific Heat - Above Freezing	0.95
Specific Heat - Below Freezing	0.51
Specific Heat - Freezing Range	0.73
Weight of Water Used in Calorimeter	352
Latent Heat in B. T. U. Lacking Per Gram	41.2

Upper point on freezing range is -1.0°C. (29.93°F.)

STRAWBERRIES

Temperature of Food	30°F.
Temperature of Water in Calorimeter	20.95°C.
Temperature of Frozen Strawberries in Centigrade	-1°C
Final Weight of Calorimeter + Food + Water	768.7
Initial Weight or Weight of Calorimeter + Water	751.0
Weight of Strawberries	17.7
Final Temperature of Mixture in Calorimeter	19.4°C.
Temperature Drop in Calorimeter	1.55°C.
Percent of Water in Strawberries	93.6%
Specific Heat - Above Freezing	0.96
Specific Heat - Below Freezing	0.52
Specific Heat - Freezing Range	0.74
Weight of Water Used in Calorimeter	352
Latent Heat in B. T. U. Lacking Per Gram	114.1

Upper point on freezing range is -1.0°C. (29.93°F.)

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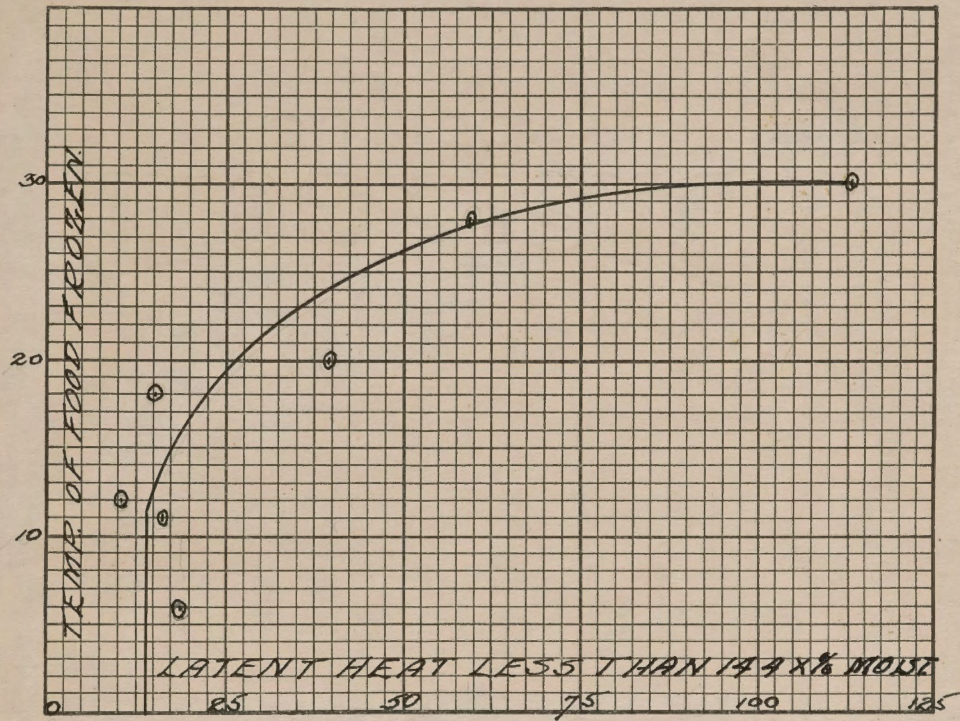

FIG. NO.

TITLE:- FREEZING RANGE OF GRAPEFRUIT

INTERPRETATION OF CURVES

GRAPEFRUIT

Temperature of Food	6°F.
Temperature of Water in Calorimeter	23.3°C.
Temperature of Frozen Grapefruit in Centigrade	-14.4°C.
Final Weight of Calorimeter + Food + Water	769.9
Initial Weight of Calorimeter + Water	748.5
Weight of Grapefruit	21.4
Final Temperature of Mixture in Calorimeter	18.1°C.
Temperature Drop in Calorimeter	5.2°C.
Percent of Water in Grapefruit	87.8
Specific Heat Above Freezing	0.92
Specific Heat Below Freezing	0.49
Specific Heat Freezing Range	0.71
Weight of Water Used in Calorimeter	352
Latent Heat in B. T. U. Unaccounted for	18.04

GRAPEFRUIT

Temperature of Food	11°F.
Temperature of Water in Calorimeter	22.4°C.
Temperature of Frozen Grapefruit in Centigrade	-12°C.
Final Weight of Calorimeter + Food + Water	755.7
Initial Weight of Calorimeter + Water	730.1
Weight of Grapefruit	25.7
Final Temperature of Mixture in Calorimeter	16.35°C.
Temperature Drop in Calorimeter	6.05°C.
Percent of Water in Grapefruit	87.62
Specific Heat Above Freezing	0.93
Specific Heat Below Freezing	0.50
Specific Heat Freezing Range	0.71
Weight of Water Used in Calorimeter	351
Latent Heat in B. T. U. Unaccounted for	17.1

GRAPEFRUIT

Temperature of Food	12°F.
Temperature of Water in Calorimeter	23.0°F.
Temperature of Frozen Grapefruit in Centigrade	-11.2°C.
Final Weight of Calorimeter + Food + Water	767.0
Initial Weight of Calorimeter + Water	730.8
Weight of Grapefruit	36.2
Final Temperature of Mixture in Calorimeter	143°C.
Temperature Drop in Calorimeter	8.7°C.
Percent of Water in Grapefruit	87.62
Specific Heat Above Freezing	0.92
Spcific Heat Below Freezing	0.50
Specific Heat Freezing Range	0.71
Weight of Water Used in Calorimeter	350
Latent Heat in B. T. U. Unaccounted for	11.2

GRAPEFRUIT

Temperature of Food	18°F.
Temperature of Water in Calorimeter	22.8°C.
Temperature of Frozen Grapefruit in Centigrade	-8°C.
Final Weigth of Calorimeter + Food + Water	776.8
Initial Weight of Calorimeter + Water	748.2
Weight of Grapefruit	28.5
Final Temperature of Mixture in Calories	16.6°C.
Temperature Drop in Calorimeter	6.2°C.
Percent of Water in Grapefruit	80.9
Specific Heat Above Freezing	0.88
Specific Heat Below Freezing	0.47
Specific Heat Freezing Range	0.68
Weight of Water Used in Calorimeter	351
Latent Heat in B. T. U. Unaccounted for	15.16

GRAPEFRUIT

Temperature of Food	20°F.
Temperature of Water in Calorimeter	21°F.
Temperature of Frozen Grapefruit in Centigrade	-6.8°C.
Final Weight of Calorimeter + Food + Water	765.8
Initial Weight of Calorimeter + Water	747.7
Weight of Grapefruit	18.1
Final Temperature of Mixture in Calorimeter	16.6°C.
Temperature Drop in Calorimeter	4.4°C.
Percent of Water in Grapefruit	80.9
Specific Heat Above Freezing	0.88
Specific Heat Below Freezing	0.47
Specific Heat Freezing Range	0.68
Weight of Water Used in Calorimeter	353
Latent Heat in B. T. U. Unaccounted for	39.3

GRAPEFRUIT

Temperature of Food	28°F.
Temperature of Water in Calorimeter	20.4°C.
Temperature of Frozen Grapefruit in Centigrade	-2.2°C.
Final Weight of Calorimeter + Food + Water	773.4
Initial Weight of Calorimeter + Water	749.6
Weight of Grapefruit	24.2
Final Temperature of Mixture in Calorimeter	16.6°C.
Temperature Drop in Calorimeter	3.8°C.
Percent Water in Grapefruit	88.33
Specific Heat Above Freezing	0.93
Specific Heat Below Freezing	0.50
Spcific Heat Freezing Range	0.71
Weight of Water Used in Calorimeter	351.5
Latent Heat in B. T. U. Unaccounted for	58.5

GRAPEFRUIT

Temperature of Food	30°F.
Temperature of Water in Calorimeter	22.9°C.
Temperature of Frozen Grapefruit in Centigrade	-1°C.
Final Weight of Calorimter + Food + Water	773.1
Initial Weight of Calorimeter + Water	749.3
Weight of Grapefruit	23.8
Final Temperature of Mixture in Calorimeter	20.9°C.
Temperature Drop in Calorimeter	2.0°C.
Percent Water in Grapefruit	88.33
Specific Heat Above Freezing	0.93
Specific Heat Below Freezing	0.50
Specific Heat Freezing Range	0.71
Weight of Water Used in Calorimeter	354
Latent Heat in B. T. U. Unaccounted for	113.4

APPLES

Temperature of Food	6°F.
Temperature of Water in Calorimeter	23.9
Temperature of Frozen Apples	-14.4
Final Weight of Calorimeter + Food + Water	767.3
Initial Weight of Calorimeter + Water	750.1
Weight of Apples	17.2
Final Temperature of Mixture in Calorimeter	19.2
Temperature Drop in Calorimeter	4.7
Percent of Water in Apples	84.84
Specific Heat of Apples Above Freezing	0.91
Specific Heat of Apples Below Freezing	0.49
Specific Heat of Apples Freezing Range	0.70
Weight of Water Used in Calorimeter	353
Latent Heat in B. T. U. Unaccounted for	5.09

Freezing point of apples is (-2°C.) or 28.44°F.

APPLES

Temperature of Food	10°F.
Temperature of Water in Calorimeter	22.35
Temperature of Frozen Apples	-12.5
Final Weight of Calorimeter + Food + Water	745.73
Initial Weight of Calorimeter + Water	730.1
Weight of Apples	15.63
Final Temperature of Mixture in Calorimeter	18.95
Temperature Drop in Calorimeter	3.4
Percent of Water in Apples	86.74
Specific Heat of Apples Above Freezing	0.92
Specific Heat of Apples Below Freezing	0.49
Specific Heat of Apples Freezing Range	0.70
Weight of Water Used in Calorimeter	352.5
Latent Heat in B. T. U. Unaccounted for	31.23

Freezing point of apples is (-2°C.) or 28.44°F.

APPLES

Temperature of Food	11°F.
Temperature of Water in Calorimeter	24.8
Temperature of Frozen Apples	-12
Final Weight of Calorimeter + Food + Water	751.0
Initial Weight of Calorimeter + Water	729.4
Weight of Apples	21.6
Final Temperature of Mixture in Calorimeter	19.9
Temperature Drop in Calorimeter	4.9
Percent of Water in Apples	86.74
Specific Heat of Apples Above Freezing	0.92
Specific Heat of Apples Below Freezing	0.49
Specific Heat of Apples Freezing Range	0.71
Weight of Water Used in Calorimeter	353
Latent Heat in B. T. U. Unaccounted for	27.0

Freezing point of apples is (-2°C.) or 28.44°F.

APPLES

Temperature of Food	16°F.
Temperature of Water in Calorimeter	20.75
Temperature of Frozen Apples	-9.0
Final Weight of Calorimeter + Food + Water	767.9
Initial Weight of Calorimeter + Water	746.4
Weight of Apples	21.5
Final Temperature of Mixture in Calorimeter	16.2
Temperature Drop in Calorimeter	4.55
Percent of Water in Apples	85.7
Specific Heat of Apples Above Freezing	0.91
Specific Heat of Apples Below Freezing	0.49
Specific Heat of Apples Freezing Range	0.70
Weight of Water Used in Calorimeter	351
Latent Heat in B. T. U. Unaccounted for	26.89

Freezing point of apples is (-2°C.) or 28.44°F.

APPLES

Temperature of Food	20°F.
Temperature of Water in Calorimeter	22.7
Temperature of Frozen Apples	-6.5
Final Weight of Calorimeter + Food + Water	762.8
Initial Weight of Calorimeter + Water	742.2
Weight of Apples	20.6
Final Temperature of Mixture in Calorimeter	18.55
Temperature Drop in Calorimeter	4.15
Percent of Water in Apples	85.55
Specific Heat of Apples Above Freezing	0.91
Specific Heat of Apples Below Freezing	0.49
Specific Heat of Apples Freezing Range	0.70
Weight of Water Used in Calorimeter	353
Latent Heat in B. T. U. Unaccounted for	34.2

Freezing point of apples is (-2°C.) or 28.44°F.

APPLES

Temperature of Food	28°F.
Temperature of Water in Calorimeter	21.7°C.
Temperature of Frozen Apples	-2.2
Final Weight of Calorimeter + Food + Water	765.8
Initial Weight of Calorimeter + Water	752.5
Weight of Apples	13.3
Final Temperature of Mixture in Calorimeter	20.2
Temperature Drop in Calorimeter	1.5
Percent of Water in Apples	85.14
Specific Heat of Apples Above Freezing	0.91
Specific Heat of Apples Below Freezing	0.49
Specific Heat of Apples Freezing Range	0.70
Weight of Water Used in Calorimeter	353
Latent Heat in B. T. U. Unaccounted for	86.9

Freezing point of apples is (-2°C.) or 28.44°F.

UNIVERSITY OF TENNESSEE

REFRIGERATION LABORATORY

DATE

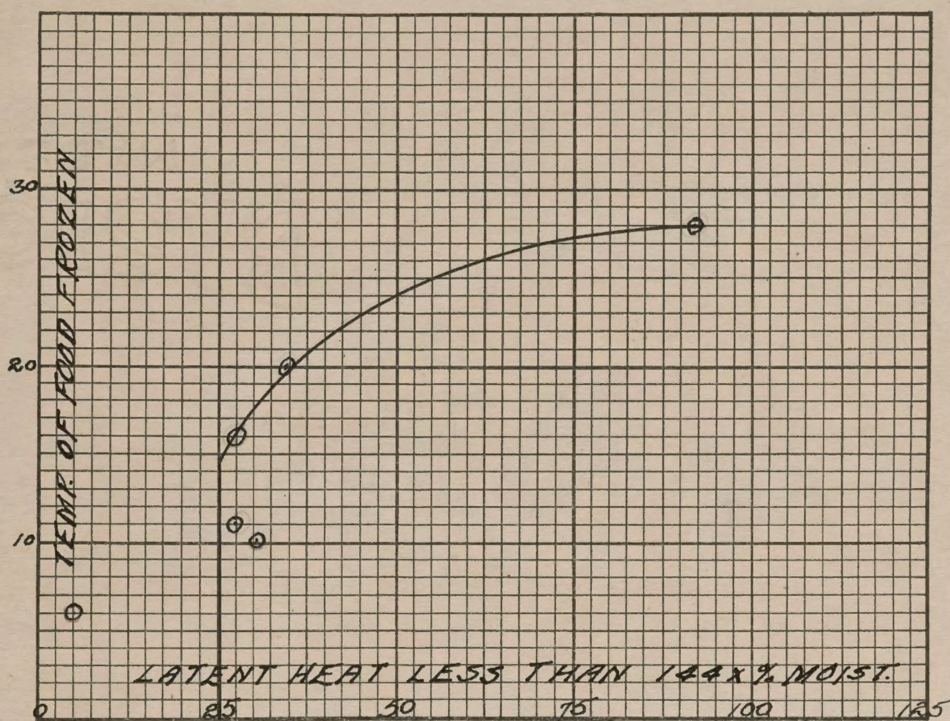

FIG. NO.

TITLE:- FREEZING RANGE OF APPLES

INTERPRETATION OF CURVES

CONCLUSION

For the best conclusion of this investigation, a thorough examination of the curves resulting from the data is necessary.

Some of the variations in these curves can be accounted for while others cannot be answered as to their position.

It can readily be seen that the assumption of the variation of latent heat while in the process of freezing was correct. Each curve shows an increase of latent heat as the food is less frozen.

It can also be seen that the assumption of a freezing point is probably correct as the ordinate and temperature at which the food is frozen as abscissa gives a curve that shows a constant latent heat at a certain point which indicates the food is fully frozen and no more transferr of heat takes place.

Strawberries

The curve obtained in plotting the data after being calculated for strawberries shows eveness throughout except for points (3) and (4). Account is made for these points being off the curve by taking into regard the factors of error, such as:

(1) Weighing.

(2) Loss in calorimeter.

(3) Change in temperature of food in transferring from box to calorimeter.

It is supposed that with these corrections these points would lie on the curve given.

Grapefruit

By plotting the data, after calculation obtained from the investigation of grapefruit, a similar curve as that found in the case of strawberries is plotted.

The points on this curve are somewhat scattered which necessitated the drawing of a curve at the approximate average points. With perfect accuracy, it is assumed that all of the points obtained woul lie on this curve.

Greater inaccuracy is prevalent in the case of grapefruit than in strawberries due to the easy frosting of this fruit that seems to insulate somewhat and increase the error since the other factors of error mentioned are also present. This curve shows constancy at its lower point, then curves rapidly as the temperature rises, which indicates as in the case of strawberries that a range of freezing is present that extends from approximately from 11°F. to 28°F. The curve shows that all of the factor controlling the freezing is not constant until the temperature of approximately 11°F. is reached.

Apples

In the case of apples, when the data is plotted in a similar manner as in the other fruits, it will be noticed that there are two points which lie very much off of the curve. Since these are the only two points that seem to break the regularity of the curve to any degree, it is assumed that an unusual amount of inaccuracy occurred in obtaining the data for these two points. This assumption seems especially reasonable since the data for both of the points was obtained at very nearly the same time and also the same conditions.

The writer also assumes that this indicates the point of constancy of the latent heat, thereby indicating the change of the freezing range. This leaves our point, whose ~~data~~ was taken at 6°F., in an isolated position.

This may indicate that the curve extends through it instead of becoming constant, but seems doubtful as it is too isolated to have any bearing.

SUMMARY

Fruit	Freezing Range °F.
Strawberries	14 to 29.9°F.
Grapefruit	11 to 28.36°F.
Apples	17 to 28°F.

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that, by this approval, the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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