THE RELATION OF VISCOSITY

TO QUALITY IN

ICE CREAM

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THESIS

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by

Everett Clifford Scott

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INTRODUCTION

The ice cream industry, in the last few years, has had such a tremendous growth that it must be placed among the most important divisions of dairying. Experimental work on ice cream has not kept pace with the growth of the industry. This is especially true of work which has as its goal the discovery of processes which are conductive to quality. The ice cream maker is vitally interested in the production of a high quality product, not merely because it is his ambition to be able to place a better product on the market than his competitor does, but because, from an economic point of view, he is forced to manufacture a quality product to hold and increase trade. It is no longer a question of choice with the ice cream manufacturer. If he is to establish and maintain a reputation for his product, he must produce one which will meet the requirements of the most critical consumer. It was to determine some of the factors which influence quality that this work has been conducted.

Most of the information available concerning quality in ice cream is to be found only in text books or trade journals. Usually only bold statements are made, which are, for the greater part, merely the ideas of the authors and are not substantiated by experimental work. Some of the statements gleaned from such sources seem from their very nature so erroneous that an attempt has been made to either verify or disprove them. The work has been confined to the effects of viscosity on quality.

REVIEW OF LITERATURE

Viscosity

Viscosity, as defined by Getman (1), is the resistance experienced by one portion of a liquid in moving over another portion. Hatschek (2) defines it as the resistance offered to shearing, to stirring, or to the flow through a capillary tube. It is known, in the ice cream mix, as the stickiness or body of the mix, and, according to Manhart (3), is desirable in that it is largely responsible for the body, texture, and melting resistance of ice cream.

Viscosity has often been considered the most important factor in determining the quality of ice cream. Writers have no doubt been prone to give more credit to this factor than it merited, as is shown by a review of the work which has been done.

The statement has often been made that the greater the viscosity of the mix, the better the ice cream will whip, or, the larger the amount of overrun that can be whipped into it. Zoller (4) holds that this is not the case. He found that the viscosity of the mix may be increased to a jelly by the use of gelatin without increasing the yield of the mix. On the other hand, he found that a very thin mix will have an overrun or yield capacity twice as great as the high viscosity mix, and, if correctly hardened and stored for serving, will hold the enmeshed air without frothing when melting down in the dish. Zoller believes that the chief physical factor in maintaining the proper yield of ice cream is not viscosity, but adhesivity. He found that the adhesivity of the ice cream mix can be increased by the addition of more milk protein or other protein which does not set to a jelly as does gelatin.

Mortensen (5) disagrees with Zoller in regard to the effect of viscosity on overrun. Mortensen states that pasteurization reduces the viscosity of milk and cream, and if the mix is frozen soon after pasteurization, the product will not enmesh or retain as much air as would have been the case had these ingredients been aged.

Investigators are united in the view that viscosity has a wholesome effect upon body, texture, and melting resistance of ice cream. Mortensen (5) states that pasteurized cream, due to low viscosity, affords less resistance to churning than does unpasteurized cream. By holding the cream within a few degrees of the freezing point for twenty-four hours before it is frozen, viscosity is increased and the formation of butter particles is less prominent.

According to Manhart (3), the body of ice cream consists of air cells with small portions of frozen mix between them. If the air cells are small and numerous, these portions of mix will be finely divided and small; the ice crystals will be very minute; the texture smooth; and the body firm. Since a viscous mix offers more resistance to the incorporation of air than a less viscous mix, the air is incorporated with difficulty and the air cells are smaller. Thus, viscosity of the mix influences the body and texture of the ice cream.

Gelatin has been found to have a great influence upon the viscosity of the mix. There has also been found to exist a wide difference in the viscosities of aged ice cream mixes of like composition but containing different gelatins.

Manhart (3) added 0.6 of 1 percent of three different gelatins to ice cream mixes of 8 percent fat and 34 percent total solids content, with the following results:

Mix Containing	Viscosity comparative to water at 15° C.	Percent increase in viscosity of gelatin mixes over control mixes
No gelatin (control	1.67	
Poor quality gelatin	4.09	144.9
Good quality gelatin	10.90	552.6
Very good quality gelatin	15.60	834.1

Manhart's (3) results show that equal amounts of a good quality gelatin increased the viscosity of the mix to nearly three times that of a similar mix containing a poor quality gelatin, and that a mix containing a very good quality gelatin was nearly four times more viscous. The mix containing the poor quality gelatin was two and a half times more viscous than that containing no gelatin.

The only conclusion that can be drawn from the work on viscosity is that not enough is known about the subject to enable one to express an opinion for or against it. This is well expressed by Clayton (6), who says, in speaking of the relationship between viscosity and overrun, and body and texture in ice cream, "It is really an open question whether viscosity can be used as a sole measure of these qualities".

Gelatin

The history of gelatin manufacturing dates back many years. It has evolved from avery crude process to such a state of perfection, through the application of chemical as well as engineering science, that the industry may well be proud of its progress. Gelatin is made from bones, hides, skins, tendons, horn piths, tannery trimmings, and connective tissue from the animal body.

Gelatin has been used in the manufacture of ice cream for the last forty years (7). It was early found that ice cream needed the assistance of some protective colloid to prevent the formation of ice crystals and to produce a smooth, firm bodied product, resistant to melting. Since gelatin answered the purposes admirably, it has become the most widely used stabilizer in the ice cream industry.

Other substances, as gum tragacanth, India gum, agar agar, vegetable gelatins, and commercial ice cream improvers, which consist essentially of gums, rennet and pepsin and combinations of these materials, are used to an extent, but their use is not so widespread as is that of gelatin. Parfitt (7) points out that approximately 8,000,000 pounds of this product is annually consumed by the ice cream industry.

Zoller (4) states that Alexander's (8) efforts are largely responsible for the use of gelatin in ice cream. Alexander not only found that the use of gelatin reduced the iciness, caused by formation of crystals in ice cream, but also that an increase in the colloidal protection of the casein by the gelatin greatly increased its digestibility (9). He also found that gelatin has the ability to emulsify the fat, which causes it to be dispersed throughout the ice cream mix in tiny globules in which state it is more digestible. Downey (10) (11) agrees with Alexander concerning the food value of gelatin in ice cream. The work done by Alexander and Downey proves definitely that from the standpoint of nutrition, gelatin is a very valuable ingredient in the ice cream mix. However, since only small amounts are added to ice cream - usually 0.5 per cent - the food value added to the product from this source is negligible. It is the increased digestibility of the casein and fat which are important.

Gelatin in ice cream prevents the formation of ice crystals, increases the viscosity of the mix, thereby giving body to the ice cream, and renders the cream resistant to melting. As expressed by Bogue (12), "the advantages attained by the use of gelatin in ice cream are found in the three colloidal properties of the substance; first, the ability of gelatin to produce a jelly at low temperature; second, the protective nature of gelatin, which prevents, or greatly diminishes, the tendency of other substances to crystallize or separate from the mixture; and third, the ability of gelatin to function as an emulsifying agent, and so render more permanent the emulsion of the milk fat in its aqueous medium".

Zoller (4) and Masurovsky (13) point out that gelatin causes the cream to freeze quicker when the mix is frozen in a power freezer. Gelatin acts like sand and other abrasives in preventing the supercooling of the mix, and by this rapid and steady freezing causes the ice crystals to exist in a finer state of division. In Zoller's work (4), in each case where supercooling was prevented, the product was very smooth and free from noticeable ice crystals.

Masurovsky (13) deduced from his work on crystallising lactose in water solutions and gelatin solutions that gelatin tends to prevent sandiness - the crystallisation of lactose - in ice cream. However, Zoller (14) found that gelatin helped rather than prevented the formation of lactose crystals in an ice cream mix containing more than the safe limit of lactose - the lactose contained in 10.5 to 11 percent normal milk solids not fat. Lucas' work (15) on the effect of gelatin and improvers upon sandiness bears out Zoller's results.

A good gelatin, as defined by Parfitt (7) and Burke (16), is made from carefully selected stock, has high jelly strength, goes into solution and solidifies quickly, has low ash content, is clean, and has no inoffensive odor; it is clear, bright, and its solution is straw colored; it is neutral or nearly neutral, has a low bacterial count of not to exceed 5,000 and no B. coli types, and is without chemical or physical impurities. The federal law states that gelatin must not contain more than thirty parts per million of copper, one hundred parts per million of zinc, twenty parts per million of lead, one and four-tenths parts per million of arsenous tri-oxide, or more than three hundred fifty parts per million of sulphur dioxide.

There is probably no other material which is manufactured on such a large scale as gelatin that is less standard in quality. The different batches made from the same kind of material, by the same manufacturer, and given identical grades vary considerably in quality.

This has made it desirable to purchase gelatin by sample, the purchaser using some test for determining quality.

Experimentalists have long sought for a gelatin test which would reliably indicate quality. The result is that many have been developed, some of which give comparatively good results, while others are practically valueless, especially from the standpoint of the ice cream maker. Many of the tests are so complicated that very costly apparatus and a trained technician are necessary to operate them.

Hall and Houtz (17) state that the following tests are indicative of those qualities of gelatin in which the ice cream manufacturer is interested; 1. Jelly Strength; 2. Viscosity; 3. Swell; 4. Clarity; 5. Odor; 6. Bacteria; 7. Ash; 8 Acidity; 9. Moisture; 10. Metallic Impurities; 11. Storage; 12. and Microscopic. Williams (18) and Manhart (19) have also used another test, the "Melting Test" in their determinations of quality in gelatin and its relation to viscosity. The "Jelly-Value" test as described by Burke (16), Turnbow, (20) and Parfitt (21) and the "Freezing" and "Melting" tests as given by Turnbow (20) are also used. A description of these various tests follows.

Jelly Strength Tests. The jelly strength test, which embraces tests of many kinds, is probably the most widely used method of determining the quality of gelatin.

It is based on the principle that if a number of gelatin samples are put into solution at a given concentration (22) and allowed to chill or set, the value of the gelatin will, in general, be proportional to the relative resiliency of the jellies so formed. The principle of all jelly strength tests is essentially the same, with the exception of the means of testing the strength of the jelly.

The finger-test (22) which is the oldest and most used test for jelly consistency, merely consists of comparing the different samples of gels at the same concentration, the same temperature, and in the same size and shape container, by pressure with the fourth finger of the left hand. A comparison of their resiliency is made in this manner. As expressed by Alexander (23), the personal element is naturally a factor with the finger-test, but it is speedy and usually considered sufficiently accurate for commercial work. Smith (24) states that the greatest trouble with the finger-test is that samples cannot be accurately compared when tested at different times, and also that the human element is too strong for the test to be very accurate.

Lipowits (22) devised one of the earliest substitutes for the finger-test. The principle of the test was the determination of the weight necessary to cause a thin disk to penetrate the surface of a jelly. This test has been the basis of many modifications. Kissling's (22) test, based on noting the time taken for rods of certain weights and dimensions to penetrate and sink through the jelly, was one of the next tests devised (about 1893). Valentia (22) improved upon the tests of Lipowitz and Kissling. His test was similar to that of Lipowitz except that a rod was used instead of a disk.

Scott (22), in 1907, invented an important modification of Lipowitz's instrument. His tester measures the pressure necessary to break the surface of the jelly by a conical shaped rod on a spring balance.

Many testers have since been invented which either work on the principle of determining the weight necessary to rupture the surface of the jelly, the time taken for a rod to sink through the jelly in a container, or the amount of depression of the surface caused by a certain weight. The latter type is by far the more common. The testers of Hall and Houtz (25) and Burke (16), which are in most general use among ice cream manufacturers today, operate on this principle.

E. S. Smith (26) in 1909 was granted a patent on a tester which measured the pressure necessary to depress the jelly a certain amount.

C. R. Smith (24), has devised two tests for the jellying power of gelatin. The first, which measures the depression of the jelly by a definite amount of suction, is a very simple apparatus. Very good results were obtained with this tester. His second method which employs the polariscope to measure the mutarotation of the gelatin solutions, seems to give good results, but is too complicated to be practical for the ice cream maker.

According to Bogue (22), the only instrument which has been devised that is truly scientific and gives absolute results is the one developed by S. E. Sheppard (27) and his colaborators, Sweet and Scott. The material is tested for torsional stress. The prepared solutions are molded into cylindrical pieces and chilled. Both the "breaking load" and the percentage twist at break are determined. The product of the breaking load times the twist, divided by the cross section of the test piece, is taken as the jelly strength. This instrument is very elaborate and costly, making its use, except in research laboratories, prohibitive.

As pointed out by Alexander in 1906 (22), all methods, which depend upon the breaking or the compression of jelly, are subject to error due to the formation of a "skin" on the surface, and also due to variations in the diameter of the vessel containing the jelly. The tester devised by Alexander to do away with this source of error, which compresses blocks of jelly (29), never became very popular, and experimental data does not prove it to be more accurate than the other types.

From a review of the jelly strength tests which have been devised, it seems that the testers which operate on the principle of depression of the jelly surface by a definite weight are best adapted to the use of the ice cream manufacturer. These testers are usually quite simple, relatively cheap, and their results compare very favorably with those which are more complex and costly.

Viscosity. The viscosity of gelatin solutions is often used as a test for quality. This test came into use at about the same time the jelly strength test was originated, and its use has continued, although it has never become as popular as this latter test.

The Saybolt, Engler, and Redwood viscosimeters were originated in the United States, Germany, and England respectively, and at about the same time, the latter part of the nineteenth century. (22) These operate on the principle of the determination of the time required for a definite amount of liquid to flow through a short capillary tube at a definite temperature. Viscosimeters of this type have been found to be rather inaccurate for gelatin.

Another type of viscosimeter which came into use was an ordinary 50 c.c. pipette of a definite size bore. According to Bogue (22), Fernback, and Alexander were the first investigators to develop this type of instrument. It has the same disadvantages found in the short capillary tube instruments.

The Long Capillary Tube, Centrifugal, Rising Bubble, and Falling Sphere viscosimeters of varying types have been developed since the pipette type of instrument was proposed, but none of the latter types have become very popular.

The torsion type of viscosimeter, which employs an oscillating cylinder or disk, is perhaps the most popular type of instrument for the determination of viscosity in use today. As given by Bogue (22), the Doolittle, Couette, Stormer, and MacMichael viscosimeters are notable examples of the torsional type. Although these instruments are subject to criticism, they are favored in most scientific work.

Garrett (30), in 1903, used a torsional type of viscosimeter for determining the viscosity of gelatin solutions. He is the first investigator who reports this type of work, but his results are not available.

Hall and Houtz (17) report testing gelatin solutions for viscosity by means of a 50 c.c. pipette, the temperature of the solutions being exactly 190°. The time taken for the pipette to empty was taken with a stop watch, and this compared with the time taken for water under identical conditions. They found that by this method the true results were not always shown, no matter how careful and accurate the operator may be. Clear, bone gelatins gave a lower viscosity than normal, while opaque hide gelatins gave a higher viscosity reading than would be expected from their jelly strengths.

Bogue (31) found, in his study of the influence of hydrogen ion concentration on the swelling, viscosity, jelly consistency, foam, turbidity, and alcohol number of gelatin, that on the acid side, the maximum viscosity and swelling occur at a pH of 3.0 to 3.5, while the maximum jelly consistency is at a pH of 4.0 to 4.5. If acid is present in excess of the optimum specified, these properties decline, while they rise with increasing alkali concentrations, but only at very high values of hydrogen ion concentration do they approach those reached on the acid side. The accompanying chart, No. I, shows graphically the effect of hydrogen ion concentration on the viscosity and jelly strength of gelatin. It brings out conclusively that different degrees of acidity in gelatin do not affect jelly strength and viscosity in the same way. A gelatin would not always test equally high by both methods. These results of Bogue agree very well with those published by Loeb (32).

From a review of the work on testing gelatin for quality by the viscosimeter, it would seem that the test is not sufficiently accurate to be relied upon.

Swell. When gelatin is added to cold water, it immediately absorbs water so that each particle swells to several times its origional size. Since it is one of the primary functions of gelatin in ice cream to surround the water particles, it seems that the best gelatin would be the one which shows the greatest swell. Hall and Houtz (17) give a very satisfactory method of testing gelatin for swell. A quarter ounce of gelatin is poured on top of five fluid ounces of water in a graduated glass and allowed to stand fifteen minutes. It is then stirred vigorously for one minute. The smaller gelatin sinks to the bottom, its top forming a definite line on the glass. The top

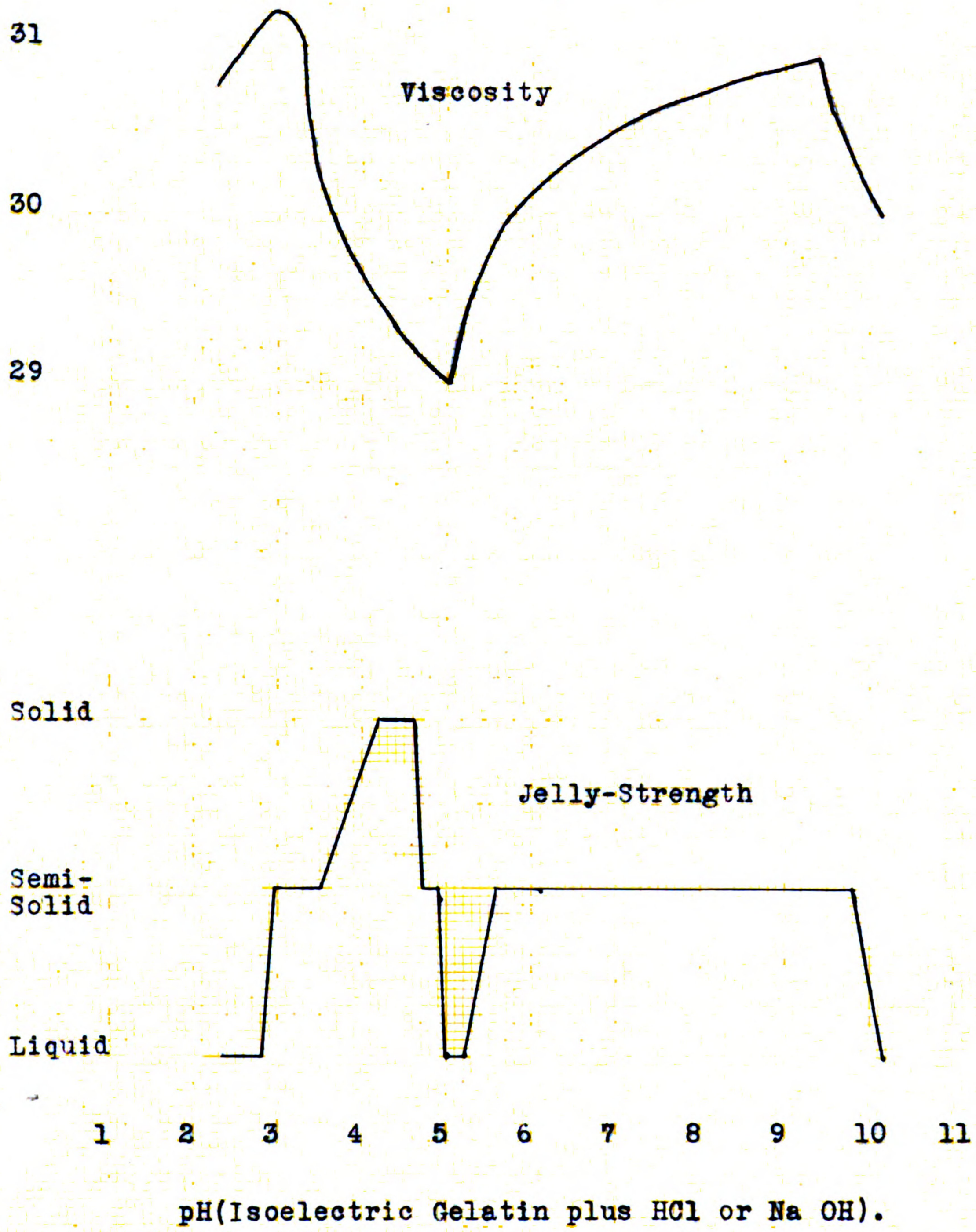

31
30
29
Viscosity
Solid
Semi-
Solid
Liquid
Jelly-Strength
1 2 3 4 5 6 7 8 9 10 11
pH(Isoelectric Gelatin plus HCl or Na OH).

CHART I.

line can be read in ounces of gelatin swell. They found that about two out of ten "swell readings" were disproportionate with their jelly strength. They consider this test unreliable.

Clarity. Many writers claim that clarity is a very good test for quality in gelatin. Manufacturers also place much stress upon this in their advertising. However, no one has proved that the clearer the solution, the better the gelatin. Clearness is merely an indication that the gelatin manufacturer has removed from the colloidal gelatin other finely divided or colloidal matter which wouldmake the gelatin turbid.

A light colored gelatin is usually conceded to be derived from high grade stock while a dark color is attributed to heating too high, improper boiling, or making from inferior stock. Hall and Houtz (17) state that this is not the case; that color is due to the bleaching or lack of bleaching of the gelatin. This would lead to the conclusion that clarity and color are quite insignificant factors in determining the quality of gelatin.

Odor. Many gelatins have unnatural, gluey, or putrid odors which make them quite undesirable for consumption. According to Hall and Houtz (17), such products should be barred from any food such as ice cream. They find that gelatins giving off such odors usually represent products which are high in bacteria and which are made from inferior stock. Burke (16) supports these other investigators in their stand that gelatins with strong odors should not be used. He states that gelatin solutions can best be tested at 140° to determine the presence of undesirable odors.

Ash. According to Hall and Houtz, the ash content is usually determined by heating two grams of gelatin in a large platinum crucible. This test is used only by chemists in analytical work, and is of little practical value to the ice cream maker. It merely discloses impurities or carelessness in manufacture, and has no relation to other tests which indicate the strength of a gelatin.

Acidity. The view has been advanced by many writers on gelatin that poor quality is associated with high acidity. Statements to this effect are often found in text books, but like other writers, these authors present no experimental data to substantiate their claims.

The reason given for the undesirability of acidity in gelatin is that the acidity of the mix will be raised, thereby increasing the danger of curdling. Burke (33) conducted experiments adding various amounts of high acid gelatins to sweet milk. He found that quantities of gelatin of 0.5 to 1 per cent would not cause curding of sweet milk, but it did increase the acidity of the milk to the danger point. Lucas (34) found that when milk, instead of water, is used as a solvent for gelatin in ice cream making, those gelatins of high acid content often cause curdling.

Hall and Houtz (25) state that the greatest jelly strength and viscosity are attained at or near the netural point. The results of Shepperd and Sweet (27) agree with this. They have definitely found a maximum of viscosity at pH_7 to 9, and the indications are that the same is true with jelly strengths, but they are not yet satisfied with the relationship found between these two.

There are two general methods of testing gelatins for acidity, the hydrogen-ion determination and neutralization with sodium hydroxide. For strictly scientific work, the hydrogen-ion determination is the better method, but costly apparatus and technical training on the part of the operator are required. This test is applicable only to research laboratories or large ice cream plants which employ a chemist.

A test which is based on the neutralization of the acid in gelatin by sodium hydroxide is a modification of the Mann's acid test (35), employed in creameries in testing cream for acidity. In conducting the test, the acid content of the gelatin is considered equivalent to a like amount of hydrochloric acid. The method given by Burke (16) has been found to be in error, due to a mistake in his formula. By the corrected formula, the percent of acid in gelatin may be computed as follows:

$$\frac{\text{c.c } n/10 \text{ alkali used} \times .00365 \times 100}{\text{gms. gelatin used}} = \text{percent acid}$$

Burke (16) found that testing the gelatin in a 10% solution at 140° F. gave very good results.

The work which has been done on acidity seems to indicate that excessive acidity in gelatin is undesirable, because it endangers the curdling of the ice cream mix and it lowers the jellying power of the gelatin.

Moisture. The percentage of moisture in gelatin, according to Hall and Houtz (17), may be determined by heating a weighed amount of gelatin to constant weight at 100° C.

Burke (33) states that different samples of gelatin vary in moisture content from 10 to 17 percent, and the higher the grade of the gelatin, the more moisture. This is no doubt due to the fact that a good grade gelatin can absorb more water than one of a poorer quality.

The work done on moisture is insufficient to draw any conclusions, but since the manner of storing the product and the length of holding could vary the moisture content considerably, it seems that this test would not be particularly valuable.

Metallic Impurities. Tests for metallic impurities in gelatin are too complicated to be conducted in most ice cream plants. Since the state and federal pure food laws amply protect the ice cream maker from this point of view, there is no need of him conducting these tests. The federal law requires that gelatin shall not contain more than 30 parts per million of copper, 100 parts per million of zinc, 20 parts per million of lead, 1.4 parts per million of arsenic oxide, and 350 parts per million of sulphur dioxide.

Storage. Hall and Houtz (17) conclude from their experience with gelatin, that it may be kept in dry storage without danger of deterioration from either atmospheric conditions or bacterial growth. This makes it necessary to exclude only flies, dust, etc. in storage. If a gelatin deteriorates in storage, when these conditons are cared for, it is an indication that the quality was inferior.

Miscroscopic. It has been found possible by Hall and Houtz (17) to grade gelatin fairly accurately by means of the miscroscope. They found that particles of low grade gelatin appeared glassy, having smoothly, rounded surfaces and little, if any, line formation. Throughout the mass were found dark yellow tints. The surface often showed a rough structure. High grade gelatin particles showed a beautiful, wave-like, delicate line formation of the fractured surfaces. They were more clear, showing an absence of yellow tints. The particles were more uniformly penetrated by light rays, seldom showing extremely dark sections or glassy surfaces. These workers found that some gelatins do not lend themselves to this test and they do not consider it universally applicable.

Melting Test. Several investigators have judged the quality of gelatin by the resistance to melting of ice cream in which it is an ingredient. Williams (18) placed two, three gallon cans of ice cream, one without gelatin and the other containing the normal amount, in an ordinary ice cream cabinet in a warm room for 48 hours. At the end of that period, the ice cream containing no gelatin had lost its identity, while the sample with no gelatin was unchanged.

Manhart (19) also used this test in his experiments. He froze ice cream with no gelatin, poor quality gelatin, good quality gelatin, and very good quality gelatin, and melted bricks of each at 86° F. His results are given on the accompanying table.

Hall and Houts (17) found that gelatin does not retard melting in ice cream, They conducted their experiment in a manner similar to that of Williams (18), but found slight difference in the melting of the two.

From the data presented, it seems that opinion is divided as to the effect of gelatin upon the melting of ice cream. However, the majority of investigators found that ice cream without gelatin melts faster than ice cream with gelatin.

Jelly Value Test. The jelly value tests, as described by Burke (16), Turnbow (20), and Parfitt (21) are all essentially the same. Concentrations of the gelatins are prepared in test tubes, ranging usually from 0.4 percent to 1.0 percent. The gelatin is dissolved in a water bath at 140° F., and is then cooled down to 50° F. After this temperature has been maintained for some time - at least 30 minutes - the tubes are inverted to note the minimum concentration which has solidified sufficiently to not run out.

Relative Influence of Gelatin on the Melting Resistance of Ice Cream

	Per cent ice cream melted at end of 30 minutes	40 minutes	50 minutes	60 minutes	90 minutes	120 minutes
Ice cream containing No gelatin (control mix)..........	9.80	16.66	26.46	33.32	55.38	71.55
Poor quality gelatin......	5.55	14.43	26.65	38.87	75.53	95.53
Good quality gelatin......	0.26	2.86	12.23	24.13	64.75	90.79
Very good quality gelatin	0.26	2.35	8.60	19.05	55.95	85.22

All writers seem to think this a very good test, but the large number of weighings required make it decidedly tedious.

Freezing Test. Turnbow (20) describes a test for gelatin wherein definite strength solutions are frozen, and the frozen product examined physically. He found that poor gelatins make long, spiny crystals, while good grades make small, mealy crystals.

It seems that this test could hardly be very accurate in rating gelatins similar in quality, and also, some gelatins, because of various reasons, might not lend themselves to this test. This test, then, could hardly be considered very satisfactory.

Melting Test. The melting point of the jelly of a given gelatin has often been regarded of importance in determining it's value. Bogue (36) has found the melting point and jelly strength to be parallel functions.

Turnbow (20) has devised a simple melting test. He places beakers containing jells at the same temperature in a water bath at 100° F. and maintains this temerature in the bath throughout the experiment. The time that each sample requires to assume the liquid state is taken. He found that this test gave very good results.

The investigators of today have quite generally decided that, among the tests for gelatin, the jelly strength test reigns supreme. Throughout most of the published work, other tests are compared with this test as being the authentic one. The general opinion is, that a jelly strength test, along with some kind of a bacterial count, gives a very good idea of the value of a gelatin.

Bacterial Count. Studies have shown that ice cream may be highly contaminated with bacteria. Since large numbers of bacteria are always undesirable in any dairy product, the ice cream manufacturer should reduce the number of organisms in his product as much as possible. A few cities have passed bacterial standards for ice cream, and others are studying the situation in order that an equitable ruling may be made.

The studies of Ellenberger (37) and Hammer (38) showthat milk, cream, and condensed milk are the most prolific sources of bacteria. They found that this contaminaton could be greatly reduced by pasteurization. Since these products are the chief ingredients of ice cream, and they are quite commonly highly infested with bacteria, it is logical that the bacterial flora of ice cream should consist essentially of those organisms found in them.

Ayers and Johnson (39) examined in Washington, D. C., 94 samples of ice cream during the summer months and 91 samples during the winter months. In the summer, they found the average count to be 37,859,907, with a maxium count of 510,000,000 and a minimum of 120,000. In winter, the average count was 10,388,222, the maximum 114,000,000 and the minimum 13,000 bacteria per cubic centimeter. These investigators found that there were five groups of bacteria in ice cream. The percentages of the various groups, together with the calculated number and percentage of each is given in the following table:

	Summer Samples		Winter Samples	
Bacterial Groups	Average no. of bacteria per c.c.	Average group percentage	Average no. of bacteria per cc.	Average group percentage.
Acid-coagulating	18,861,805	49.82	3,203,728	30.84
Acid-forming	7,844,575	20.72	3,950,641	38.03
Inert	5,292,815	13.98	499,673	4.81
Alkali-forming	704,195	1.86	563,042	5.42
Peptonizing	5,156,519	13.62	2,171,138	20.90
Total	37,859,909	100.00	10,388,222	100.00

The bacterial groups have much the same relation to each other in the winter and summer samples. The summer samples showed a higher percentage of the acid coagulating group and a lower percentage of the alkali and peptonizing groups than did the winter samples. However, since there was a lower average count in the winter, there were fewer of these last two groups than in the summer samples.

Gas forming bacteria of the colon aerogenes group were determined on litmus-asparagin agar on 88.33 per cent of the samples tested. The average number in the entire series of samples was 16.298 per cubic centimeter. The presence of any considerable number of members of this group in dairy products is looked upon with suspicion, since B. typhous belongs to this group and it is associated with fecal or decaying matter.

Ellenberger (37) and Hammer (38) found that there is no radical change in the total number of bacteria in ice cream during storage. Ellenberger reports a slight decrease during the first two to four days, with a more noticeable increase and then a corresponding decrease between the fourth and twenty-first day, after which time, a falling off in numbers was again noted.

Ellenberger found that aside from the utensil contamination, which is negligable, there is usually a great increase in the number of bacteria resulting from the freezing process. This is probably due to the breaking up of bacterial clumps. He found an average increase of 48% in bacterial count due to the freezing process. Gordon, Prescott, Heinmann and Pease (40) obtained similar results.

To determine the importance of gelatin as a source of bacteria in ice cream has been the object of considerable research. Many investigators have found that gelatin contains large numbers of bacteria. However, the effect of these organisms on the final count in the ice cream is not established. Ellenberger (37), Hammer (38), Gordon (41), Parfitt (42), and Brannon and Tracy (43) have shown that different brands of gelatin vary widely in the number of bacteria they contain. Hammer examined a number of samples of gelatin and after dissolving them with gentle heat, plated them on agar. The following table shows the variations which he encountered:

Sample number	Bacteria per Gram	Bacteria in 1 c.c. ice cream due to gelatin
1	113,000,000	565,000
2	14,000,000	70,000
3	35	0.2
4	4,200	21
5	85,000	425

The results in column three were derived by multiplying the number of bacteria in a gram of gelatin by .005, since 0.5% gelatin is commonly used in ice cream. This calculation means little, since the volume relations and the number of bacteria killed by heat are ignored.

The variations in bacterial count of different gelatins as reported by Hammer compare very favorably with variations reported by other experimentialists. Brannon and Tracy (43) found that, in general, the grades within the different brands ran fairly uniform in bacterial count. This lead them to conclude that the method of manufacture is a very important factor in the number of bacteria present in gelatin.

Parfitt (42) found the organisms in gelatin to be resistant to heat, cold, and drying to a marked degree. He found Bacterium coli in all samples examined, the total count being more than 5,000 organisms. This organism is associated with fecal and decaying matter, and, as expressed by Parfitt, to find Bacterium coli in our city water is considered serious. Parfitt also found another type of organism predominant in gelatin, the liquifier or protein digesting organism. Its presence is highly undesirable because it breaks down the protein into lower protein compounds as amino acids, and renders the gelatin useless as a colloid and in jellying power.

Brannon and Tracy (43) found that heating gelatin to 140 and 160° F. greatly reduces the number of bacteria present, even though the gelatin may be highly contaminated. The efficiency of pasteurization seems to be greater in a water solution than in a skimmilk solution. Brannon and Tracy (43) and Hammer (38) concluded, as a result of their studies, that the addition of gelatin to ice cream results in a slight increase in the number of bacteria, and that the use of high connt gelatin is undesirable.

From a review of the data presented on bacteria in ice cream and the effect of gelatin on the count, it is concluded that both ice cream andgelatin contain large numbers of bacteria; that it is very desirable to keep the bacterial count of ice cream as low as possible; and that the use of high count gelatins should not be permitted in ice cream making.

EXPERIMENTAL WORK

Object of Experiment

The primary object of this experiment was to determine the effect of viscosity of the mix upon the quality of ice creams of uniform swell.

Plan of Experimental Work

Procedure. Inasmuch as gelatin is an essential ingredient of ice cream and causes in part the viscosity of the mix, this study of viscosity has been concerned chiefly with gelatins.

In order to study the effects of different gelatins on the mix, seventeen lots of gelatin were obtained from thirteen different manufacturers and distributors. Three grades were secured from one company, two from another, while one grade each of the other brands were obtained. Many of these proved to be of extra high quality, while others were only fair, and others, inferior. However, since the purpose of this work was not to determine the best quality gelatin on the market, but rather, to compare different gelatins with their differing viscosities and their relative influences upon ice cream, the wide range in quality of thegelatins gave a very satisfactory group to use in conducting the work.

The work was divided into two parts or divisions:

Part I, the freezing experiment. It was in this work that the primary viscosity determinations were made. The melting test, employed to determine the true worth of the gelatins in the ice cream, was included.

Part II, gelatin quality determinations. This consisted of several tests for gelatin which were employed upon the seventeen samples. These were then compared with the melting test to determine their value.

Part I

Freezing Experiment

In order to determine conclusively the effect of the seventeen different gelatin samples on ice cream, an ice cream batch was prepared and divided into seventeen portions of 22.5 pounds each. To each of these individual mixes 0.12 of a pound of the different gelatins was added, after having been dissolved in water and made up to 1.5 pounds. This gave seventeen, twenty-four pound ice cream batches which were of exactly the same composition, other than containing different kinds of gelatin.

The mix was composed of cream, skimmilk, skim-milk powder, cane sugar, and the gelatin-water solution. The computed composition of the mix was as follows:

Fat.................................12.00 %

Milk solids not fat...............11.00 %

Sugar...............................14.00 %

Gelatin............................. 0.5 %

Total solids........................37.5 %

The batch was made up in a pasteurizing vat. The skim-milk powder and sugar were mixed together and added to the skimmilk and cream. The mixture was then pasteurized at 145° for thirty minutes, after which it was immediately cooled down to 110° F., viscolized at this temperature at a pressure of 1500 pounds and run over a surface cooler, where it was cooled to 70° F. with cold water. The batch was then divided into seventeen mixes of 22.5 pounds each.

In the preparation of the gelatin, 0.12 of a pound of each brand was weighed out. This was made up to 1.5 pounds by the addition of cold water. It was allowed to soak for 15 minutes, after which it was put in a water bath, the temperature raised to 150° F., and the gelatin thoroughly dissolved. The solutions were immediately added to the respective ice cream mixes.

The mixes were aged for 42 hours at 35° F. Samples were then taken for viscosity determinations. The mixes were frozen in a horizontal United States freezer. The ice cream was drawn off at an over run of 80 percent, as determined by the Mojonnier over-run tester. A quart brick and a pint container of each ice cream were taken, the former for the melting test, and the latter to be scored for texture and body.

The viscosity determinations were made by means of a Stormer viscosimeter. This is an instrument in which a cylinder is caused to rotate in the liquid under examination, through the influence of a weight. As the rotation of the cylinder under the influence of any given weight is assumed to be proportional to the viscosity of the liquid, the time is seconds taken for 100 revolutions of the cylinder is used as the measure of viscosity. Water is taken as unity, therefore the quotient obtained by dividing the time taken in water gives the relative viscosity in terms of water.

Samples of the mixes were taken for the viscosity determinations immediately before they were frozen, and tested without delay. In conducting these tests, a 102.49 gram weight was used. A temperature of 20° C. or 68° F. was maintained.

The viscosity determinations were made only on the third, fourth, and fifth mixes. Dr. Miller, of the Chemistry Experiment Station, Michigan State College, made these tests. He considered the results of the three determinations so conclusive that further work on this phase of the problem was considered unnecessary.

From the observations made in conducting the viscosity tests, it was noted that stirring the samples materially affected the resulting viscosity readings. Accordingly, mix 5 was treated in varying ways to determine the effect of stirring upon viscosity. The samples were stirred in the usual manner, in adjusting the temperature to 20° C. The readings were then made as usual. Some of the samples were tested three or four times, to note the effect of the revolving cylinder on the viscosity. Other samples were stirred vigorously after the first viscosity reading, and then read again. Part of the samples were only stirred slightly after the first agitation to note the effect of this treatment, while others were stirred vigorously, allowed to stand a few moments, and then stirred slightly. These results are later presented in tabular form.

The ice cream samples were scored for body and texture. A sample having ideal body and texture was given a perfect score of 25. To merit a perfect score, it was necessary that the sample be firm, free from air bubbles, ice crystals and sandiness; it could not be snowy, powdery, or spongy; it must resist melting and have "body" when melted in the mouth; it must cut a clean bore and pull out with comparative ease when the trier was inserted. Since only very high quality gelatins could produce an ice cream capable of meeting these requirements, it was considered a very good test for quality in gelatin.

The ice cream samples were placed in the zero room immediately after freezing and were kept there approximately a week, when they were withdrawn and scored. The samples were scored by Professor P. S. Lucas and the writer.

The Melting Test, which consisted of melting down the quart bricks of ice cream after they had been in the zero room for three days, was considered by far the most important part of the experiment. This test was used as the confirmatory test in determining the best gelatin. It gave definite results as to which gelatin was most capable of producing an ice cream which could best resist melting.

In conducting the melting test, a wire screen with one-eighth inch mesh was stretched on a wooden frame, 2-1/2 by 6 feet. This frame was placed two and a half feet from the floor of a 10 by 13 room, with all doors and windows closed to prevent air currents. The temperature in the room was maintained at approximately 29° C. (84° F.) throughout the melting period. The bricks of ice cream were placed on the screen, approximately 6 inches apart. Each brick was placed on a piece of cardboard, the exact shape of the brick, in order to prevent the melting due to the weight of the brick and its pressure on the screen. A nail was punched through the cardboard into the center of the brick to hold the brick in place.

Observations of the melting bricks were made from time to time, and the exact time taken for each brick to melt was recorded.

This test is especially valuable as a check on the relation of viscosity to quality in ice cream. Since the chief property of a good ice cream, from the standpoint of body and texture, is to be firm and resist melting, the different ice creams could be rated exactly by the time it took the bricks to melt down.

The seventeen mixes of ice cream were prepared six times. Results were taken of the melting and scoring each time. The melting ice cream bricks of the fourth, fifth, and sixth batches were photographed approximately two hours after their exposure in the incubation room. These photographs illustrate both the differences in time and type of melting.

Part II

Gelatin Quality Determinations

In order to compare the most common methods of testing gelatin with the melting test, a series of gelatin tests or quality determinations were conducted. The results of the melting test were taken as showing which gelatin performed its function best in the ice cream. It was used as the basis of comparison for all the other tests employed.

The viscosities of the gelatin solutions were determined by the use of the Mojonnier - Doolittle Viscosimeter. This instrument is a modification of the torsion viscosimeter devised by Doolittle in 1893. A metal sphere, fastened to a dial, is suspended by a wire, about twenty-five inches long, from the top of a goose neck support which extends from the base of the instrument. The wire fastens into a knurled nut at the top. The metal sphere is lowered into the liquid to be tested until it is completely covered. The dial is then turned clockwise through one revolution, stopping with the zero degree in line with the pointer. The dial is held in place by means of a lug and trip. When ready to make the determination, the trip is released. Due to the torque on the wire, the cylinder will revolve back to the zero point and continue in the same direction a certain distance, dependent on the viscosity of the liquid. The degree at which the dial stops represents the viscosity of the sample, expressed in degrees of retardation.

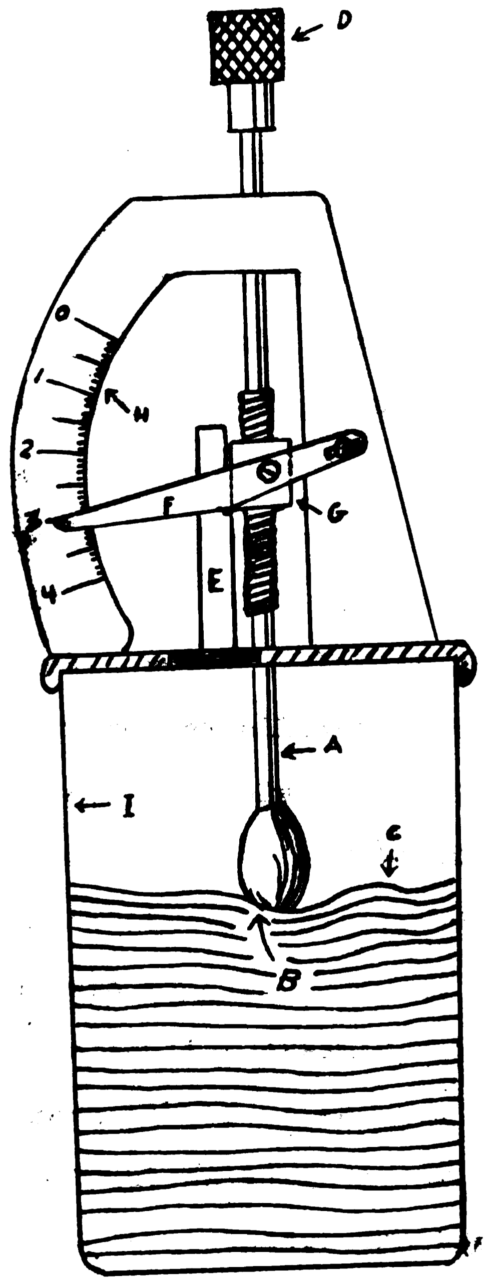
Since temperature exerts a large influence upon viscosity, the solutions to be tested must be accurately standardized as to temperature. The solutions tested were made up to a definite concentration, placed in a refrigerator at 35° F. and left there over night. They were withdrawn early the following day, adjusted to 70° F., and tested.

Different concentrations of the gelatins were tried, in order to determine which gave the best results.

It was found that 0.75% solutions at 70° F. gave very good results, and the data presented on viscosities was obtained at this concentration and temperature.

Jelly Strength. Investigators agree quite generally that the jelly strength test is the most accurate method of testing gelatin for quality. These gelatins were tested by means of a Hall Jelly Strength Tester. This tester, (Figure I) is a very simple device and it no doubt gives as good results as any other tester on the market.

There would appear to be some features of this tester which are quite undesirable. The dial on the scale has only four main divisions, each having ten subdivisions. This gives a total of forty possible valuations for the gelatins. It was found that in the seventeen gelatin samples examined, the variation ranged from 1.2 to 2.8, a difference of sixteen marks on the scale. This gives too many of the medium gelatins the same value, or practically the same value, so that there is no differentiation between their qualities. If the scale were made larger, so that values which are identical as read on the present scale could be distinguished between, the apparatus would be more valuable. Regardless of how carefully the jelly strength test is made, it is practically impossible to get identical duplicate results. This makes the apparatus undesirable for scientific purposes.



A - Plunger

B - Junction of Plunger and Gelatin

C - Gelatin

D - Knurled Handle

E - Lever

F - Recording Hand

G - Screw Block

H - Scale

I - Glass

Hall Jelly Strength Tester.

Figure I.

There is also considerable tendency for friction in the working parts, so special care must be taken that it is well lubricated at all times.

The jelly strength test, as employed, was divided into three operations: first, putting the gelatin samples into solutinn; second, cooling the solution overnight; and third, testing the jelly.

In putting the gelatin into solution, a sample was first taken from different portions of the container. This was thoroughly mixed and 7.1 grams accurately weighed out. Beakers were included in the equipment which have an etched line around them. A beaker was filled with cold water up to the line after which the 7.1 grams of gelatin was added. The beaker is so graduated that this produces a ratio of 1 part gelatin to 33 parts of water. The mixture was allowed to stand for fifteen minutes, in order that the gelatin might settle and swell, a water bath was heated to 140 to 150° F. and the soaked gelatin placed in it. The gelatin soon went into solution. The beaker was removed from the water bath and placed in a three gallon ice cream can. This can was placed in an ice cream tub or packer and the tub filled with crushed ice (without salt) in order that a temperature of 40° F. might be maintained. The beaker was left in the ice can over night - approximately fourteen hours in this experiment - and then taken out and tested immediately.

To make the strength determination, the tester is placed upon the beaker. Care must be taken that the screw block rests upon the top of the lever, so that the recording hand rests exactly at the zero mark. The plunger is now lowered until the bottom joint just clears the gelatin surface. This can be accomplished best by lowering the plunger until its shadow just meets the gelatin.

The depression reading is secured by turning the lever, thus disengaging the plunger which allows it to fall by gravity onto the jelly. The jelly strength is read directly on the scale, the value being at that point where the top of the recording hand rests on the dial.

The jelly strengths of all the gelatin samples were run in duplicate. The value of each sample was taken three times and the average of the three figures as the value.

<u>Acidity Test.</u> Since the statement is so commonly made that acidity in gelatin is undesirable, it was deemed wise to determine the acidities of the different gelatins in order to learn what relationship exists between acidity and quality.

A modification of the Mann's Acid Test was used to determine the acidities. This test is based on the principle of neutralizing the acid present with N/10 sodium hydroxide, using phenolphthalein as an indicator.

The acid present in the gelatin is considered to be equivalent to a like amount of hydrochloric acid. The percent of acid in the gelatins was computed by the following formula:

$$\frac{\text{c.c. N/10 NaOH used} \times .00365}{\text{grams gelatin used}} \times 100 \text{ equals the percent acid.}$$

In making the determinations, one gram of gelatin was weighed out and added to 15 cc. cold water. The gelatin was permitted to soak for approximately five minutes after which it was dissolved in a water bath at 150° F. Three drops of phenolphthalein solution were then added and N/10 sodium hydroxide was dropped in from a burette, until a faint pint color, which persisted for a minute, was obtained. This was taken as the neutral point and the number of cubic centimeters of sodium hydroxide required to produce this color was used in making the calculation to determine the percent of acidity. Two acidity determinations of each gelatin were made.

Clarity, Color, and Odor. When the gelatin solutions were heated to approximately 150° F., immediately before the acidity determinations were made, observations were made of the clarity, color, and odor of the solutions. The object in view was to find if any relationship existed between these factors and quality in gelatin. The results of these observations are presented in tabular form in the "Results" section of this paper.

Bacterial Counts. In order to determine to what extent the gelatins were contaminated with bacteria and how much each would contaminate the ice cream, bacterial counts were made of each gelatin sample. These counts were made by members of the Bacteriology Department, Michigan State College. Milk powder agar and standard agar were used as media. In making these analyses, one gram of the gelatin was weighed into a sterile dilution flask. Sterile saline solution was added to the dilution flask until the desired dilution was obtained. The gelatin was then melted in a water bath at about 50° C. After it was melted, the flask was thoroughly shaken and one cubic centimeter portions were immediately plated on standard nutrient agar and milk powder agar. The plates were incubated at room temperature and counted at the end of forty-eight hours. The counts represent an average of two plates, unless otherwise noted.

Fermentation Test. The presence of liquifying and gas producing organisms in the gelatin samples was determined by the fermentation test. To each of a series of sterile test tubes, 10 cubic centimeters of sterile water was added. Samples of the gelatins were carefully taken to avoid contamination, and 0.5 of a gram was added to each tube. The gelatins were thoroughly shaken up, allowed to swell for approximately 10 minutes, and were then dissolved by placing the tubes in a water bath at 150° F. The tubes were then placed in the refrigerator at 35° F. for three hours, so that the gelatins might thoroughly jell. They were then exposed at room temperature - approximately 70° F. - for six days, in order to determine which gelatins contained liquifiers and gas producers. This test was made in duplicate.

<u>Price.</u> Although price is not a recognized index of quality in gelatin, it is quite often customary to purchase gelatin on the basis of price alone. Consequently, the prices of the different gelatin samples are quoted and a curve made to compare with the curve prepared from the results of the melting test.

RESULTS and DISCUSSION

Part I - Freezing Experiment

Melting Test

The time required for the ice cream bricks to melt at a standard temperature is presented in Table No. I. The melting time for each of the seventeen bricks in the six different batches is given in hours and minutes. The average melting period of the ice cream samples stabilized with a particular gelatin in the six determinations is also given. Due to an error, the results of numbers 6, 10, and 14, were not secured in batch No. I. In batch No. V, there was an unaccountable discrepancy in the time of melting of number 13, as compared with its melting time in the other batches.

Considerable difference was noted in the way different samples melted. Those ice creams containing gelatin which were not especially resistant to heat, as samples Nos. 2, 3, 8, 9, 11, 12, 14, and 17 usually started to melt quite soon after exposure. The melted part ran down the sides and through the screen. They melted very much like frozen milk, in that the melted portion was liquid in nature. Numbers 1, 4, 5, 7, 15, and 16 did not melt so quickly and the melting was of a different nature. The

TABLE NO. I

Melting of Ice Cream Bricks - Expressed in Hours and Minutes

Number of Gelatin	Mix Number I		II		III		IV		V		VI		Average	
	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Min.
1	4	0	4	20	3	55	4	32	4	7	4	45	4	26
2	4	20	3	38	3	22	3	39	3	42	4	20	3	50
3	4	10	3	30	3	42	3	38	3	35	4	07	3	47
4	3	25	4	00	4	10	4	22	5	5	4	43	4	17
5	3	55	3	50	4	15	4	30	4	50	4	59	4	23
6	-		6	40	5	20	6	06	5	35	7	25	6	13
7	3	55	4	20	3	38	3	26	4	50	4	50	4	28
8	3	40	3	55	3	26	3	12	4	30	4	35	3	53
9	3	25	3	20	3	15	3	9	3	15	3	48	3	22
10	-		4	45	4	44	5	50	6	10	6	45	5	39
11	3	45	3	25	3	40	4	03	4	35	4	43	4	2
12	3	50	3	45	3	40	4	18	3	55	5	40	3	51
13	4	10	5	00	4	24	5	25	3	21	5	35	4	39

TABLE NO. I - continued

Number of Gelatin	Mix Number I		II		III		IV		V		VI		Average	
	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Minutes	Hour	Min
14	-	-	3	30	3	26	3	53	4	33	3	54	3	51
15	3	15	3	35	3	20	3	49	5	10	4	50	4	--
16	3	35	4	20	3	34	4	35	4	45	5	17	4	21
17	3	25	3	25	3	25	3	32	3	58	4	5	3	38

melted portion was foam-like in consistency, resembling whipped cream. It did not readily pass through the screen. Numbers 6, 10, and 13 melted still differently. They stood very firmly, and instead of melting and running down the sides as was common with the other samples, divided, or broke down in layers. They were heavy, or plastic, in consistency and did not melt down to a liquid. After several hours exposure, they softened and flattened out on the screen, but very little passed through. The photographs of the melting bricks, Plates I, II, and III, show the relative types and times of melting of the different ice cream bricks. These photographs show the melting of the samples in batches 4, 5, and 6. The numbers given the bricks refer to the numbers of the gelatin samples used, for which see Table I in the appendix.

As noted from the results of the melting test, there are several discrepancies in the melting times of the different ice cream samples from the several batches, but in most cases, there is little variation. This indicates that the test is quite constant, and therefore, reliable. Since resistance to melting is the most desirable characteristic of ice cream from the standpoint of body, this test can well be chosen as the confirmatory test for quality in this product.

Scores and Melting Test

The scores of the ice cream samples for each of the six batches, with the average score, are given in

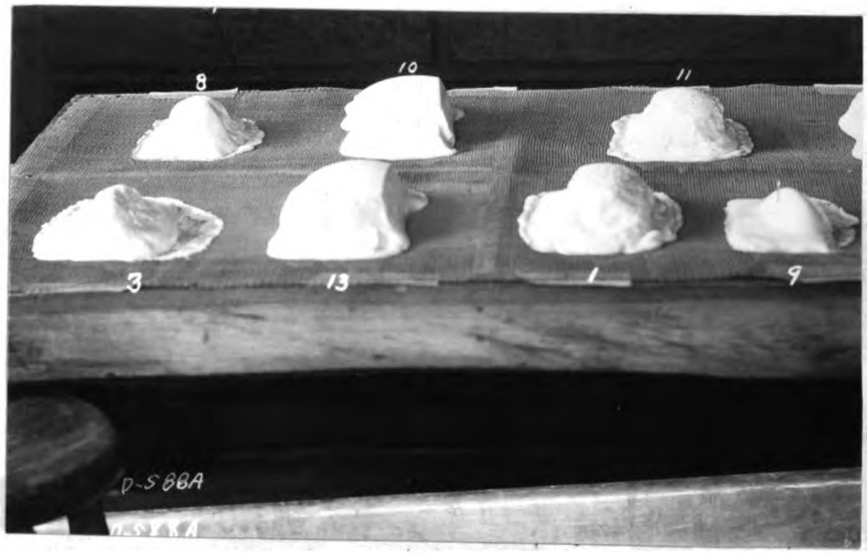


Plate No. I

Melting of ice cream bricks from

Mix No. 4 - two hours after exposure.

Plate No. II

Melting of ice cream bricks
from Mix No. 5 - two hours
after exposure.

Plate No. III

Melting of ice cream bricks from Mix No. 6
two hours after exposure.

Table II. The scores of numbers 3, 16, and 17 in batch number 4 were not secured. A survey of Table II shows that with few exceptions, the scores of the ice cream made from the different gelatins in the six batches or mixes are quite uniform. The two most outstanding exceptions are number 6, mix V, and number 10, mix II, neither of which can be accounted for.

Graph I gives the curves plotted from the average time taken to melt and the average scores of the ice cream made from the seventeen samples of gelatin, the data being taken from Tables I and II. As can readily be seen, the curves follow the same general direction except in four instances, which indicates that considerable correlation exists between the two methods of determining the quality of ice cream from the standpoint of resistance to melting.

In order to determine the correlation that exists between the two tests, the correlation coefficient was calculated mathematically. The correlation between the two tests, Time of Melting, and Score, was found to be 0.26 ± 0.065. This gives a correlation value of four times the probable error, which indicates that the chances are 140 to 1 that if the experiments were repeated, the correlation between the two tests would be at least 0.26. These results are confirmatory that considerable correlation exists between the two tests, since odds of 30 to 1 are

TABLE NO. II

Ice Cream Scores

Number of Gelatin	Mix I	Mix II	Mix III	Mix IV	Mix V	Mix VI	Average
1	21.5	23.25	22.5	22.5	22.25	23.0	22.67
2	20.0	22.0	22.75	23.0	22.25	22.75	22.14
3	22.0	23.0	23.0	--	23.25	23.25	22.90
4	23.5	22.5	23.5	23.75	23.0	23.25	23.21
5	22.5	23.25	24.0	24.0	22.75	23.0	23.25
6	25.0	24.0	24.5	24.5	22.5	24.0	24.08
7	22.0	22.5	22.0	22.5	22.25	22.5	22.29
8	20.0	22.5	22.0	23.0	21.5	22.75	21.96
9	22.0	22.0	22.0	22.5	22.5	22.5	22.25
10	24.5	21.0	24.0	24.25	23.5	23.0	23.38
11	23.0	22.0	22.5	23.0	23.25	22.75	22.75
12	22.5	23.0	21.5	22.25	22.5	22.25	23.33
13	22.0	22.0	22.5	23.0	23.5	23.0	22.67
14	23.0	22.0	23.0	23.0	22.5	22.5	22.67
15	24.5	23.25	23.0	23.5	23.0	23.5	23.46
16	23.5	23.25	23.5	--	23.5	23.5	23.45
17	21.0	22.0	23.0	--	22.0	23.0	22.20

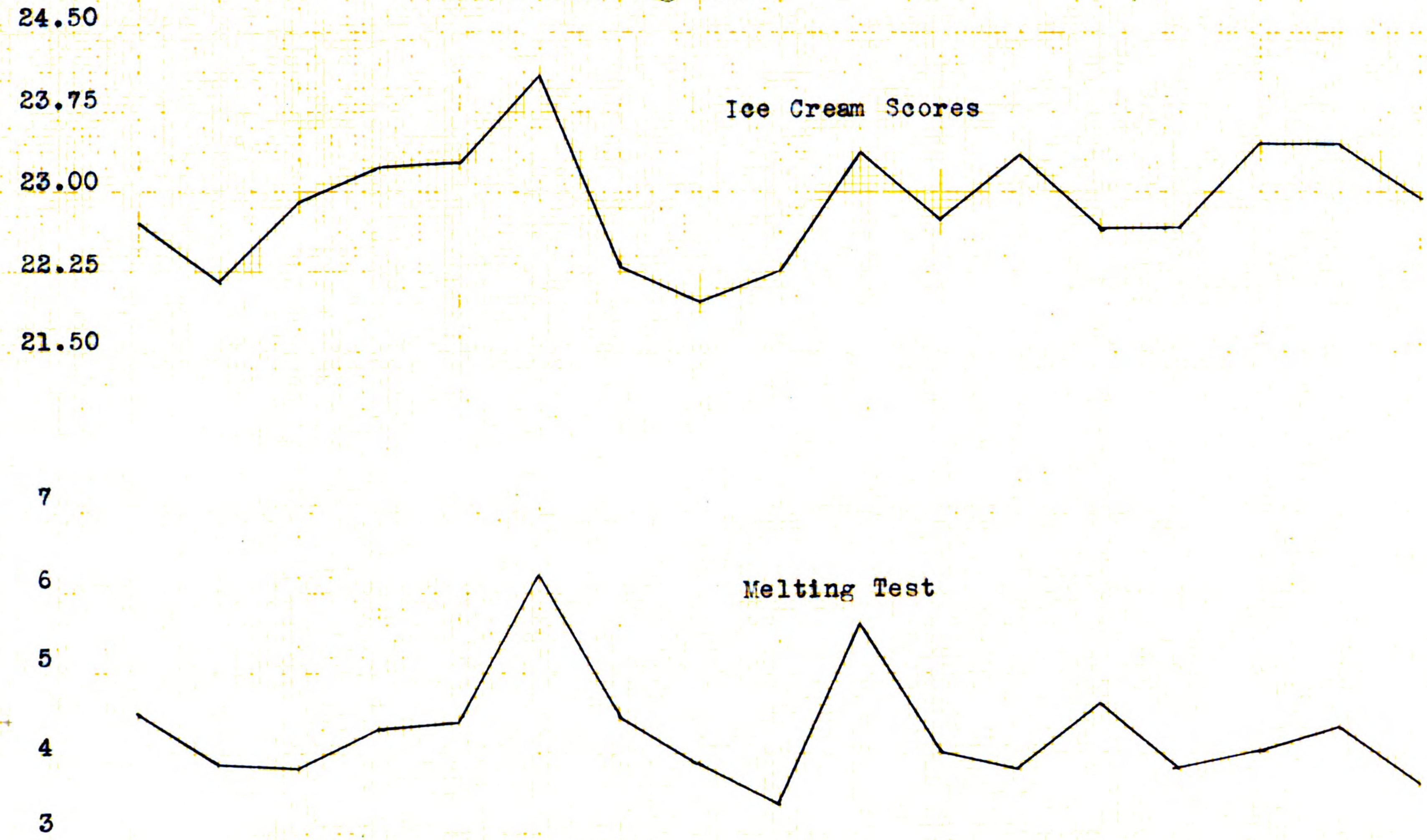
considered quite significant.

Viscosity of Mix and Melting Test

Tables III and IV give the viscosities of the different ice cream samples as taken from the third, fourth and fifth mixes, tested by the Stormer viscosimeter. Table III expresses the viscosity in seconds, while Table IV gives the relative viscosity, using water as the standard for comparison. Wide variations in the viscosity of the ice cream in the three different mixes are very apparent. These variations seem to be in no way consistent, since those samples having the highest viscosities in one determination often have the lowest in another. It would seem, therefore, that viscosity of the ice cream mix as a measurement of quality in icecream is of very little, if any, value.

Graph II gives a comparison of the average viscosities and melting times of the ice cream samples in mixes 4, 5 and 6. As can be noted from the curves, there is a decided tendency for the two lines to follow the same course, there being only three exceptions. However, since the curves are drawn from the values obtained by averaging the three determinations, and there are so many large variations in the individual viscosity determinations, it seems that the correlation between the two tests is coincident, or more apparent than real. This contention

Graph I :- Showing Relation of Ice Cream Scores to Melting Test.



is borne out by the mathematical correlation coefficient, which shows the correlation between the two tests to be 0.273 ± 0.088. This gives a correlation value of 3.10 times the probable error, which indicates that the chances are only 26 to 1 that if the work were repeated, the correlation would be as high as 0.278. This indicates that there is a certain amount of correlation existing between the two tests, but since odds of at least 30 to 1 are necessary before the results are significant, the correlation existing between the two is negligable.

Effect of Stirring on Viscosity

The effect of stirring upon the viscosity of the ice cream mix is given in Table V. The results indicate that only slight agitation causes a material decrease in viscosity, while vigorous stirring reduces the reading nearly one-half. Since in preparing mixtures for viscosity readings the agitation is rarely considered, it is self evident that this test is too easily varied to be a good indication of quality. It is not possible to age the ice cream mix at a sufficiently low temperature and then retemper it so that it can be tested for viscosity without agitation. In fact, it would be very difficult to test aged ice cream with the viscosimeter without first stirring it, due to its heavy consistency. It would be possible to test the ice cream mix very easily with the viscosimeter before the mix is aged, but at this stage the results would show nothing, since the gelatin has not had an opportunity to swell and surround the water particles. Consequently, before ageing, the ice cream samples made from all gelatins would test the same or practically the same.

A great change occurs in the consistency of the ice cream mix during the ageing period prior to freezing. When ageing begins, the mix is a viscous fluid, due to its high solids content and low temperature. As the ageing proceeds, the gelatin swells, absorbing water. Since it is a protective colloid, it surrounds the water particles with a film, preventing their union with each other. The formation of a jelly by the gelatin increases its water absorbing capacity. When most of the water is removed by this increased hydration, and the adjacent heavily swollen aggregates cohere, a jelly like consistency is assumed by the mix. The mix gradually becomes more viscous throughout the ageing process. When practically all of the water has been absorbed, it becomes heavy and plastic, resembling clabbered milk. Just when the mix ceases to become more viscous and plasticity begins cannot be determined.

The plasticity of an aged mix interfers with its viscosity test. This may partly account for the fact that viscosity of mix cannot be regarded as a true criteron of quality.

TABLE NO. III

Viscosity of Ice Cream Mixes

Time Expressed in Seconds.

Number of Gelatin	Mix III	Mix IV	Mix V	Average
1	61	215	130	135
2	68	88	52	69
3	55	56	65	59
4	44	42	68	51
5	39	52	79	57
6	331	102	93	175
7	103	244	133	160
8	185	71	98	118
9	29	175	28	77
10	211	345	189	248
11	355	77	63	58.5
12	314	109	185	203
13	158	122	95	125
14	46	142	57	82
15	45	68	24	48.5
16	202	83	75	120
17	40	74	28	47

TABLE NO. IV

Relative Viscosity of Ice Cream Mixes

Number of Gelatin	Mix III	Mix IV	Mix V	Average
1	7.18	25.30	15.29	15.92
2	8.00	10.35	6.12	8.16
3	6.47	6.59	7.65	6.90
4	5.18	4.94	8.00	6.04
5	4.59	6.12	9.30	6.67
6	38.94	12.00	10.94	20.63
7	12.12	28.71	15.65	18.83
8	21.76	8.35	11.53	13.88
9	3.41	20.59	3.29	9.10
10	24.82	50.59	22.24	29.22
11	4.18	9.06	7.41	6.88
12	36.94	12.82	21.76	23.84
13	18.59	14.35	11.18	14.71
14	5.41	16.71	6.71	9.61
15	5.29	8.00	2.82	5.39
16	23.77	9.77	8.81	14.12
17	4.71	8.71	3.29	5.57

Graph II :- Showing Relation of Viscosity of Ice Cream Mixes to Melting Test.

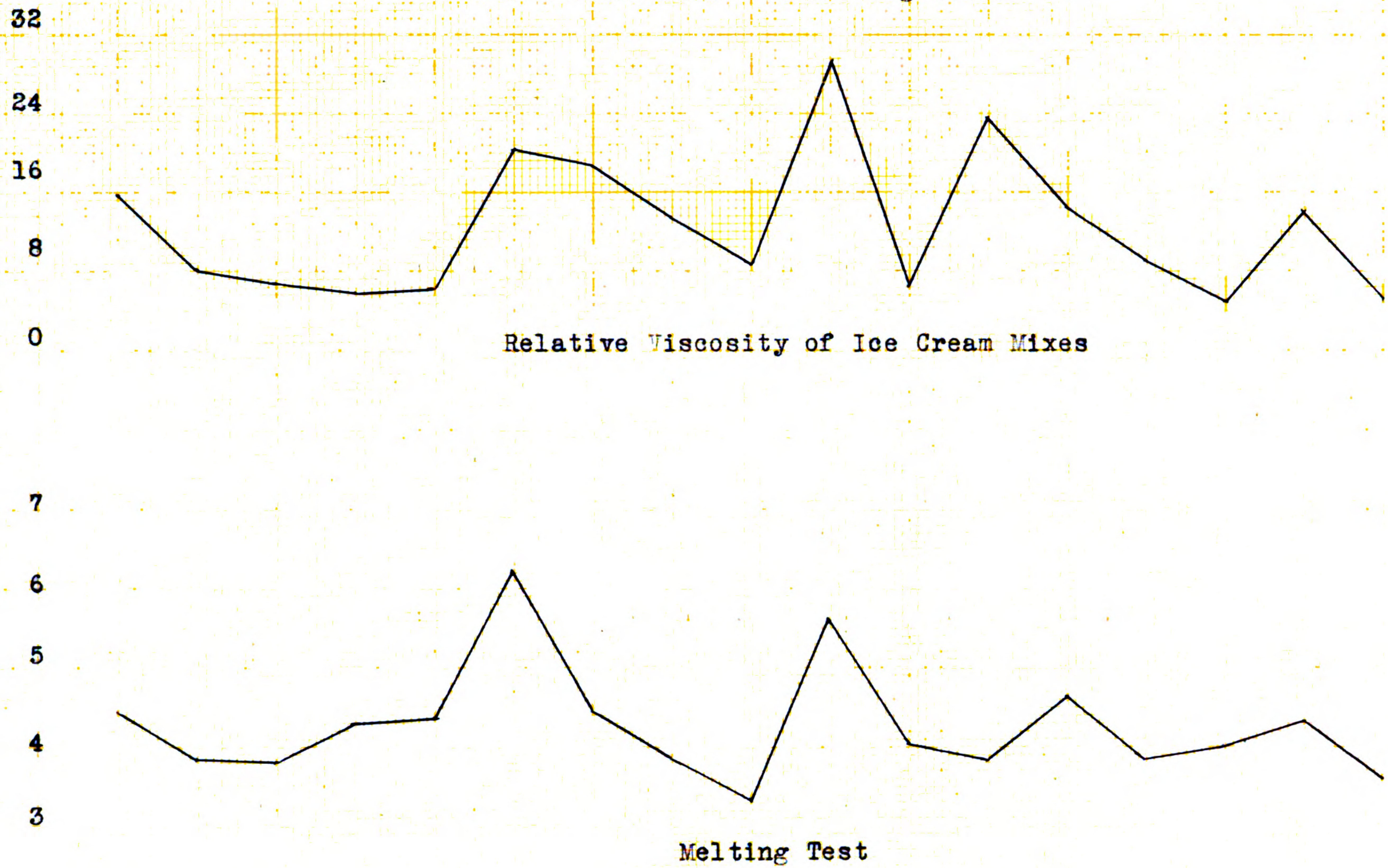


TABLE NO. V

Effect of Stirring upon Viscosity of Ice Cream Mix

Number of Gelatin	Stirred only in Warming Sample				Stirred Vigorously		Stirred Slightly	
	Test I	Test II	Test III	Test IV	Test I	Test II	Test I	Test II
1	130				85			
2	52	50						
3	65	64	63				58	
4	68	60	56	54				
5	79	75	68	66.5				
6	93	92						
7	133				83	83	76	
8	98	89					75	73
9	28	27.5						
10	189	176						
11	63	59	54	50				
12	185	150	120	115				
13	95	80						
14	57	51	48					
15	24	24.5						
16	75						66	66
17	28	28						

Part II - Gelatin Quality Determinations

Viscosity of Gelatin Solutions and Melting Test

The results of the viscosity determinations of the gelatin solutions by means of the McJonnier-Doolittle Viscosimeter are given in Table VI. The results of the two determinations differ enormously in many cases, while they are practically the same in others. Although the variations between the two tests seem quite large, when they are averaged, the value checks very closely with the value of the quality determinations given by the melting test. That these two tests compare quite favorably is shown by Graph III, which shows the values of the gelatins as determined by the two tests. The two curves are quite similar, with three minor exceptions.

The calculated correlation coefficient between the two tests is 0.740 ± .031. This is a very high correlation, since a correlation of 1.0 is perfect. The correlation coefficient is 23.87 times greater than the probable error, which indicates that the results are infinite, that if the work were repeated, the correlation would be at least 0.740 ± .031. This shows that for a gelatin quality test, the viscosity of the gelatin solution compares quite favorably with the melting test.

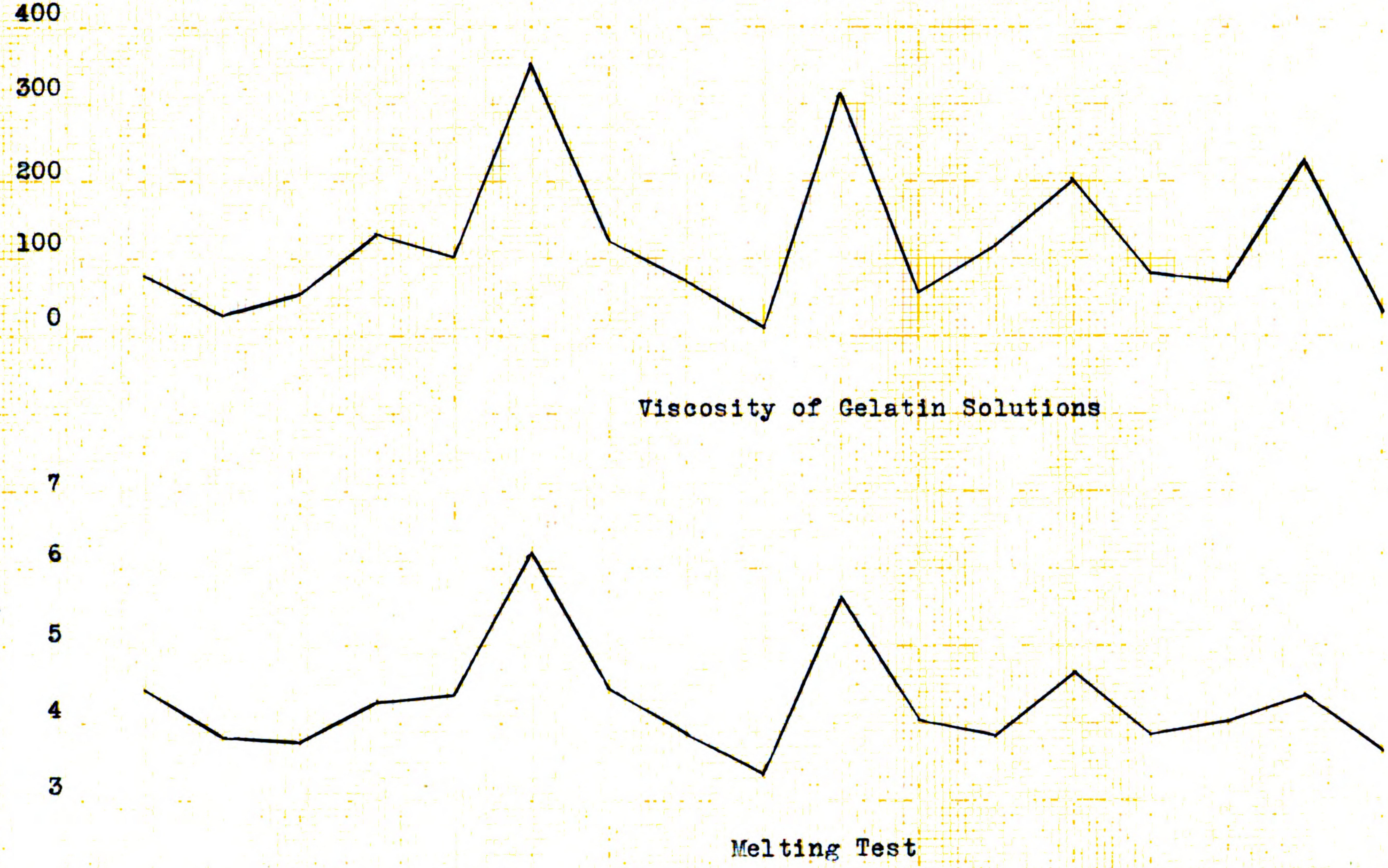
The chief limitation of the test is the difficulty

TABLE NO. VI

Viscosity of Gelatin Solutions

Number of Gelatin	First Determination	Second Determination	Average
1	25	135	80
2	15	45	30
3	22	90	56
4	135	132	134
5	62	145	104
6	355	352	354
7	25	230	128
8	40	115	73
9	16	12	14
10	265	360	313
11	31	86	59
12	67	270	119
13	149	256	203
14	18	143	81
15	27	112	70
16	85	270	128
17	26	40	33

Graph III :- Relation of Viscosity of Gelatin Solutions to Melting Test.



encountered in getting the results to check. If a sufficient number of tests are made on the gelatin and the averages made, this test should give results which are quite confirmatory of quality.

Jelly-Strength and Melting Test

The results of the jelly-strength test are given in Table VII. These determinations were made in duplicate, and check very closely in most instances, as may readily be seen from the table. However, there are in some cases wide variations between the two results. The inability to secure checks with this apparatus seems to be its greatest limiting factor. A thick skin often forms on top of the gelatin to be tested, and this, no doubt, often influences the reading somewhat.

Graph IV shows the curves plotted from the average values obtained by this test, as compared with the values obtained by the melting test. These curves are practically the same, having only two slight discrepancies, indicating that considerable correlation exists between the two tests.

The correlation coefficient between Jelly Strength and the Melting Test is -0.583 ± 0.045. This value is 12.96 times the probable error, indicating that the odds are infinite that if the experiment were repeated, the results would be -0.583 ± 0.045. The correlation, in this instance, is negative due to the way the jelly strength values are read on the Hall Jelly Strength Tester. On this tester, the higher the quality of gelatin, the lower the value. A negative correlation is just as significent as a positive correlation, and it therefore carries the same value as though it were 0.583 ± 0.045.

This proves that a very strong correlation exists between Melting Time and Jelly Strength. This latter test may consequently be used as an indication of quality in a gelatin.

Acidity and Melting Test

As is indicated by Table VIII, the acidities of the seventeen different gelatins ranged from neutral to 1.15 percent acidity. Taking the latter sample as a basis for calculation and using the usual amount of gelatin, 0.5 per cent, in the mix, it is apparent that the use of this gelatin would only increase the acidity of the ice cream mix by the following amount: 1.15 x 0.005 = 0.00575 per cent acidity. Since as much as 0.35 per cent acidity is often developed in the ice cream mix without any disastrous results, it is apparent that the amount added by this gelatin is negligible. It is possible that other commercial gelatins have a considerably higher acidity than those used in this study, but it is not likely that they will have a sufficiently high acid content to imperil the ice cream.

The only possibility of undesirable results from

TABLE NO. VII

Jelly Strengths

Number of Gelatin	First Determination	Second Determination	Average
1	1.9	1.9	1.9
2	2.2	2.2	2.2
3	2.0	2.0	2.0
4	1.8	2.1	1.95
5	1.7	2.0	1.85
6	1.2	1.4	1.3
7	1.8	1.9	1.85
8	1.9	2.1	2.0
9	2.8	2.8	2.8
10	1.4	1.4	1.4
11	1.9	1.9	1.9
12	1.8	1.8	1.8
13	1.6	1.8	1.7
14	2.5	2.2	2.35
15	2.1	2.2	2.15
16	1.8	1.8	1.8
17	2.2	2.3	2.25

Graph IV :- Relation of Jelly Strength Test to Melting Test.

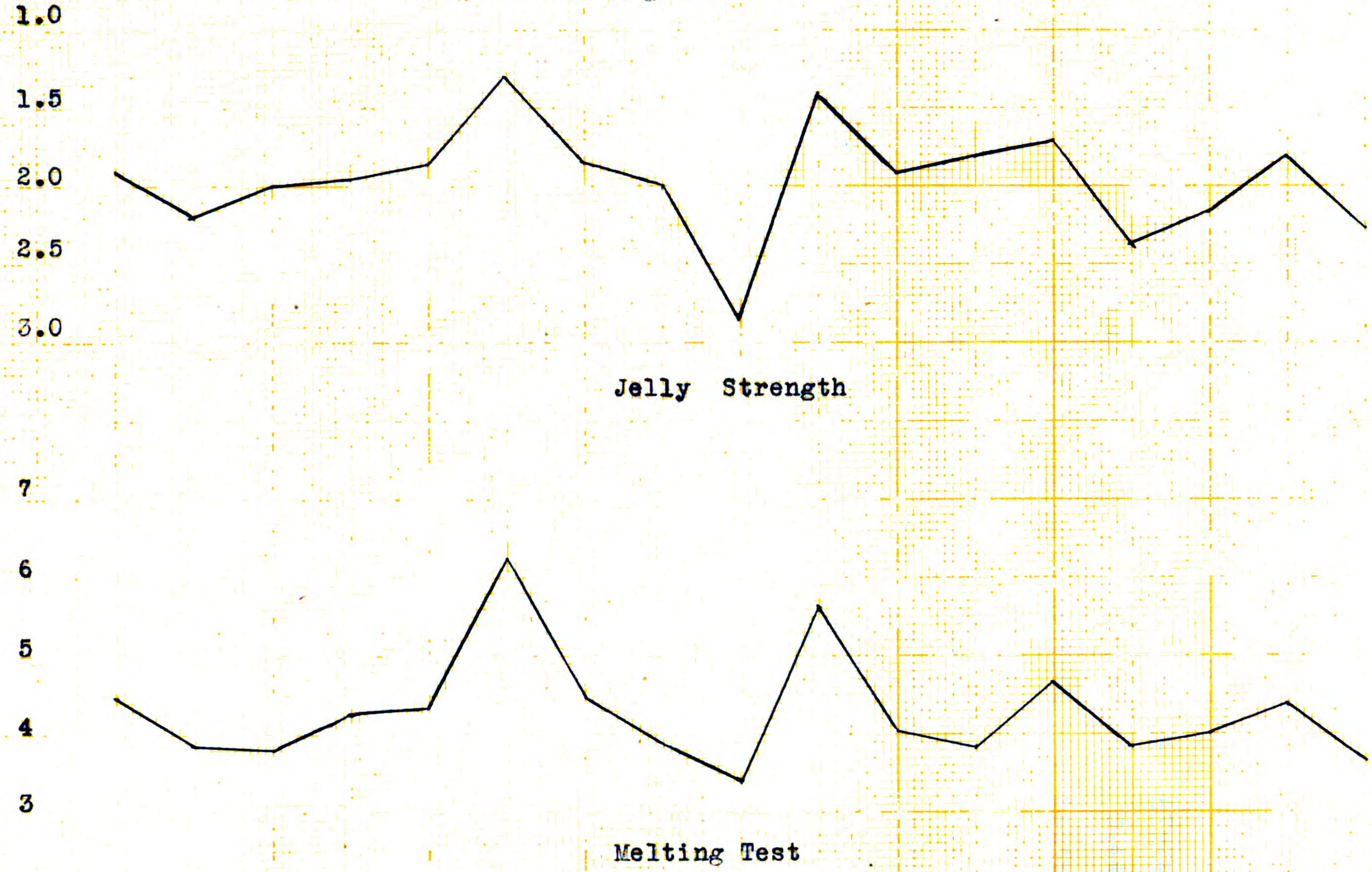
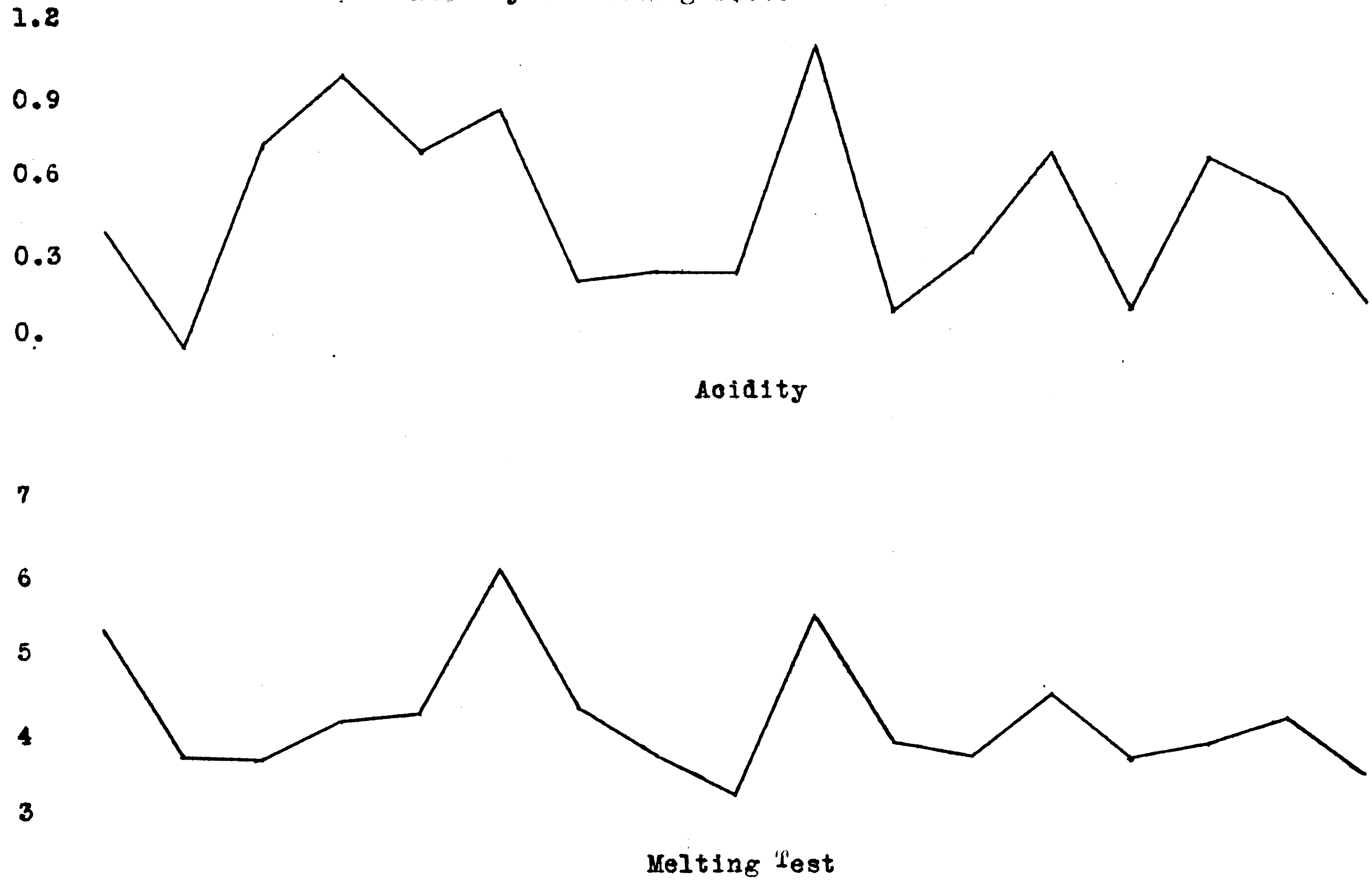


TABLE NO. VIII

Gelatin Acidities

Number of Gelatin	First Determination	Second Determination	Average
1	0.44	0.44	0.44
2	neutral	neutral	neutral
3	0.80	0.76	0.78
4	1.02	1.06	1.04
5	0.73	0.77	0.75
6	0.91	0.91	0.91
7	0.26	0.26	0.26
8	0.29	0.29	0.29
9	0.29	0.29	0.29
10	1.13	1.17	1.15
11	0.15	0.15	0.15
12	0.37	0.37	0.37
13	0.77	0.73	0.75
14	0.15	0.15	0.15
15	0.73	0.73	0.73
16	0.58	0.58	0.58
17	0.18	0.18	0.18

Graph V :- Relation of Gelatin
Acidity to Melting Test.



the use of high acid gelatin would occur when a small amont of milk, either skim or whole, is used in dissolving the gelatin. When this method of dissolving the gelatin is practiced, the mixture of milk and gelatin is quite concentrated, and the acidity present in the gelatin may be sufficient to curdle the milk. The danger is enhanced when the acidity of the milk is already high. However, when the gelatin is added dry to the entire mix, or is dissolved in a small amount of water and is then added to the mix, there is no danger of curdling.

Graph V, which compares the acidity curve with the melting test curve of the different gelatins indicates that little correlation exists between the two tests. However, when the mathematical test is applied, we find that this is erroneous. The correlation coefficient between the two tests is 0.593 ± 0.044. It has a value of 13.48 times the probable error, showing that the odds are infinite. If the work were repeated, the value of the correlation would be 0.593 ± 0.044, making the correlation between the two tests very significant.

From this we may conclude that, though high acidity itself is not to be desired in gelatin, it is associated with high quality.

Clarity, Color and Odor

The clarity, color, and odor of the solutions of the gelatin samples are given in Table IX. A study of these results indicates that no relationship exists between these three factors and quality, as determined by the melting test. These factors are too easily affected and controlled by the process of manufacture to be good indices of quality.

Bacterial Counts and Fermentation Test

The bacterial counts of the gelatin samples are given in Table X. The counts made on Standard Agar No. I, and Milk Powder Agar No. I, were made six months before those which are marked No. II. They were probably contaminated during this time, which accounts for the higher count on the later date.

It will be noted that the results of the bacterial counts compare quite favorably with those of the fermentation test as given in Table XI. Gas producing or liquifying bacteria might be suspected in those samples containing the largest numbers of organisms. Such was the case with two exceptions, numbers 3 and 13, which had relatively high counts but did not show the presence of liquifiers or gas producers.

Price and Melting Test

Table XII and Graph VI show the price of the gelatins and the relation of price to quality as determined by the melting test. In the sames 1 to 7 and 14 to 17, the curves

TABLE NO. IX

Clarity, Color, and Odor

Number of Gelatin	Clarity	Color	Odor
1	slightly cloudy	white	strong
2	" "	amber	very strong
3	clear	light amber	tankage
4	"	white	good
5	"	"	slightly strong
6	"	"	good
7	"	"	"
8	cloudy	light yellow	slightly pig
9	clear	amber	" strong
10	"	white	" pig
11	cloudy	"	good
12	clear	"	"
13	"	"	slightly strong
14	"	"	good
15	slightly cloudy	"	strong
16	" "	light amber	slightly strong
17	clear	white	" "

TABLE NO. X

Bacterial Counts

Number of Gelatin	Standard Agar No. I	Standard Agar No. II	Milk Powder Agar No. I	Milk Powder Agar No. II
1	150	350	50	200
2	1,200	136 ,000	300	-
3	50	5,250	100	1,200
4	50	8	50	100
5	50	275	50	-
6	100	300	150	50
7	1,750	4,850	-	3,500
8	150	180,000	250	165,000
9	50	175	50	-
10	50	350	50	-
11	100	150	50	-
12	100	300	150	-
13	50	20,000	150	60,000
14	100	300	100	200
15	50	-	50	-
16	50	-	50	-
17	-	150	150	50

TABLE NO. XI

Fermentation Test

Number of Gelatin	First Determination	Second Determination
1	-	- *
2	+	+
3	-	-
4	-	-
5	-	-
6	+	-
7	+	-
8	+	+
9	-	-
10	-	-
11	-	-
12	-	-
13	-	-
14	+	+
15	-	-
16	-	-
17	-	-

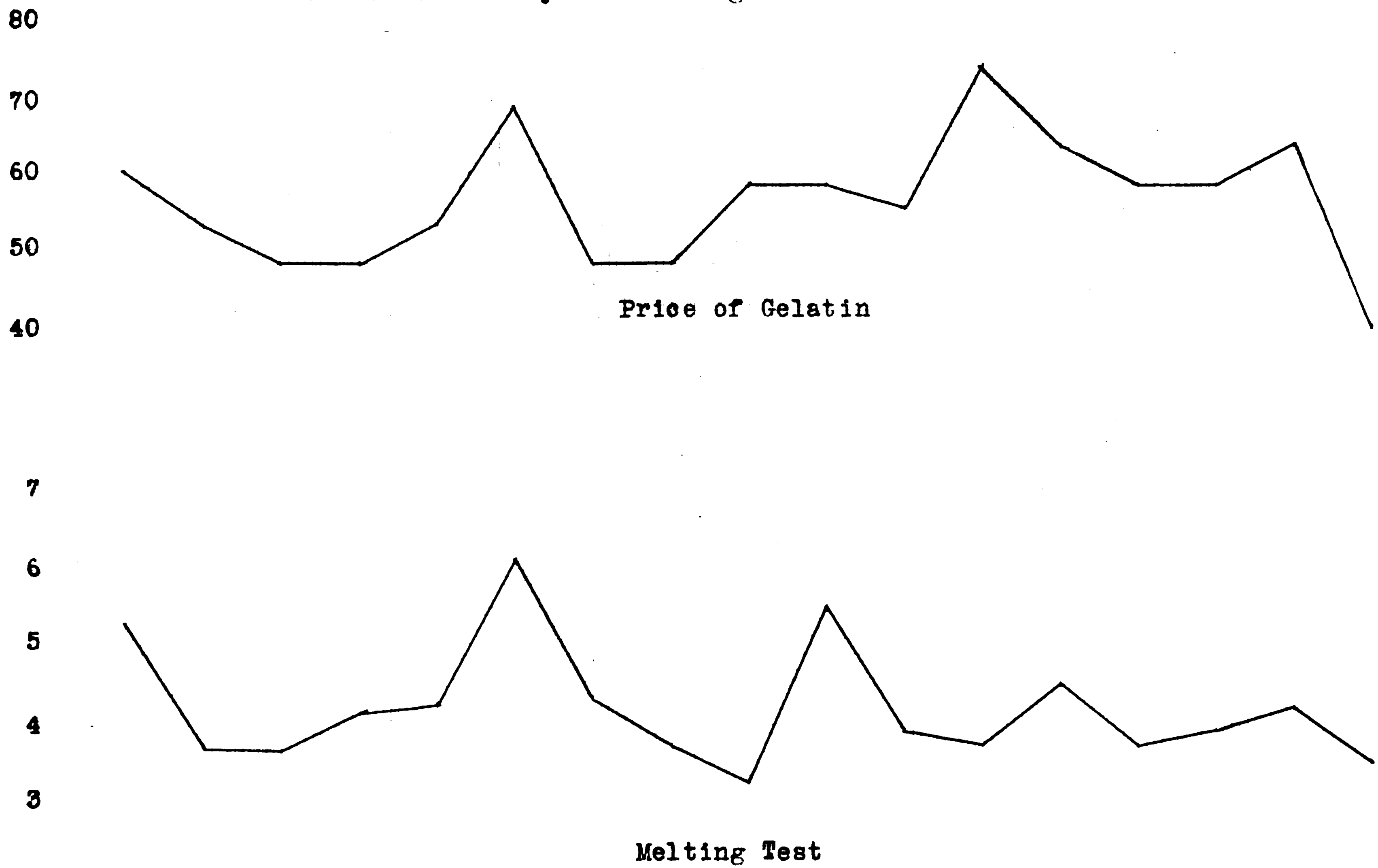
* The plus sign indicates the presence of liquifying or gas producing bacteria; the minus sign indicates that no gas or liquifaction was produced.

TABLE NO. XII

Price of Gelatins

Number of Gelatin	Price (cents)
1	62
2	55
3	50
4	50
5	55
6	70
7	50
8	50
9	60
10	60
11	57
12	75
13	65
14	60
15	60
16	65
17	42

Graph VI :- Relation of Price of Gelatin to Quality
as Determined by the Melting Test.



would lead to the belief that considerable relationship exists between price and quality gelatin, but with the other five samples, there seems to be no relationship whatsoever. However, that there is considerable relation between the two is proven by the calculated correlation coefficient. The correlation between price and melting test is 0.311 ± 0.060. Thus, the correlation has a value of 5.18 times the probable error, which indicates that the odds are 1400 to 1 that if the work were repeated, the correlation would be 0.311 ± 0.060. The relationship between the two factors is very significent, so we can cohclude that price and quality bear considerable correlation.

Comparison of Tests

Table XIII gives a mathematical comparison of the important tests discussed with the melting test. These tests are listed, from top to bottom, in the order of their correlations. The first three tests listed, Viscosity of Gelatin Solutions, Acidity, and Jelly Strength tests, have very high correlations. These correlations are so much greater than their probable error that the odds are infinite thatwere the work repeated, the correlation would fall within the same limits of error. Since the Score correlation was the smallest of the lot, it was taken to be basic. A survey of the three highest valued correlations shows that their Differences (the correlations minus the correlation of the base) are greater than their Probable Errors of the Differences, so that the differences in value of these correlations and that of the base are quite significant.

The three tests showing the lowest correlations with the Melting Test, Price, Viscosity of Mix, and Score, are so similar in value that there is little difference. Both Price and Score show greater Odds than does Viscosity of Mix, due to the high Probable Error of this later test, but the Probable Error of the Difference of both Price and Viscosity of Mixes is greater than the Difference. The difference in value of these latter three tests is less than the Probable Error, showing that the differences are not significant.

TABLE NO. XIII

Mathematical Comparison of Tests

	Correlation Coefficient	Probable Error	Correlation ÷ Probable Error	Odds	Difference (Correlation minus base)	Probable Error of Difference
Viscosity of Gelatin Solutions	0.740	0.031	23.87	Infinite	0.480	.0650
Acidity	0.593	0.044	13.48	"	0.363	.0783
Jelly Strength	-0.583	0.045	12.96	"	0.323	.0789
Price	0.311	0.060	5.18	1400 : 1	0.051	.0992
Viscosity of Mixes	0.273	0.088	3.10	26 : 1	0.016	.1094
Score	0.260	0.065	4.00	140 : 1	Base	-----

Summary and Conclusions

1 The melting time of the ice cream bricks proved to be a very good index of quality.

2 Little correlation exists between the scores of the ice cream samples and the melting test. The human element undoubtedly enters in too much to make scoring an accurate test for quality.

3 The work done on the viscosities of the mixes tended to show that viscosity, as a measurement of quality in ice cream, is practically valueless.

4 Viscosity as a measurement of quality in gelatins compared very favorably with the melting test, indicating that as a test for quality, viscosity of the gelatin solution can well be adopted.

5 The jelly-strength test gave results comparable to those secured by the melting test.

6 The acidity of the gelatin samples was insufficient to endanger the ice cream mix. A high positive correlation exists between acidity and quality in gelatin.

7 Clarity, color, and odor showed no relationship to quality.

8 The gelatins containing gas-producing and liquifying organisms as determined by the fermentation test, were

with two exceptions, found to be among those with the highest bacterial counts.

9 A high correlation exists between price of gelatin and quality.

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Appendix

Table No. I.

Number of Gelatin	Brand
1	United Chemical Company
2	Chalmers
3	Atlantic
4	Swifts 3A
5	Swifts 4A
6	Swifts 8A
7	Duche
8	United States
9	Crandell Pettee
10	Grayslake
11	Whitten
12	Crystal
13	Dunns
14	Milligan and Higgins
15	Delft Imperial
16	Delft Supreme
17	Essex