A STUDY OF THE EFFECT OF SEVERAL PROPOSED STABILIZERS ON ICE CREAM

THESIS FOR THE DEGREE OF M. S.

IRA GOULD, JR.

1933

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Thesis

Respectfully submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science.

by

Ira Gould, Jr.

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THESIS

ACKNOWLEDGMENTS

The author expresses his sincere appreciation to Professor E. L. Anthony for making this study possible and for his kind advice and guidance throughout the period during which this work was carried on, and to Professor P. S. Lucas for directing the study and for his aid in the correction and preparation of the manuscript.

The writer also acknowledges with gratitude the helpful suggestions of Professor G. Malcolm Trout relative to the procedure of the study and to the arrangement of the thesis material.

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INTRODUCTION

Ice cream consumers have for many years favored a smooth textured product, one free from an icy, coarse, granular structure. It is necessary, therefore, that certain precautions in processing and handling be used by the manufacturer in order that the ice cream, when placed before the consumer, possesses the desired smoothness.

Commercially manufactured ice cream is not sold immediately after the freezing process, but is stored in a hardening or cold room at low temperatures for several days before it is marketed. If the ice cream is made only from milk, cream, and sugar in normal amounts, it becomes granular and icy during this storage period. This is due to the formation of comparatively large ice crystals.

In order to prevent this undesirable crystallization, small amounts of certain colloidal substances have been used by manufacturers to protect the ice cream from such ice formation and consequent coarseness. These colloids also serve to stabilize the ice cream, and to make it more resistant to melting.

Gelatin has been the most popular and widely used of any of the colloids listed as ice cream stabilizers. Because of its source, however, many people have opposed its use as an ingredient of ice cream.

Various vegetable products have been used to a small extent in the past as substitutes for gelatin, and recently many more have been placed on the market under trade names. Very little information is available as to the

efficiency of these products as ice cream stabilizers. It was for the purpose of gaining additional information concerning these vegetable substances that this study was carried out.

Any study made of different ice cream ingredients would not be complete without considering each substance from an economical and nutritional viewpoint. If one stabilizer is as efficient as others and is less expensive, it probably should be the one used. Also, even though only small amounts of a stabilizer are used in ice cream, the nutritional value of the product should not be entirely disregarded.

It must be kept in mind, that the texture and body of ice cream is not dependent altogether on the stabilizer used, but is influenced by other factors.

SCOPE OF INVESTIGATION

This investigation includes a study of seven vegetable stabilizers: gum tragacanth, gum arabic, agar agar, Colace, Krabyn, Lakoe A, and Kelco Gel. Since these substances are advocated for use in a food product, it is of interest to the general public to know something of their nature and origin. The following brief discussion, therefore, enumerates a few of their properties and tells something of their source and importance.

Nature and Origin of Stabilizers:

Gums of one type or another are used either directly for stabilizers in ice cream or are the basis for many gelatin substitutes now on the market bearing various trade names.

Persia and Turkey are the principal sources of gum tragacanth. The gum is obtained from the Astragalus genus of botanicals, and is secured by gashing the trunks of the shrub near the ground, from which exudes the juice or gum. It must be collected within 24 hours if it is to be of the pure white variety of highest grade. The longer it remains on the tree the darker it becomes and the grades and value are reduced accordingly.

Gum Arabic is secured from the acacia tree in Egypt. The gum is collected during the dry season from October to June, at which time the natives puncture the bark of the tree with a sharp instrument. The gum exudes in the form of a tear which may be collected several weeks after tapping. The process may be repeated every few weeks during the season.

Locust bean gum, bearing the trade name of tragasol, is made from the seeds of the carob tree. Although the carob tree is found in the western section of the United States, from which some of the gum is obtained, the largest source of supply of the gum is from the vicinity of the Medi-

terranean Basin from Spain to Palestine. This gum is coming into prominence as an ice cream stabilizer and furnishes the basis for several of the newer vegetable stabilizers including Krabyn and Lakoe A.

Kadaya gum or Indian gum is said to come from the Sterculia genus of botanicals which grow profusely in British India. This gum has been prominent during the past few years in ice cream manufacture, being used in sherbets and ices. It is no doubt, present in some of the newer vegetable stabilizers.

It is generally accepted that the active stabilizing agent for the commercial product, Colace, is a gum of some type, although the exact gum is not as yet known.

Kelco Gel, another vegetable product used as an ice cream stabilizer, is said to be pure sodium alginate, a product obtained by chemical treatment of algae. Its source is southern California.

Although these newer type vegetable stabilizers differ in composition, those containing gums as the stabilizing agent consist principally of the same substances. These substances, however, are present in different stabilizers in greater or lesser amounts. Table I gives the chemical analysis of one of these vegetable stabilizers. For obvious reasons, the commercial name of the product having this analysis is omitted.

Table I. Approximate Chemical Composition of Vegetable Stabilizer which Has Gum as Its Stabilizing Agent

Components	Approximate Percentage
Galactan	25
Mannan	65
Pentosans	4
Albuminoids	2
Cellular Tissue	1
Mineral Matter	3
Laevulan	trace
Nitrogen	small

Agar, as pointed out later in the review of literature, is secured from algae. The red algae of the Pacific Coast furnish a large amount of the commercially used agar. Agar usually contains about 80 per cent of carbohydrate material and about three per cent of ash. The best quality agar has the lowest percentage of ash.

Gelatin, the most popular stabilizer, is an animal product, a protein obtained by the processing of calf skin trimmings, pork skin, or bones. It is derived specifically by hydrolysis from the two proteins, collagen and ossein.

LITERATURE REVIEW

Much research has been done and considerable literature is available on the use of stabilizers in ice cream. Most of it, however, deals with gelatin. As early as 1909, Alexander (1) noted that ice cream made with gelatin was smooth and "velvety", while that made without gelatin was sandy and grainy. In general, he concluded that ice cream made with eggs, gelatin, or some other colloidal ingredient was superior to that made without such substances, the colloid acting as an inhibitor of crystallization or as a preserver of texture. In another article (2), he pointed out that gelatin in ice cream was advisable as it made an ice cream of better consistency.

The protective action of gelatin against ice crystallization has been mentioned by Washburn (39), Downey (12), and others. Dahlberg (7), found that it was not due to the protective action of the colloid that ice cream is kept smooth, but due instead to the ability of the gelatin to form a gel in the ice cream when added in sufficient amounts. This fact was further stressed by Dahlberg, Carpenter, and Hening (9), who pointed out that the amount of gelatin ordinarily used in ice cream is sufficient to bring about gel formation.

The most generally accepted definition of a gel is that given by Getman and Daniels (15) who state that gel formation results from the "agglomeration of the hydrated particles, forming a structure of filaments, with the free water retained in the capillary spaces between the filaments which have been likened to a brush pile, and filaments which interconnect with each other to form a honeycombed structure."

Results of work done by Leighton and Williams (4) substantiate the conclusions drawn by Dahlberg. They state that the gelatin in its protective action "merely retards the rate at which equilibrium is established when a solid crystallizes from solution in its presence."

Sommers (35) concludes that if smoother texture is brought about by gel formation, it is due to the interference by the gel filaments with the formation of large ice crystals, rather than because of a greater amount of the water being held in a bound form.

Several investigators have studied the viscosity of mixes as influenced by gelatin and its jellying properties. The associates of Rogers (4) point out that ice cream mix exhibits both a structural and a basic viscosity, the structural viscosity being broken down on agitation.

Turnbow and Milner (36), in discussing the two types of viscosity state that real viscosity is found "in crystalloids and colloids alike which have no connection with colloidal behavior, and apparent viscosity is due to the swelling of submicroscopic solid particles in a solution." The latter type is unstable under certain conditions. They conclude that gelatin is largely responsible for the amount of viscosity that may develop during aging.

De Pew (11) observed that at low aging temperatures a definite gel structure is built up which is largely destroyed by agitation. He concluded that gelatin greatly increased the apparent or structural viscosity of the mix, and when excessive gelatin was used the structural viscosity could not be broken down to the same point as that obtained in mixes having a lower gelatin content.

That basic viscosity applies to a value secured under specific conditions and it is not a correct minimum value from the viewpoint of the lowest viscosity that might be present without fat clusters, is the opinion of Hening (18). Wright (41) found that greater basic viscosity was developed in gelatin mixes when high initial temperature of 80° to 100° F. was used in the aging period.

That agar is like gelatin in that it increases the viscosity by the formation of a gel is the opinion of Sommer (35) and Dahlberg (7) (8). Sommer (35) also concludes that gums increase the viscosity of ice cream mixes because of their high degree of hydration.

Associates of Rogers (4) concluded that theoretically a high viscosity and a low surface tension should favor overrun, but that no data give results in accord with the theory. Turnbow and Raffetto (37) state that "the lower the surface tension, the faster the mix whips in the freezer." Results obtained by Reid and Russell (33) and Gebhardt (14) are contrary to this theory, however, and show no correlation between surface tension and whipping ability.

Experimental results secured by Leighton and Williams and reported by associates of Rogers (4) indicate that in certain cases high basic viscosity favored overrun while in other cases it hindered overrun. Wright (41) reports that the whipping property of the mix was decreased as viscosity increases. This same conception is held by Sommers (35) who states, however, that such is not always the case.

DePew (11) found that mixes with high viscosity incorporated overrun more slowly and in smaller amounts than those with less viscosity. Conclusions drawn by Gregory and Manhart (17), after reviewing literature pertaining to this subject, were that under most conditions viscosity is

necessary to obtain maximum overrun, but certain substances when added to the mix may increase the viscosity but decrease the ability of the mix to incorporate air.

Sommers (35) concluded that "differences in the whipping ability of ice cream mixes cannot be explained on the basis of viscosity and surface tension."

Gelatin is a deterrent of overrun in both time and degree, according to the associates of Rogers (4). Mortensen (30) had previously found that stabilizers did not influence the yield of ice cream. Washburn (39) likewise concluded that the swell was not affected by gelatin, gum tragacanth, or other binders. Both Downey (12), and Dahlberg, Carpenter, and Hening (9) found that variations of amounts of gelatin from 0.2 to 0.6 per cent did not influence the overrun obtained. However, although the yield was not affected, Dahl and Caulfield (10), Horrall (20), and Mortensen (30) agree that gelatin lengthens the time required to reach a desired percentage of overrun.

Several tests have been devised to determine the efficiency of stabilizers, or more specifically, gelatin, in ice cream. Moore, Combs and Dahle (29) tested six samples of gelatin for gold number, pH, ash, and moisture content, bacterial count, swelling strength, solubility, gel strength, jelly value, and viscosity. They found no relationship to exist between these tests nor between the gel strength and amount of gelatin to use. They concluded that the amount of gelatin to be used is best judged by a standing up test at room temperature.

Similar results were obtained by Serex and Goodwin (34). Lucas and Scott (27) concluded that there was high correlation between the gel strength

of gelatin as determined by the Bloom test and the melting down test. They stated that "since the resistance to melting is one measure of the colloidal properties of the stabilizer, the melting test results obtained were used as a standard against which to compare the results from other tests for quality in gelatin for ice cream."

Downey (12) and Moore, Combs, and Dahle (29) found that gelatin samples melted down less slowly than samples without gelatin. Dahlberg, Carpenter and Hening (9) noted that ice cream without gelatin began to melt first, but a frothy or foamy covering was left over the brick which seemed to insulate the brick and caused less rapid melting than that taking place on samples containing a small amount of gelatin.

The rate of melting of gelatin mixes was decreased as the viscosity of the mix increased, according to Wright (41), who found that the manner of melting down was also influenced by viscosity.

Dahlberg, Carpenter, and Hening (9) noticed that ice cream containing too small an amount of gelatin melted and flowed away in small streams and resembled thin cream or milk. A proper amount of gelatin produced a melted ice cream which, though fluid, had a viscosity comparable with heavy cream, and from which much of the air escaped as the ice cream melted.

There is little available information relative to the use of gums and agar in ice cream. Washburn (39), Fisk (13), and Larson and White (25) mention that gum tragacanth is an efficient stabilizer even when used in small quantities. Fisk (13) states that the gum will absorb fifty times its weight of water.

Holdaway and Reynolds (19) noted that the resulting ice cream was glossy when gum tragacanth was used, which became slimy with excessive amounts of the gum. They concluded that gum tragacanth is a filler and

not a binder as it caused the ice cream to be smooth, but to melt faster than that with no stabilizer when mixes were used containing high percentages of fat (19 and 30 per cent). In an eight per cent mix, however, the gum caused greater resistance to melting than the control sample. In all cases, the gum gave a harder ice cream than the control but not as hard as the gelatin sample. The gum samples melted faster than the gelatin samples in every instance.

Turnbow and Rafetto (37) and Washburn (40) appear to be opposed to the use of gums or similar substances in ice cream to take the place of gelatin. The former agree with Holdaway and Reynolds (19) when they state that gums are fillers and not stabilizers. They comment on gums as follows: "It is the belief of the authors that these products (gum tragacanth and gum arabic) have no place in the manufacture of ice cream. They perform no function, as does gelatin, and are comparable to it only as fillers. Gum tragacanth may have a place in combination with some other colloid, such as agar."

In making a study of various stabilizers in sherbets and ices, Dahlberg (8) found that gum tragacanth and India gum prevented the syrup from settling out, but the body of the sherbet was crumbly and hard. Low grade gums gave a low overrun while the high grade gums gave a high overrun. Mixtures of agar and gelatin or agar and gums (high grade gums) gave excellent results, the agar inhibiting excessive overrun.

Crowe (6) found that gum tragacanth and gum arabic imparted objectionable flavors to sherbets and ices, while India gum and agar gave good results excepting when used in high concentration. Lucas and Scott (26) and Judkins (23) found that gum tragacanth gave objectionable flavors to sherbets and ices.

That agar did not exhibit the property of reforming a gel structure at low temperature after the gel had been destroyed by agitation was pointed out by Dahlberg, Carpenter, and Hening (9). This property was shown by gelatin. They also obtained results showing that agar solutions gelatinized immediately upon cooling, and aging did not increase the strength of the gel as it did in the case of gelatin. Whipped agar gels did not regelatinize without a change in temperature.

Their experiments using agar as a stabilizer in ice cream indicated that it improved the texture, but not as much as did gelatin in the proper concentration. A crumbly bodied ice cream resulted when agar was used. From these results they concluded the poorer bodied ice cream resulted because agar did not form a gel in the frozen product.

Dahlberg (8) found 0.15 per cent to 0.20 per cent of agar enough to form a gel in water ices, while more than this amount caused the formation of too stiff a gel for commercial purposes. Overrun obtained in these trials averaged about 10 per cent, and since this amount of overrun could be obtained with plain sugar solutions, the author stated "it is evident that agar cannot be of any value in permitting the incorporation of air."

Differences in opinion as to the amount of gum tragacanth to use in ice cream occur in the literature. Holdaway and Reynolds (19) concluded that one ounce of the gum was sufficient for 20 to 30 gallons of ice cream. Washburn (39) recommends using one ounce of the gum for 10 gallons of finished ice cream. Lucas and Scott (26) found that two ounces of the gum was sufficient when used in sherbets.

Five stabilizers of vegetable origin including Krabyn, Hygell, Colace, Sure Bet, and Kelco Gel, were studied by Caulfield and Martin (5). Chemical

analysis of the samples showed that gums in amounts ranging from 28.5 to 80.5 per cent proved to be the active stabilizing agent. Sugar was present in varying amounts from 42.5 to 54.1 per cent, "indicating that the gum content had been adjusted so that the product could be used in ice cream in approximately the same proportions as gelatin."

In studying the use of three of these stabilizers in ice cream, Caulfield and Martin (5) experienced no difficulty in incorporating the substances in the mix after first mixing them with sugar. Their results indicate that some of these stabilizers caused a wheying off of the mix upon allowing it to age at 40° F. for 24 to 48 hours.

The gelatin samples froze and whipped in about one minute less time than the samples made from the vegetable compounds and they were all slower than the check mix.

Prescott, Heifeltz, and Stanley (32) compared eight samples of 200 Bloom gelatins with four vegetable substitutes, namely, Krabyn, Tragon, Colace, and Stabilor. When 0.3 per cent solutions of the gelatins and vegetable stabilizers were prepared and photographed, the gelatin solutions were clear while the substitutes all showed material of varied sizes in suspension. The authors also noted that when suspensions were prepared of the stabilizers, the gelatin suspensions retained their homogeneous character regardless of temperature, while the vegetable products became lumpy and swelled irregularly when the suspension was prepared, and on cooling tended to appear as flocculent, gummy masses.

Bacteriological results of this study showed both the gelatins and vegetable stabilizers to have average counts within limits free from objections, but the vegetable compounds showed a distinctly higher percentage of

fermenting types and liquefying types of organisms. The mold count of the gelatin samples was also superior to that of the vegetable substances.

Further analysis of the results found by Prescott, Heifeltz, and Stanley (32) indicated that no marked change in acidity of the mix was introduced by the stabilizing agents. Freezing and whipping data, secured from varying freezing conditions, showed that the mixes containing gelatin whipped to a maximum overrun of 137.5 per cent while the average for the substitutes was 130 per cent. They assumed that if "the gelatin and substitute mixes were subjected to the same freezing temperature, the desired overrun could be obtained more easily and more quickly with a gelatin mix than with a substitute mix."

When the ice cream was allowed to melt down at room temperatures, these investigators found that the gelatin-containing ice cream melted down cleanly while the substitutes invariably left an unmeltable gummy mass behind on the screen. Judges chose the gelatin samples in every case as being superior in texture and flavor. Contrary to this, Caulfield and Martin (5) found no difference between the quality of the ice cream made from the vegetable substances as compared to gelatin and they were all superior to the unstabilized sample. They found, too, that all the samples melted down normally and showed no material difference in resistance to melting. Prescott, Heifeltz, and Stanley (32) agreed with Caulfield and Martin (5) in finding that mix made from the substitutes showed a pronounced separation of whey if held at 40° F. for 48 hours.

The value of gelatin from a nutrient and food standpoint is well established. Alexander (1) stated that gelatin, gums, and similar colloids had a beneficial effect on the digestion of cow's milk. He declared further

that "the added colloid, especially gelatin, may serve as a protective colloid in preventing the coagulation of casein, apparently an irreversible hydrosol and a normal constituent of ice cream." He concluded that gelatin renders ice cream more digestible, a view held by Downey (12) and Prescott, Heifeltz, and Stanley (32).

Downey (12) found that the addition of one per cent of gelatin to milk increased the availability of nutrients to a marked degree, produced noticeable improvement in growth rate, and prolonged well being and reproduction.

Prescott, Heifeltz, and Stanley (32) state that gelatin contains a majority of the amino acids, and Downey (12) found that gelatin was sufficient as the sole source of protein if the amino acids, cystine, tyrosine, and tryptophane were added. Contrary to this, Jones and Nelson (22) found no improvement in the rate of growth to result from the addition of 20 per cent of gelatin either alone or with a mixture of 0.2 per cent cystine, 0.2 per cent tyrosine, and 0.5 per cent tryptophane to a potato-protein diet. They noticed great improvement when casein and lactalbumin were added to the diet, and concluded that casein and lactalbumin contained some essential dietary factor lacking in the potato-protein preparation and in gelatin, which is not one of the known essential amino acids.

These results were substantiated by Jackson, Sommer, and Rose (21), who found that diets in which gelatin was the main source of protein were not suitable sources of nitrogen even when supplemented with cystine, tyrosine, and tryptophane. They stated that "attempts to improve the quality of gelatin are complicated by what appears to be a deleterious action exerted by the protein when fed at a 35 per cent level which is shown by the

early fatal outcome of many of the experiments and the frequent incidence of severe renal injury."

Prescott, Heifeltz, and Stanley (32) point out that the vegetable stabilizers have some food value since they contain starch, gum, dextrin, or other carbohydrate materials. Analysis of five vegetable stabilizers by Caulfield and Martin (5) showed no starch to be present.

Gortner (16) in discussing gums states that relatively little is known in regard to the exact nature of the carbohydrate groups in such compounds. He describes gums as "more or less glucoside-like compounds consisting of hexoses or pentoses (or both), combined with other substances, generally complex acids. On hydrolysis they usually yield galactose, arabinose, or xylose, either alone or in mixtures." He concluded that gum arabic is a calcium or calcium magnesium salt of arabic acid, a relatively strong acid. Norman (31) found gum arabic to consist, in general, of a nucleus acid consisting of galactose, and uronic acid, probably galacturonic acid, to which is linked arabinose by glucoside linkages.

Various diastases, some of which are present in the alimentary tract of animals, are capable of converting gums slightly into reducing sugars, according to Voskressensky (38). He found that rats could live on a diet containing 50 per cent gum.

Agar agar is classed as a mucilage by Gortner (29), who observes that it is a structural component of the cells of algae, and is obtained from "sea-weeds". He also points out that the animal body does not possess enzymes capable of digesting agar and, therefore, it cannot be utilized as a food. That it has a place in the diet to furnish bulk is mentioned by Gortner (16) and further stressed by Mitchell (28). The latter found that

by replacing five per cent of the starch in the standard casein diet used by Osborne and Mendel which was fed to white rats, with agar, successful reproduction resulted. He considered that agar supplied necessary bulk to the ration.

Some effort has been made to displace stabilizers entirely in ice cream by increasing homogenizing pressures. Anderson, Lyons, and Pierce (3) concluded that gelatin could be reduced by increasing the homogenization pressure, and possibly eliminated entirely. Judkins (24) and Horrall (20) found that gelatin could be reduced to some extent by an increase in pressure, but could not be entirely replaced.

PURPOSE OF THE EXPERIMENT

The purpose of this study was to determine the efficiency of various substances of vegetable origin as ice cream stabilizers, and to compare their ability to make a smooth textured ice cream with that of gelatin.

More specifically, the experiment was to include a study of the following points:

1. A determination of the general physical characteristics of these proposed gelatin substitutes.

2. To learn the effect of vegetable stabilizers on the ice cream mix.

3. To study the effect of these substances on the freezing and whipping of ice cream.

4. To compare the quality of the ice cream containing stabilizers of vegetable nature with that containing gelatin in proper amounts.

5. To study the hardness and resistance to melting of ice cream as affected by gelatin substitutes.

PROCEDURE

Composition of the Mix:

Ice cream mixes containing 12 per cent fat and 37 per cent total solids were used for the experimental trials. The ingredients used and their composition are given in Table II. The calculations for the table

Table II. The Composition of the Mix.

Ingredients	Ingredients lbs.	Fat lbs.	Serum Solids lbs.	Total Solids lbs.
Skim Milk Powder (97% s.s.)	3.9		3.783	3.783
Whole Milk (4% fat)	47.423	1.897	4.097	5.994
Cream (30% fat)	33.677	10.103	2.122	12.225
Sugar (100%)	15.000			15.000
Total	100.00	12.000	10.002	37.002

were based on a 100 pound mix. The stabilizers were not included as part of the basic mix, but were added as extra substances. This would, in most cases, increase the total solids about 0.3 to 0.4 of a per cent.

A 200-Bloom strength gelatin was used for the trials, and was added to the mix at the rate of 0.4 per cent.

The percentages of solids and moisture in each of the stabilizers studied are given in Table III. These samples had been sealed and stored in the same room and under the same conditions for several weeks before the moisture determinations were made.

Table III. Normal Percentage of Moisture and Solids in Stabilizers (Determined by heating in oven at 100° C. at 20 inches vacuum for 30 minutes).

Stabilizer	Moisture per cent	Solids per cent
Gelatin	10.83	89.17
Gum Tragacanth	11.70	88.30
Gum Arabic	13.16	86.84
Agar Agar	13.97	86.03
Colace	9.92	90.08
Krabyn	7.42	92.58
Kelco Gel	15.96	84.04
Lakoe A	11.73	88.27

Mix Preparation and Freezing:

Eight batches of ice cream weighing 65 pounds each composed each series. At least one batch of each series, and sometimes two, contained gelatin, and there was usually the same number of batches containing no stabilizer, i. e. the control batches. The rest of the lots of the series contained various amounts of the gelatin substitute, or substitutes, under consideration.

The powdered skim milk, whole milk, and cream for the series were mixed in a 50 gallon pasteurizing vat and heated to about 110° F. Proportionate amounts were weighed into eight 10-gallon milk cans. To each of these cans was added the correct amount of stabilizer. These were mixed well with the necessary sugar. The stabilizers were weighed, and recorded, by ounces, each ounce equaling approximately 0.1 per cent.

The sugar-stabilizer mixture was stirred into the mix and then the eight cans of mix were pasteurized at 145° F. for 30 minutes by setting them in a large water bath which was heated to the proper temperature by the use of live steam. The mix was stirred at frequent intervals during the heating and holding periods.

At the close of the holding period, the mixes were viscolized at 2500 pounds pressure at the pasteurizing temperature, and immediately cooled to approximately 40-45° F. by running over a tubular cooler. Samples which were to be used for viscosity and surface tension measurements were taken at this point in the process, and the mixes were then stored in a cold room at about 40° F.

After a 24-hour storage period, the mixes were frozen. Fifty-five pounds of each batch were frozen in a 50-quart, direct expansion freezer. The freezer was washed out with cold water between each batch so that all lots would be frozen under as near as possible identical conditions.

Each batch was frozen to the same hardness as determined by a Draw-rite regulator, having selected a reading of six, and the batches were allowed to whip for 16 minutes after the freezing medium was shut off. Overrun determinations were taken at one minute intervals during the whipping period, a Mojonnier Overrun Tester being used for the determinations. Two quart samples in sealrights and one quart brick sample were taken when 100 per cent overrun was attained. These samples were stored in the hardening room for scoring and melting down tests.

Surface Tension and Viscosity:

The samples of mix that were taken after the mix had been cooled over the tubular cooler, were stored in the cooler for 24 hours. At this time they were tempered to 20° C., and surface tension and viscosity measurements were made.

A DuNuoy Direct-Reading Tensiometer was used for the surface tension measurements, and the viscosity was determined by using a MacMichael Viscosimeter.

In many cases, both the apparent and real viscosities were taken. The apparent viscosity was taken on a sample of the mix that had been held for the 24-hour period, carefully tempered, and poured into the receptacle of the viscosimeter without any previous agitation.

The real or basic viscosity was taken on a sample of mix which had been shaken for 10 minutes in a shaking machine, a length of time which had previously been found sufficient to break down the structural viscosity of exceedingly heavy mixes.

A standardized No. 30 wire was used for the normal mixes, but in abnormally viscous ones, a No. 26 wire was substituted.

Scoring of the Ice Cream:

The ice cream samples taken at the freezer were stored in the hardening room at approximately -5° to -10° F. They were scored after storage periods of one week and three weeks by Prof. P. S. Lucas and the author. The body and texture of the ice cream was particularly criticized, and the official score card allowing 25 points for perfect body and texture was used as the basis of scoring. Any off-flavors due to the stabilizer present were also noted.

Testing the Ice Cream for Hardness:

The hardness of the ice cream after storing was determined by the use of the Hardness Tester shown in Figure I. The determination of the hardness of the ice cream is made by noting the depth the blunt needle will penetrate into a brick of ice cream, the force back of the needle being the same in each case.

An explanation of the manipulation of the tester is as follows: The plunger, 1/8 inch in diameter, with its frame, is held above the brick of

ice cream by an electro-magnet which secures its current from two dry cells, providing, of course, the switch of the circuit is closed. When the brick is in place, the switch is thrown off. With no current, the magnetic force ceases, and the plunger is released and strikes the brick.

The platform holding the brick is adjustable so that the upper surface of each brick is the same distance from the electro-magnet. This being the case, the plunger falls the same distance each time, and, also, with the same force since the weight of the frame and plunger is kept constant. It can be noted that the frame holding the plunger is so constructed that additional weights may be added if more penetration is desired.

The plunger is calibrated into equal units of about one millimeter each, and the number of units it penetrates can be secured directly by using the swinging pointer. This pointer can be so adjusted that it will point directly at the marker after the plunger strikes the brick and the reading can be quickly made. Obviously, the distance the plunger sinks into the brick of ice cream is dependent upon the firmness or hardness of the ice cream.

A machine of this type was designed because it was thought to give accurate and uniform determinations due to its elimination of friction.

Before the readings were made on any series of ice cream, the machine was cooled by allowing it to remain in the cooler (36-40° F.) for not less than one hour. The measurements were made in the cooler at the same temperature, and the bricks were brought out of the hardening room one at a time so that no softening of the ice cream would occur before the readings were obtained.

At least six measurements were made on each brick, and an average was taken of these measurements.

Melting Down Tests:

After the bricks of ice cream were tested for hardness, they were weighed and placed on pieces of cardboard of approximately the same size as the bricks. A nail protruded through the cardboard which kept the brick from slipping from the board after it began to melt. The bricks were then placed on a coarse wire screen and kept at room temperature. Under each brick was placed a tared pan which caught the melted portion. In most trials the pans were weighed at one-half hour intervals during the melting period of five hours.

EXPERIMENTAL RESULTS

General Physical Characteristics of Stabilizers:

Several of the gelatin substitutes made decidedly opaque or milky colored suspensions when efforts were made to get them into a uniform aqueous solution. It was noticed, also, that some of these suspensions, when heated and then cooled, showed the presence of more or less flocculent masses of material which either separated out on cooling or had failed to disappear throughout the heating process.

The following table (Table IV) gives the general appearances of the stabilizers in their original powdered form, and after suspensions had been made of them.

Table IV. General Appearance of the Stabilizers in Original Powdered Form and in a 0.5 Per Cent Water Suspension in which They Were Heated to 185° F. and Allowed to Cool Slowly.

Stabilizer	Description of Stabilizer	Description of Cooled 0.5% Suspension
Gum Tragacanth	Fine, white powder	Opaque with white precipitate and in some cases flocculent masses of material.
Gum Arabic	Fairly fine, white powder.	Clear
Agar Agar	Grayish-white powder.	Very slightly opaque, practically clear.
Gelatin	Light-brown granulated.	Clear
Colace	Fairly fine, white powder.	Opaque with white flocculent precipitate.
Krabyn	Whitish-powder, speckled with brown material.	Slightly opaque with small amount of fine white precipitate.
Lakoe A	Like Krabyn but not so many brown specks.	Opaque with large clumps of flocculent materials.
Kelco Gel	Dark khaki brown very finely divided.	Free from precipitate but dark brown in color.

The table shows that gum arabic, agar, and gelatin gave the clearest liquid dispersion of any of this group. Of the stabilizers in the powdered form, it appears that only three might be open to criticisms as to their appearance, these three being Krabyn, Lakoe A, and Kelco Gel. Krabyn and Lakoe A show undesirable dark brown specks which are the seed coats, and Kelco Gel possessed an abnormal brown color. The stabilizers as a whole showed no undesirable odors with the possible exceptions of agar and Kelco Gel which had distinct "weedy" or vegetable aroma.

Some of the stabilizers showed great hydration power as denoted by their ability to take on water and to thicken considerable quantities of it. Gum tragacanth, Lakoe A, and Kelco Gel all swelled to a large extent when placed in water and showed great affinity for it. Krabyn and Colace were inferior to these mentioned above in this respect, while gum arabic showed

practically no imbibition and hydration property.

Agar agar and gelatin exhibited their natural property of gel forming, with the agar having the ability to form a gel at a lower concentration than the gelatin.

PART I

Gum Tragacanth

In order to determine the proper amount of gum tragacanth to use in ice cream to give results comparable with gelatin, amounts varying from 0.5 ounce to seven ounces were added to 65 pounds of the mix. No difficulty was experienced in incorporating the gum into the mix after it was first mixed well with the sugar.

Lots I to III contained batches having from 0.5 ounce to three ounces of the gum. Batches in Lot IV contained three and four ounces of the vegetable stabilizer.

Miscellaneous batches were processed containing from four to seven ounces of the gum. The results from these particular batches are tabulated throughout the study in the averaged results, but no individual lot data are given since these were but single trials, and served only as tentative guides to determine the effect on the ice cream of exorbitant amounts of gum tragacanth.

Viscosity and Surface Tension:

Gum tragacanth showed great ability to increase the viscosity of the ice cream mix. Table V shows the viscosity of three series having the gum present in amounts varying from 0.5 to three ounces. As a rule, the lot containing two and one-half ounces of gum tragacanth had a viscosity greater than the gelatin sample, which contained 4.16 ounces (0.4%) of gelatin.

Table V. Viscosity in Centipoises of Ice Cream Mixes Containing Three Ounces or Less of Gum Tragacanth.

Amounts Used	Lot I Viscosity	Lot II Viscosity	Lot III Viscosity	Average Viscosity
0.5 oz. Gum	27.6	26.6	57.7	37.3
1.0 oz. Gum	79.9	44.4	75.0	66.4
1.5 oz. Gum	58.1	57.7	95.2	69.7
2.0 oz. Gum	107.6	79.9	97.6	95.0
2.5 oz. Gum	113.7	88.7	125.0	109.1
3.0 oz. Gum	127.9	135.1	245.5	168.8
4.1 oz. Gelatin	66.9	79.9	181.9	109.6
Control	18.9	26.6	44.4	30.0

Although Lot III gives the same general trend in viscosity as do the other series, it showed higher readings throughout. Difficulties were experienced during the processing of these three trials in keeping the temperature of the mix uniform during viscolization. No doubt, the higher viscosities of Lot III are due to viscolizing at lower temperatures than those normally used.

As shown by this table (Table V), and, as would be expected, the greater the amount of gum used the higher becomes the viscosity. It was found that when six and seven ounces of the gum were used the mix became excessively thick and viscous, and much loss occurred during the processing due to the high adhesiveness of the mix. Six ounces of the gum gave a mix viscosity of 1943 centipoises, and the viscosity reading for seven ounces was about 2839 centipoises.

The viscosity and surface tensions of mixes containing three and four ounces of gum tragacanth are given in Table VI. The results of this table indicate that the mixes containing gum in these quantities show considerable structural or apparent viscosity.

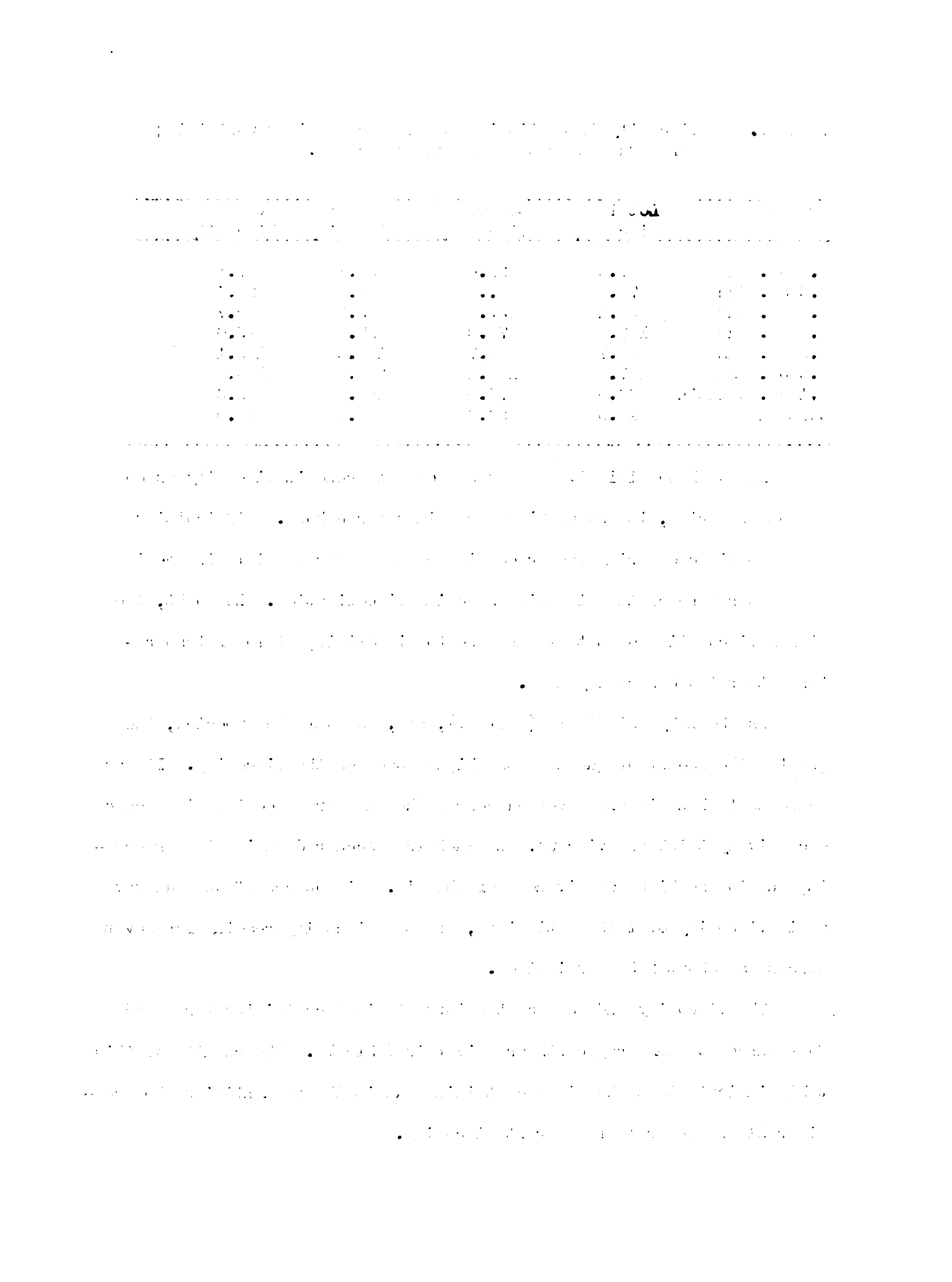


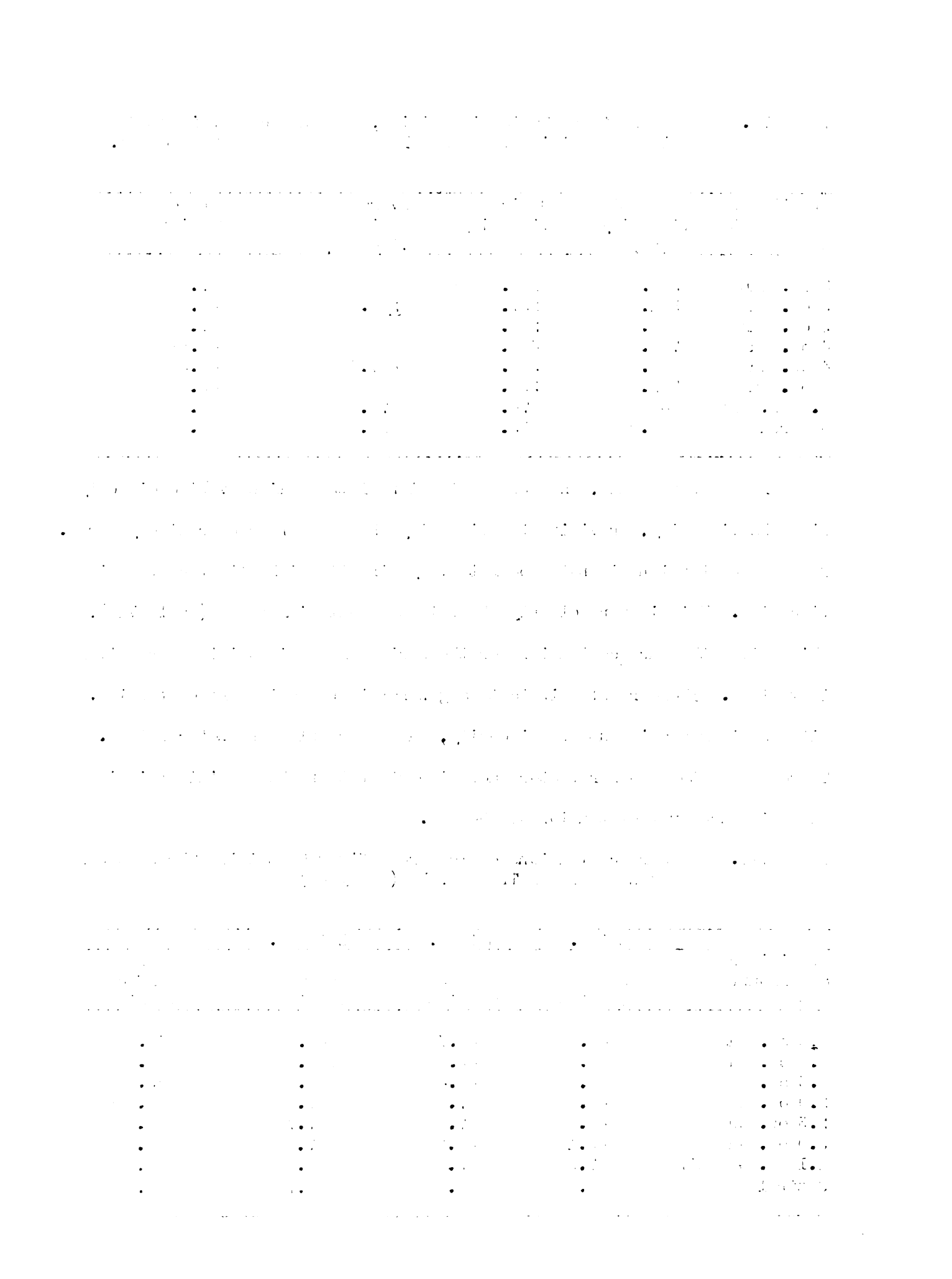
Table VI. Apparent and Basic Viscosities, and Surface Tensions of Mixes Containing Three and Four Ounces of Gum Tragacanth.

Stabilizer and Amount Used	Apparent Viscosity (cp)	Basic Viscosity	Average Basic Viscosity	Surface Tension
3 oz. Gum	590.0	241.0		47.3
3 oz. Gum	581.0	257.0	246.0	47.3
3 oz. Gum	416.0	260.0		47.3
4 oz. Gum	754.0	463.0		48.3
4 oz. Gum	854.0	528.0	461.0	48.3
4 oz. Gum	772.0	391.0		48.0
4.1 oz. Gel	---	76.0	76.0	45.3
Control	25.0	25.0	25.0	45.6

As a general rule, the surface tension of these mixes varied directly with the viscosity, providing the viscosity changes were comparatively large. The surface tension did not appear to vary directly with slight changes in viscosity. This is more clearly shown in the following table (Table VII), which gives the surface tension for the series whose viscosities were given in Table V. These results indicate a general increase in surface tension with the increase in gum and viscosity, but the results are not constant. There appear to be other factors more important than the stabilizer in influencing the surface tension of the mix.

Table VII. Surface Tensions of Ice Cream Mixes Containing Three Ounces or Less of Gum Tragacanth (In dynes).

	Lot I.	Lot II.	Lot III.	
Stabilizer and Amount Use	Surface Tension	Surface Tension	Surface Tension	Average Surface Tension
0.5 oz. Gum	44.1	44.7	45.5	44.8
1.0 oz. Gum	45.2	45.0	45.0	45.1
1.5 oz. Gum	45.0	45.4	46.1	45.5
2.0 oz. Gum	45.0	47.0	47.0	46.0
2.5 oz. Gum	45.0	47.0	47.7	46.6
3.0 oz. Gum	45.1	48.2	47.3	46.9
4.1 oz. Gelatin	47.3	45.2	46.8	46.4
Control	44.4	45.2	45.7	44.4



Freezing and Whipping of Gum Tragacanth Mixes:

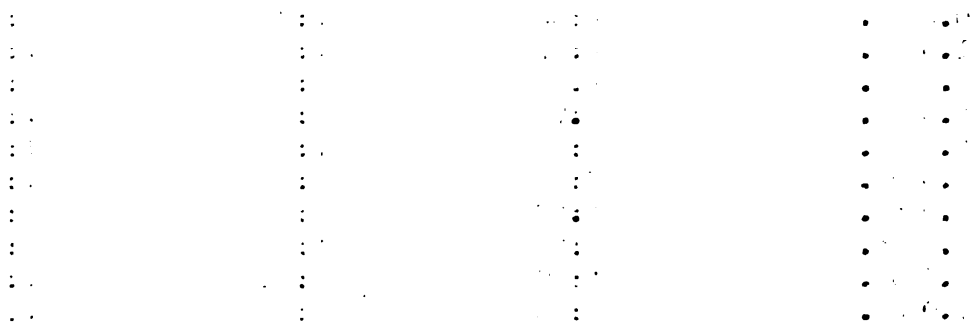
The addition of gum tragacanth to the ice cream did not have any noticeable effect on the time of freezing, as shown in Table VIII. Even when as high as seven ounces of the gum were used no deleterious action was noted.

Table VIII. Average Freezing Time of Ice Cream Mixes Containing Varying Amounts of Gum Tragacanth (Time in minutes and seconds).

Amount of Gum Used	Freezing Time	Gelatin Freezing Time	Control Freezing Time
0.5 oz.	4:55	5:00	5:00
1.0 oz.	4:57	5:00	5:00
1.5 oz.	4:75	5:00	5:00
2.0 oz.	4:74	5:00	5:00
2.5 oz.	4:58	5:00	5:00
3.0 oz.	4:40	5:00	5:00
4.0 oz.	2:28	2:35	5:00
5.0 oz.	2:25	2:35	5:15
6.0 oz.	2:26	2:31	5:05
7.0 oz.	2:30	2:31	5:05

Ice cream containing four ounces or less of gum tragacanth incorporated air with as much ease as did the gelatin sample. There is a direct relationship between the amount of gum used and the quickness with which the overrun is obtained; i. e., as the concentration of gum increased, the time to secure 100 per cent overrun is also increased. Table IX gives the average results of the overrun determinations, and Tables LXI to LXIV give the overruns by batches for Lots I, II, III and IV.

The results shown point out that the samples containing three ounces of gum or less whipped considerably more rapidly than the gelatin sample, with the control sample being superior in this respect to any of the samples containing a stabilizer. There was practically no difference among these samples as to the maximum amount of air that could be whipped into them.



However, when more than five ounces of the gum were used, the maximum amount of air incorporated was decreased, while the sample containing seven ounces of gum failed to secure 100 per cent overrun in 16 minutes of whipping.

Chart I is plotted from the data given in Table IX and illustrates the deterrent effect on overrun of larger amounts of gum tragacanth. In the preceding discussion, it was noted that the gum greatly increased the viscosity of the mix. It is, probably, the enormous viscosity of mixes containing more than four ounces of the gum that hinders the incorporation of air rather than the effect of the gum itself.

Quality of Ice Cream Made with Gum Tragacanth:

In the study of gum tragacanth, the first consideration was to find the amount of the gum that would make an ice cream of equal quality with that made with gelatin. Three series were processed in which the amounts of gum varied from 0.5 ounce to three ounces. The scores for these three trials are given in the following table, which notes also the comparative quality of the samples after the one week and three week storage periods.

Table IX. Average Overrun by Minutes of Ice Cream Mixes Containing Gum Tragacanth in Varying Amounts.

Minutes	Batch No. 1	2	3	4	5	6	7	8	9
0	78	69	59	55	28	25	20	61	69
1	84	79	54	49	42	42	37	66	80
2	97	89	76	69	64	64	58	78	90
3	102	101	97	88	84	77	68	90	106
4	109	105	112	105	100	85	73	102	111
5	115	110	115	111	107	95	77	111	118
6	115	116	122	121	120	100	77	117	125
7	122	125	128	128	120	105	83	126	128
8	128	128	130	133	120	107	85	128	132
9	134	128	138	134	129	109	87	130	135
10	132	130	135	135	130	112	87	130	135
11	134	132	135	132	130	118	90	132	130
12	133	134	136	132	133	118	91	132	128
13	133	134	135	131	131	119	92	131	128
14	130	135	133	132	131	118	98	130	126
15	130	135	131	131	130	118	97	129	127
16	127	133	131	131	130	118	96	128	125

Batch No.	Stabilizer Used
1	1 oz. Gum Tragacanth
2	2 oz. Gum Tragacanth
3	3 oz. Gum Tragacanth
4	4 oz. Gum Tragacanth
5	5 oz. Gum Tragacanth
6	6 oz. Gum Tragacanth
7	7 oz. Gum Tragacanth
8	0.4% Gelatin
9	Control

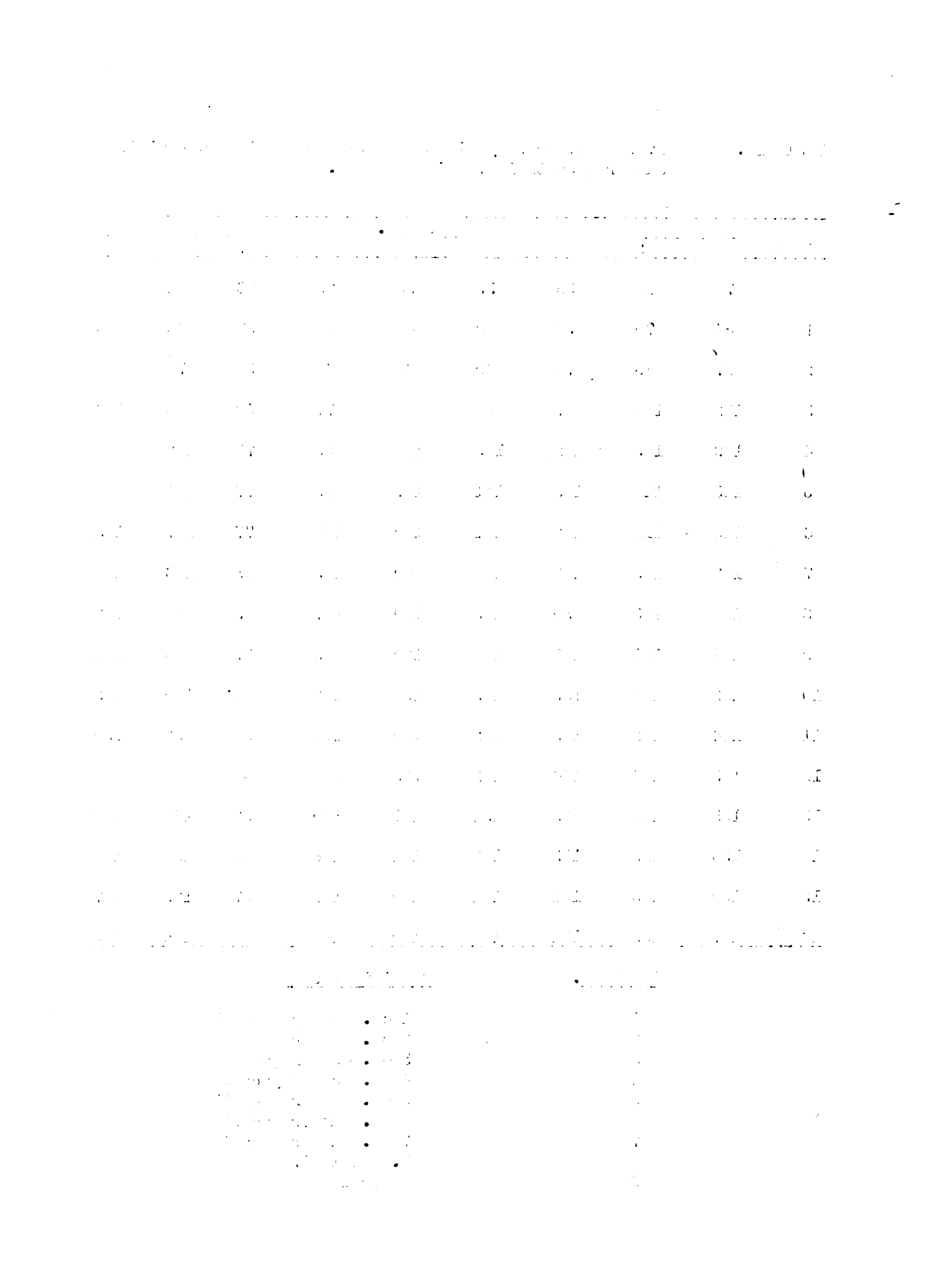


Chart I. Showing the Per Cent Overrun of Ice Cream Mixes Containing Various Amounts of Gum Tragacanth.

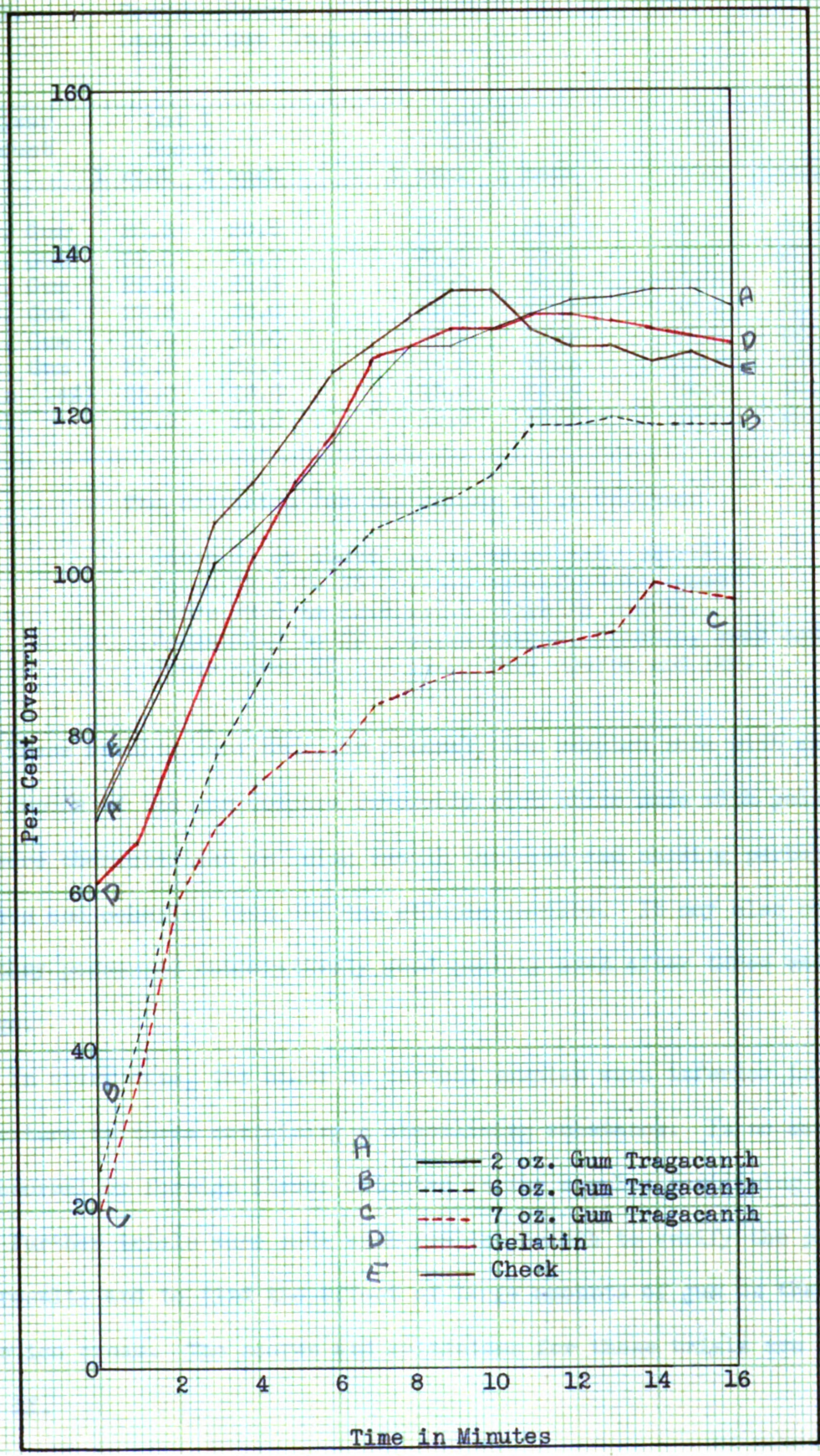


Table I. Texture Scores of Ice Cream Containing Three Ounces or Less of Gum Tragacanth.

Stabilizer and Amount Used	Lot I Score		Lot II Score		Lot III Score	
	1 week	3 week	1 week	3 week	1 week	3 week
0.5 oz. Gum	20.5	20.5	21.0	21.0	21.0	20.0
1.0 oz. Gum	22.0	21.5	21.5	22.0	21.0	21.0
1.5 oz. Gum	22.5	21.5	22.0	22.0	21.5	21.0
2.0 oz. Gum	22.5	22.0	22.5	22.5	21.5	21.5
2.5 oz. Gum	23.0	22.0	22.5	22.5	23.0	23.0
3.0 oz. Gum	23.0	22.5	23.0	23.5	22.75	23.0
Gelatin (.4%)	23.0	23.0	23.0	22.0	22.5	23.0
Control	20.0	21.0	19.0	20.0	19.0	19.0

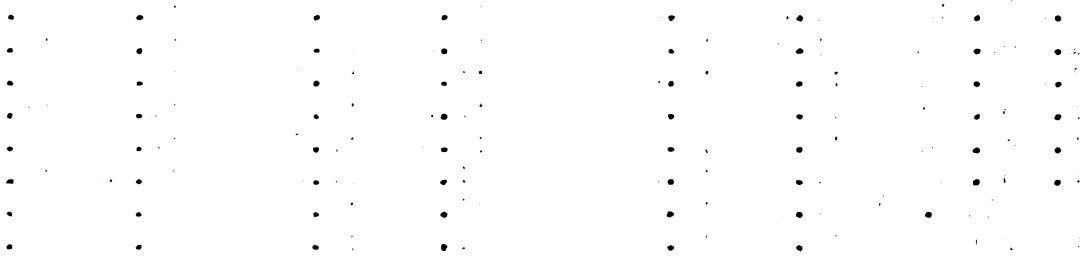
The criticism for the scores is as follows:

Score 23 or above ..... excellent, smooth.
Score 22.5 to 23 ..... satisfactory, good.
Score 22.0 to 22.5 ..... slightly coarse.
Score 21.0 to 22 ..... coarse, friable, weak bodied.
Score under 21 ..... very coarse and icy.

These results show that, in general, the samples made with about three ounces of the gum compare favorably with those made with gelatin. They were characterized as being smooth textured and showing perhaps more firmness and cohesion than did the gelatin samples. It may also be noted that they possessed comparatively good quality even after three weeks of storage.

In every case, the check or control samples were inferior in body and texture to those containing a stabilizing substance. In no case was any abnormal or foreign flavor detected in the samples containing gum.

Further trials were made with gum tragacanth to verify the preliminary results and to find the effect of large amounts of gum on the quality of the ice cream. The scores and criticisms for these trials are shown in Table II.



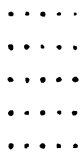


Table XI. Scores and Criticisms of Body and Texture of Ice Cream Containing Three Ounces or More of Gum Tragacanth.

Samples	Scores	Criticisms
3 oz. Gum	22.75	Smooth, desirable.
4 oz. Gum	23.00	Exceedingly smooth, excellent body.
5 oz. Gum	23.00	Very smooth, sl. gummy, questionable taste.
6 oz. Gum	22.50	Slippery, hard, "off taste".
7 oz. Gum	22.00	Slippery, hard, "off taste".
Gelatin (.4%)	22.75	Smooth, desirable.
Control	21.00	Coarse, friable, lacks cohesion.

The results given in this table are for ice cream stored for a one week period. There appeared to be no difference in the scores after storing the ice cream for three weeks in the hardening room.

The results of all organoleptic tests on the gum tragacanth samples indicate that samples containing three to four ounces of the gum have a body and texture equal, or perhaps superior, to that possessed by ice cream containing the correct amount (0.4 per cent) of gelatin. These samples also possessed desirable dipping qualities.

The taste of the ice cream was not affected by the gum until five ounces or more of the gum were used. These amounts of gum also gave an undesirable slipperiness or sliminess to the ice cream.

Hardness Tests on Gum Tragacanth Samples:

Results obtained by the use of the Hardness Tester on the gum tragacanth samples, show that an increase in the amount of gum increases the hardness of the ice cream. The average readings of the various trials are given in Table XII. The gum when present in normal amounts, i. e. three or four ounces, makes an ice cream that is practically of the same hardness as that containing gelatin.

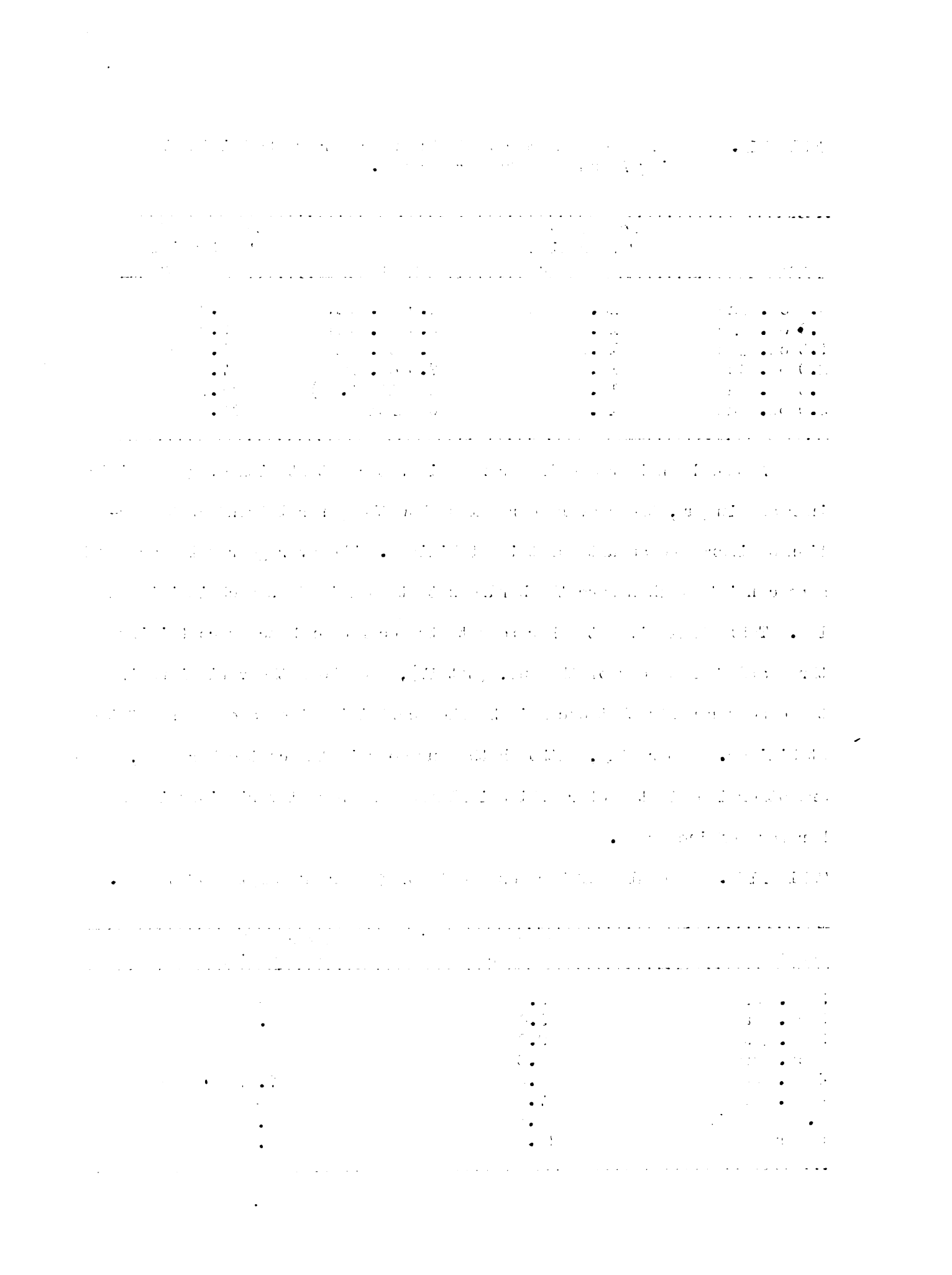
Table XII. Average of Hardness Tests on Ice Cream Containing Varying Amounts of Gum Tragacanth.

Samples	Degrees of Penetration of Plunger	Samples	Degrees of Penetration of Plunger
0.5 oz. Gum	13.5	4.0 oz. Gum	8.9
1.0 oz. Gum	13.4	5.0 oz. Gum	9.0
1.5 oz. Gum	13.0	6.0 oz. Gum	8.4
2.0 oz. Gum	12.5	7.0 oz. Gum	7.0
2.5 oz. Gum	10.8	Gelatin (.4%)	11.7
3.0 oz. Gum	10.6	Control	13.5

Although an increase in hardness is not constant with every specific increase in gum, these average results show the general trend of the action of increased amounts of this stabilizer. The average results are much more consistent than were the hardness tests obtained on each individual lot. Table XIII gives the hardness tests secured on batches containing three and four ounces of the gum, (Lot IV), and shows the variations in these measurements that occur in batches containing the same amount of the stabilizer. Apparently, although the gum does influence the hardness, there are other important factors which influence the normal variations in the hardness of ice cream.

Table XIII. Results of Hardness Tests on Ice Cream Samples of Lot IV.

Samples	Degrees Penetration of Plunger	Average Degrees Penetration of Plunger
3 oz. Gum	9.9	-
3 oz. Gum	9.4	9.43
3 oz. Gum	9.0	-
4 oz. Gum	8.6	-
4 oz. Gum	8.3	7.97
4 oz. Gum	7.0	-
0.4% Gelatin	8.8	8.80
Control	13.0	13.00



These results verify those of Table XII, in showing that the gelatin samples are not greatly different in hardness from those containing three ounces of gum, although in these results the ice cream containing gelatin was slightly harder than those containing three ounces of gum, while in Table XII it was slightly less resistant to the plunger. The control sample in every instance was inferior to the stabilized samples from the standpoint of hardness.

Melting Downof Ice Cream Containing Gum Tragacanth:

Normal amounts of gum tragacanth exhibits little effect on the melting resistance of ice cream. Tables XIV and XV show that ice cream containing gum tragacanth in amounts of three ounces or less melts faster than the samples containing gelatin. When the gum is present in amounts of from one and one-half to three ounces, the samples melt faster than the samples containing no stabilizer. The control sample melts more rapidly than do the gum samples for the first hour, but thereafter the control shows more stability than the gum-stabilized lots. In fact, the control sample was practically equal in stability to the gelatin sample at the end of the first half of the melting period.

The influence of more than three ounces of gum tragacanth is shown in Table XV. The results verify the preceding ones relative to samples containing three ounces of gum, and show that the four and five ounce samples were but slightly better.

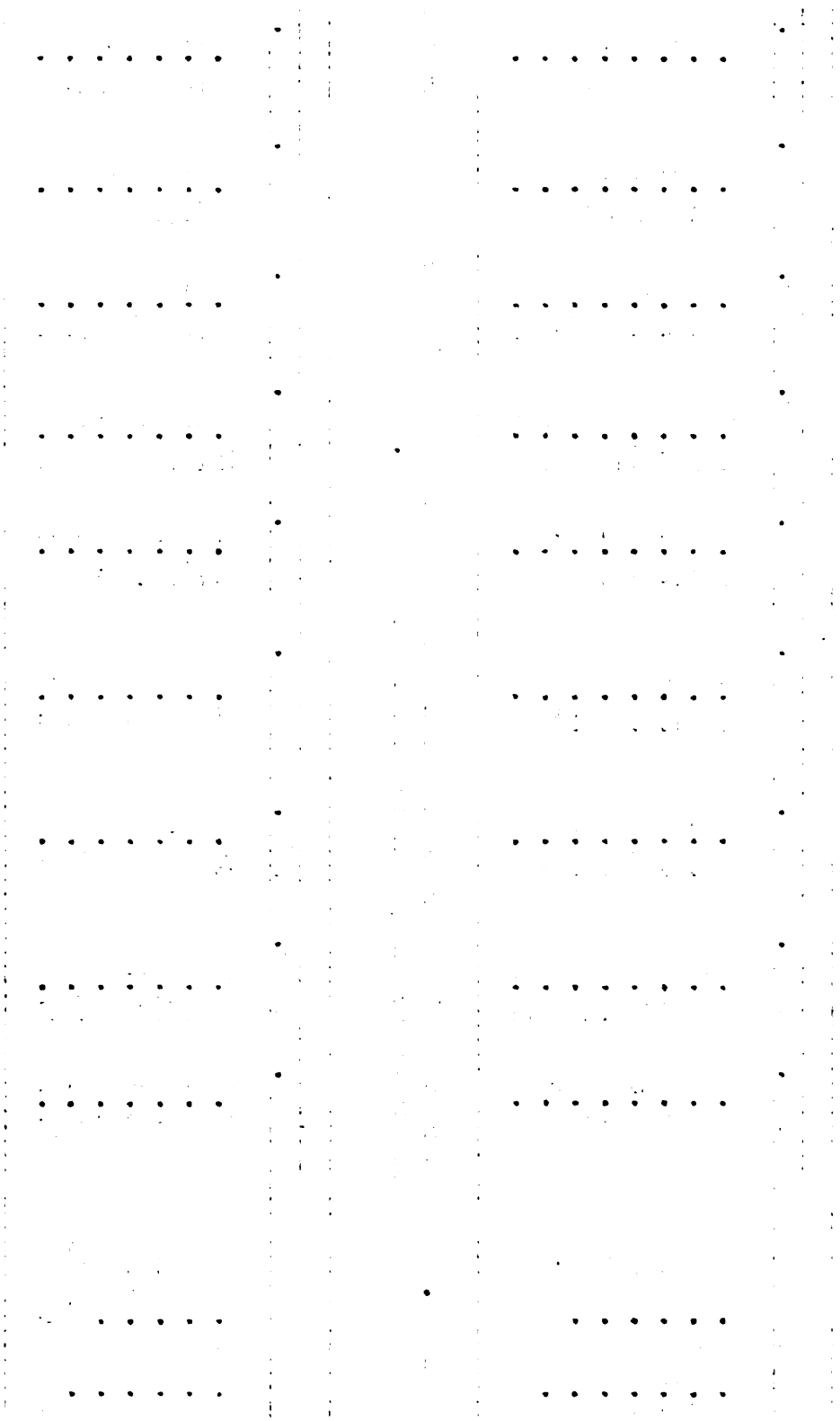
The addition of six and seven ounces of the gum made an ice cream more resistant to melting than that made with gelatin. However, the ice cream in these cases were abnormal, and failed to melt down even after the total five-hour melting period had elapsed.

Table XIV. Average Melting Down Results of Ice Cream Samples Containing Three Ounces or Less of Gum Tragacanth (Tabulated as Percentage Melted)

Samples	Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
0.5 oz. Gum	4.0	15.5	29.6	36.7	47.4	55.6	62.9	66.7	69.0
1.0 oz. Gum	1.5	18.6	33.2	45.9	60.7	66.9	72.7	75.4	75.9
1.5 oz. Gum	4.8	27.9	43.2	59.2	70.4	77.2	79.8	81.6	81.6
2.0 oz. Gum	4.5	25.6	41.9	56.1	68.0	75.1	78.3	80.3	80.3
2.5 oz. Gum	3.9	21.0	38.7	54.5	69.1	76.3	80.2	81.3	81.3
3.0 oz. Gum	4.9	22.7	38.3	55.9	66.1	75.4	76.1	80.4	80.4
0.4% Gelatin	0.0	3.5	14.8	27.4	39.6	50.4	62.6	70.8	74.7
Control	9.5	16.9	24.6	33.9	42.3	50.0	57.7	63.2	68.7

Table XV. Average Melting Down Results of Ice Cream Samples Containing Three Ounces or More of Gum Tragacanth (Tabulated as Percentage Melted).

Samples	Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
3.0 oz. Gum	14.4	46.9	65.7	69.8	78.5	80.4	84.2	84.2	84.2
4.0 oz. Gum	9.5	50.0	53.9	65.0	71.4	73.2	76.1	76.1	76.1
5.0 oz. Gum	3.7	21.0	40.7	60.3	70.3	73.0	74.0	79.0	81.4
6.0 oz. Gum	0.0	2.7	6.7	16.0	28.0	37.3	45.9	54.6	58.6
7.0 oz. Gum	0.0	0.0	0.0	5.5	19.4	25.0	33.3	38.8	40.2
0.4% Gelatin	2.1	20.5	27.5	45.2	53.5	69.8	75.8	79.4	79.4
Control	17.7	27.9	33.8	42.6	54.4	61.7	70.5	76.4	80.8



These samples were unmeltable masses of very thick, smooth material resembling clabbered milk.

The other samples all melted down normally, leaving practically no residue on the screen. The controls usually left a layer of foam on the board. Figures 2 and 3 show the appearances of ice cream containing three, four, and five ounces of gum at the end of the one and one-half hour and the three hour period.

It may again be noticed in Table XV that the control sample, though starting to melt first, melted at a slower rate than did the samples containing normal amounts of gum, and practically as slowly as did the gelatin sample.

The drippings from all the samples, with the exception of those containing six and seven ounces of gum, did not appear to be abnormal. In some cases in which the samples were held for several months in the hardening room, all lots containing stabilizers showed a curdled condition in the melted portion. The control lot did not show this peculiarity. In all the cases, also, the control drippings showed less foam than did the drippings from ice cream containing stabilizers, and its melted portion was considerably less viscous and resembled a fairly rich milk.

Summary of Results of Gum Tragacanth Study:

Gum tragacanth is efficient in increasing the viscosity of the mix. In general, the surface tension of the mixes increased with an increase in viscosity, although the results were consistent. Three ounces (approximately 0.3 per cent) of the gum made ice cream comparable in smoothness and quality to that made with gelatin. The gum samples were about the same hardness as those stabilized with gelatin, but melted more rapidly.

PART II.

Gum Arabic

Gum arabic was used in amounts varying from one to ten ounces for 65 pounds of mix, or in approximate amounts of 0.1 per cent to 1.0 per cent. Lots I and II contained from one to six ounces of gum, Lots III and IV contained from seven to ten ounces of the gum, and Lots V and VI contained from two to ten ounces of gum. In the last two series, the variation of the amount of gum between batches was two ounces, while in the first four lots the variations were by one ounce amounts.

Gum arabic was somewhat easier to incorporate in the mix than was gum tragacanth, and showed less tendency to lump. Large amounts of the gum gave no abnormal appearance or flavor to the mix.

Viscosity and Surface Tension:

The viscosity and surface tension measurements for Lots I-IV are given in Tables XVI and XVII, with the average results tabulated in Table XVIII.

The ability of this gum to increase the viscosity of the mix is comparatively small. As great a concentration as ten ounces (1%) failed to increase the viscosity greatly. Gelatin samples of these lots possessed much higher viscosities.

Table XVI. Viscosity and Surface Tension of Ice Cream Mixes Containing Gum Arabic (Lots I and II).

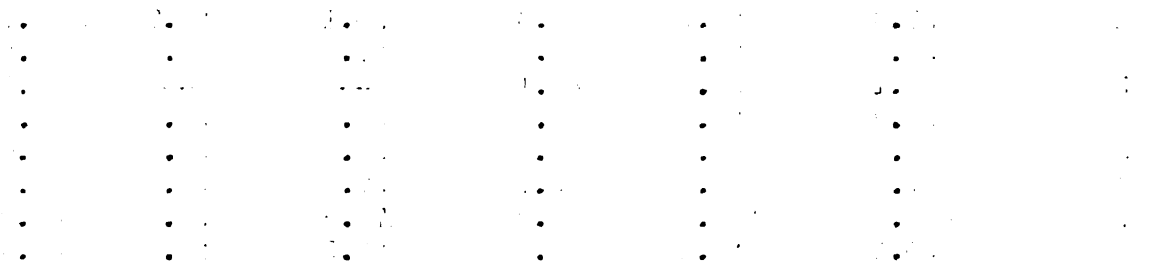
Batch No.	Lot I Viscosity Apparent (cp)	Lot I Viscosity Basic (cp)	Lot I Surface Tension (dynes)	Lot II Viscosity Apparent (cp)	Lot II Viscosity Basic (cp)	Lot II Surface Tension (dynes)
1	27.6	24.7	43.6	26.1	24.7	44.7
2	33.4	29.1	44.3	27.6	26.2	45.2
3	29.1	26.1	44.1	—	—	44.6
4	34.9	26.1	44.1	36.3	33.4	45.2
5	42.2	34.9	45.5	31.9	30.5	45.0
6	47.9	43.6	45.7	37.8	36.3	45.3
7	456.1	266.2	46.8	171.5	98.8	44.0
8	30.5	29.1	44.0	23.3	23.3	43.4

Batches 1-6 contain gum arabic in amounts from one to six ounces; each succeeding batch containing an increase of one ounce of the gum.
Batch 7 contains 0.4% Gelatin.
Batch 8 contains no stabilizer.

Table XVII. Viscosity and Surface Tension of Ice Cream Mixes Containing Gum Arabic (Lots III and IV).

Batch No.	Lot III Viscosity Apparent (cp)	Lot III Viscosity Basic (cp)	Lot III Surface Tension (dynes)	Lot IV Viscosity Apparent (cp)	Lot IV Viscosity Basic (cp)	Lot IV Surface Tension (dynes)
1	42.2	33.4	44.2	40.3	36.3	46.6
2	45.1	45.1	44.4	42.2	36.3	46.9
3	50.9	47.9	44.4	45.1	42.2	46.9
4	71.2	55.2	44.6	58.1	52.3	47.2
5	71.2	58.1	44.4	348.8	260.2	48.5
6	20.4	20.4	43.9	20.1	20.0	48.4

Batches 1-4 contain gum arabic in amounts from seven to ten ounces; each succeeding batch containing an increase of one ounce of the gum.
Batch 5 contains 0.4% Gelatin.
Batch 6 contains no stabilizer.



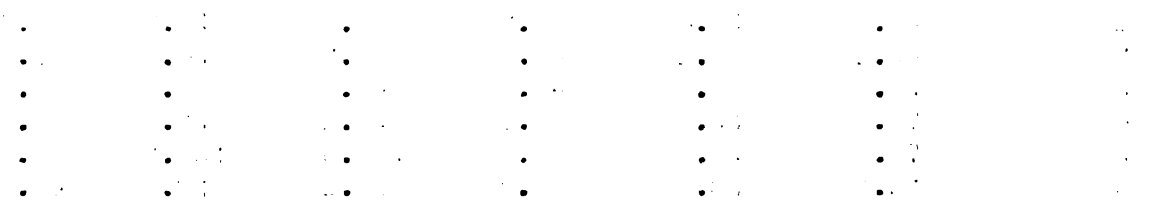


Table XVIII. Average Viscosities and Surface Tensions of Mixes Containing Gum Arabic (Lots I-IV).

Amount Stabilizer	Average Viscosity Apparent (cp)	Average Viscosity Basic (cp)	Average Surface Tension (dynes)
1 oz. Gum	26.9	24.7	44.2
2 oz. Gum	30.5	27.7	44.8
3 oz. Gum	29.1	26.1	44.4
4 oz. Gum	35.6	29.8	44.7
5 oz. Gum	37.1	32.7	45.5
6 oz. Gum	42.9	39.9	45.5
7 oz. Gum	41.3	34.9	45.4
8 oz. Gum	43.7	40.7	45.7
9 oz. Gum	48.0	45.1	45.7
10 oz. Gum	64.7	53.8	45.9
0.4% Gelatin	256.9	170.8	46.5
Control	23.6	23.2	44.9

Surface tensions of these mixes showed no abnormalities. They appeared, in general, to increase with an increase in viscosity, although the results are not consistent. The gelatin samples, with higher viscosities, also showed higher surface tensions.

Freezing and Whipping of Gum Arabic Samples:

Gum arabic does not influence the time of freezing. Results of this effect are shown in Table XIX. The averages of the trials do not show any noticeable difference in the freezing time of the gum, gelatin, or control samples.

Samples of ice cream containing gum arabic whipped more rapidly than those containing gelatin. Specific data for the trials are shown in Tables LXV to LXX inclusive. Average results are presented in Table XX and Table XXI.

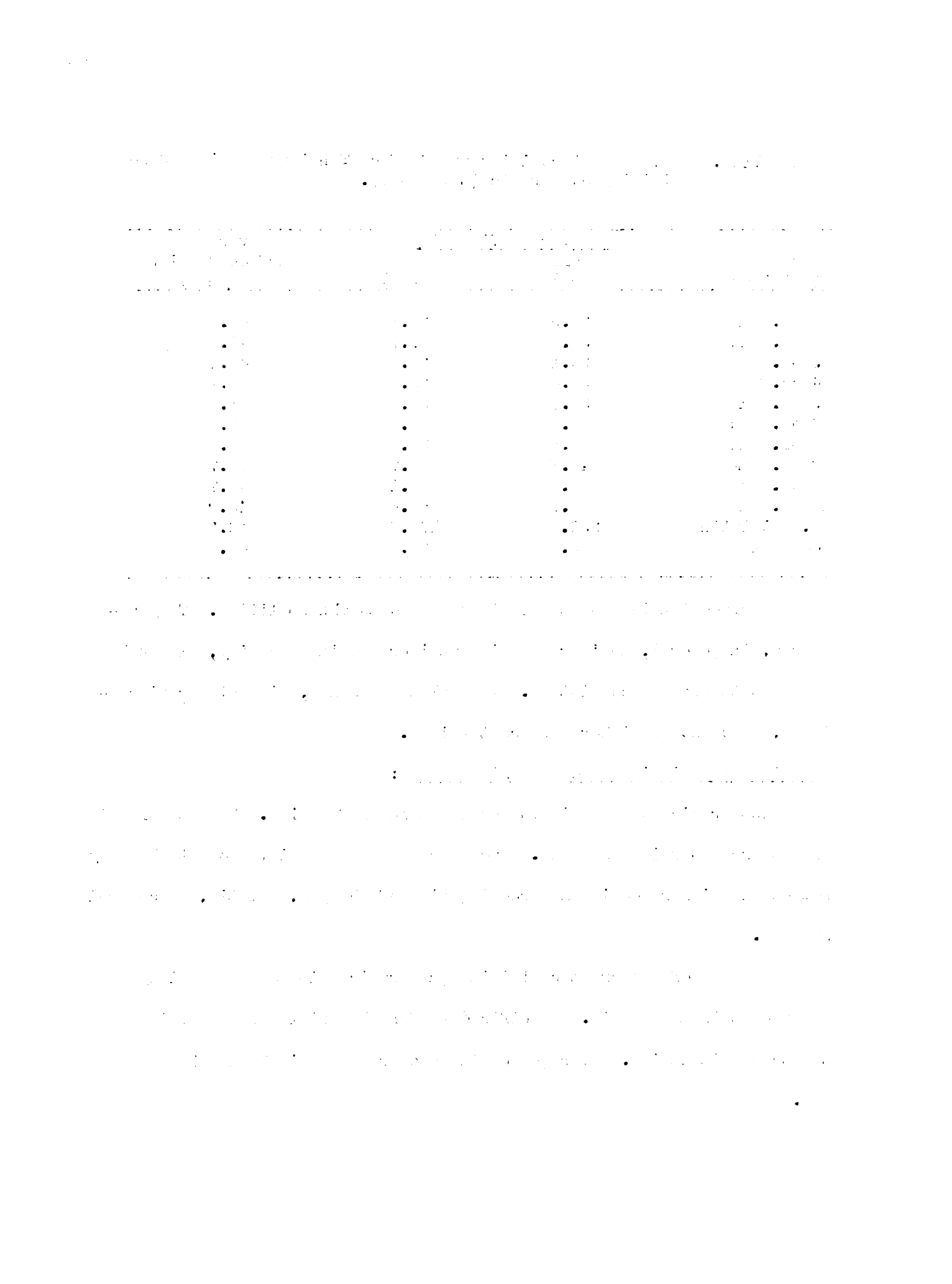


Table XIX. The Freezing Times of Ice Cream Mixes Containing Gum Arabic in Varying Amounts. (Recorded in Minutes and Seconds).

Batch No.	Lots I and III Freezing Time	Lots II and IV Freezing Time	Lots I - IV Average Time	Lot V Freezing Time	Lot VI Freezing Time	Lots V - VI Average Time
1	2:05	2:50	2:28	—	—	—
2	3:08	2:55	3:02	—	4:30	4:30
3	2:50	2:35	2:43	—	—	—
4	3:00	2:40	2:50	4:25	4:25	4:25
5	2:45	2:30	2:38	—	—	—
6	2:50	2:25	2:38	4:17	4:25	4:21
7	2:40	2:46	2:43	—	—	—
8	2:25	3:05	2:45	4:25	4:30	4:28
9	2:35	2:53	2:44	—	—	—
10	2:35	2:49	2:42	4:25	3:48	4:07
11	2:43	2:48	2:46	4:19	3:55	3:57
12	3:01	2:45	2:53	5:05	4:35	4:50

Batch No.	Stabilizer Used:
1	1 oz. Gum Arabic
2	2 oz. Gum Arabic
3	3 oz. Gum Arabic
4	4 oz. Gum Arabic
5	5 oz. Gum Arabic
6	6 oz. Gum Arabic
7	7 oz. Gum Arabic
8	8 oz. Gum Arabic
9	9 oz. Gum Arabic
10	10 oz. Gum Arabic
11	0.4% Gelatin
12	Control

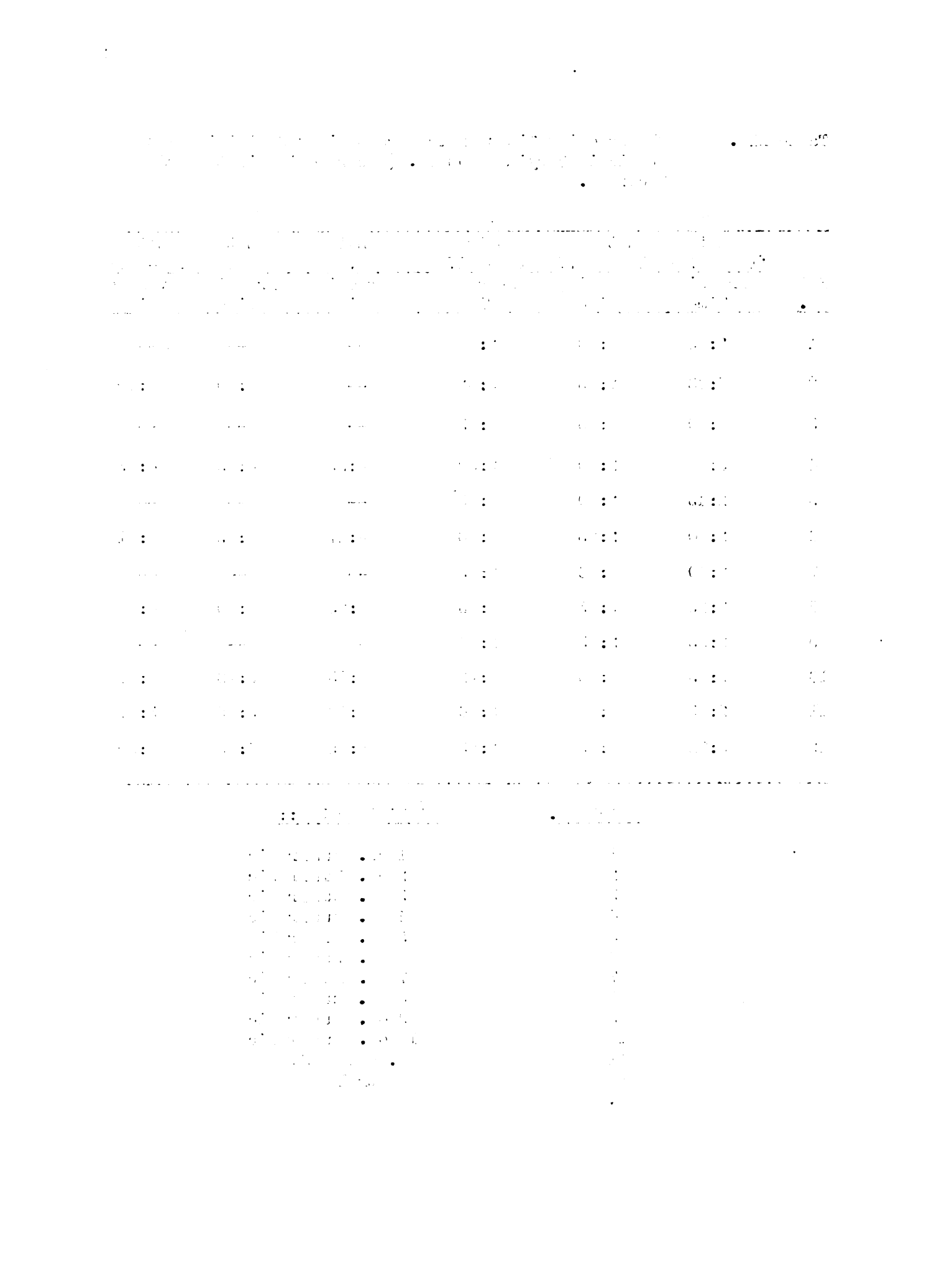


Chart II is plotted from the average data. Results show gum arabic samples to whip to 100 per cent swell from one to two minutes sooner than do the gelatin samples, a saving in whipping time of from twenty to forty per cent. Even though large amounts of the gum (one per cent) were used in some cases, no deleterious effect on the efficiency of whipping was observed.

The control samples whipped as rapidly as did the gum stabilized batches. In many trials, also, the gum samples incorporated a greater percentage of maximum swell than the gelatin stabilized mixes.

Body and Texture of Gum Arabic Samples:

Gum arabic appears to be so inconsistent as to be of little value as a means of improving the texture and body of ice cream. Tables XXII and XXIII, having data from Lots I-IV, show that a wide difference in scores occurred, and there was no correlation between an increase in smoothness of the ice cream and an increase in the amount of the gum used. A sample with less gum was sometimes chosen as being smoother than one with a larger amount.

Table XX. The Average Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic in Varying Amounts (Lots I-IV).

Minutes	Batch No. 1	2	3	4	5	6	7	8	9	10	11	12
0	78	60	59	58	57	52	56	55	52	52	54	60
1	91	72	73	73	67	67	66	66	65	63	59	73
2	102	92	91	91	87	86	87	86	82	83	75	97
3	105	110	105	105	106	104	108	106	104	103	87	110
4	109	116	112	115	111	113	118	115	112	113	100	118
5	112	122	120	119	116	121	128	127	120	121	110	129
6	116	128	122	123	123	128	138	130	130	123	119	133
7	116	134	123	125	126	127	143	135	134	133	128	134
8	116	136	131	133	128	132	146	141	142	136	130	135
9	117	135	127	135	133	132	142	138	142	140	131	137
10	118	134	126	130	132	132	141	139	141	140	132	132
11	117	133	129	128	130	132	141	139	142	138	132	132
12	118	133	128	127	130	132	140	139	139	138	134	130
13	116	131	128	129	130	132	140	137	137	137	132	130
14	116	131	130	131	130	132	138	137	134	133	132	130
15	116	130	132	132	129	132	138	136	134	133	133	130
16	115	130	130	132	129	132	138	136	134	133	132	130

Batches 1-10 inclusive contain gum arabic in amounts varying from one ounce to ten ounces, each succeeding batch having an increase of one ounce of the gum.
Batch 11 contains 0.4% Gelatin.
Batch 12 contains no stabilizer.

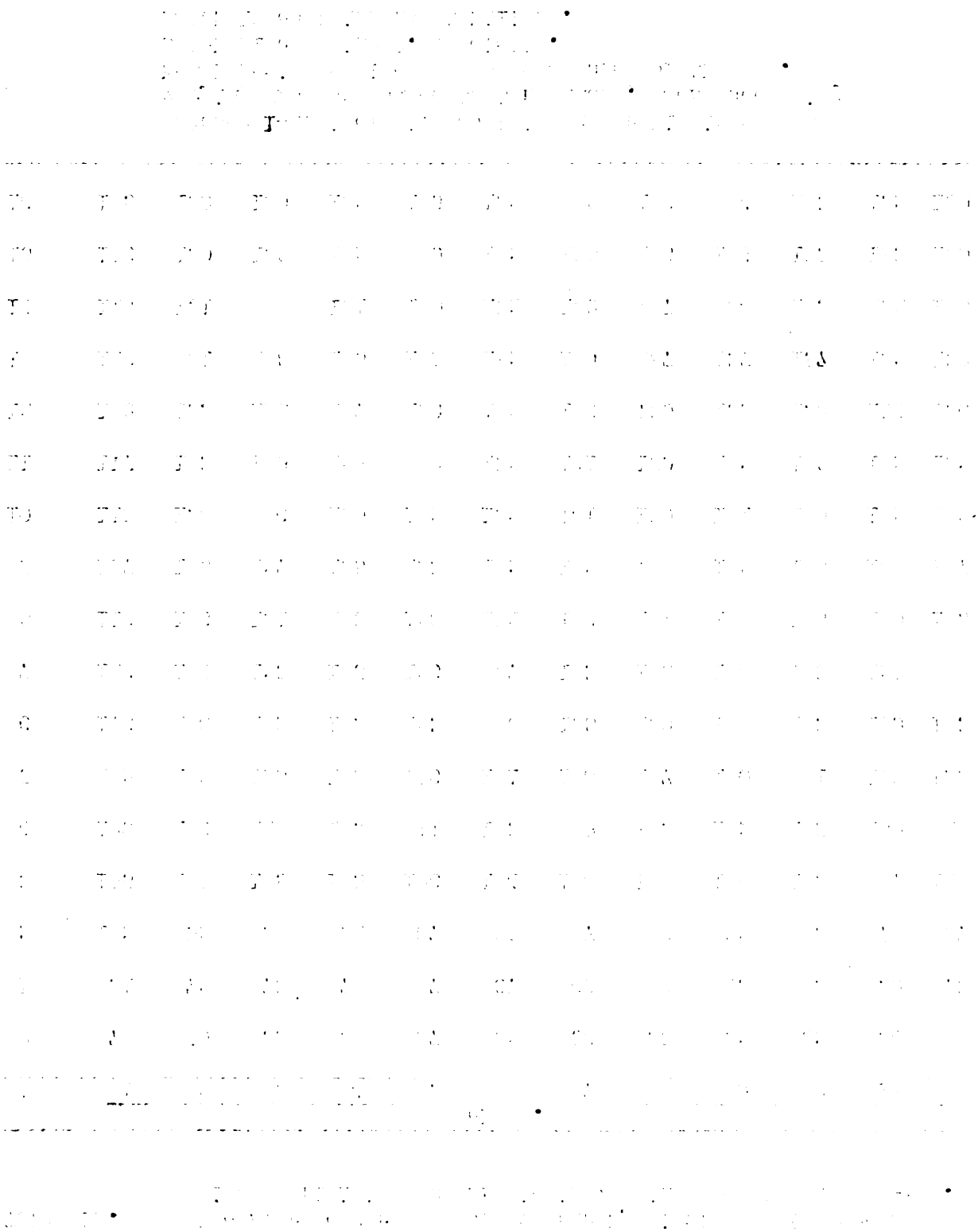


Table XXI. The Average Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic in Varying Amounts (Lots V-VI).

Minutes	Batch No. 1	2	3	4	5	6	7
0	78	74	74	71	67	70	79
1	88	81	80	77	75	72	85
2	106	94	90	88	86	80	94
3	118	104	103	101	99	87	106
4	129	117	114	109	114	95	116
5	136	125	126	120	125	102	135
6	140	132	128	134	131	111	134
7	141	142	138	137	141	120	144
8	144	142	141	142	141	127	148
9	145	142	143	148	144	132	145
10	144	144	143	148	146	135	143
11	143	143	143	148	144	135	142
12	141	140	139	144	140	134	139
13	141	141	139	140	140	134	137
14	140	138	137	140	139	134	137
15	139	138	137	140	138	133	137
16	139	138	137	140	138	132	137

Batch No.	Stabilizer Used
1	2 oz. Gum Arabic
2	4 oz. Gum Arabic
3	6 oz. Gum Arabic
4	8 oz. Gum Arabic
5	10 oz. Gum Arabic
6	0.4% Gelatin
7	Control

Chart II. Showing the Per Cent Overrun of Ice Cream Mixes Containing Various Amounts of Gum Arabic.

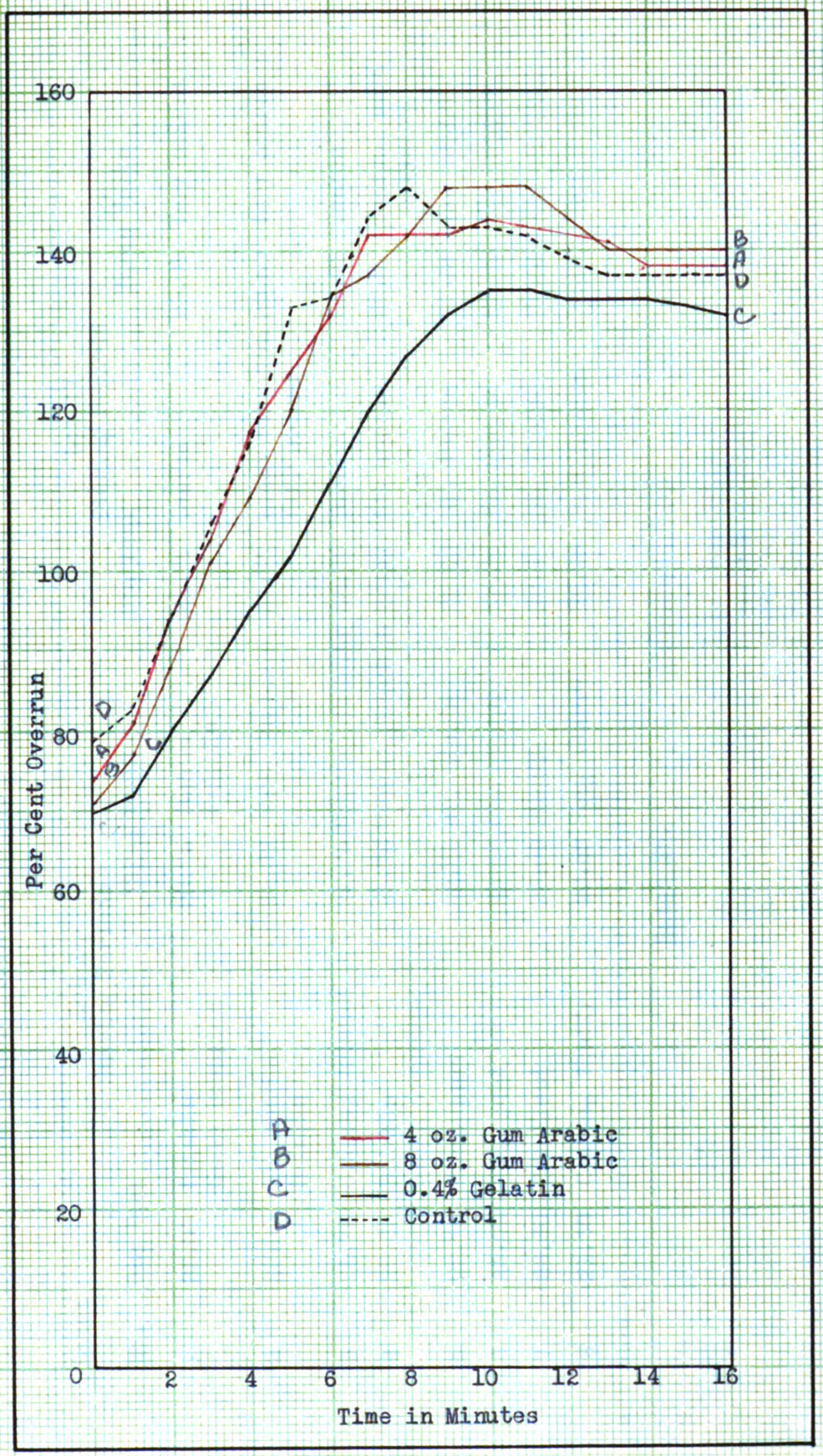


Table XXII. Body and Texture Scores and Criticisms of Ice Cream Containing Varying Amounts of Gum Arabic. (Lots I and II).

Batch No.	Lot I Storing Periods One Week		Three Weeks		Lot II Storing Periods One Week		Three Weeks	
1	22.00	Friable Lacks cohesion	20.75	Coarse Friable	20.75	Coarse	20.00	Very coarse
2	22.00	Sl. coarse Friable	21.00	Very coarse	20.75	Lacks cohesion Very coarse	20.50	Very coarse
3	21.75	Coarse, friable	21.75	Coarse, friable	22.25	Same	21.25	Coarse
4	22.25	Friable Lacks cohesion	21.75	Coarse, friable	22.50	Sl. coarse	22.0	Coarse, more cohesion
5	22.75	Firm, good	22.25	Sl. coarse	22.50	Sl. coarse	22.25	Sl. coarse
6	23.00	Very good	22.25	Sl. coarse	22.00	Sl. coarse	22.00	Sl. coarse
7	23.50	Excellent	23.00	Smooth	22.50	Sl. Coarse	22.25	Sl. coarse
8	21.50	Coarse, fluffy	20.50	Very coarse	21.00	Very coarse	20.00	Very coarse

Batch No.	Stabilizer Used
1	1 oz. Gum Arabic
2	2 oz. Gum Arabic
3	3 oz. Gum Arabic
4	4 oz. Gum Arabic
5	5 oz. Gum Arabic
6	6 oz. Gum Arabic
7	0.4% Gelatin
8	Control

Table XXIII. Body and Texture Scores and Criticisms of Ice Cream Containing Varying Amounts of Gum Arabic (Lots III and IV).

Batch No.	Lot III Storing Periods				Lot IV Storing Periods			
	One Week		Three Weeks		One Week		Three Weeks	
1	21.50	Coarse, friable	22.00	Coarse, friable	21.00	Very coarse	22.50	Sl. coarse Friable
2	21.50	Same	22.25	Same	21.50	Coarse, friable	25.00	Excellent
3	22.00	Sl. coarse	22.50	Sl. coarse	21.50	Same	22.75	Very good
4	21.50	Coarse, friable	22.75	Sl. coarse, good	22.00	Sl. coarse Friable	25.00	Excellent
5	22.50	Good, smooth	22.00	Coarse	22.50	Smooth, Sl. gummy	25.00	Excellent
6	21.50	Coarse	21.00	Coarse	21.00	Very coarse	21.00	Very coarse

Batch No.	Stabilizer Used
1	7 oz. Gum Arabic
2	8 oz. Gum Arabic
3	9 oz. Gum Arabic
4	10 oz. Gum Arabic
5	0.4% Gelatin
6	Control

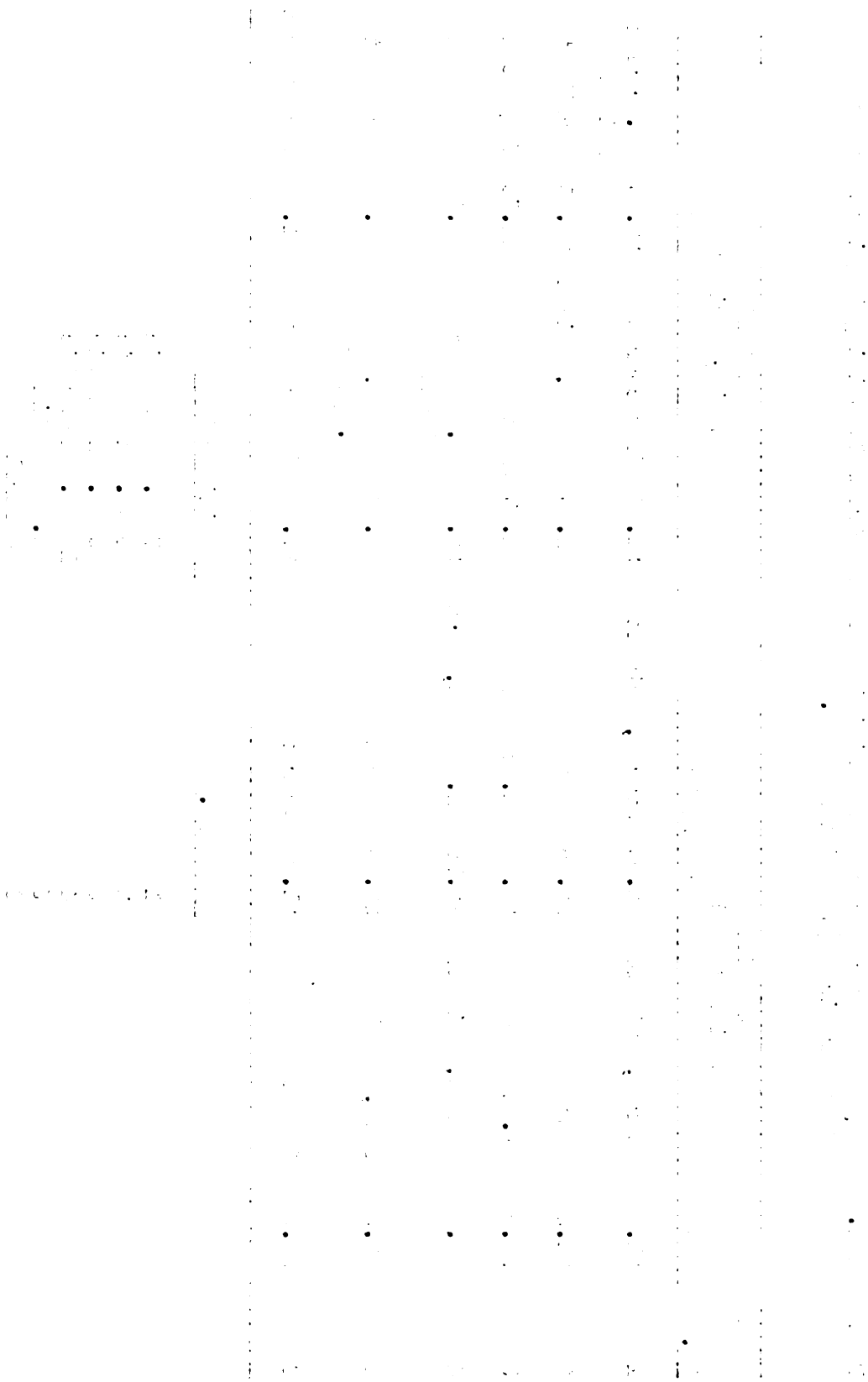


Table XXIV. Body and Texture Scores and Criticisms of Ice Cream Containing Varying Amounts of Gum Arabic (Lots IV and V).

Amount Stabilizer	Lot IV		Lot V	
	Scores	Criticisms	Scores	Criticisms
0.2 oz. Gum	21.50	Coarse, friable	22.00	Sl. coarse Friable
0.4 oz. Gum	22.00	Sl. coarse, friable	22.00	same
0.6 oz. Gum	22.00	same	22.00	same
0.8 oz. Gum	22.25	Sl. coarse	21.50	Coarse
10.0 oz. Gum	22.75	Good, smooth	22.00	Sl. coarse
0.4% Gelatin	22.75	Very smooth	22.5	Sl. coarse
0.4% Gelatin	22.75	Very smooth	22.5	Sl. coarse
Control	21.50	Very coarse	21.50	Coarse

Gelatin stabilized samples were usually superior to the gum batches after both the one week and three weeks storage period in lots I and II. The gum samples were characterized as being friable, coarse, and lacking cohesion. In Table XXIII peculiar results are shown indicating that gum samples scored more after the longer than after the shorter storage period. In fact, they were superior to the gelatin samples after the three-weeks period after having been judged inferior in body and texture at the one-week trials.

There is no plausible explanation for this peculiarity, unless it is due to different standards of scoring which might unintentionally be set up by the judges from one day to the next. This point is of minor importance from a commercial standpoint since ice cream is not usually stored for this long a period.

Lots V and VI scored similarly to those of the previous lots, as shown in Table XXIV. Although some batches were as good with gum as with gelatin, the majority of the gum samples were inferior.

With the consideration of the available data, it would appear that gum arabic shows inconsistently in its ability to improve the body and texture of ice cream, and as a rule, an inferior product would result from its use as an ice cream stabilizer.

Effect of Gum Arabic on the Hardness of Ice Cream:

This gum apparently has no effect on the hardness of the ice cream. Table XXV, although showing variations throughout, gave results indicating no general trend toward an increase in hardness with an increase in gum.

These trials show slight difference in hardness between the control, gelatin, or gum samples, all of them giving about the same average penetration of the plunger. One per cent (approximately ten ounces) of gum arabic gave an ice cream no firmer than the sample containing only 0.1 per cent (about one ounce) of the gum. The gelatin samples on an average, were somewhat more firm.

These results again show as in Part I that other factors than the stabilizer play an important part in determining the hardness of the ice cream, as illustrated by the variations that occur among individual samples in Table XXV.

Table XXV. Results of Hardness Tests on Ice Cream Containing Varying Amounts of Gum Arabic (Lots I-IV).

Amount Stabilizer	Lots I and III Penetration of Plunger in Degrees	Lots II and IV Penetration of Plunger in Degrees	Average Penetration in Degrees
1 oz. Gum	12.4	12.5	12.45
2 oz. Gum	13.7	13.6	13.65
3 oz. Gum	13.4	12.7	13.05
4 oz. Gum	14.5	13.4	13.95
5 oz. Gum	12.2	14.6	13.40
6 oz. Gum	12.4	13.3	12.85
7 oz. Gum	13.5	12.4	12.95
8 oz. Gum	12.1	10.8	11.45
9 oz. Gum	13.1	14.8	13.95
10 oz. Gum	14.2	12.6	13.40
0.4% Gelatin	12.5	12.0	12.20
Control	11.9	14.9	13.40

These variations are so great in many cases, and there is such a lack of correlation between similar samples, that results obtained by the use of the Hardness Tester appear to be of little value. Indications are that comparative firmness of ice creams cannot be measured accurately by apparatus of this type.

Melting Down Tests on Gum Arabic Samples:

Gum arabic shows no influence toward increasing the resistance to melting of the ice cream containing it as a stabilizer. This holds true, even though comparatively large amounts of the gum may be used, as shown in the average melting down results (Table XXVI).

Samples containing the gum start to melt as quickly as samples containing no stabilizers, and an increase in gum did not retard the rate of melting. About 15 to 20 per cent of the total weight of the brick had melted by the end of the first hour in the case of gum stabilized samples and the controls, while only about two per cent had melted of the gelatin samples.

Table XXVI. Average Results of Melting Down Tests on Ice Cream Containing Varying Amounts of Gum Arabic. (Tabulated as Percentage Melted)

Amount Stabilizer	Time Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
1 oz. Gum	11.2	19.4	33.3	40.2	47.2	54.1	61.1	68.0	69.4
2 oz. Gum	13.9	22.2	37.5	45.2	52.8	58.9	65.9	70.1	72.2
3 oz. Gum	15.9	26.4	46.5	54.1	61.8	70.1	75.7	80.5	81.2
4 oz. Gum	17.3	25.7	40.3	47.2	54.8	60.4	65.3	68.7	69.4
5 oz. Gum	18.5	28.4	47.2	54.8	60.4	70.8	74.9	78.4	79.1
6 oz. Gum	15.2	26.4	47.2	55.5	62.5	69.4	73.6	75.7	75.6
7 oz. Gum	14.7	25.4	41.7	43.3	62.4	65.7	70.3	76.1	79.4
8 oz. Gum	16.2	28.8	46.5	47.9	66.2	67.1	76.5	78.0	85.7
9 oz. Gum	17.3	28.5	48.7	49.1	64.3	67.1	76.1	77.1	85.1
10 oz. Gum	18.4	39.1	56.4	59.4	70.1	75.6	79.0	83.4	85.4
0.4% Gelatin	2.1	5.6	22.2	31.2	41.6	54.1	65.3	73.6	75.0
Control	17.3	25.0	41.6	47.9	55.5	62.5	68.7	75.7	77.0

The gum-stabilized ice cream melted rapidly throughout the period of melting, while the gelatin samples did not begin to melt rapidly until about two hours had elapsed. The gelatin samples melted down more cleanly than the gum samples. The ice cream from both the gum and control lots left considerable foam on the screen after melting.

The melted portion of the gum samples was foamy and coarse in appearance, showing large air cells, an undesirable feature which the gelatin batches did not possess.

Figures II and III show the rapidity of melting which samples containing large amounts of gum arabic exhibit. It may be noted that the gelatin stabilized sample is much more resistant.

Summary of Results of Gum Arabic Study:

Gum arabic showed little influence on the viscosity and surface tension of ice cream mixes. Mixes stabilized with this gum whipped to 100 per cent overrun from one to two minutes faster than the gelatin samples. The gum appeared to be unreliable as a stabilizer since it did not make a smooth textured ice cream uniformly even though used in ten-ounce amounts. The gum samples melted at a much more rapid rate than the gelatin samples.

PART III.

Agar Agar

Amounts of powdered agar agar varying from one to six ounces were used in the mixes. No extra precautions were used to incorporate this stabilizer in the mix, and when it was properly mixed with the sugar before adding it to the warm mix no difficulty was experienced.

Lots I and II contained batches stabilized with from one to six ounces of agar, as well as the gelatin and control samples. Six batches containing two ounces of agar were studied in Lot III, while Lot IV contained six batches with three ounces of agar as the stabilizing agent. Lots III and IV each contained two batches stabilized with gelatin, and two containing no stabilizer.

Viscosity and Surface Tension:

The viscosity and surface tension measurements of two series of mixes containing from one to six ounces of agar are given in Table XXVII, with the average results of the trials being given in Table XXVIII. Agar agar shows great ability to thicken the mix, and two ounces of it gave a mix with a viscosity somewhat greater than the same mix with about four ounces of gelatin. A large amount of structural viscosity is created by agar, especially noticeable when as high as three ounces or more of the vegetable product is used.

Table XXVIII. Average Viscosity and Surface Tension of Ice Cream Mixes Containing Varying Amounts of Agar Agar (Lots I and II).

Stabilizer and Amount Used	Average Viscosity in Centipoises		Average Surface Tension
	Apparent	Basic	
1 oz. Agar	79.8	66.6	44.7
2 oz. Agar	186.4	155.3	45.2
3 oz. Agar	301.7	221.9	45.7
4 oz. Agar	825.3	483.6	46.0
5 oz. Agar	1539.6	754.3	46.4
6 oz. Agar	2391.4	1571.0	47.5
0.4% Gelatin	195.3	153.1	44.5
Control	39.9	39.9	43.6

Agar batches, in general, show a greater surface tension than the gelatin samples, with all of them giving a higher value than the control. Again, it may be noted that the surface tension increases with an increase in viscosity although not uniformly.

Four to six ounces of agar caused such great viscosity that great loss was experienced in handling the mix due to it clinging to the tubular cooler, pipes, and other processing equipment. It also gave a somewhat gramular appearance when flowing over the cooler, although it was smooth to the touch and to the taste.

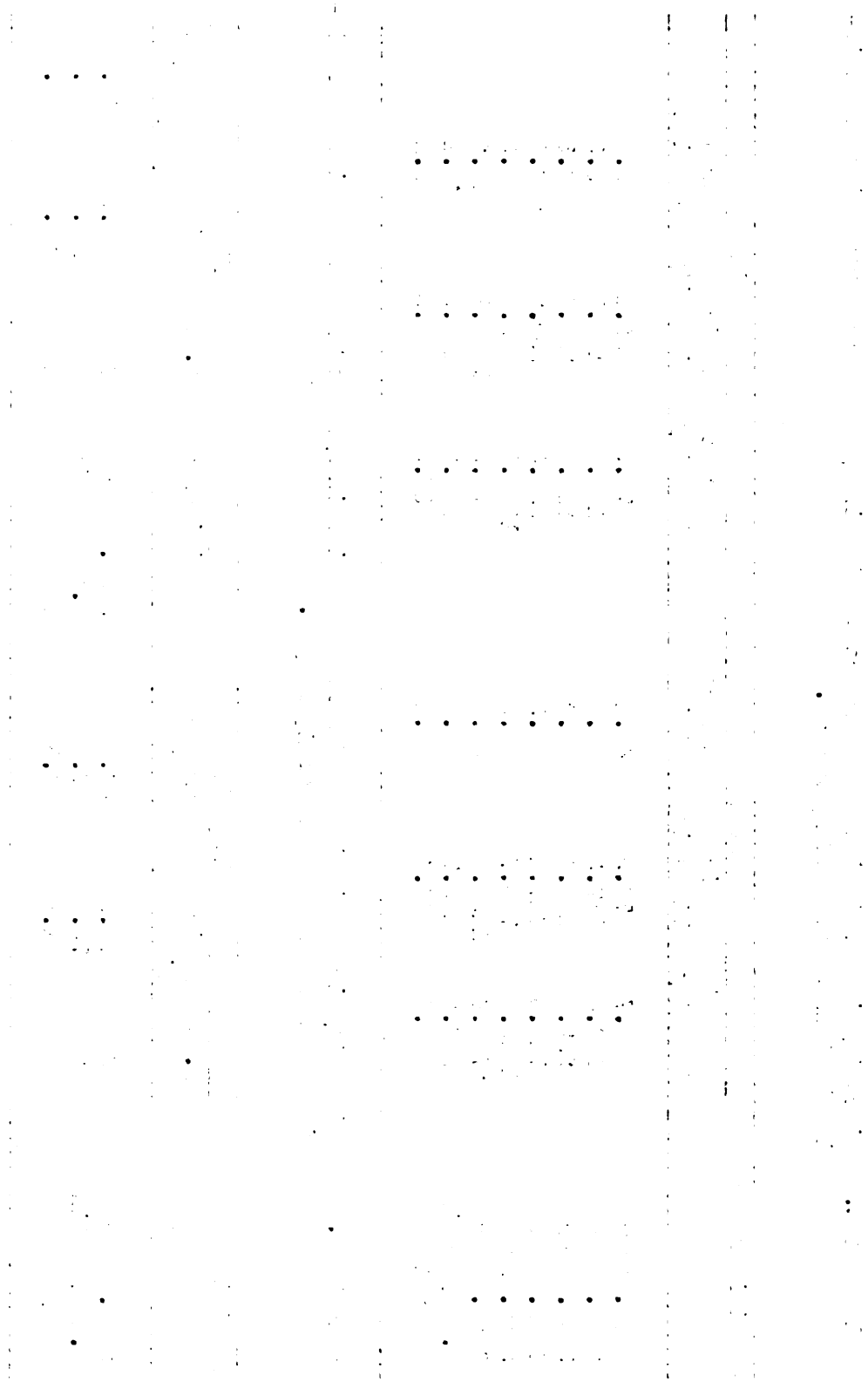
Further viscosity and surface tension measurements were made on agar batches containing two and three ounces of the stabilizer. The results of these readings are shown in Table XXIX. It is again shown that two ounces of agar give a viscosity to the mix slightly higher than that of the gelatin-mix, although the difference is so slight as to be negligible. In Lot IV, when the viscosities of both the gelatin and the agar were high, the surface tension was also higher. In Lot III, the viscosities were considerably lower, and coincidentally there was practically no difference between

Table XXVII.. Viscosity in Centipoises and Surface Tension in Dynes of Ice Cream Mixes Containing Various Amounts of Agar Agar.

Stabilizer and Amount Used	Lot I			Lot II		
	Apparent Viscosity	Basic Viscosity	Surface Tension	Apparent Viscosity	Basic Viscosity	Surface Tension
1 oz. Agar	88.7	70.9	44.4	70.9	62.1	45.0
2 oz. Agar	186.4	177.5	45.0	186.4	153.1	45.5
3 oz. Agar	292.8	186.4	45.0	510.6	257.4	46.3
4 oz. Agar	718.8	417.1	45.5	951.8	550.2	46.5
5 oz. Agar	1819.2	798.7	46.3	1260.1	709.9	46.5
6 oz. Agar	2706.6	1197.9	46.6	2076.5	1544.1	48.2
0.4% Gelatin	266.2	159.7	44.9	124.2	106.5	44.1
Control	44.4	44.4	44.1	55.5	55.5	43.1

Table XXIX. Viscosity in Centipoises and Surface Tension in Dynes of Ice Cream Mixes Containing Two and Three Ounces of Agar Agar.

Stabilizer and Amount Used	Lot III			Lot IV			
	No. of Lots	Basic Viscosity	Surface Tension	Stabilizer and Amount Used	No. of Lots	Basic Viscosity	Surface Tension
2 oz. Agar	6	79.9	46.8	3 oz. Agar	6	290.7	48.2
0.4% Gelatin	2	75.6	47.0	0.4% Gelatin	2	119.0	48.1
Control	2	21.8	46.8	Control	2	21.8	46.6



the surface tension of the stabilized and unstabilized samples.

Although efforts were made continuously throughout the study to control all conditions relative to processing, it appeared impossible to control factors so that the gelatin lots would have approximately the same viscosity. Differences in cooling or slight variations in the aging temperature appeared to have a marked effect on the gelatin stabilized mixes. However, it is to be remembered that comparisons should not be made between series but between members of the same series.

Effect of Agar Agar on Freezing:

Preliminary examination of the effect of agar on the time of freezing was made on series of mixes containing the stabilizer in varying amounts. These results are tabulated in Table XXX.

Table XXX. Freezing Time of Ice Cream Mixes Containing Different Amounts of Agar Agar.

Stabilizer and Amount Used	Freezing Time in Minutes and Seconds		
	Lot I	Lot II	Average
1 oz. Agar	5:05	2:20	2:42
2 oz. Agar	2:45	2:22	2:33
3 oz. Agar	2:48	2:20	2:32
4 oz. Agar	2:05	2:22	2:14
5 oz. Agar	2:55	2:19	2:37
6 oz. Agar	2:35	2:20	2:28
0.4% Gelatin	2:25	2:28	2:27
Control	3:00	3:00	3:00

These results would seem to indicate that the agar had no effect on the freezing of the ice cream, even though used in large amounts. The control sample appeared to be the slowest to freeze in both trials, although the difference in time was slight. The average results show the control to require from 20 to 40 seconds longer to freeze than do the samples containing stabilizers.

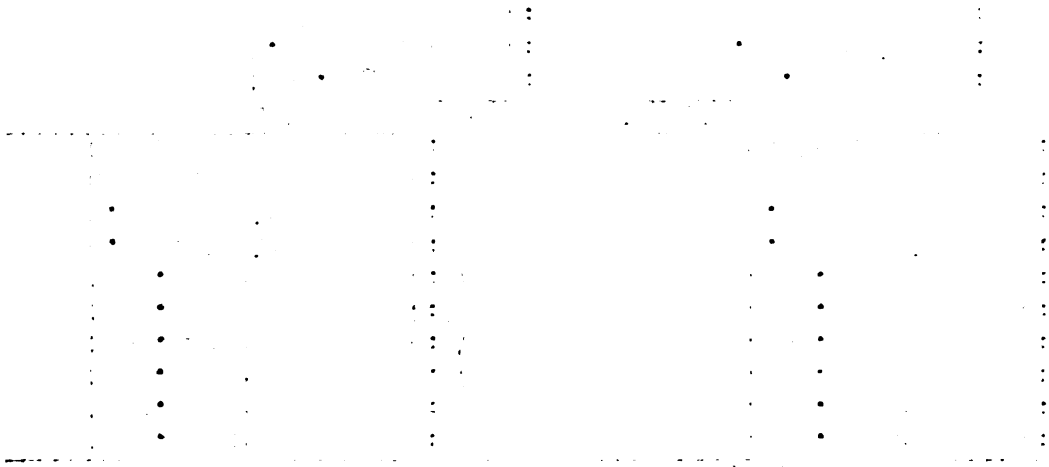
Somewhat different results were obtained when several batches were frozen which contained two and three ounces of agar. These freezing times are recorded in Table XXXI, and although the results are not constant, it would seem that the gelatin samples freeze in shorter time than do those containing agar. The averages show quite conclusively that gelatin freezes from one minute to one-half minute more quickly than the agar samples, a saving of from 10 to 20 per cent of the freezing time. The lagging in the freezing of the control samples which was noted in the preliminary trials was not constant in these trials, although it was noticeable in Lot III.

The difference in the freezing time of agar and gelatin samples was not detected in the preliminary trials (Table XXX) probably because of the rapidity with which these lots were frozen. They were frozen in approximately one-half the time required for the final trials, the difference being due to changed conditions in the freezer and in the freezing medium. Apparently, the longer freezing time made conditions more ideal for detecting freezing-time differences.

Table XXXI. Freezing Time of Ice Cream Mixes Containing Two and Three Ounces of Agar (Recorded in Minutes and Seconds).

Lot III		Lot IV	
Stabilizer and Amount Used	Freezing Time	Stabilizer and Amount Used	Freezing Time
2 oz. Agar	4:50	3 oz. Agar	3:55
2 oz. Agar	4:35	3 oz. Agar	4:20
2 oz. Agar	5:05	3 oz. Agar	4:20
2 oz. Agar	4:57	3 oz. Agar	4:45
2 oz. Agar	5:10	3 oz. Agar	3:50
2 oz. Agar	5:05	3 oz. Agar	3:45
0.4% Gelatin	3:50	0.4% Gelatin	3:30
0.4% Gelatin	4:00	0.4% Gelatin	3:40
Control	4:35	Control	4:40
Control	5:30	Control	3:40

Lot III	Average Freezing Time	Lot IV	
2 oz. Agar	4:54	3 oz. Agar	4:06
0.4% Gelatin	3:55	0.4% Gelatin	3:35
Control	5:03	Control	3:70



Effect of Agar on Overrun:

The average overrun of the series containing from one to six ounces of agar is given in Table XXXII. The original data are tabulated in Tables LXXI and LXXII (Appendix). Batches containing three ounces of agar whipped to 100 per cent overrun as rapidly as did the gelatin samples. The less the amount of agar used, the faster the mix whipped, with the sample containing one ounce being very similar to the control, both of which whipped more rapidly than any of the other batches.

The sample containing four ounces of agar was practically identical in whipping ability with the gelatin sample, being but slightly slower in reaching the standard overrun. However, when five and six ounces of the vegetable stabilizer were used, the ability of the mix to incorporate air was greatly reduced. All lots but those containing exorbitant amounts of agar appeared to have approximately equal ability to incorporate the maximum amount of air. Chart III is taken from the data given in this table, and illustrates the effect of various amounts of agar on the swell.

Further studies to determine the effects of normal amounts of agar agar on overrun gave results showing that two and three ounces of agar gave a mix that whipped more rapidly than the gelatin mix. The lots containing these amounts of agar whipped to 100 per cent overrun in about two minutes, while about four minutes were required for the gelatin samples to reach the same point. The results are tabulated in Tables LXXIII and LXXIV, with the average overruns shown in Table XXXIII.

The two-ounce agar batches whipped somewhat faster than the control, while there was little difference between the control and the three-ounce agar samples from this standpoint. In all cases, the control whipped more rapidly than did the gelatin mixes.

Table XXXII. The Average Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Agar Agar (Lots I and II, Part III).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	54	42	40	30	32	27	46	57
1	68	56	55	49	48	44	61	69
2	90	77	77	69	65	63	74	86
3	107	99	95	87	80	74	91	103
4	116	115	109	102	88	86	105	114
5	123	120	114	111	94	92	116	115
6	127	123	119	114	97	99	122	122
7	129	129	124	125	101	101	126	128
8	131	135	129	125	105	103	128	127
9	131	133	128	125	105	104	129	127
10	130	132	126	125	107	106	127	125
11	129	131	126	125	107	108	127	124
12	129	130	126	124	106	107	127	123
13	128	130	125	124	106	108	127	123
14	128	130	124	124	106	108	127	123
15	127	129	123	124	107	107	127	122
16	127	129	123	124	107	106	127	122

Batch No.	Stabilizer Used
1	1 oz. Agar
2	2 oz. Agar
3	3 oz. Agar
4	4 oz. Agar
5	5 oz. Agar
6	6 oz. Agar
7	0.4% Gelatin
8	Control

Table XXXIII. The Average Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Agar Agar (Lot III, Part III).

	Lot III Batch No.			Lot IV Batch No.		
Minutes	1	2	3	1	2	3
0	75	60	70	64	56	75
1	85	67	80	74	62	79
2	100	79	91	88	74	90
3	110	90	103	104	84	104
4	119	103	114	117	94	111
5	124	111	118	124	104	122
6	130	120	128	134	113	129
7	138	129	134	141	121	135
8	145	135	141	145	129	144
9	145	140	145	151	135	151
10	147	140	147	155	140	153
11	148	140	142	155	142	153
12	146	141	140	153	143	154
13	144	139	138	154	145	148
14	145	138	137	152	143	148
15	141	137	136	150	143	148
16	141	137	135	147	143	147

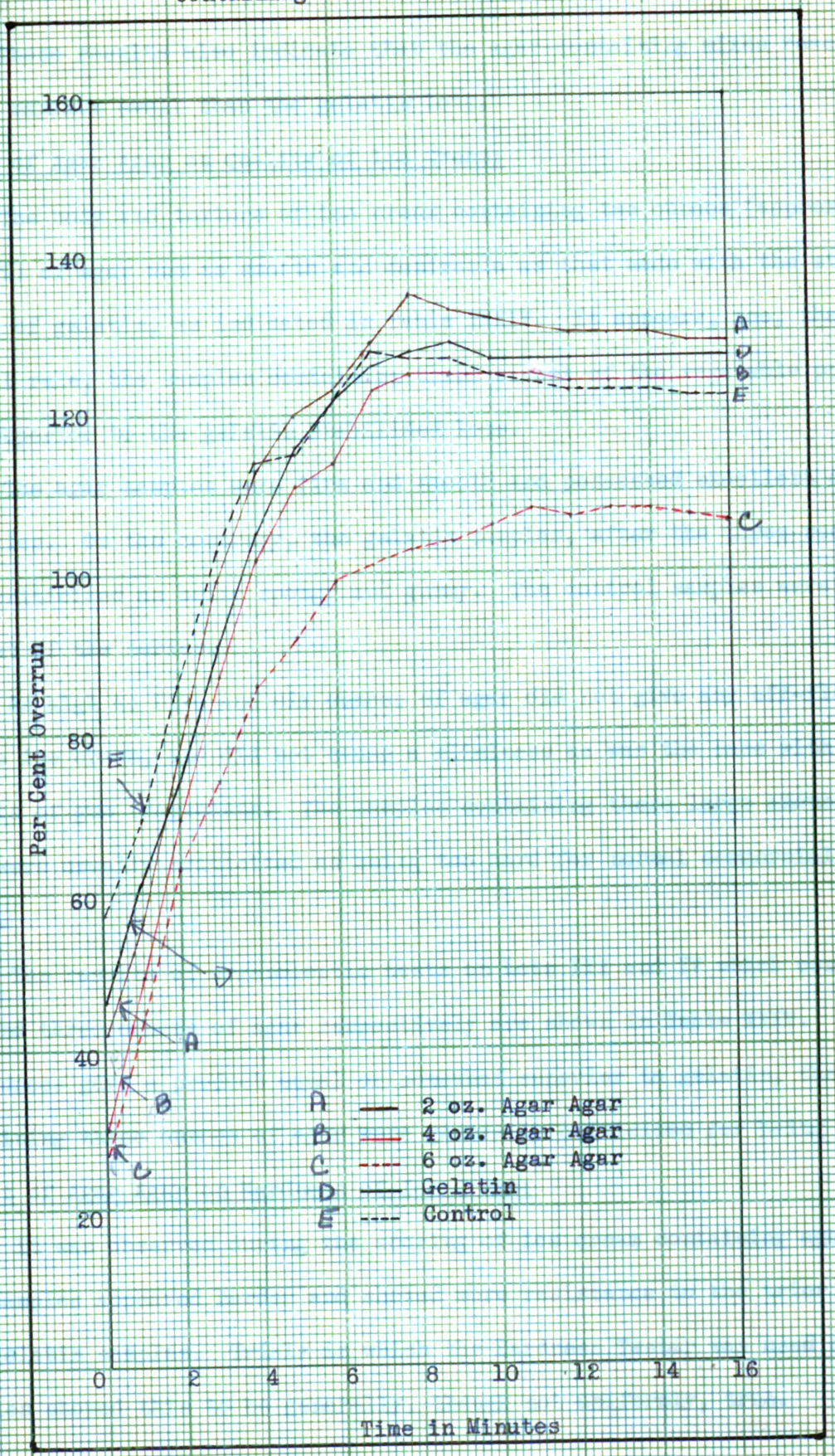
Lot III

Batch No.	Stabilizer Used
1	2 oz. Agar
2	0.4% Gelatin
3	Control

Lot IV

1	3 oz. Agar
2	0.4% Gelatin
3	Control

Chart III. Showing the Per Cent Overrun of Ice Cream Mixes Containing Various Amounts of Agar Agar.



These results also indicate that the agar-containing mixes reach a higher maximum swell than the gelatin lots.

Effect of Agar Agar on Quality of Ice Cream:

The body and texture of ice cream containing two ounces (approximately 0.2%) of agar was as smooth and desirable as that made with the standard amount of gelatin, as indicated in Table XXXIV. It appears, too, that as a general rule, the samples containing three ounces of the vegetable product were superior to the gelatin stabilized lots.

The agar samples were firm and smooth and possessed excellent dipping qualities. On the contrary, the gelatin samples, after the three-week period, were criticized as being spongy and gummy. The control samples were the poorest of the series.

As high as five and six ounces of agar did not give any off-flavor to the ice cream, and did not cause a sliminess as was the case with large amounts of gum tragacanth. The samples containing these large amounts of agar were usually criticized as being too hard for normal commercial ice cream.

The results of organoleptic tests on Lots III and IV which contain two and three ounces of agar respectively are shown in Table XXXV. Although two ounces gave a product equal or somewhat superior to gelatin, the samples containing three ounces of agar were generally criticized for being crumbly.

Effect of Agar Agar on Hardness of Ice Cream:

It was observed during the scoring of ice cream containing agar that the samples appeared harder and showed more resistance to the trier than the gelatin samples. Trials in which the Hardness Tester was used on the samples showed this to be generally, though not uniformly, true.

Table XXXIV. Body and Texture Scores and Criticisms of Ice Cream Containing Varying Amounts of Agar Agar.

Batch No.	Lot I Storing Periods One Week		Three Weeks		Lot II Storing Periods One Week		Three Weeks	
1	22.00	Firm, sl. coarse	22.00	Sl. coarse	21.50	Coarse	21.00	Coarse
2	22.50	Good	22.00	Sl. coarse	22.50	Good, very firm	22.00	Good - fine for dipping
3	23.00	Very good	22.75	Smooth	22.50	Good, very firm	22.50	Good - fine for dipping
4	22.75	Very good	22.50	Very sl., coarse	22.50	Good, very firm	22.50	Good - fine for dipping
5	23.00	Smooth, very firm	22.75	Smooth, very firm	22.50	Very hard Sl.slippery	22.50	Very good,but too hard
6	23.50	Excellent, very firm	22.75	Smooth, very firm	22.50	Very hard Sl.slippery	22.50	Very good, but too hard
7	22.50	Smooth, not so firm	21.75	Smooth, spongy	22.25	Not so hard Smooth	22.00	Smooth, but spongy
8	22.00	Slight coarse	21.50	Coarse	20.00	Very coarse no cohesion	20.00	Very coarse

Batch No.	Amount of Stabilizer Used
1	1 oz. Agar
2	2 oz. Agar
3	3 oz. Agar
4	4 oz. Agar
5	5 oz. Agar
6	6 oz. Agar
7	0.4% Gelatin
8	Control

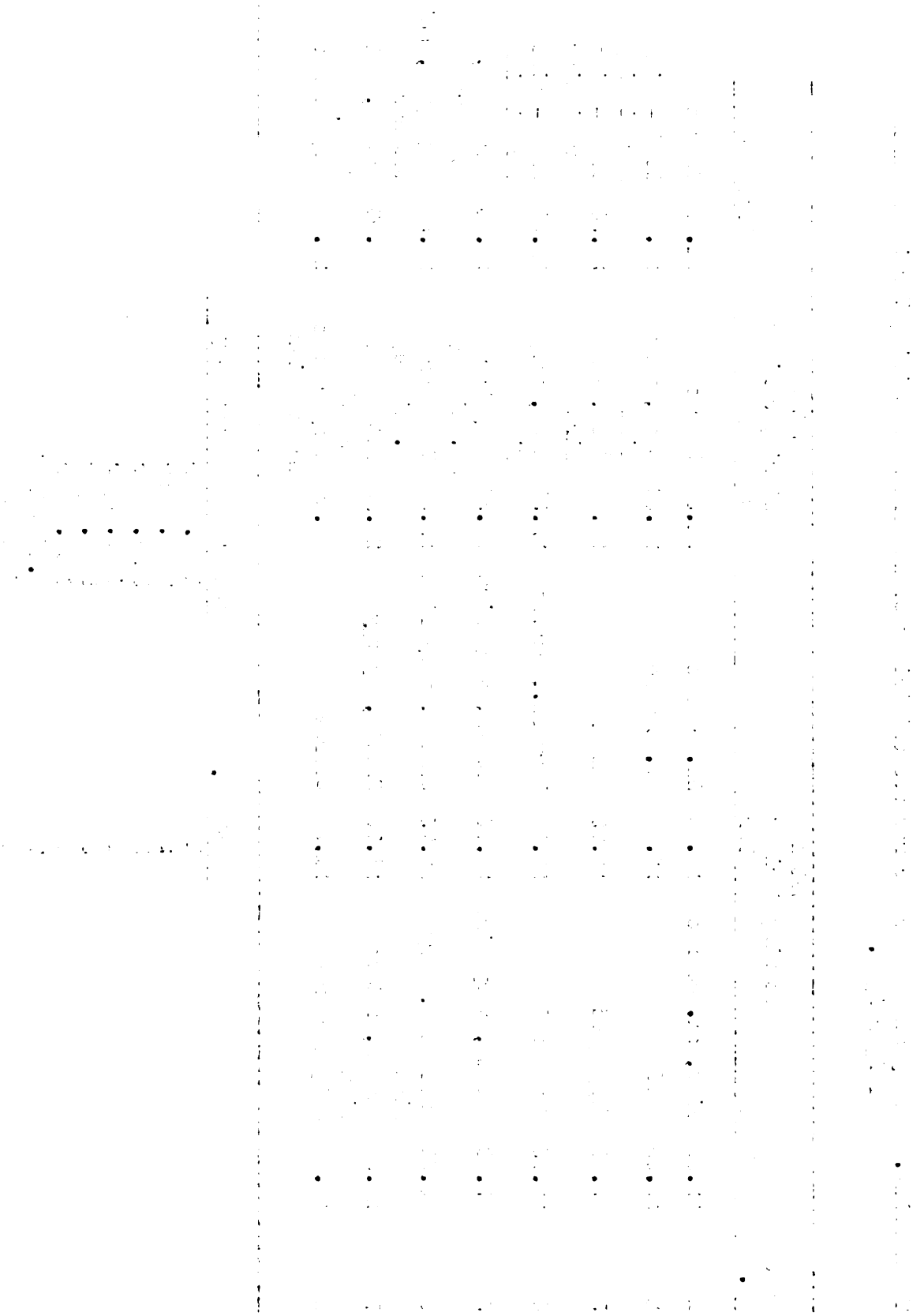


Table XXXV. Body and Texture Scores and Criticisms of Ice Cream Containing Agar Agar (Lots III and IV).

Batch No.	Lot III Scores	Lot III Criticisms	Lot IV Scores	Lot IV Criticisms
1	23.00	Excellent	22.50	Smooth, crumbly
2	23.00	Excellent	22.75	Smooth, sl.crumbly
3	22.50	Sl. crumbly	22.50	Smooth, crumbly
4	22.50	Sl. crumbly	22.50	Smooth, crumbly
5	23.00	Very good	22.50	Smooth, crumbly
6	23.00	Very good	22.50	Smooth, crumbly
7	22.50	Gummy, spongy	22.50	Very smooth, gummy
8	22.50	Gummy, spongy	22.50	Very smooth, gummy
9	21.00	Very coarse	21.00	Very coarse
10	21.00	Very coarse	21.00	Very coarse

Lot III

Batches 1 - 6 contain 2 oz. Agar
Batches 7 - 8 contain 0.4% Gelatin
Batches 9 - 10 contain no stabilizer

Lot IV

Same as Lot III with exception
Batches 1 to 6 contain 3 oz. Agar

These results are given in Table XXXVI and Table XXXVII. Table XXXVI shows that although the general trend is an increase in hardness with an increase in agar, variations occur which cannot be ignored. The average penetration of the plunger holds more nearly to what would be expected than do the trials on the individual samples. These average results indicate samples containing two ounces or more of agar are firmer than are samples containing gelatin, and all stabilized samples are harder than are the controls.

Table XXXVII gives results on similar trials made on samples of ice cream containing two and three ounces of agar. Again variations may be observed in the hardness tests on individual samples. The average results, however, verify those of Lots I and II, showing that two and three ounces of agar make a harder bodied ice cream than does the regular amount of gelatin.

Table XXXVI. Results of Hardness Tests on Ice Cream Containing Varying Amounts of Agar Agar (Lots I and II).

Amount Stabilizer	Lot I Penetration of Plunger in Degrees	Lot II Penetration of Plunger in Degrees	Average Penetration in Degrees
1 oz. Agar	18.0	14.3	16.1
2 oz. Agar	15.1	14.1	14.6
3 oz. Agar	16.3	13.8	15.1
4 oz. Agar	16.0	12.2	14.1
5 oz. Agar	12.8	7.5	10.2
6 oz. Agar	13.0	9.0	11.0
0.4% Gelatin	18.8	13.5	16.2
Control	17.1	17.3	17.2

Table XXXVII. Results of Hardness Tests on Ice Cream Containing Two and Three Ounces of Agar Agar (Lots III and IV).

Amount Stabilizer	Lot III Penetration of Plunger in Degrees	Amount Stabilizer	Lot IV Penetration of Plunger in Degrees
2 oz. Agar	14.6	3 oz. Agar	13.0
2 oz. Agar	14.5	3 oz. Agar	14.5
2 oz. Agar	13.0	3 oz. Agar	14.5
2 oz. Agar	13.5	3 oz. Agar	12.0
2 oz. Agar	13.5	3 oz. Agar	12.2
2 oz. Agar	13.5	3 oz. Agar	12.8
0.4% Gelatin	14.0	0.4% Gelatin	14.0
0.4% Gelatin	17.0	0.4% Gelatin	16.5
Control	16.4	Control	19.0
Control	19.6	Control	21.0

Table XXXVIII. Average of Hardness Tests on Ice Cream Containing Two and Three Ounces of Agar Agar (Lots III and IV).

Samples	Lot III Degree of Penetration	Samples	Lot IV Degree of Penetration
2 oz. Agar	13.8	3 oz. Agar	13.2
0.4% Gelatin	15.5	0.4% Gelatin	15.5
Control	18.0	Control	20.0

Melting Down Tests on Ice Cream Containing Agar Agar:

Samples of ice cream containing four ounces or less of agar melted down much faster than samples stabilized with gelatin. In fact, the ice cream containing two ounces or less of agar began melting more rapidly than the unstabilized samples, and the batches containing three ounces melted almost as rapidly. The average of these results are given in Table XXXIX.

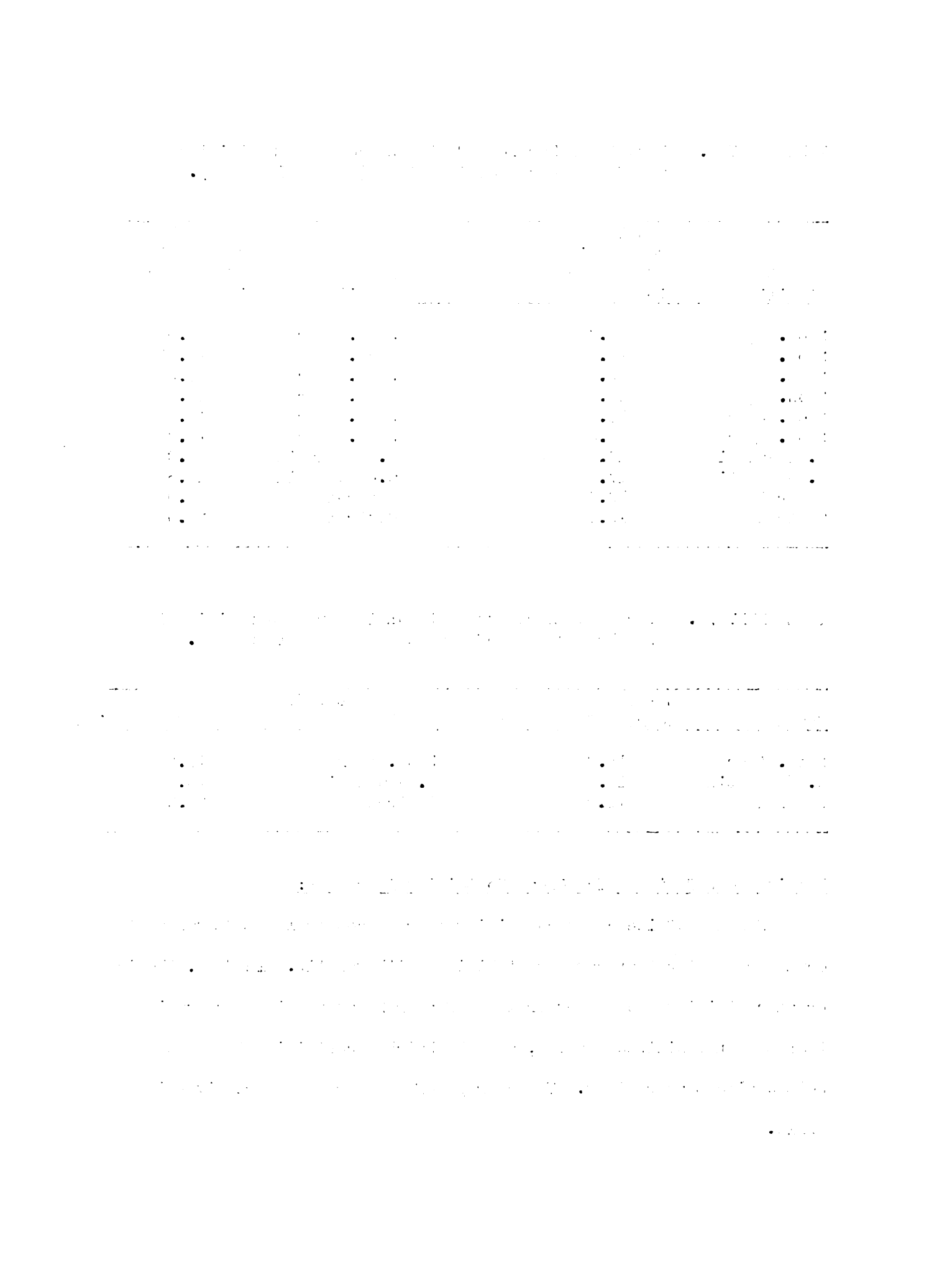


Table XXXIX. Average Results of Melting Down Tests on Ice Cream Containing Varying Amounts of Agar Agar (Lots I and II, Part III). (Tabulated as Percentage Melted)

Amount Stabilizer	Time Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
1 oz. Agar	15.1	33.1	48.2	61.8	70.3	76.7	79.8	81.4	81.4
2 oz. Agar	13.9	33.7	52.3	63.5	77.4	82.1	84.9	85.4	85.4
3 oz. Agar	9.7	27.0	45.1	60.1	70.1	76.0	79.5	81.2	81.2
4 oz. Agar	6.1	24.9	45.3	59.6	72.9	76.6	83.1	83.7	83.7
5 oz. Agar	0.0	7.2	23.6	38.8	49.1	60.6	68.0	72.2	72.8
6 oz. Agar	0.0	6.2	20.3	38.1	47.4	58.3	62.6	71.3	73.0
0.4% Gelatin	1.4	8.9	20.0	41.3	54.0	67.4	78.4	82.8	83.3
Control	11.6	21.1	32.6	43.2	53.6	64.1	70.2	75.1	76.8

At the end of one and one-half hours, the check samples showed superiority in resistance to melting to samples containing four ounces or less of agar.

The batches containing five and six ounces of agar were more stable than the gelatin samples, but these samples stood up abnormally for almost two hours, and resembled a smooth curd which had been set with rennet. However, once they began to melt they disappeared very rapidly. The gelatin samples melted at about the same rate as the lots containing five and six ounces of agar for the entire melting period.

Figure IV shows a series containing agar agar after exposure to room temperatures for two hours.

Agar samples melted down cleanly, but the melted portion was usually coarse and foamy in appearance.

Summary of Results of Agar Agar Study:

The viscosity of the mix was greatly increased by small amounts of agar agar. Again, as in the previous parts of this study, the surface tension varied directly with the viscosity. Agar Agar in two ounce amounts made a very smooth ice cream, and one which scored as high as the gelatin samples. Three ounces of the agar gave a smooth ice cream but one which was characterized in several trials as being crumbly. The agar-stabilized samples melted more rapidly than samples containing gelatin when exposed to room temperatures.

PART IV.

A Study of Vegetable Stabilizers Having Trade Names

Four stabilizers are included in this part of the study. Lot I contained Colace, Lot II Kelco Gel, Lot III Krabyn, and Lot IV was made up with Lakoe A.

Each lot consisted of a series of eight batches of mix, the first five stabilized with recommended amounts of the above mentioned vegetable products, two stabilized with gelatin, and the eighth batch served as the control.

Kelco Gel was the only stabilizer of the group which affected the appearance of the mix. Due to its brown color, it imparted a tint of brown to the mix which was not noticeable, however, in the finished ice cream.

Viscosity and Surface Tension:

Viscosities and surface tensions of each of these lots are given in Tables XL - XLIII. The average results are tabulated in Table XLIV. Lakoe A shows great ability to increase the viscosity of the mix, and normal amounts of it gave a viscosity from three to four times greater than that obtained with the use of the other stabilizers, including gelatin.

Colace samples had about the same apparent viscosity readings as the gelatin-stabilized mixes. However, the basic viscosity of the gelatin samples were considerably lower, since Colace did not show any tendency to form a gel structure. In fact none of the vegetable stabilizers showed the tendency to form structural viscosity to any great degree.

Table XL. Viscosities and Surface Tensions of Mixes Containing Colace (Lot I, Part IV).

Amount Stabilizer	Viscosity in Centipoises		Surface Tension in Dynes
	Apparent	Basic	
0.4% Colace	129.3	129.3	47.3
0.4% Colace	126.4	120.6	47.2
0.4% Colace	120.6	116.2	47.1
0.4% Colace	113.3	116.2	47.0
0.4% Colace	119.1	119.1	47.3
0.4% Gelatin	138.0	88.6	47.3
0.4% Gelatin	129.3	81.4	47.2
Control	23.2	23.2	46.4

Table XLI. Viscosities and Surface Tensions of Mixes Containing Kelco Gel (Lot II, Part IV).

Amount Stabilizer	Viscosity in Centipoises		Surface Tension in Dynes
	Apparent	Basic	
0.3% Kelco Gel	94.4	90.1	47.1
0.3% Kelco Gel	88.6	81.4	47.1
0.3% Kelco Gel	94.4	90.1	47.1
0.3% Kelco Gel	88.6	84.3	47.0
0.3% Kelco Gel	94.4	87.2	47.1
0.4% Gelatin	107.5	72.7	47.5
0.4% Gelatin	120.6	95.9	47.5
Control	31.9	30.5	46.8

Table XLII. Viscosities and Surface Tensions of Mixes Containing Krabyn (Lot III, Part IV).

Amount Stabilizer	Viscosity in Centipoises		Surface Tension in Dynes
	Apparent	Basic	
0.5% Krabyn	62.5	58.1	46.4
0.5% Krabyn	72.7	65.4	46.7
0.5% Krabyn	66.8	59.6	46.4
0.5% Krabyn	65.4	59.6	46.7
0.5% Krabyn	69.7	58.1	46.7
0.4% Gelatin	71.2	58.1	47.0
0.4% Gelatin	69.7	55.2	46.7
Control	21.8	18.9	45.9

Table XLIII. Viscosities and Surface Tensions of Mixes Containing Lakoe A (Lot IV, Part IV).

Amount Stabilizer	Viscosity in Centipoises		Surface Tension in Dynes
	Apparent	Basic	
0.5% Lakoe A	427.2	390.9	48.6
0.5% Lakoe A	451.2	409.7	48.6
0.5% Lakoe A	420.4	403.9	48.7
0.5% Lakoe A	427.0	395.2	48.5
0.5% Lakoe A	344.4	316.6	48.5
0.4% Gelatin	155.5	114.8	47.8
0.4% Gelatin	82.8	69.7	47.2
Control	24.7	24.7	45.2

Table XLIV. Average Viscosity and Surface Tension of Mixes Containing Different Vegetable Stabilizers.

Amount Stabilizer	Viscosity in Centipoises Apparent	Basic	Surface Tension in Dynes
0.4% Colace	121.7	120.3	47.2
0.3% Kelco Gel	92.1	86.6	47.1
0.3% Krabyn	67.4	60.1	46.6
0.3% Lakoe A	412.5	383.3	48.6
0.4% Gelatin	109.4	82.8	47.3
Control	25.4	24.3	46.1

Surface tension results did not show any striking changes nor abnormalities in any of the lots. They do show, however, that the surface tension tends to increase with an increase in viscosity. The average figures show the mix having the highest viscosity (Lakoe A mixes) to have also the greatest surface tension.

Separation of Whey from Mixes Containing Vegetable Stabilizers:

Other investigators have observed that several of the commercially used vegetable stabilizers caused a separation of whey from the mix if the mix was stored for two days at 40° F.

In the preliminary trials of this study, it was observed that only Colace samples showed wheying off when stored for 72 hours at 36° F. However, when several of the mixes made with other stabilizers were allowed to set at room temperature for about two days, considerable separation of whey occurred in some.

Further trials were made to determine the effect of different storage temperatures on the separation of whey. Mixes containing these various stabilizers were stored at 34-36° F. and at 42-45° F. for several days. The results are shown in Table XLV. The samples were stored in 100 cc. gradu-

ated cylinders, so that the results could be tabulated in cubic centimeters.

Table XLV. Wheying Off of Mixes Containing Vegetable Stabilizers when Stored at Different Temperatures. (Tabulated as cc. of whey)

Stabilizer Used	Storage Periods and Temperatures					
	48 hrs.		72 hrs.		96 hrs.	
	35°F.	43°F.	35°F.	45°F.	35°F.	43°F.
0.4% Colace	0	1	½	5	5	10
0.5% Kelco Gel	0	0	0	0	0	0
0.5% Krabyn	0	0	0	0	0	0
0.5% Lakoe A	0	0	0	0	0	2
0.4% Gelatin	0	0	0	0	0	0
Control	0	0	0	0	0	0

The results indicate that the samples containing Colace begin to whey off at the end of 48 hours when the storage temperature was 45° F. This was considerably more pronounced when held for 72 hours. The Lakoe A mix showed slight separation of the whey at 96 hours when held at the higher temperature.

The lower storage temperatures limit the rapidity with which the whey separates. This is shown in the results of the Colace mix. The lower temperature not only reduced the rapidity of whey formation, but reduced the extent of the total amount of separation.

When a sample, in which the whey separation occurs, is examined, the curd appears pithy as in a badly gassy condition. No doubt, the stabilizers causing this trouble affect the casein.

Although Kelco Gel mixes did not show wheying off, they showed a brown discoloration in the bottom of the cylinder. The mix appeared to be curdled in the region of the discoloration.

The discoloration of Kelco Gel samples and also the wheying off of mixes containing the other vegetable stabilizers are shown in Figure V. The samples in this photograph were stored for one week at the higher storing temperature, and it is interesting to note the extent to which the Colace mix has shown the separation of whey.

Freezing and Whipping of Mixes Containing Vegetable Stabilizers:

No uniform difference in freezing time was noticed for any one of the four stabilizers studied. Results for each lot are given in Table XLVII, with the average appearing in Table XLVI.

Table XLVI. Average Freezing Times of Mixes Containing Different Vegetable Stabilizers. (Recorded in minutes and seconds)

	Time of Freezing	Corresponding Time of Freezing	
Vegetable Stabilizers		Gelatin Mixes	Control Mixes
Colace	2:32	2:45	2:45
Kelco Gel	2:48	2:27	3:33
Krabyn	2:09	2:37	3:20
Lakoe A	2:34	3:09	3:46

The average results indicate that all mixes when compared to gelatin samples, freeze in about the same length of time. It is true, the control samples in most cases required somewhat longer to freeze to the proper hardness. However, so few of the control mixes were studied that evidence concerning the slight difference in freezing time should not be considered conclusive.

Table XLVII. Freezing Times of Ice Cream Mixes Containing Various Commercial Vegetable Stabilizers (Lots I-IV). (Recorded in Minutes and Seconds)

Batch No.	Freezing Time			
	Lot I	Lot II	Lot III	Lot IV
1	2:52	2:54	1:45	2:10
2	2:57	2:52	2:05	2:54
3	2:40	2:42	2:12	2:12
4	2:20	2:44	2:10	2:27
5	2:09	2:48	2:10	2:29
6	2:32	2:22	2:38	2:54
7	2:58	2:32	2:35	3:20
8	2:45	3:33	3:20	3:46

Batch No.	Lot I	Lot II	Lot III	Lot IV
1-5	Colace	Kelco Gel	Krabyn	Lakoe A
6-7	Gelatin	Gelatin	Gelatin	Gelatin
8	Control	Control	Control	Control

Table XLVIII gives the average overrun results obtained from these trials. Specific data for each stabilizer are given in Tables LXXV - LXXVIII. The average figures show Lakoe A stabilizer to be the only vegetable stabilizer to have a deleterious effect on whipping. At that, however, batches containing this stabilizer whipped to 100 per cent overrun in practically the same time as did the gelatin samples. The mixes containing Colace, Krabyn, and Kelco Gel whipped in about the same length of time, all of them reaching 100 per cent swell approximately one minute sooner than the Gelatin or Lakoe A mixes.

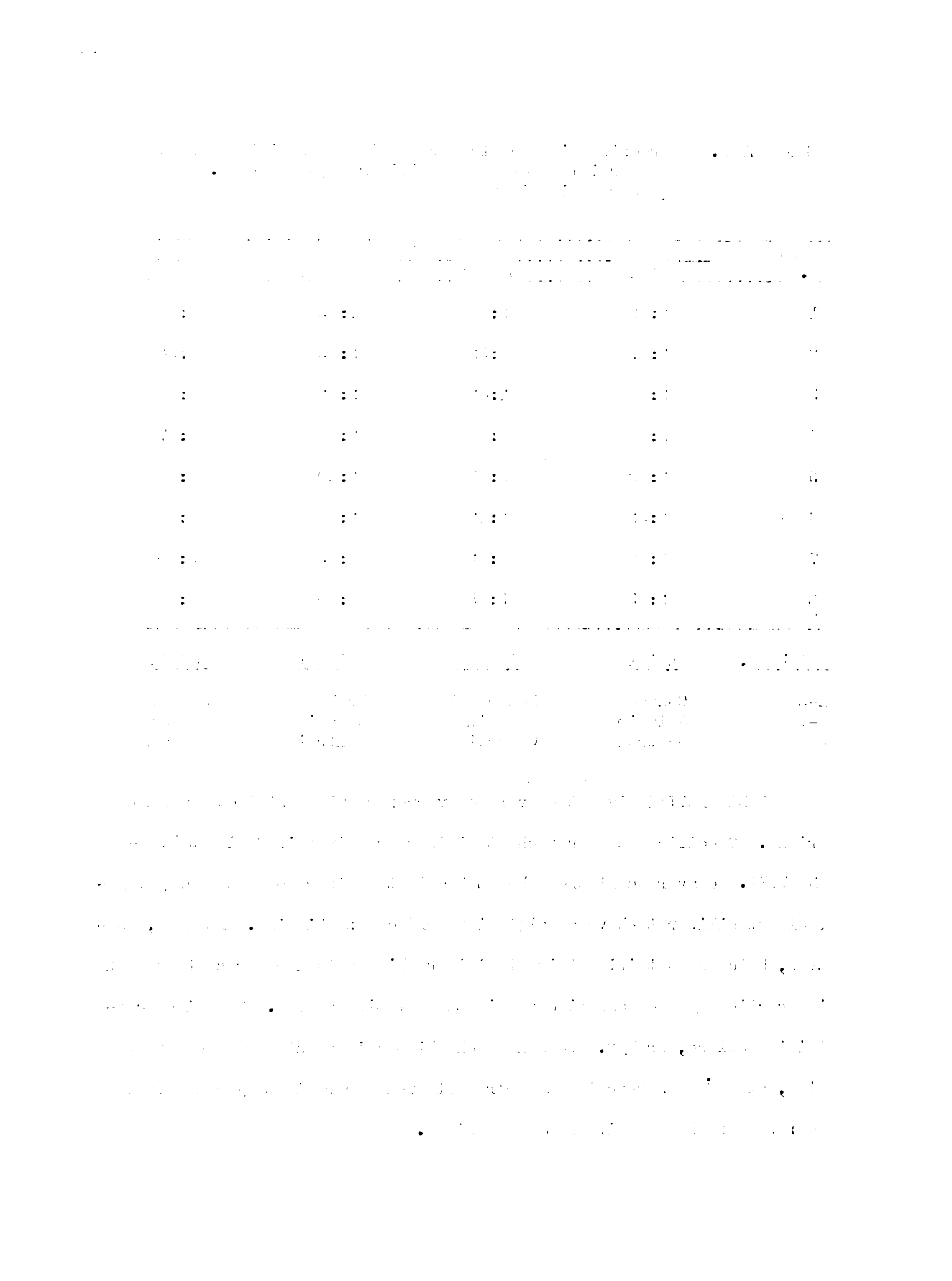


Table XLVIII. The Average Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Different Vegetable Stabilizers (Lots I-IV).

Minutes	Colace Lot I	Kelco Gel Lot II	Krabyn Lot III	Lakoe A Lot IV	Gelatin All Lots	Control All Lots
0	60	67	80	54	62	71
1	66	70	77	55	66	74
2	77	80	85	66	76	85
3	90	93	94	77	86	100
4	106	107	103	89	98	110
5	114	117	110	103	106	121
6	122	126	115	113	113	131
7	130	136	121	120	121	135
8	136	143	126	125	125	137
9	136	145	129	129	130	140
10	136	149	132	133	133	141
11	135	147	134	134	133	138
12	135	145	134	134	133	135
13	134	146	135	134	132	134
14	133	145	134	135	130	134
15	133	145	133	132	130	132
16	131	145	132	131	128	130

The control lots, on the average, assumed the normal amount of swell in from one to two minutes less time than any of the stabilized mixes. Charts IV and V show the rapidity with which the different batches incorporated air.

Chart IV. Showing the Per Cent Overrun of Ice Cream Mixes Containing Colace and Kelco Gel.

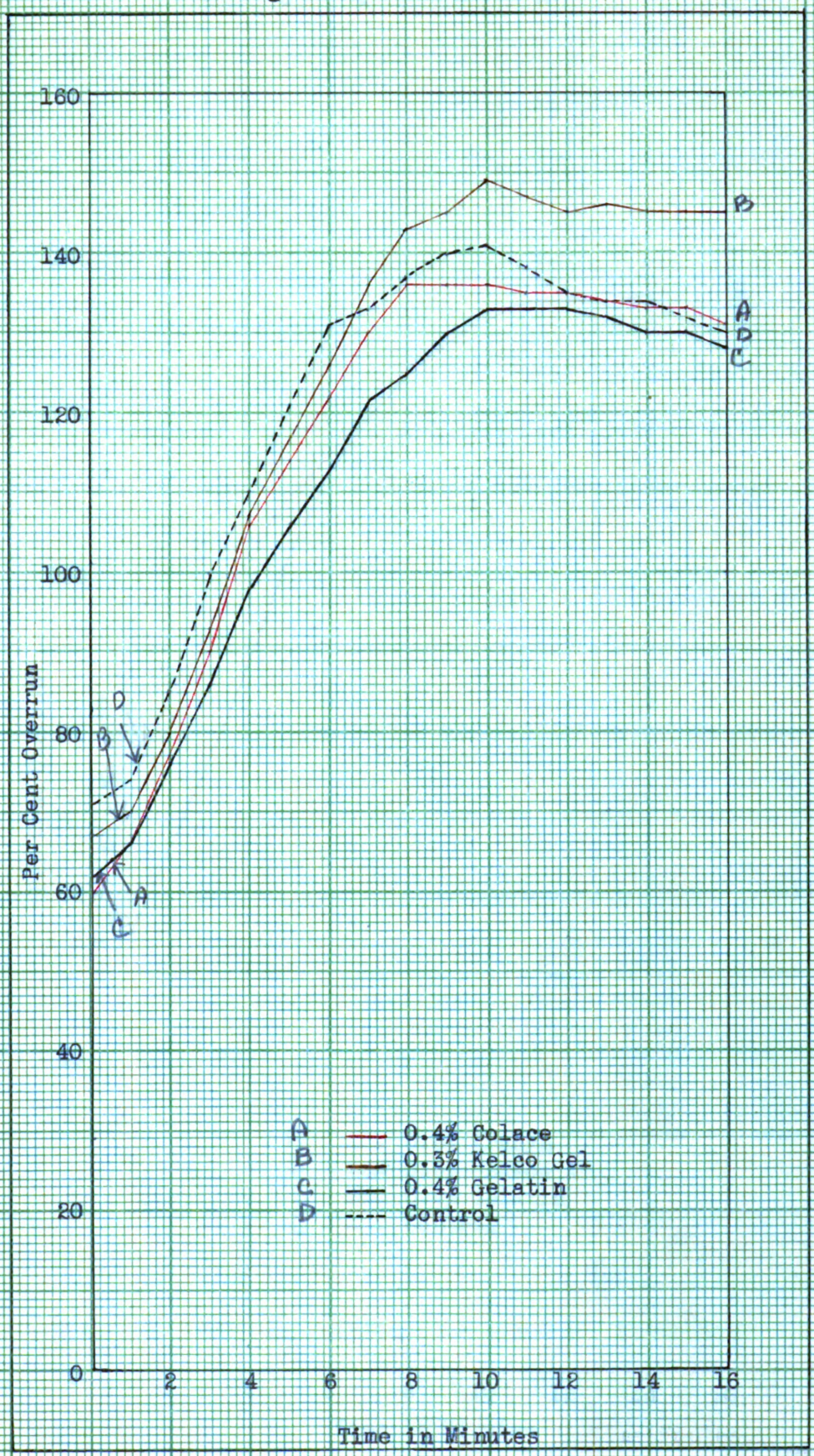
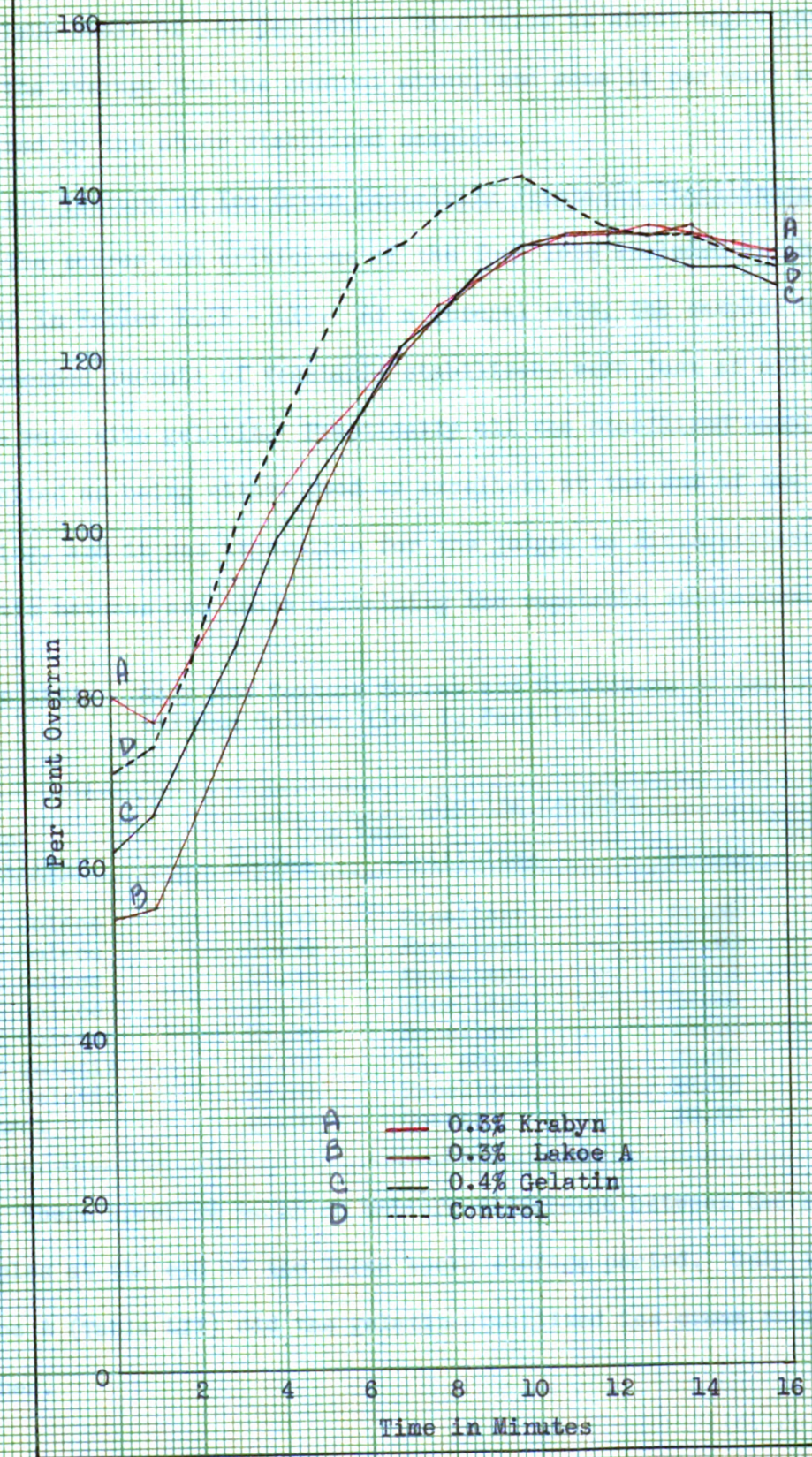


Chart V. Showing the Per Cent Overrun of Ice Cream Mixes Containing Krabyn and Lakoe A.



The Kelco Gel batches possessed more ability to hold air, reaching a maximum swell of 149 per cent. This value is about eight per cent more than the average for the control mixes, and some 15 per cent more than that obtained by the other stabilized samples.

Body and Texture of Ice Cream Containing Vegetable Stabilizers:

The scores and criticisms of the four lots included in the study are listed in Tables XLIX - LII. As a general rule, the samples containing the recommended amounts of vegetable stabilizers were just as satisfactory as those made with gelatin. Practically all the stabilized samples were characterized as being either good or excellent at the end of the first week of storing, and it was impossible for the judges to differentiate between the gelatin batches and those containing the vegetable substances.

Table XLIX. Body and Texture Scores and Criticisms of Ice Cream Containing Colace (Lot I, Part IV).

Amount Stabilizer	Storing Periods: One Week Scores	One Week Criticisms	Three Weeks Scores	Three Weeks Criticisms
0.4% Colace	23.00	Excellent	22.00	Sl. coarse
0.4% Colace	23.00	Excellent	22.50	Good
0.4% Colace	23.00	Excellent	22.25	Good
0.4% Colace	23.00	Excellent	22.25	Good
0.4% Colace	23.00	Excellent	22.50	Good
0.4% Gelatin	22.00	Sl. coarse	22.50	Sl. coarse
0.4% Gelatin	23.00	Excellent	22.75	Excellent
Control	21.00	Coarse	20.50	Very coarse

There appeared to be no uniform difference between the stabilized samples at the end of the three weeks storage period. Only in the case of Lakoe A (Table LII) did the gelatin-stabilized ice cream score uniformly higher.

Table L. Body and Texture Scores and Criticisms of Ice Cream Containing Kelco Gel (Lot II, Part IV).

Amount Stabilizer	Storing Periods: One Week Scores	One Week Criticisms	Three Weeks Scores	Three Weeks Criticisms
0.3% Kelco Gel	22.50	Good	22.00	Sl. coarse
0.3% Kelco Gel	22.00	Sl. coarse	22.25	Good
0.3% Kelco Gel	22.50	Good	22.75	Excellent
0.3% Kelco Gel	22.50	Good	22.50	Good
0.3% Kelco Gel	22.50	Good	23.00	Excellent
0.4% Gelatin	22.50	Good	22.75	Excellent
0.4% Gelatin	22.50	Good	23.00	Excellent
Control	21.50	Coarse	21.50	Coarse

Table LI. Body and Texture Scores and Criticisms of Ice Cream Containing Krabyn (Lot III, Part IV).

Amount Stabilizer	Storing Periods: One Week Scores	One Week Criticisms	Three Weeks Scores	Three Weeks Criticisms
0.3% Krabyn	22.00	Sl. coarse	21.50	Coarse
0.3% Krabyn	22.50	Good	22.00	Sl. coarse
0.3% Krabyn	22.75	Good	22.00	Sl. coarse
0.3% Krabyn	22.50	Good	22.50	Good
0.3% Krabyn	22.50	Good	22.50	Good
0.4% Gelatin	22.75	Good	22.00	Sl. coarse
0.4% Gelatin	22.75	Good	22.00	Sl. coarse
Control	21.50	Coarse	20.50	Very coarse

Table LII. Body and Texture Scores and Criticisms of Ice Cream Containing Lakoe A (Lot IV, Part IV).

Amount Stabilizer	Storing Periods: One Week Scores	One Week Criticisms	Three Weeks Scores	Three Weeks Criticisms
0.5% Lakoe A	22.50	Smooth	22.00	Sl. coarse
0.5% Lakoe A	23.00	Excellent	22.00	Sl. coarse
0.5% Lakoe A	23.00	Excellent	22.25	Sl. coarse
0.5% Lakoe A	23.00	Excellent	22.00	Sl. coarse
0.5% Lakoe A	23.00	Excellent	22.00	Sl. coarse
0.4% Gelatin	23.00	Excellent	22.50	Spongy, smooth
0.4% Gelatin	22.50	Good	22.50	Spongy, smooth
Control	21.00	Very coarse	21.50	Very coarse

In all the trials, the controls were coarse and icy, and scored less than did any of the stabilized samples.

Effect of Vegetable Stabilizers on the Hardness of Ice Cream:

Again in these trials, as in the previous ones, the results obtained by the use of the Hardness Tester were of such variations as to appear worthless. In samples of ice cream containing the same stabilizer present in equal amounts, the Tester gave widely different results. The results for each of the trials are given in Table LIII, and the average figures are tabulated in Table LIV.

Table LIII. Results of Hardness Tests on Ice Cream Containing Different Vegetable Stabilizers (Tabulated as Degrees Penetration of the Plunger).

Lot No.	Batch No. 1	2	3	4	5	6	7	8
1	-	25.8	22.6	26.0	21.2	19.2	16.8	24.0
2	12.6	12.9	11.2	9.5	12.0	12.5	11.2	15.2
3	11.7	12.7	12.5	14.7	14.8	8.9	10.0	11.5
4	8.4	7.5	8.5	9.1	7.7	7.5	7.5	8.3

Table LIV. Average Results of Hardness Tests on Ice Cream Containing Different Vegetable Stabilizers. (Tabulated as Degrees Penetration of the Plunger)

Amount Stabilizer	Penetration	Penetration (Gelatin)	Penetration (Control)
0.4% Colace	23.9	18.0	24.0
0.3% Kelco Gel	11.6	11.9	13.2
0.3% Krabyn	13.2	9.5	11.5
0.3% Lakoe A	8.2	7.5	8.3

If the average results are any indication, the gelatin stabilized samples were practically of equal hardness as those containing Lakoe A and Kelco Gel, and somewhat more firm than the ice cream stabilized with Colace and Krabyn. However, the wide variations which occur among members of the same series (Table LIII) indicate that the results obtained by the use of this type of Hardness Tester are not reliable.

Melting Down Tests on Ice Cream Containing Vegetable Stabilizers:

Lakoe A was the only one of the four vegetable stabilizers to compare with gelatin in making the ice cream resistant to melting. This is shown in Table LVIII and in the average results in Table LIX. In Table LVIII, the Lakoe A stabilized ice cream appeared to melt but slightly faster than the gelatin samples, while in the average results it appears somewhat more stable. This difference is due to the fact that the gelatin results for all trials were averaged, while the Lakoe A results of one series only were averaged. This makes the gelatin stabilized samples appear sometimes high and sometimes low in the average results when they are compared to the individual lot measurements.

Although the average melting down results show the trend in all cases, the individual trials are superior in giving accurately the difference between the melting times of the gelatin and the gelatin substitute samples.

Colace is somewhat inferior to Lakoe A in making the ice cream stable, but is superior to the other two vegetable stabilizers in this respect. These results are shown in Tables LIX, but more clearly in Table LV.

Tables LVII and LVI show the results of the melting down of lots containing Krabyn and Kelco Gel respectively. The samples containing these two stabilizers melted even more rapidly than the unstabilized batches and they melted from three to four times more rapidly than the gelatin samples for the first hour. From the standpoint of stability of ice cream, the samples containing Kelco Gel were the least stable of any studied. The appearance of these vegetable stabilized samples after two hours exposure is shown in Figure VI.

The control samples melted considerably more rapidly at first than did the batches containing Lakoe A and Colace. However, samples containing Colace left a mass of residue on the screen which did not melt down even though the samples were left at room temperatures over night. All of the other samples melted down normally. As usual, the controls left a layer of foam on the screen, a feature also shown by the Krabyn samples.

The melted portion of Kelco Gel appeared to be the coarsest and most foamy of any in this group, although drippings of Krabyn were somewhat coarse in appearance.

Table LV. Results of Melting Down Tests on Ice Cream Containing Colace (Lot I, Part IV). (Tabulated as percentage melted).

Stabilizer Used	Time Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
0.4% Colace	-	-	-	-	-	-	-	-	-
0.4% Colace	12.0	22.6	32.0	52.0	61.3	68.0	73.3	74.8	76.0
0.4% Colace	8.5	20.0	27.1	42.8	50.0	57.1	64.2	65.7	65.7
0.4% Colace	2.7	10.9	23.2	39.7	45.2	50.6	57.5	61.6	64.3
0.4% Colace	8.2	19.1	27.3	47.9	57.5	72.6	78.0	79.4	80.8
0.4% Gelatin	0.0	7.8	15.6	40.6	54.6	68.7	81.2	82.8	82.8
0.4% Gelatin	1.4	8.4	19.7	42.2	54.9	66.1	77.4	80.2	81.6
Control	14.4	23.1	31.8	49.2	59.4	69.5	79.7	84.0	84.0

Table LVI. Results of Melting Down Tests on Ice Cream Containing Kelco Gel (Lot II, Part IV). (Tabulated as percentage melted).

Stabilizer Used	Time Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
0.3% Kelco Gel	28.5	41.5	57.1	70.1	84.4	90.9	90.9	90.9	90.9
0.3% Kelco Gel	26.9	41.0	55.1	74.3	85.8	91.0	91.0	91.0	91.0
0.3% Kelco Gel	22.8	35.7	51.4	77.1	80.0	87.1	87.1	87.1	87.1
0.3% Kelco Gel	17.6	29.4	45.6	66.1	76.4	83.8	83.8	83.8	83.8
0.3% Kelco Gel	18.9	31.0	48.6	70.2	83.7	85.1	85.1	85.1	85.1
0.4% Gelatin	9.1	21.2	37.8	57.5	68.1	78.7	80.4	86.3	86.3
0.4% Gelatin	8.5	18.5	37.1	51.4	64.2	72.8	84.3	85.7	85.7
Control	12.8	20.0	28.5	42.8	51.4	60.0	72.8	77.1	78.5

Table LVII. Results of Melting Down Tests on Ice Cream Containing Krabyn (Lot III, Part IV). (Tabulated as percentage melted).

Stabilizer Used	Time Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
0.3% Krabyn	16.6	33.3	51.3	66.6	79.1	86.1	86.1	86.1	86.1
0.3% Krabyn	16.4	31.5	49.3	64.3	78.0	83.5	84.9	84.9	84.9
0.3% Krabyn	16.9	32.3	52.1	67.6	80.2	85.9	87.3	87.3	87.3
0.3% Krabyn	24.2	37.8	56.0	69.6	77.2	84.8	84.8	84.8	84.8
0.3% Krabyn	20.0	34.2	54.2	68.3	81.4	85.7	87.1	87.1	87.1
0.4% Gelatin	5.7	14.2	34.2	51.4	65.7	77.1	85.7	87.1	87.1
0.4% Gelatin	14.7	27.9	47.0	61.7	76.4	85.2	88.2	89.7	89.7
Control	14.0	21.8	34.3	45.3	56.2	64.0	71.8	81.2	81.2

Table LVIII. Results of Melting Down Tests on Ice Cream Containing Lakoe A (Lot IV, Part IV). (Tabulated as percentage melted).

Stabilizer Used	Time Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
0.3% Lakoe A	4.1	20.8	26.3	47.2	62.5	68.0	75.0	77.7	77.7
0.3% Lakoe A	0.0	5.7	8.6	26.0	33.3	43.4	49.2	57.9	63.7
0.3% Lakoe A	1.4	11.5	21.7	30.4	47.8	53.6	62.3	66.6	69.5
0.3% Lakoe A	0.0	14.9	23.8	29.8	55.2	61.6	70.1	73.1	74.6
0.3% Lakoe A	2.7	19.1	24.6	36.9	39.7	60.2	69.8	73.9	75.3
0.4% Gelatin	0.0	4.2	11.2	28.1	40.8	52.1	64.7	71.8	77.4
0.4% Gelatin	0.0	16.4	21.9	36.9	54.7	71.2	73.9	79.4	79.4
Control	9.6	22.5	27.4	37.0	48.3	56.4	67.7	74.1	77.4

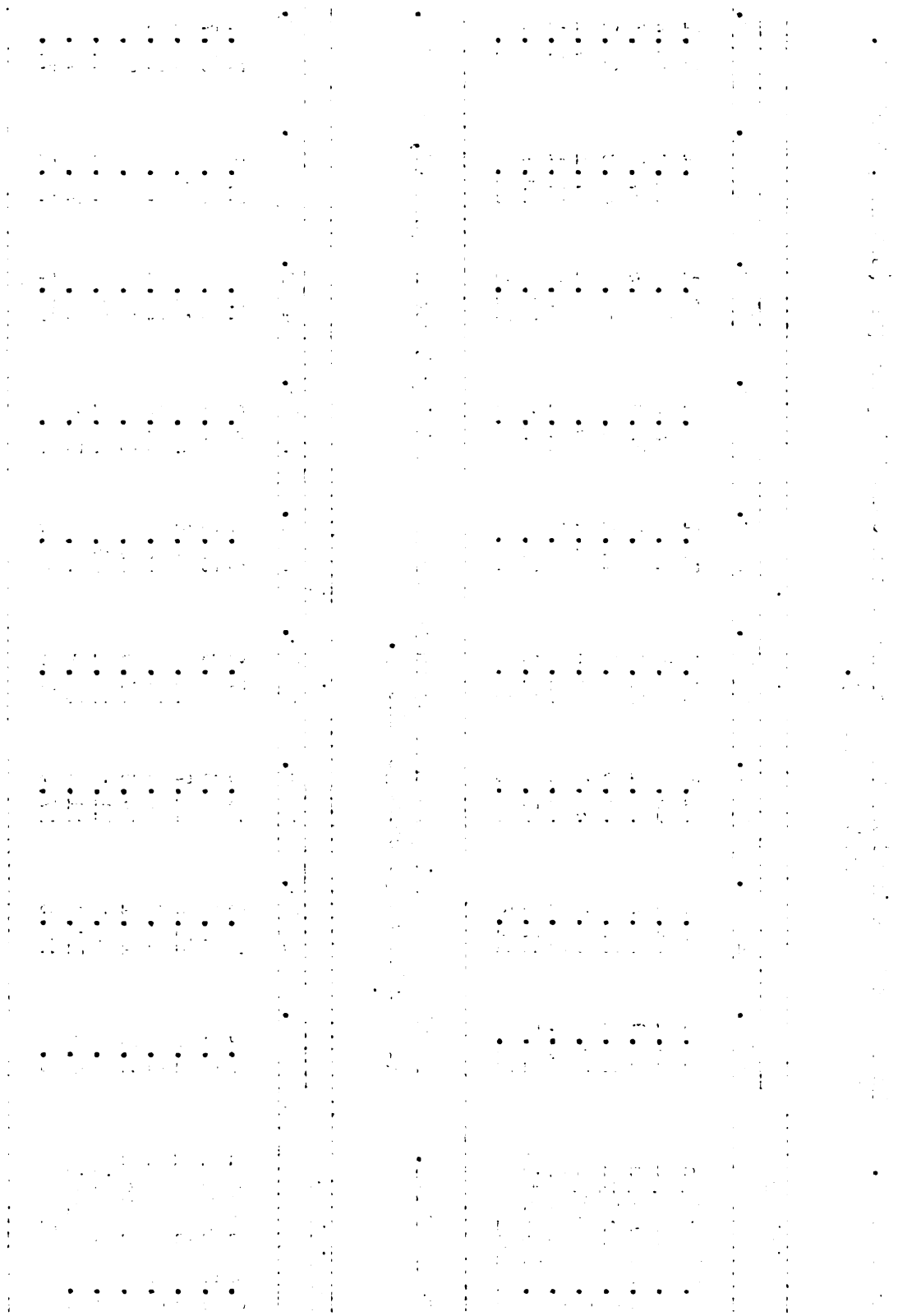


Table LIX. Average Melting Down Results of Ice Cream Containing Different Vegetable Stabilizers.

Amount Stabilizer	Time Periods								
	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
0.4% Colace	7.8	18.1	27.4	45.6	53.5	62.0	68.2	70.3	71.7
0.3% Kelco Gel	22.9	35.7	51.5	71.5	82.0	87.5	87.5	87.5	87.5
0.3% Krabyn	18.8	33.8	52.5	67.3	79.1	85.2	86.0	86.0	86.0
0.3% Lakoe A	1.6	14.4	21.0	34.0	47.7	57.0	67.2	69.8	72.1
0.4% Gelatin	4.8	19.6	28.0	46.2	59.9	71.4	79.4	82.8	83.7
Control	12.7	21.8	30.5	43.5	53.8	62.4	73.0	79.1	80.2

Summary of Study of Commercial Vegetable Stabilizers:

Lakoe A was the only one of the group to greatly increase the viscosity and surface tension. However, the whipping of mixes containing this stabilizer was slower than the whipping of the other stabilized samples with the exception of gelatin. All stabilized samples of ice cream, regardless of the stabilizer, appeared to be of equal quality. Measurements of the hardness of the ice cream by the Hardness Tester used in this study appear to be of little value. Mixes made with Colace showed wheying off in about 48 hours at 45° F. The same peculiarity was shown in Lakoe A samples stored at the same temperature for 96 hours. Colder storage temperatures retarded the separation of whey.

Ice cream containing Krabyn and Kelco Gel melted down faster than any of the other stabilized samples and also more rapidly than the controls. Lakoe A was the only vegetable stabilizer which, in the melting test, compared favorably with gelatin.

COMPARISON OF COSTS OF ICE CREAM STABILIZERS USED IN STUDY AND A DISCUSSION OF THEIR FOOD VALUE

Costs of Stabilizers:

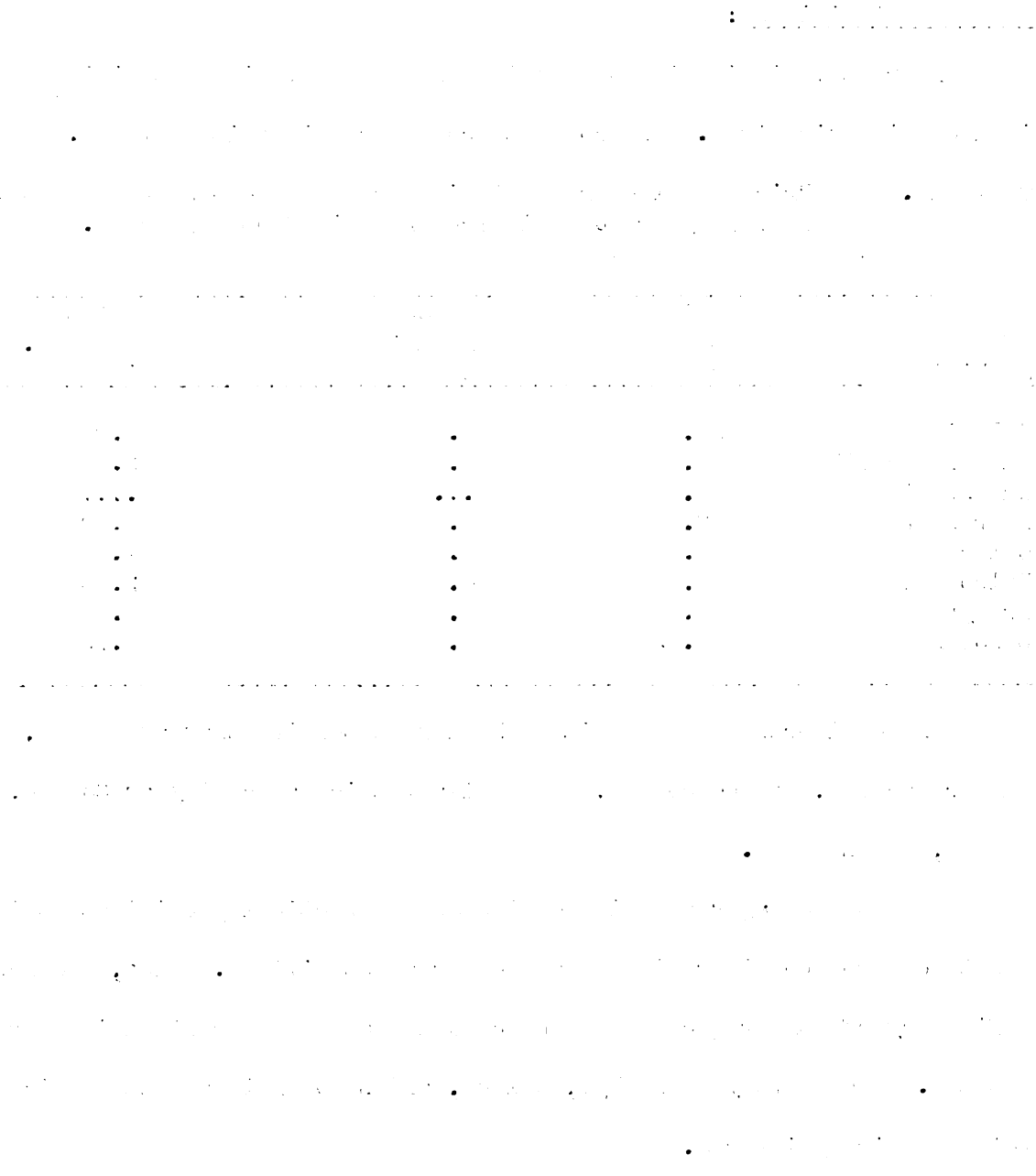
A great variation in costs exists among the various stabilizers included in this study. The complete costs are given in Table LX.

Table LX. Prices of Ice Cream Stabilizers and the Comparative Costs When They Are Used in Ice Cream in Proper Amounts.

Name of Stabilizer	Price per Pound	Recommended Amount to Use	Cost per 1000 lbs. Mix
Gelatin	$0.52	0.4%	$2.08
Gum Tragacanth	0.95	0.3%	2.85
Gum Arabic	0.40	...	....
Agar Agar	2.30	0.2%	4.60
Colace	0.25	0.4%	1.00
Kelco Gel	0.95	0.3%	2.85
Krabyn	0.29	0.3%	0.87
Lakoe A	0.25	0.3%	0.75

These figures show gelatin to be less expensive than agar agar, gum tragacanth, and Kelco Gel, but at least twice as costly as Colace, Krabyn, and Lakoe A.

The cost of agar agar is so high as to practically eliminate this substance from consideration as an ice cream stabilizer. Also, the normal efficiency of gum tragacanth and Kelco Gel does not warrant their extra expense. The economy of Krabyn, Colace, and Lakoe A is a factor which cannot be entirely ignored.



Food Value of Stabilizers:

Gelatin has long been given high consideration from a nutritive standpoint. It contains a majority of the necessary amino acids, and while there is some doubt as to its ability to furnish all the protein of a diet with good results, most authorities agree that it can be used successfully to furnish a large part of the protein required.

Gelatin, also, is credited, when present, with aiding in the assimilation of milk and milk products by its emulsifying and protective action which prevents the coagulation of casein.

The gums and other similar stabilizers are not entirely lacking in food value. They, like gelatin, are listed by some authorities as being protective against the coagulation of casein. Also, gums and gum stabilizers, contain carbohydrate materials which can be used to some extent by the body.

Agar agar has no food value as it is not assimilated by the body but passes through the digestive system unused. Agar is used in some cases to add bulk to the diet. It is doubtful if Kelco Gel, being an ash product of algae, has any food value.

SUMMARY

Gum Tragacanth

1) Gum tragacanth possessed great ability to increase the viscosity of the ice cream mix. Three ounces gave a viscosity somewhat greater than the gelatin stabilized mixes.

2) Surface tension of the mixes containing gum tragacanth appeared to increase with an increase in viscosity although the results were not consistent. A mix containing three ounces of gum had a greater average surface tension than did the mix containing gelatin.

3) Three ounces of the gum made an ice cream as smooth as that containing gelatin, even after storing the ice cream for three weeks.

4) Not until at least five ounces of gum tragacanth were used did it impart an objectionable flavor to the ice cream.

5) Hardness tests on the ice cream were not consistent but indicated that only normally large amounts of the gum affected the hardness to any noticeable degree. There appeared to be a general tendency for the ice cream to become harder with each increase in gum.

6) Mixes containing three ounces or less of gum tragacanth whipped slightly more rapidly than the gelatin samples, and those with four and five ounces whipped just as rapidly.

7) When six ounces or more of the gum were used the whipping ability of the mix was greatly retarded, and samples containing seven ounces failed to reach 100 per cent swell in 16 minutes of whipping.

8) The failure of mixes to whip when containing more than five ounces of the gum is probably due to the enormously high viscosity and correspond-

ingly high surface tension, created by these amounts of the stabilizer.

9) Control samples usually whipped more rapidly than those containing stabilizers.

10) Samples containing normal amounts of the gum melted down more rapidly than the gelatin samples but somewhat more slowly than the control samples for the first hour. After the first hour of melting, the control sample appeared superior to the gum samples in this respect.

Gum Arabic:

1) The viscosities and surface tensions of mixes were but little increased by the addition of gum arabic, even though the gum was used in amounts as high as eight to ten ounces (0.8% to 1.0%).

2) Gum arabic mixes whipped to 100 per cent overrun in from 20 to 40 per cent less time than the gelatin samples, and in about the same time as the controls. An increase in the amount of gum did not affect the overrun. Gum samples usually whipped to a greater maximum swell than the gelatin lots.

3) The time of freezing was not affected by gum arabic.

4) The Hardness Tester gave such wide variations of readings on the gum samples that the results appear valueless. However, in general, the gum did not appear to influence the hardness of the ice cream.

5) The gum arabic did not consistently make an ice cream comparable with gelatin, even though used in one per cent amounts. It is unreliable as an ice cream stabilizer.

6) The samples containing the gum melted much more rapidly than those containing gelatin, and practically as fast as the controls.

7) An increase in gum arabic did not retard the rate of melting.

8) The gum samples left a layer of foam on the screen after melting, and the melted portion appeared coarse and foamy in comparison to the gelatin stabilized samples.

Agar Agar:

1) Agar agar greatly increased the apparent and basic viscosities of ice cream mixes when present in more than two ounce amounts. The surface tensions were increased accordingly and were higher than those of the gelatin mixes.

2) Agar mixes, in general, froze in about the same length of time as the gelatin and control mixes.

3) The mixes containing agar in less than four ounce amounts whipped more rapidly than the gelatin samples, and slightly slower than the controls.

4) When five and six ounces of the agar was used, the ability of the mix to whip was greatly hindered.

5) Agar samples containing three ounces of the stabilizer appeared to be somewhat harder than the gelatin samples. However, many variations occurred in the individual trials, and the Hardness Tester used did not give accurate enough results throughout so that definite conclusions could be drawn.

6) Samples containing from two to three ounces of agar scored as high as did the gelatin samples. However, the ice cream containing three ounces of agar was criticized for being somewhat crumbly. The controls were characterized in every trial as being coarse and undesirable.

7) Agar samples melted more rapidly than the gelatin samples. When two ounces or less of agar were used the samples melted somewhat more rapidly than the controls. The melted portion of the agar mixes was generally coarse in appearance.

Newer Vegetable Stabilizers:

1) No difficulty was experienced in incorporating these stabilizers in the mix. Kelco Gel was the only one of the four to impart any color or flavor to the mix. It gave the mix a brown shade which was so slight as not to be detectable in the finished ice cream.

2) Lakoe A greatly increased the viscosity of the ice cream mix, a property not shown to any large extent by the other stabilizers of this group.

3) The mix containing this stabilizer whipped more slowly than that made with Kelco Gel, Krabyn, and Colace, and approximately as rapidly as the gelatin samples. The control lots whipped to 100 per cent swell in less time than the stabilized mixes.

4) Mixes containing these stabilizers when stored for 96 hours at 43° F., showed considerable whey separation in samples containing Colace, and a small amount in those containing Lakoe A. This wheying off was retarded when the samples were stored at about 35° F.

5) Although Kelco Gel mixes did not whey off, they showed a brown discoloration and curdling at the base of the cylinder in which they were stored.

6) Ice cream containing Kelco Gel and Krabyn melted considerably faster than the gelatin samples and even more rapidly than the controls.

7) Lakoe A was the only one of the stabilizers in this group to make an ice cream comparable with that containing gelatin from the standpoint of resistance to melting.

8) The melted portion from the Kelco Gel samples was extremely coarse in appearance. Krabyn also showed this coarseness in the melted ice cream, but to a less degree.

9) All of the samples excepting Colace melted down cleanly. Colace left a mass of unmeltable material on the screen which did not melt down even after exposing to room temperatures overnight.

Miscellaneous:

1) Agar, gum tragacanth, and Kelco Gel are more expensive than gelatin, and appear to be no more efficient.

2) Krabyn, Lakoe A, and Colace cost less than one-half as much as gelatin.

3) Little comparison can be made between the nutritive properties of gum stabilizers and of gelatin, until more is learned of the true food value of gums. Present information in this respect favors gelatin.

4) Agar agar, though not assimilated by the body as food, is of some benefit in certain foods by adding bulk to the diet. Doubtless this property is valueless in ice cream. The food value of Kelco Gel is not exactly known,but its source and properties indicate that it is practically worthless excepting from its action as an emulsifier.

5) In general, there appeared to be a direct relationship between the surface tensions and viscosities of mixes. There was no correlation, however, between these factors and the whipping ability of normal mixes.

LITERATURE CITED

1. Alexander, J.
   1909 Protective Effects of Colloidal Binders and Fillers Against the Growth of Ice Crystals
   Jour. Soc. Chem. Indus. 28:284-285

2. Alexander, J.
   1909 The Effect of Colloids on Crystallization
   Z. Chem. Ind. Kolloide 4, 86
   Chem. Abstracts, 3:1315

3. Anderson, E. O., Lyons, T. A., and R. L. Pierce
   1930 Gelatin Percentage Can Be Reduced
   Ice Cream Trade Jour. 26, 11:81-3

4. Associates of Rogers
   1928 Fundamentals of Dairy Science
   Monologue Series No. 41, pp. 235-8
   The Chemical Catalogue Company, Inc., N. Y.

5. Caulfield, W. J. and Martin, W. H.
   1932 The Use of Vegetable Stabilizers in Ice Cream
   Proc. 27th Convention Am. Dairy Sci. Assoc., p. 69

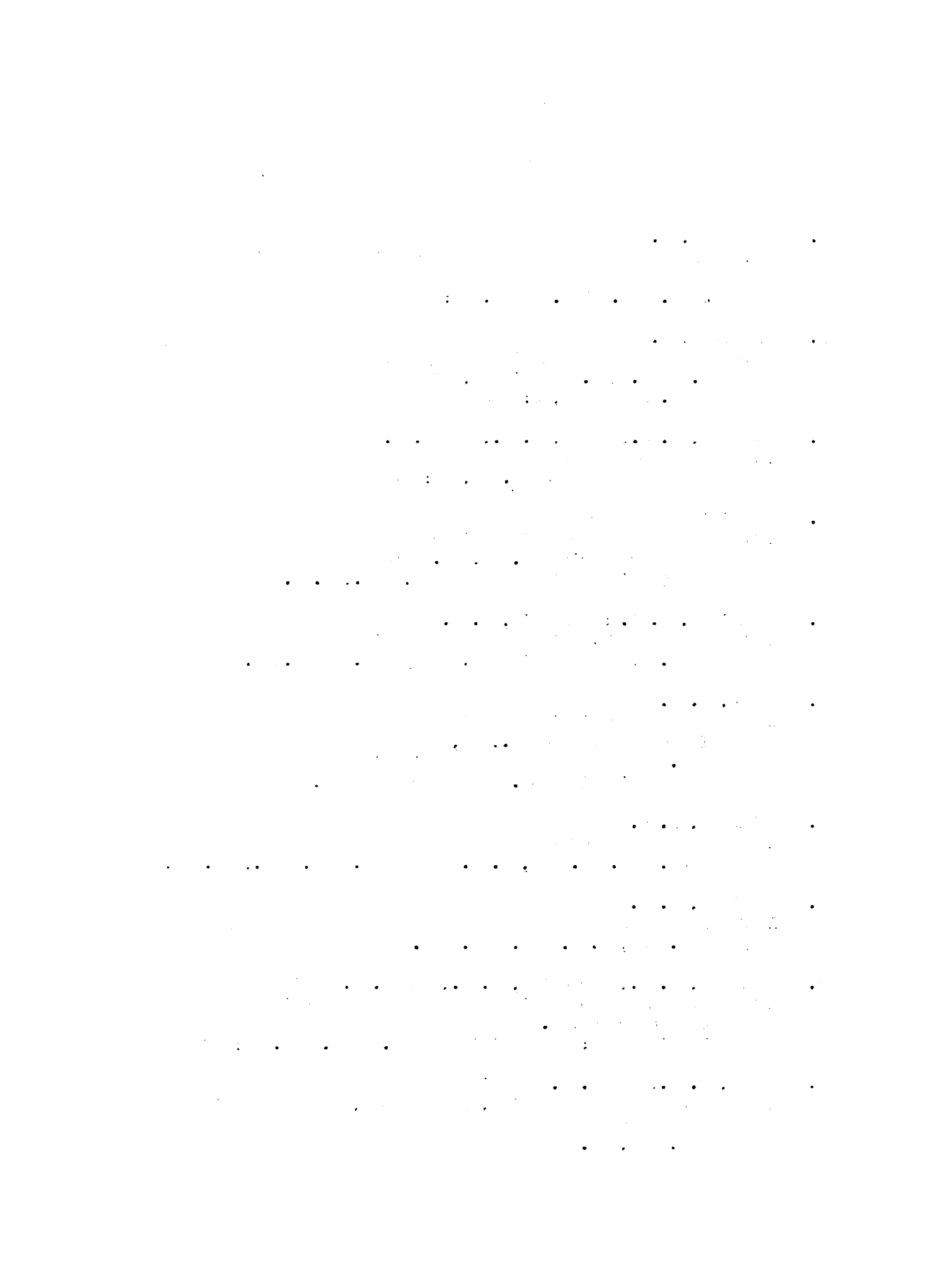
6. Crowe, L. K.
   1928 Sherbet Crustation Remedies
   Ice Cream Trade Jour., 24, 2
   Abs. on Manufacture and Distribution of Ice Cream
   International Assoc. of Ice Cream Mfgrs.

7. Dahlberg, A. C.
   1925 The Texture of Ice Cream
   Tech. Bul. No. 111, N. Y. State Agr. Exp. Sta., pp. 20, 21-7

8. Dahlberg, A. C.
   1926 A Study of the Manufacture of Water Ices and Sherbets
   Bul. 536, N. Y. Agr. Exp. Sta.

9. Dahlberg, A. C., Carpenter, D. C., and J. C. Hening
   1928 Grading of Commercial Gelatin and Its Use in the Manufacture of Ice Cream Vol. II
   Reprint from: Industrial and Eng. Chem. Vol. 20:516

10. Dahle, C. D., and W. J. Caulfield
    1926 Factors Affecting Time, Temperature, and Overrun in Freezing Ice Cream
    Bul. 204, Pa. State College



11. DePew, H. F.
1928 Viscosity in Ice Cream Mixes
Tech. Bul. 58, N. H. Agr. Exp. Sta., pp. 12-4

12. Downey, T. B.
1925 Gelatin
Textbook - The Edible Gelatin Research Society, pp. 18, 26-37

13. Fisk, W. W.
1919 The Book of Ice Cream
First Edition, pp. 54-5
The Macmillan Company, N. Y.

14. Gebhardt, H. T.
1928 M. S. Thesis, University of Wisconsin
Reported in "Theory and Practice of Ice Cream Making",
by Sommers, H. H.
First Edition, pp. 201-2
The Olsen Publishing Company, Milwaukee.

15. Getman, F. H. and Daniels, F.
1931 Outlines of Theoretical Chemistry
Fifth Edition, pp. 233-4
Wiley and Sons, Publishers, N. Y.

16. Gortner, R. A.
1929 Outlines of Biochemistry
First Edition, pp. 537, 560-2
Wiley and Sons, N. Y.

17. Gregory, H. W. and Manhart, V. C.
1924 Factors Affecting the Yield of Ice Cream
Bul. 287, Purdue Agr. Exp. Sta., pp. 22-3

18. Heming, J. C.
1931 Some Observations on the Basic Viscosity of Ice Cream Mixes
Jour. Dairy Sci. Vol. XIV, 1:84-91

19. Holdaway, C. W. and Reynolds, R. R.
1916 Effects of Binders Upon the Melting and Hardness of Ice Cream
Bul. 211, Va. Exp. Sta.

20. Horrall, B. E.
1930 Gelatin Will Not Be Replaced
Ice Cream Trade Journal 26, 11:80-1
Chem. Abs. 25:1918

21. Jackson, R. W., Sommer, B. E., and W. C. Rose
1928 The Nutritive Properties of Gelatin
Jour. Biol. Chem. 80, 167-86
Chem. Abs. 23:418

22. Jones, D. B. and Nelson, E. M.
1931 Nutritive Value of Potato Protein and of Gelatin
Jour. Biol. Chem. 91, 705-15
Chem. Abs. 25:4028

23. Judkins, H. F.
1928 Some Fundamental Rules to Follow when Making Sherbets and Ices
Ice Cream Trade Jour. 24, 6.
Abs. on Manufacture and Distribution of Ice Cream
International Assoc. of Ice Cream Mfgrs.
Vol. 2:157

24. Judkins, H. F.
1928 Is Your Homogenizing Process Always Effective?
Report of Proceedings of International Assoc. of Ice Cream
Manufacturers
Vol. 2:45

25. Larsen, C. and White, W.
1914 Dairy Technology
First Edition, pp. 148-9
Wiley and Sons, N. Y., Publishers

26. Lucas, P. S. and Scott, E. C.
1929 A Study of the Use of Gums in Sherbets
Mich. Agr. Exp. Sta.
Unpublished.

27. Lucas, P. S. and Scott, E. C.
1928 A Study of Gelatins and Their Effect on Ice Cream
Tech. Bul. 94, Mich. Agr. Exp. Sta., pp. 13, 23

28. Mitchell, H. S.
1923 Reproduction on Synthetic Diets when Purified Agar Is Added
to the Mixture
Am. Jour. Physiol. 62:557-8
Chem. Abs. 17:1272

29. Moore, H. C., Combs, W. B., and C. D. Dahle
1925 Relation Between Gold Number of Gelatin and Its Value in the
Ice Cream Mix
Jour. Dairy Sci. 8:500-11

30. Mortensen, M.
1918 Factors Which Influence the Yield and Consistency of Ice Cream
Bul. 180, Iowa State Agr. Exp. Sta., pp. 264-5

31. Norman, A. G.
1929 The Chemical Constituents of Gums. I. The Nature of Gum Arabic and the Biochemical Classification of the Gums
Biochem. J. 23:524-35
Chem. Abs. 23:4842

32. Prescott, S. C., Heifeltz, A., and D. S. Stanley
1932 A Study of Ice Cream Stabilizers
Mass. Institute of Technology
Dept. of Public Health, pp. 3, 22-6

33. Reid, W. H. E., and Russell, L. B.
1930 Mo. Agr. Exp. Sta. Bul. 134

34. Serex, P. and Goodwin, M. W.
1927 Commercial Gelatins, Their Jelly Strength, Gold Number, and Hydrogen Ion Concentration

35. Sommers, H. H.
1932 The Theory and Practice of Ice Cream Making
First Edition, pp. 195-8, 218, 284-5
Olsen Publishing Company, Milwaukee, Wis.

36. Turnbow, G. D. and Milner, F. W.
1927 The Role of Gelatin in Ice Cream
Jour. Dairy Sci. Vol. X, 5:202-9

37. Turnbow, G. D. and Raffetto, L. A.
1928 Ice Cream
First Edition, pp. 130-5
Wiley and Sons, Publishers, N. Y.

38. Voskressensky, A.
1924 Digestion of Gums by Organisms and Enzymes -- Digestion of Cherry Gum in Vitro
Bul. Soc. Chem. Biol. 6:226-30
Chem. Abs. 18:3406

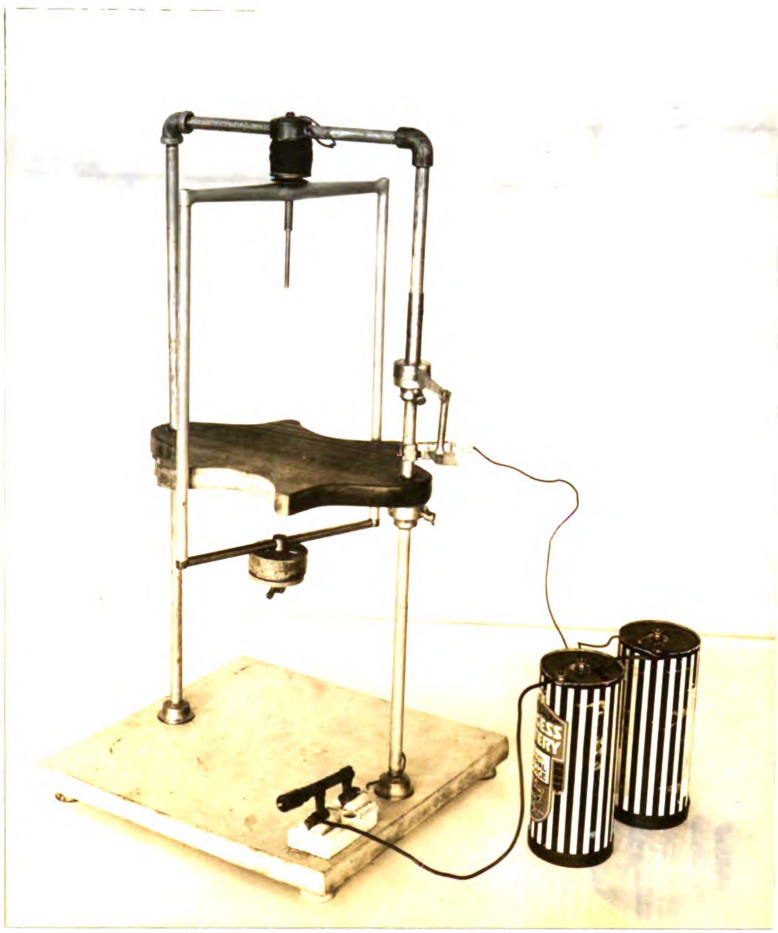
39. Washburn, R. M.
1910 Principles and Practice of Ice Cream Making
Bul. 155, University of Vermont and State Agr. College, pp. 42-5

40. Washburn, R. M.
1932 Why Gelatin in Ice Cream
The Ice Cream Review, Vol. 15, 10:46-8

41. Wright, K. E.
1930 The Effect of Initial Cooling Temperatures on Gelatin in the Aging of the Ice Cream Mix
Jour. Dairy Sci. Vol. XIII, 5:406

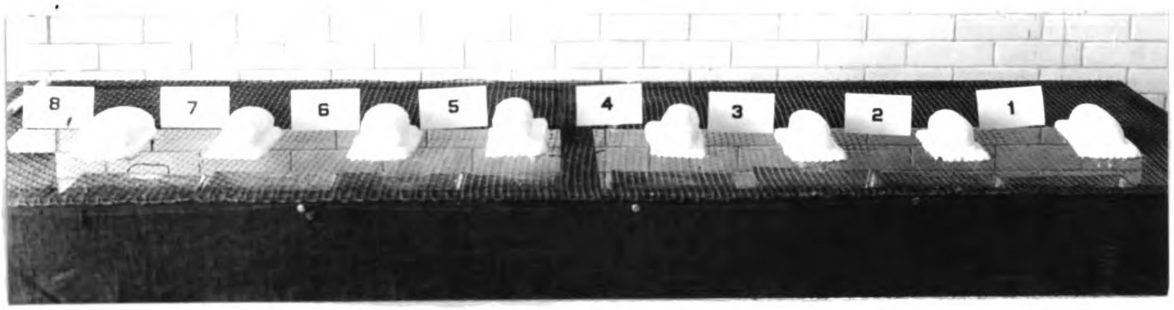
APPENDIX

FIGURE I.



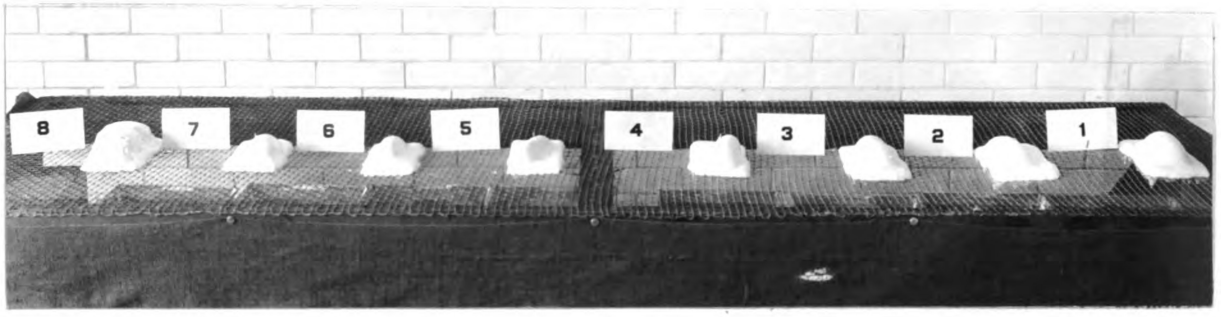
Ice Cream Hardness Tester Used in this Study.

FIGURE II.



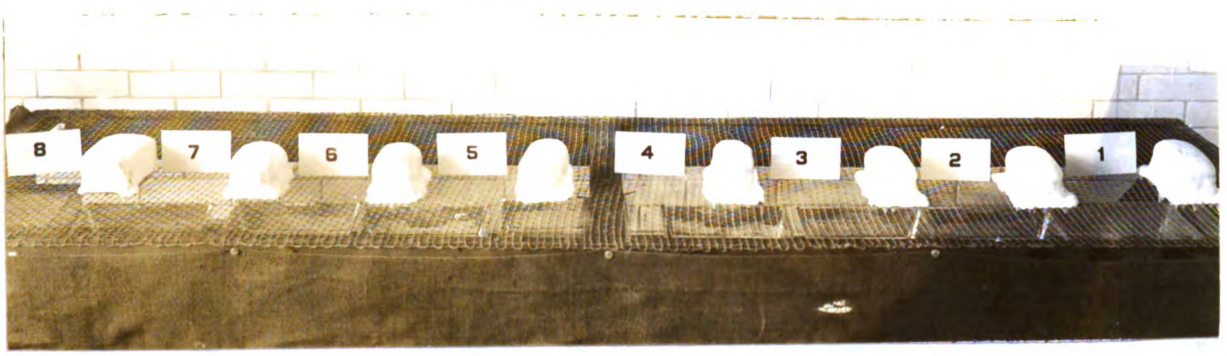
Ice cream samples containing gum tragacanth and gum arabic after exposure at room temperature for 1½ hours. Nos. 1 to 4 inclusive contain gum arabic in amounts varying directly from seven to ten ounces, and Nos. 5 to 7 inclusive contain from three to five ounces of gum tragacanth. Sample No. 8 contains 0.4% Gelatin.

FIGURE III.



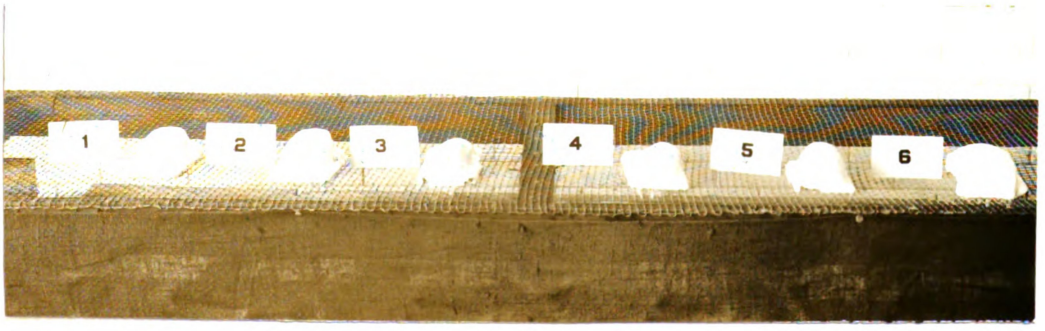
Same as above after three hours exposure to melting temperature.

FIGURE IV.



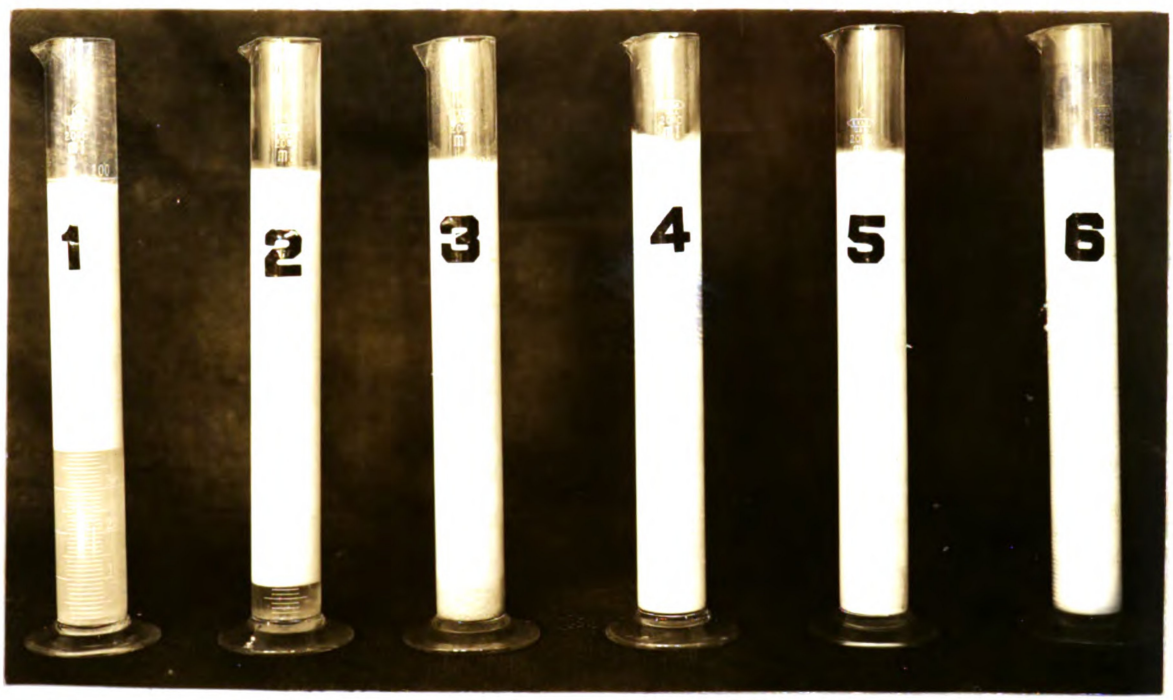
Samples of ice cream containing various amounts of agar agar after exposure at room temperature for two hours. Nos. 1 to 6 contain agar in amounts varying from one to six ounces; No. 7 contains gelatin, and No. 8 is the control.

FIGURE V.



Samples of ice cream containing different vegetable stabilizers after exposure at room temperatures for two hours. No. 1 contains Colace, No. 2, Lakoe A, No. 3, Kelco Gel, No. 4, Krabyn, No. 5, Gelatin, and No. 6 is the control.

FIGURE VI.



Wheying off of ice cream mixes containing vegetable stabilizers, after storing for one week at 43° F. No. 1 contains Colace, No. 2, Lakoe A, No. 3, Kelco Gel, No. 4, Krabyn, No. 5, Gelatin, and No. 6 is the control. Note the dark discoloration and curdling at the base of the cylinder containing Kelco Gel.

Table LXI. The Per Cent Overrun by Minutes of Ice Cream Mixes Containing Gum Tragacanth (Lot I, Part I).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	63	63	64	66	61	71	64	77
1	83	83	79	78	76	79	77	84
2	98	100	102	90	99	90	84	94
3	106	102	106	107	107	100	94	98
4	116	109	114	105	113	103	102	101
5	120	113	121	112	115	110	108	106
6	121	115	128	121	116	115	109	111
7	135	130	126	124	120	114	113	113
8	131	133	126	136	129	117	116	115
9	129	140	136	131	128	134	117	116
10	129	140	129	131	128	132	120	125
11	127	137	130	131	128	132	120	128
12	127	137	129	131	128	132	120	128
13	127	136	128	130	128	132	120	127
14	126	135	128	129	126	132	120	127
15	126	135	128	129	126	130	121	127
16	126	135	128	129	126	130	121	127

Batch No.	Stabilizer Used
1	0.5 oz. Gum Tragacanth
2	1.0 oz. Gum Tragacanth
3	1.5 oz. Gum Tragacanth
4	2.0 oz. Gum Tragacanth
5	2.5 oz. Gum Tragacanth
6	3.0 oz. Gum Tragacanth
7	0.4% Gelatin
8	Control

Table LXII. The Per Cent Overrun by Minutes of Ice Cream Mixes Containing Gum Tragacanth (Lot II, Part I).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	74	79	77	71	69	70	72	-
1	83	85	86	77	76	72	80	-
2	91	93	99	86	87	73	89	-
3	98	102	101	94	96	76	105	-
4	104	102	108	100	103	87	102	-
5	108	112	107	108	104	89	109	-
6	115	111	108	108	114	94	110	-
7	119	112	117	121	118	94	111	-
8	119	121	117	118	115	99	117	-
9	122	128	124	123	121	105	117	-
10	125	128	129	125	128	104	115	-
11	123	129	132	131	127	111	119	-
12	129	129	131	132	131	115	122	-
13	129	128	136	136	130	110	121	-
14	125	127	133	138	130	115	121	-
15	123	130	132	135	129	115	119	-
16	120	125	132	134	129	116	118	-

Batch No.	Stabilizer Used
1	0.5 oz. Gum Tragacanth
2	1.0 oz. Gum Tragacanth
3	1.5 oz. Gum Tragacanth
4	2.0 oz. Gum Tragacanth
5	2.5 oz. Gum Tragacanth
6	3.0 oz. Gum Tragacanth
7	0.4% Gelatin
8	Control

Table LXIII. The Per Cent Overrun by Minutes of Ice Cream Mixes Containing Gum Tragacanth (Lot III, Part I).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	68	77	76	70	58	67	68	77
1	80	86	87	81	68	77	75	89
2	90	97	98	90	82	91	85	98
3	93	102	103	102	89	100	92	103
4	102	117	110	110	95	107	99	109
5	105	113	113	111	100	109	102	110
6	119	118	120	118	103	118	106	117
7	112	123	120	123	107	126	109	118
8	118	131	127	130	113	125	113	125
9	122	135	125	130	113	140	118	131
10	123	136	133	134	116	139	118	131
11	123	139	132	134	119	134	120	129
12	125	137	135	136	123	135	119	126
13	126	137	135	132	125	134	120	125
14	124	132	136	133	125	134	120	123
15	123	132	134	135	127	136	121	123
16	122	129	133	132	125	135	121	123

Batch No.	Stabilizer Used
1	0.5 oz. Gum Tragacanth
2	1.0 oz. Gum Tragacanth
3	1.5 oz. Gum Tragacanth
4	2.0 oz. Gum Tragacanth
5	2.5 oz. Gum Tragacanth
6	3.0 oz. Gum Tragacanth
7	0.4% Gelatin
8	Control

Table LXIV. The Per Cent Overrun by Minutes of Ice Cream Mixes Containing Gum Tragacanth (Lot IV, Part I).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	35	40	37	33	39	47	60	61
1	52	56	51	49	53	59	62	70
2	72	78	74	67	77	78	76	86
3	95	94	96	88	92	90	87	105
4	120	115	114	106	105	99	100	116
5	138	115	115	110	112	100	115	122
6	150	124	123	120	126	107	120	136
7	152	126	133	130	133	106	126	153
8	150	130	136	140	133	111	130	143
9	146	141	132	141	134	109	130	138
10	146	144	132	141	134	110	128	139
11	145	140	131	141	128	111	130	133
12	143	143	130	132	134	109	131	134
13	143	142	129	130	132	112	130	133
14	140	135	130	132	131	113	131	129
15	138	131	129	135	130	116	128	129
16	138	132	130	130	130	114	128	127

Batch No.	Stabilizer Used
1	3 oz. Gum Tragacanth
2	3 oz. Gum Tragacanth
3	3 oz. Gum Tragacanth
4	4 oz. Gum Tragacanth
5	4 oz. Gum Tragacanth
6	4 oz. Gum Tragacanth
7	0.4% Gelatin
8	Control

Table LXV. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic (Lot I, Part II).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	76*	63	63	62	60	54	50	57
1	90	75	79	76	69	69	58	71
2	104	94	92	92	86	87	73	94
3	105	111	109	107	103	102	89	109
4	105	117	114	120	109	113	100	119
5	113	125	125	123	117	121	106	123
6	118	131	124	126	123	127	111	128
7	118	136	128	130	125	126	117	133
8	115	135	131	136	128	132	118	133
9	115	136	128	139	132	134	121	134
10	117	134	128	133	130	134	123	132
11	117	133	129	128	130	134	123	130
12	114	135	127	128	130	134	127	130
13	114	135	128	130	131	134	126	130
14	114	134	129	133	131	133	128	130
15	113	134	129	134	132	134	129	131
16	111	134	130	134	132	134	129	131

Batch No.	Stabilizer Used
1	1 oz. Gum Arabic
2	2 oz. Gum Arabic
3	3 oz. Gum Arabic
4	4 oz. Gum Arabic
5	5 oz. Gum Arabic
6	6 oz. Gum Arabic
7	0.4% Gelatin
8	Control

* Batch frozen too hard which may account for low maximum overrun.

Table LXVI. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic (Lot II, Part II).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	79	57	54	54	53	50	50	61
1	92	69	66	70	64	64	56	73
2	100	90	90	90	87	85	71	97
3	105	108	101	103	108	106	84	110
4	112	115	110	110	113	112	98	117
5	111	118	115	115	114	121	110	130
6	113	125	120	119	123	128	118	134
7	114	132	118	121	127	127	126	134
8	116	136	131	130	128	132	129	135
9	118	133	126	130	133	129	131	137
10	119	133	124	127	133	129	131	132
11	117	133	129	127	130	129	131	132
12	119	130	128	126	129	130	130	129
13	118	127	128	127	128	129	129	129
14	118	127	130	128	126	130	130	129
15	118	127	129	129	126	129	132	129
16	118	127	128	129	126	129	132	129

Batch No.	Stabilizer Used
1	1 oz. Gum Arabic
2	2 oz. Gum Arabic
3	3 oz. Gum Arabic
4	4 oz. Gum Arabic
5	5 oz. Gum Arabic
6	6 oz. Gum Arabic
7	0.4% Gelatin
8	Control

Table LXVII. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic (Lot III, Part II).

Minutes	Batch No. 1	2	3	4	5	6
0	58	56	50	53	65	66
1	66	63	61	63	66	78
2	84	83	77	81	77	94
3	109	104	101	99	89	117
4	117	116	110	109	102	119
5	133	128	120	118	114	131
6	143	134	128	119	119	137
7	145	139	132	127	125	136
8	147	142	137	132	128	139
9	142	138	138	137	128	139
10	140	138	137	137	130	138
11	140	139	138	133	135	136
12	140	138	135	131	134	133
13	140	135	133	131	132	133
14	136	135	130	128	132	133
15	136	134	130	128	132	132
16	136	134	130	128	131	130

Batch No.	Stabilizer Used
1	7 oz. Gum Arabic
2	8 oz. Gum Arabic
3	9 oz. Gum Arabic
4	10 oz. Gum Arabic
5	0.4% Gelatin
6	Control

Table LXVIII. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic (Lot IV, Part II).

Minutes	Batch No. 1	2	3	4	5	6
0	53	54	53	52	48	-
1	65	68	64	63	55	-
2	90	88	86	84	71	-
3	107	108	107	105	85	-
4	119	113	114	114	100	-
5	122	125	119	123	112	-
6	133	128	132	127	125	-
7	140	130	136	138	141	-
8	145	140	148	139	140	-
9	142	138	145	143	144	-
10	142	139	145	143	142	-
11	142	139	145	143	138	-
12	140	139	142	145	144	-
13	140	138	141	142	140	-
14	140	138	138	138	138	-
15	140	137	138	138	135	-
16	140	137	138	137	136	-

Batch No.	Stabilizer Used
1	7 oz. Gum Arabic
2	8 oz. Gum Arabic
3	9 oz. Gum Arabic
4	10 oz. Gum Arabic
5	0.4% Gelatin
6	Control

Table **LXIX.** The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic (Lot V, Part II).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	81	75	73	66	66	70	72	81
1	94	81	79	75	73	74	73	85
2	111	92	90	84	83	80	80	95
3	128	104	103	97	96	86	85	111
4	139	119	118	105	108	94	91	118
5	152	128	130	115	115	100	101	135
6	152	135	134	125	125	110	109	137
7	150	143	145	133	135	120	116	147
8	152	143	144	140	135	121	125	153
9	148	143	146	147	140	127	133	142
10	144	146	144	147	143	132	132	142
11	143	146	139	150	143	135	132	143
12	142	142	139	147	138	135	132	138
13	142	142	139	140	138	135	132	139
14	140	140	138	140	138	135	132	139
15	140	140	138	140	136	134	129	139
16	140	140	138	140	136	133	127	139

Batch No.	Stabilizer Used
1	2 oz. Gum Arabic
2	4 oz. Gum Arabic
3	6 oz. Gum Arabic
4	8 oz. Gum Arabic
5	10 oz. Gum Arabic
6	0.4% Gelatin
7	0.4% Gelatin
8	Control

Table LXX. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Gum Arabic (Lot VI, Part II).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	74	73	74	76	67	67	69	77
1	81	80	80	78	76	67	72	81
2	99	95	90	91	88	75	81	92
3	107	104	102	105	103	85	90	100
4	118	115	110	113	119	94	99	113
5	119	121	121	125	130	99	107	130
6	128	128	122	143	137	108	115	130
7	131	140	130	140	147	116	127	140
8	136	140	137	143	146	124	138	143
9	142	141	140	148	148	126	138	143
10	143	141	142	145	148	133	139	143
11	143	139	147	145	144	133	139	140
12	139	138	139	141	142	133	135	140
13	139	140	139	140	142	133	135	136
14	139	136	135	140	141	133	135	136
15	138	136	135	140	140	133	135	136
16	138	136	135	140	140	132	135	136

Batch No.	Stabilizer Used
1	2 oz. Gum Arabic
2	4 oz. Gum Arabic
3	6 oz. Gum Arabic
4	8 oz. Gum Arabic
5	10 oz. Gum Arabic
6	0.4% Gelatin
7	0.4% Gelatin
8	Control

Table LXXI. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Agar Agar (Lot I, Part III).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	48	42	38	25	31	27	47	53
1	65	57	55	48	50	43	54	69
2	88	80	78	68	68	64	70	91
3	101	103	95	86	78	76	89	106
4	107	119	107	101	86	85	105	117
5	110	120	113	113	87	88	118	113
6	116	125	117	120	91	99	127	118
7	114	126	119	133	94	99	129	124
8	120	133	124	130	97	99	131	124
9	122	130	124	129	99	102	130	121
10	120	128	121	130	98	103	127	120
11	119	129	122	130	99	105	129	120
12	119	127	127	134	100	103	129	120
13	119	127	125	134	101	103	127	120
14	119	126	125	133	100	103	127	120
15	119	126	123	133	102	103	127	120
16	119	126	123	133	103	103	127	120

Batch No.	Stabilizer Used
1	1 oz. Agar
2	2 oz. Agar
3	3 oz. Agar
4	4 oz. Agar
5	5 oz. Agar
6	6 oz. Agar
7	0.4% Gelatin
8	Control

Table LXXII. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Agar Agar (Lot II, Part III).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	59	43	41	34	33	27	45	60
1	71	55	56	49	45	45	68	69
2	92	74	76	69	63	61	78	80
3	113	95	94	87	83	77	92	100
4	126	107	109	104	90	86	106	110
5	137	120	115	108	100	96	114	117
6	138	120	121	109	102	99	117	127
7	145	131	129	113	107	103	122	131
8	143	137	133	119	108	105	124	129
9	140	135	129	119	108	107	127	130
10	139	134	129	120	112	109	127	128
11	139	132	129	120	112	110	127	127
12	138	132	127	123	112	111	127	126
13	138	132	127	123	113	113	129	125
14	138	132	127	120	116	112	128	125
15	138	132	127	120	115	112	129	124
16	138	132	127	120	115	112	128	124

Batch No.	Stabilizer Used
1	1 oz. Agar
2	2 oz. Agar
3	3 oz. Agar
4	4 oz. Agar
5	5 oz. Agar
6	6 oz. Agar
7	0.4% Gelatin
8	Control

Table **LXXIII.** The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Agar Agar (Lot III, Part III).

Minutes	Batch No. 1	2	3	4	5	6	7	8	9	10
0	74	74	70	74	74	73	65	55	64	75
1	83	82	81	83	85	84	70	64	77	83
2	103	100	97	100	100	100	82	76	84	97
3	117	118	105	110	105	104	93	86	101	105
4	126	131	109	114	118	114	105	101	110	118
5	136	140	118	116	118	114	115	107	117	118
6	145	145	121	125	122	123	125	114	126	130
7	150	150	135	139	125	127	134	123	129	138
8	152	153	135	141	143	133	139	131	142	140
9	154	158	135	145	143	133	140	140	142	147
10	146	158	145	150	143	138	143	137	144	149
11	146	154	150	146	147	142	143	137	143	140
12	146	147	146	145	147	143	143	138	139	140
13	145	144	146	143	145	143	140	137	138	137
14	143	144	146	143	140	141	139	136	136	137
15	143	143	143	143	134	141	139	135	136	136
16	143	142	143	143	134	141	138	135	134	136

Batch No.	Stabilizer Used
1	2 oz. Agar
2	2 oz. Agar
3	2 oz. Agar
4	2 oz. Agar
5	2 oz. Agar
6	2 oz. Agar
7	0.4% Gelatin
8	0.4% Gelatin
9	No stabilizer
10	No stabilizer

Table **LXXIV.** The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Agar Agar (Lot IV, Part III).

Minutes	Batch No. 1	2	3	4	5	6	7	8	9	10
0	68	65	64	68	60	57	54	58	77	68
1	76	76	74	76	72	69	59	64	82	75
2	90	92	88	88	86	82	71	77	95	85
3	108	114	103	100	105	94	81	87	110	98
4	125	128	114	107	117	108	90	97	116	105
5	130	136	120	112	131	115	99	108	132	111
6	140	145	129	125	142	124	108	117	142	116
7	148	153	133	130	150	133	113	129	144	126
8	150	157	145	130	155	134	119	139	150	137
9	150	157	153	140	160	143	128	142	160	141
10	155	163	150	152	165	145	134	145	160	146
11	155	163	150	152	160	152	138	145	155	150
12	150	157	150	152	157	153	140	145	152	155
13	150	160	148	150	156	159	145	145	148	147
14	148	157	145	150	155	155	144	142	148	148
15	146	155	143	150	154	154	144	141	148	147
16	146	150	143	148	153	153	144	141	148	145

Batch No.	Stabilizer Used
1	3 oz. Agar
2	3 oz. Agar
3	3 oz. Agar
4	3 oz. Agar
5	3 oz. Agar
6	3 oz. Agar
7	0.4% Gelatin
8	0.4% Gelatin
9	No stabilizer
10	No stabilizer

Table LXXV. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Krabyn (Lot III, Part IV).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	80	72	84	81	82	69	65	74
1	79	72	79	79	78	69	67	72
2	88	82	85	86	84	76	76	82
3	94	93	95	94	94	84	83	95
4	101	105	104	105	100	93	91	110
5	107	115	111	110	107	102	97	120
6	112	120	117	115	112	107	105	130
7	115	130	124	119	119	112	108	131
8	120	137	126	122	124	117	111	134
9	125	140	130	125	128	122	114	138
10	127	144	130	129	130	125	116	136
11	128	146	130	132	132	128	119	135
12	129	147	131	131	133	128	120	131
13	127	147	134	131	134	128	120	131
14	127	146	132	130	134	128	121	131
15	128	145	131	130	133	128	120	129
16	128	144	128	130	130	127	120	127

Batch No.	Stabilizer Used
1	0.3% Krabyn
2	0.3% Krabyn
3	0.3% Krabyn
4	0.3% Krabyn
5	0.3% Krabyn
6	0.4% Gelatin
7	0.4% Gelatin
8	No stabilizer

Table LXXVI. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Colace (Lot I, Part IV).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	65	65	62	59	62	56	62	74
1	69	67	61	66	65	64	66	72
2	80	80	72	77	78	75	78	85
3	94	93	86	90	89	87	88	95
4	106	108	100	113	103	99	102	111
5	120	118	112	106	112	110	108	130
6	125	127	125	113	120	116	115	135
7	133	134	132	115	135	124	120	138
8	141	140	140	126	132	130	121	142
9	141	142	138	120	140	133	129	141
10	141	143	139	117	138	142	130	140
11	141	142	138	120	135	133	132	140
12	141	142	138	119	135	138	131	137
13	141	140	136	120	134	132	131	135
14	141	139	135	117	134	129	130	135
15	140	139	135	115	133	131	130	135
16	139	139	134	114	130	127	127	134

Batch No.	Stabilizer Used
1	0.4% Colace
2	0.4% Colace
3	0.4% Colace
4	0.4% Colace
5	0.4% Colace
6	0.4% Gelatin
7	0.4% Gelatin
8	No stabilizer

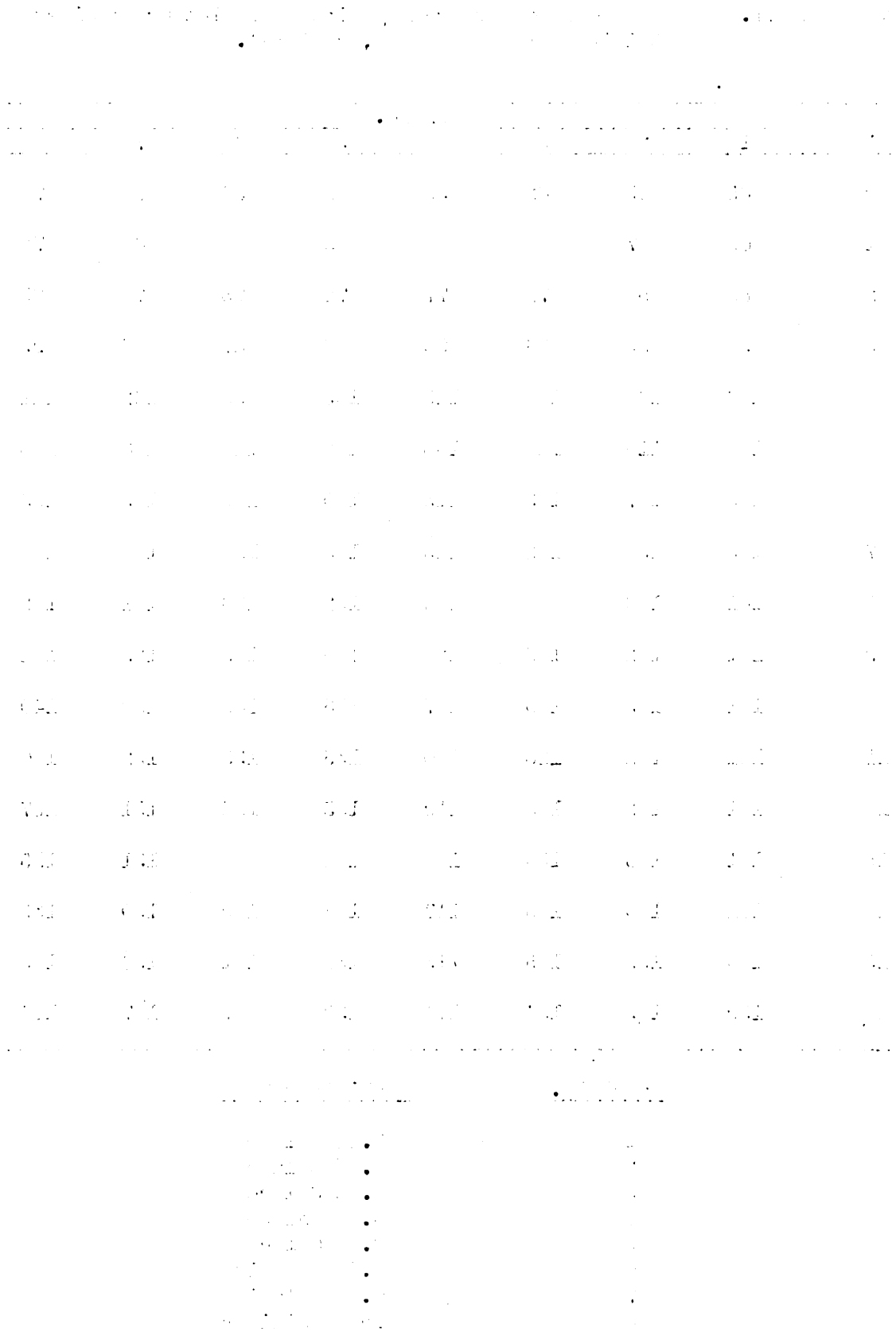


Table LXXVII. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Lakoe A. (Lot IV, Part IV).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	52*	52	45	57	62	59	60	66
1	52	56	47	55	60	64	63	74
2	56	72	58	65	70	74	75	88
3	61	84	73	78	84	87	89	99
4	69	91	83	89	95	101	103	104
5	77	105	94	105	108	110	110	112
6	82	111	110	115	115	121	115	121
7	87	115	119	120	125	125	126	131
8	94	117	124	128	132	135	127	132
9	101	119	128	133	136	140	129	135
10	105	125	134	135	139	140	133	136
11	108	125	134	138	140	140	133	125
12	111	127	134	138	140	138	133	125
13	115	127	134	137	139	137	131	125
14	116	125	132	136	138	135	129	125
15	120	124	131	135	137	133	128	122
16	123	124	130	134	136	132	126	120

Batch No.	Stabilizer Used
1	0.3% Lakoe A
2	0.3% Lakoe A
3	0.3% Lakoe A
4	0.3% Lakoe A
5	0.3% Lakoe A
6	0.4% Gelatin
7	0.4% Gelatin
8	No stabilizer

* Drawrite regulator worked improperly during this trial.

Table LXXVIII. The Per Cent of Overrun by Minutes of Ice Cream Mixes Containing Kelco Gel (Lot II, Part IV).

Minutes	Batch No. 1	2	3	4	5	6	7	8
0	71	71	70	61	64	64	65	69
1	74	71	68	67	70	66	64	76
2	85	82	77	79	81	77	74	88
3	97	95	91	91	91	87	84	110
4	110	109	105	107	105	97	94	116
5	120	119	113	115	118	108	106	125
6	136	131	119	121	125	115	115	136
7	150	139	131	130	131	125	125	135
8	155	148	145	139	132	132	130	138
9	155	150	141	142	138	135	138	145
10	157	153	142	144	151	139	138	152
11	157	153	142	142	145	138	138	150
12	153	155	142	140	144	138	136	148
13	153	153	142	140	142	138	135	145
14	150	152	142	139	145	135	134	145
15	150	150	142	139	145	134	134	142
16	150	150	141	139	145	133	132	140

Batch No.	Stabilizer Used
1	0.3% Kelco Gel
2	0.3% Kelco Gel
3	0.3% Kelco Gel
4	0.3% Kelco Gel
5	0.3% Kelco Gel
6	0.4% Gelatin
7	0.4% Gelatin
8	No stabilizer