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REQUIREMENTS FOR INSTANT PREPARED, READY-TO-EAT, FREEZE-DRIED SCRAMBLED EGG

by

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Swift & Company
Chicago, Illinois

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FOREWORD

To fill a need for a cooked egg product in the breakfast menus of Quick Serve Meals, which comprise one of our proposed Military combat feeding systems, a scrambled, cooked, freeze dried egg product was developed. A U. S. patent for this product (3,009,818) was granted to Louis Jokay and Richard I. Meyer and has been assigned to the United States of America as represented by the Secretary of the Army.

When newly developed products are taken from the laboratory or pilot plant stage to plant production, unforeseen problems are often encountered. Such was the case with the new egg product covered in this report when plant size production lots were contracted for.

This study was therefore designed to obtain comprehensive information on raw material requirements, refinements in processing methods, packaging, chemical and bacteriological specifications, keeping quality and a processing equipment design for efficient large scale production of scrambled, cooked freeze dried egg product.

The work covered in this report was performed by Swift and Company, Chicago, Illinois, under Contract No. DA19-129-AMC-121(N) and was entitled: Requirements for Instant Prepared, Ready-to-Eat, Freeze-Dried Scrambled Egg. Mr. P. E. Mone and L. D. Mink were the Official Investigators. Their Collaborators were Messrs. D. L. Davies, J. K. McAnelly and J. M. Weybright.

Project Officer for the U. S. Army Natick Laboratories was Dr. Charles C. Walts of the Animal Products Branch, Food Division. Alternate Project Officers were Lt. Clayton S. Huber also of the Animal Products Branch, Food Division and Mr. Louis Jokay of the former Armed Forces Food and Container Institute.

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ABSTRACT

In the design of "Quick Serve Meals" as a military operational ration, there was a need for a quickly prepared egg product in the breakfast menus. A prototype scrambled, cooked, freeze-dried whole egg product was developed which possessed the appearance, aroma, flavor and texture similar to pan-fried scrambled egg, after rehydrating in hot water for 1 to 3 minutes. More complete information covering raw material and processing procedures was needed in order to produce a satisfactory product on a plant scale. The work covered in this report was carried out to investigate the raw material, processing methods and equipment necessary for the efficient production of freeze dried scrambled eggs.

Summer and winter produced USDA table grades A and B shell eggs were obtained from 6 different geographical areas of the United States to provide for a random selection of eggs from major egg producing areas. In addition, table grade frozen egg prepared from table grade shell eggs was included in the study. The eggs were produced from predominately White Leghorn flocks. All eggs after receipt were held at 40°F until processed except that the frozen table grade egg was held at -10°F. The eggs were weighed, check graded, broken, homogenized, pasteurized, stabilized (desugared), precooked, frozen, freeze-dried and vacuum and nitrogen treated before sealing in both cans and pouches. The packaged freeze dried eggs were stored at 38°-40°F and 100°F for six months. They were evaluated organoleptically for quality by a trained panel initially and at the end of the storage period. Bacteriological and chemical data was obtained on the raw and processed eggs.

Geographical source of the eggs had no effect on the quality of the end product. There were no significant differences in the organoleptic criteria of the finished product produced from grade A or grade B table grade shell eggs. Finished product produced from grade B frozen egg was significantly poorer in organoleptic properties than from grades A and B eggs. Freeze-dried scrambled egg packed in cans kept better in storage than when packed in pouches. Oxygen level in headspace gas did not appear to affect flavor stability. Overcooking in the scrambling process and rehydration procedure had a deleterious effect on quality. Increasing the levels of enzyme preparation and hydrogen peroxide and raising the incubation temperature to 105°-112°F reduced the desugaring time to 2 hours.

Detailed recommendations are provided for raw material, plant equipment and processing procedure.

SUMMARY

This study was carried out to investigate the raw material, processing methods and equipment necessary for the efficient production of freeze-dried scrambled eggs.

Grade A and Grade B shell eggs and Table Type frozen eggs were processed to prepare freeze-dried scrambled eggs which were stored under varied conditions to determine the effects of egg source, egg grade, time-temperature interaction, package and oxygen level in headspace of package.

The quality of freeze-dried scrambled eggs is affected by egg grade, storage time and temperature and type of package.

The aroma, flavor and texture of freeze-dried scrambled eggs prepared from frozen eggs were significantly poorer than those of the finished product prepared with Grade A and Grade B shell eggs, but there were no differences in the organoleptic criteria of finished product prepared from either Grade A or Grade B shell eggs.

The aroma and flavor of freeze-dried scrambled eggs are affected by time and temperature, the quality decreased with an increase in these variables.

Freeze-dried scrambled eggs packed in cans possessed better appearance and texture than those of eggs packaged in pouches.

The geographical source of raw material and oxygen level in headspace of package had no effect on the quality of freeze-dried scrambled eggs.

Other factors influencing the quality of freeze-dried scrambled eggs are overcooking or prolonged heating time and method of rehydration.

A study of the glucose removal process revealed that desugaring time can be decreased to 2 hours by increasing the levels of enzyme preparation and hydrogen peroxide and raising the incubation temperature to 105 - 112°F.

A complete description of the raw material, equipment and processing methods is provided in this report.

PURPOSE OF THE STUDY

The general objective of this study was to investigate the requirements for raw materials and processing techniques necessary for the production of freeze-dried scrambled eggs, which after storage at 100°F. for a period of 6 months, will rehydrate with hot water to yield cooked scrambled eggs that will more nearly be organoleptically representative of those prepared from fresh shell eggs or Table Type frozen eggs.

This study was designed to provide a comprehensive description of raw material, processing, packaging, chemical and bacteriological specifications and handling for efficient large scale production of freeze-dried scrambled eggs.

PROCEDURE

Egg Source

Grade A and Grade B shell eggs were obtained from 6 geographical locations in the United States to provide for a random selection of eggs from major egg producing areas. These locations are as follows:

1. Salina, Kansas
2. Sauk Center, Minnesota
3. Harrisonburg, Virginia
4. Douglas, Georgia
5. [illegible], California
6. [illegible], Texas

[illegible] sources supplied one case of Grade [illegible] shell [illegible] cases of Grade B shell eggs during the 1963 summer season (June, July and August) and an identical shipment was supplied at the beginning and the end of the 1964 winter season (February, March, and April). The White Leghorn was the predominant breed of laying hens in these 6 areas.

In the second phase of this study 12 cases of Grade B shell eggs and 8 cases of Grade A shell eggs were obtained from Sauk Center, Minnesota, the closest of the major sources of shell eggs.

The cases of shell eggs were stored in a cooler having a temperature of 40°F. until they were processed.

Egg Grading and Breaking

The 54 cases of shell eggs were regraded according to "Regulations Governing The Grading And Inspection Of Shell Eggs and United State Standards, Grades And Weight Classes For Shell Eggs", July 1, 1960. The unacceptable eggs were discarded.

The 20 cases of shell eggs used in the second phase of this study were not regraded.

The total net weight of the shell eggs in each case was obtained and then the shell eggs were broken using standard breaking equipment. The shelled eggs were organoleptically checked, and any additional unacceptable eggs were also discarded. In part of this study an ultraviolet light was employed to examine individual eggs at breaking to detect unacceptable eggs. None of the shell eggs used were low enough in quality to be graded as unacceptable by ultraviolet light technique.

The weights of the acceptable liquid whole eggs and the shells were recorded. The raw liquid eggs were thoroughly mixed to obtain representative samples for chemical and bacteriological analyses. After sampling the raw liquid eggs were filtered through a stainless steel funnel having 1/16 inch openings to remove the non-filterable material. At this stage in processing the filtered and raw liquid eggs, which represented the second case of Grade B shell eggs in the 3 shipments received from the 6 sources, were placed in a 30 pound egg can and frozen to provide Table Type frozen eggs. The cans of frozen eggs were stored at -10°F. until they were processed.

Frozen Egg Handling

The frozen blocks of eggs were drilled to obtain representative samples for chemical and bacteriological analyses. Following this step in handling the cans were held overnight at a temperature of 38°F. To avoid possible contamination by using a grinder, the frozen eggs were thawed in a water bath (80 - 100°F.) and stirred. When thawing was completed the cans of raw liquid eggs (48 - 50°F.) were briefly held at approximately 40°F. until pasteurized.

Egg Pasteurization

To pasteurize, the raw liquid eggs were fed into a single system consisting of a holding tank, an homogenizer, a flow diversion valve and a holding tube. Processing was accomplished under normal procedures described in "Regulations Governing The Grading Of Egg Products", August 28, 1962.

Representative samples of the pasteurized eggs were taken for chemical and bacteriological analyses.

Glucose Depletion

At the completion of pasteurization the temperature of the whole eggs was 86°F. This was the incubation temperature maintained to enzymatically remove glucose by employing a commercially available enzyme preparation containing glucose oxidase and catalase and U. S. Pharmacopoeia grade hydrogen peroxide (30%) at levels of 300 ml. and 600 ml., respectively, for 1,000 pounds of pasteurized eggs.

At the start of the desugaring process one-third of the total amount of hydrogen peroxide was added to eggs followed by the addition of the entire amount of enzyme preparation. The remainder of the hydrogen peroxide was added in equal aliquots at intervals of 15 minutes until the removal of glucose was completed.

The determination of glucose present in liquid whole eggs was accomplished by the use of the Somogyi Method. This method is adequate for routine analyses of egg samples, but very time consuming for the efficient preparation of freeze dried scrambled eggs. A more rapid method to detect the presence of glucose was needed in order to begin the cooking process immediately after glucose removal. The use of Clinistix and Peroystyx reagent strips in conjunction with the Somogyi Method revealed that the reagent strips could be employed as a rapid method (about 20 seconds) for a qualitative glucose determination.

A study to evaluate the following factors influencing the rate of glucose removal was carried out.

1. Interaction of enzyme and hydrogen peroxide levels.
2. Level of pH.

3. Higher incubation temperatures.

4. Levels of enzyme and hydrogen peroxide.

5. Additional catalase.

6. Crystalline enzymes

Nine cases of Grade B shell eggs were shelled, hashed and pasteurized. The pH of the pasteurized eggs was adjusted to 7.2 and 7.7. Samples weighing 500 grams were placed in quart jars and immediately placed in a freezer.

For each experiment the required number of jars were removed from the freezer and the contents thawed in running tap water. The jars were then placed in a constant temperature water bath, and with continuous agitation the eggs were allowed to reach the temperature desired for the desugaring process. At various times during the desugaring process, samples of eggs weighing 5 grams were placed into bottles containing barium hydroxide to stop the enzymatic action. These samples were refrigerated until analyzed for glucose content by the Somogyi Method.

Preparation Of Cooked Scrambled Eggs

The following formula was used for the scrambled egg mixture.

	Percent in Weight
Fresh or frozen pasteurized, deglucosed eggs	75.00
Water at a temperature of 130 - 140°F.	24.61
Salt dissolved in the water	0.39
	100.00

The types of salt and water were those as specified in LP/P DES C-203-63, 1 February, 1963.

In the second phase of this study the salt was deleted and the remainder of the formulation was made up with water. Also, the amount of water in the formula was varied to determine the effects upon aroma, flavor and texture of freeze dried scrambled eggs prepared from the modified egg mixtures.

The egg mixtures were slowly heated with constant mechanical agitation in a water bath or a hot water jacketed kettle until the temperature reached a range of 160 - 162°F., the rise in temperature not exceeding 10°F. per minute. At this temperature a custard-like coagulum formed indicating the completion of the cooking process. The cooked egg mixture was quickly poured into stainless steel drying trays to a height of 1/2 inch and placed in a plate freezer having a temperature of -30°F.

Because of the important role played by the temperature and time in the cooking process, these factors were studied to establish the time rate required and the critical temperature range.

Freeze Drying Of Eggs

The frozen cooked egg mixtures were dried in a laboratory scale freeze dryer having a capacity of approximately 12 square feet. The trays of frozen eggs were weighed and placed into the drying chamber. During the drying cycle the maximum platen temperature was 110°F. and pressures of less than 100 microns were maintained. The time required for the drying cycle was 18 - 20 hours. At the termination of the drying process the moisture content of the eggs was less than 2%. The finished product was packaged in both cans and pouches, which were randomly selected for chemical and bacteriological analyses. The packaged freeze dried scrambled eggs were held at 40°F. until each shipment of shell eggs was processed.

In an attempt to improve the quality of freeze dried scrambled eggs, trays of liquid cooked scrambled eggs were also dried.

Storage Tests

The storage tests were designed to evaluate the effect of the following factors on the quality of freeze dried scrambled eggs:

1. Egg source
2. Egg grade
3. Time and temperature
4. Package
5. Headspace oxygen

Phase I The freeze dried scrambled eggs, representing the 54 cases of eggs received during the 1963 summer and 1964 winter seasons, were packaged in heavy plate 300 x 407 cans under 28 inches of vacuum held for 30 seconds before sealing. The headspace oxygen level in each can was less than 2%.

Half of the canned samples of freeze-dried scrambled eggs, which represented Grade A and Grade B shell eggs and Table Type frozen eggs from each of the 6 sources, was stored at 40°F. and the other half at 100°F.

Each sample was evaluated for aroma, flavor and texture by a trained panel of judges at the 0, 3, and 6 month storage time.

Phase II - In this phase of the project freeze dried scrambled eggs were prepared from government inspected Grade A and Grade B shell eggs purchased from a source located in Sauk Center, Minnesota.

The freeze dried scrambled eggs were packaged in heavy plate 300 x 407 cans and 6 x 6-1/2 inch pouches (0.5 mil mylar, 35 gauge foil and 3 mil polyolefin). Some of each type of package contained a headspace oxygen level of less than 2% and others a level of approximately 5%. The two types of packaged freeze dried scrambled eggs were stored at 40°F., 70°F., and 100°F. for a period of 6 months.

The same panel of judges, involved in the storage tests of the first part of this study, again evaluated each sample for aroma, flavor and texture at the 0, 3, and 6 month storage periods.

Evaluation Of Freeze Dried Scrambled Eggs

A panel of 8 judges was trained to evaluate the aroma, flavor and texture of freeze dried scrambled eggs using a 1-10 qualitative scale. A sample of cooked scrambled eggs prepared from fresh frozen eggs, all from the same lot, was served as an open reference before each panel session. After scoring the reference sample the judges were presented with unknown samples of freeze dried scrambled eggs. The judges were instructed to evaluate aroma and flavor for mildness; scoring higher on the scale for more mildness and lower on the scale for strong or "foreign" (fishy, cheese-like) aroma and flavor. Similarly, texture (mouth-feel) approaching that of the reference was scored high on the scale.

The evaluation of each sample of freeze dried scrambled eggs was replicated in a second panel session. All of the panel data was subjected to a statistical analysis.

Analyses Of Egg Samples And Methods

Liquid and frozen whole eggs

1. **Solids** — **A.O.A.C.**
2. **pH** — **A.O.A.C.**
3. **Acidity of ether extract** — **A.O.A.C.**
4. **Free ammonia** — **A.O.A.C.**
5. **Free amino acids** (1)
6. **Total plate count - Standard Plate Total Bacterial Count.**
7. **Coliform - Standard Plate Coliform Presumptive Count.**

8. Salmonella - Determination Of Salmonella In Foods - Modified Canadian Method.

9. Mold & Yeast - Standard Plate Mold and Yeast Count.

10. Direct Count - Direct Microscopic Bacteria Count.

(1) Method I - Analyses By Deproteination With Picric Acid And In Exchange Chromotography.

Method II - Analyses By Ninhydrin - CO_2 - Titration Method On Whole Eggs.

Freeze Dried Scrambled Eggs

1.	Moisture	A.O.A.C.
2.	Salt	A.O.A.C.
3.	Glucose	A.O.A.C.

4. Oxygen in headspace - Beckman oxygen headspace analyses.

5. Total plate count - Same as for liquid and frozen eggs.

6. Coliform - Same as for liquid and frozen eggs.

7. Salmonella - Same as for liquid and frozen eggs.

8. Mold and Yeast - Same as for liquid and frozen eggs.

In the second part of this study analyses for free ammonia, free amino acids, salmonella and direct count were eliminated.

All of the bacteriological analyses were performed with methods used by Swift & Company Research and Development Center.

RESULTS

Egg Source And Quality

Grading results of the 3 shipments of shell eggs received from each of the 6 major egg producing areas in the United States are summarized in Table I. The data indicates that 53 of the 54 cases of shell eggs used for the preparation of freeze dried scrambled eggs were in compliance with grade requirements. The one case of shell egg which did not fulfill grade requirements was the first shipment of Grade A shell eggs received from Fresno, California. Upon regrading, this case of shell eggs contained 53.6% Grade A eggs and 40.8% Grade B eggs.

Due to long distance transportation the number of checks and leakers was higher than normally expected. The presence of inedibles in the graded eggs was probably due to human handling during grading at the source.

The mean holding time at 40°F. for the 54 cases of shell eggs prior to regrading was 4.4 days, the range being 0 to 12 days.

Analysis Of Eggs

Data accumulated from the chemical and bacteriological analyses of liquid whole eggs and freeze dried scrambled eggs are summarized in Tables II through XII. The results of the analyses provide a comprehensive picture of the raw material and its end product; and also reveal the effectiveness of the processing techniques employed to maintain the quality of the egg products involved in this study.

A study of the data disclosed that there was no correlation between the analytical results obtained from the raw material and quality of freeze dried scrambled eggs. Variations in the analytical data were similar regardless of the source or grade of eggs.

One of the interesting aspects of the chemical data was the variation in the acidity of ether extract of shell eggs received during the month of February. The data shown in Table III point out that the ether extract acidity of these eggs was significantly lower than those of eggs received during July, August, and April. It was also found that the acidity of ether extract of shell eggs received during April was significantly increased when held in storage at 40°F. for a period of one week. As the storage time increased so did the ether extract acidity increase. The average ether extract acidity of eggs stored at 40°F. for one week was 1.02% compared to that of 2.12% for eggs held 10 - 11 weeks. However, this range in acidity of ether extract had no apparent bearing on the quality of freeze dried scrambled eggs as determined by panel evaluation.

An examination of the bacteriological data shown in Tables VIII and X will reveal that the total plate count of 23 of the 51 samples exceeded the value specified for the grade of egg. Of the 23 samples, 17 represented Grade B shell eggs. Eight of the egg samples had excessive coliform counts; of these, 7 represented Grade B shell eggs. These results indicate that at a storage temperature of 40°F., the Grade B shell eggs deteriorated more rapidly than did that of Grade A shell eggs.

As was the case with the chemical data, there was an absence of correlation between bacteriological data and quality of freeze dried eggs.

Processing Equipment For Liquid Whole Eggs

The processing equipment necessary for pasteurizing, desugaring and cooking whole eggs is shown in Figure 6. The arrangement of the equipment is a suggested plan for commercial production.

All of the equipment coming in contact with the egg must be constructed of stainless steel. The size of the equipment is dependent on the daily volume of eggs to be processed. The capacity of each desugaring and cooking vat should be such that it would hold the total amount of liquid whole eggs pasteurized in one hour by the heat exchanger unit plus the volume of water required for the cooking process.

The vats are of the jacketed type insulated to prevent heat loss and are equipped with a single or double blade agitator which is activated by an electric motor mounted at the top of the unit. Heat required for both the desugaring and cooking processes is supplied by circulating hot water stored in the larger water tank. The most important feature of the vat is to have adequate surface area in contact with the eggs to provide enough heat transfer to cook the pasteurized and desugared eggs in less than one hour. Prolonged heating will affect the quality of freeze dried scrambled eggs produced from the cooked eggs. Based on data obtained from this study a contact surface area of approximately 16 square inches per pound of eggs was required to cook the eggs in one-half hour.

Both of the water tanks shown in Figure 6 should be covered and completely insulated to minimize the variation in temperature between the water and the eggs heated by the water. The temperature of the water in the smaller tank should not exceed 148°F. An automatic cut-off valve shuts off the flow of steam when this water temperature is reached. The hot water in this tank supplies the heat necessary to pasteurize the eggs as they pass through the heat exchanger. In the larger tank the water temperature should remain below 170°F. and should also be controlled by an automatic steam cut-off valve. The hot water in this tank serves as the source of heat needed in the desugaring and cooking processes.

The temperature of each phase of the processing line should be constantly checked. This can be done with the use of two recorders located as shown in Figure 6. The recorder at the right is connected to the raw liquid egg storage tank, both ends of the holding tube and to the smaller water tank, while the recorder at the left checks the temperature of the eggs in each of the four desugaring and cooking vats and the temperature of the water in the larger tank.

Processing Of Liquid Whole Eggs

Raw liquid whole eggs are passed through a high-speed egg hasher and collected in the storage tank shown at the bottom in Figure 6. The temperature of the hashed eggs should remain below 50°F. The raw eggs are pumped from the storage tank to the heat exchanger unit where the eggs are heated to a temperature of 140 - 142°F. by using circulating hot water stored in the smaller tank.

The heated eggs then flow into the insulated holding pipe system where the temperature of the eggs remains at 140 - 142°F. for 3 to 4 minutes to complete the pasteurization process. If the temperature drops below 140°F. where the eggs reach the end of the holding pipe system, the diversion valve automatically opens and the eggs flow back into the storage tank. However, if the egg temperature does not drop below 140°F., they pass through the middle section of the heat exchanger to preheat the cold raw liquid eggs that have been pumped into this section. Following this step, the pasteurized eggs flow into the first desugaring and cooking vat. After one hour the flow of pasteurized eggs is diverted to the second vat and the desugaring process can be started in the first vat. At the end of the second hour the flow of pasteurized eggs is routed to the third vat, desugaring can be started in the second vat and the cooking process is begun in the first vat. At time intervals of one hour these procedures can be repeated in their proper order until all of the eggs in the four vats have been desugared and cooked. Therefore, by using the system of vats shown in Figure 6, it is possible to continuously pasteurize eggs and carry out the separate desugaring and cooking processes in each vat.

The processed eggs are drawn from the vats through valves located near the bottom of the vat and poured into drying trays to a height not exceeding one-half inch. The trays are frozen in a conveyor type freezer system and stored at -10°F. until dehydrated.

Desugaring Process

The rate and degree of glucose removal from liquid whole eggs are influenced by many factors, one of which is the method of adding hydrogen peroxide during the desugaring process. The data shown in Tables V and VII reveals that the glucose content of freeze dried scrambled eggs prepared in Phase II was significantly lower than that of similar eggs prepared in Phase I. In Phase II the hydrogen peroxide was added to the eggs at a point below the surface; whereas, in Phase I it was dripped onto the surface of the eggs.

The results of the study to determine which conditions and interactions play a significant role in the desugaring process are as follows:

A. Initial Experimentation

The conditions studied were pH (6.8 and 7.2), incubation temperature (85°F. and 110°F), methods of enzyme addition (lump, slow and fast log decreasing), methods of hydrogen peroxide addition (standard increments and log decreasing) and Ovazyme level (0.33 ml. and 0.66 ml. per 500 grams of eggs). The 0.33 ml. and 0.66 ml. levels of Ovazyme were accompanied by either 20 ml. or 40 ml. of 3% hydrogen peroxide, respectively, per 500 grams of eggs. The 0.33 ml. level of Ovazyme is equivalent to the recommended level of 300 ml. per 1,000 pounds of liquid whole eggs,

and the 20 ml. level of 3% hydrogen peroxide is equivalent to the recommended level of 0.4%. The response was measured as the percent of glucose remaining in solution at 0, 30, 60, 120, and 180 minutes for each treatment combination.

A preliminary screening of 23 variables and interactions led to a prediction model with 14 variables and interactions. The prediction model showed that the level of enzyme, the time of sampling and the following interactions were significant variables: (time)(enzyme level); (temperature)(enzyme level) and (time)(method of enzyme addition). The optimum conditions of those studied were the high enzyme level, the high temperature, the lump addition of enzyme and a long time. The statistical analysis indicated that the predicted time to desugar liquid whole eggs to the 0.008% glucose level (0.03% on a dry basis) with the above optimum conditions would be 2 hours and 35 minutes. This time, of course, includes the variation.

A typical curve of two conditions of enzyme and hydrogen peroxide levels may be seen in Figure 1. The results plotted in Curve 2 indicate that by using .66 ml. of Ovazyme and 40 ml. of 3% hydrogen peroxide at a temperature of 110°F. and pH of 7.2 the level of glucose was reduced to 0.008% in 2 hours. As it is known that during the early stages of enzymatic reaction the reaction proceeds logarithmically, the data are plotted on semi-logarithmic paper. Also it was necessary to plot the data on this type of paper to indicate the magnitude of changes desired at the very low levels (below 0.01%) of glucose.

B. Interaction Of Enzyme And Hydrogen Peroxide Levels

The objective of the second series of experiments was to investigate the possible interaction of the levels of hydrogen peroxide on the levels of Ovazyme. A 23 fractorial design was used with two replications. The hydrogen peroxide levels were 20 ml. and 40 ml. of a 3% solution per 500 grams of eggs and the Ovazyme levels were 0.33 ml. and 0.66 ml. per 500 grams of eggs. The two methods of adding hydrogen peroxide were equal increments and log decreasing. The response was measured as percent glucose remaining at 0, 15, 30, 45, 60, 90, 120, 150, and 180 minutes, respectively. An analysis of variance was carried out for each time period.

The analysis showed that the higher Ovazyme level gave very significant increases in activity for all times except for 30 minutes. The higher level of hydroger peroxide gave significant increases in activity during the 45 to 120 minute period. The log decreasing method of addition showed increased activity over the 45 to 90 minute readings. None of the interactions, except the hydrogen peroxide by method of audition, showed significance. This interaction showed significance over the 45 to 180 minute range. Thus, this series of experiments demonstrated that the level of Ovazyme, the level of hydrogen peroxide and the method of hydrogen peroxide addition were important for the most rapid desugaring.

C. Effect of pH 7.7

The initial series of experiments indicated that there was no difference in the rate of desugaring at either pH 6.8 or 7.2. However, it is known from the literature that as the alkalinity of eggs increases, the rate of desugaring decreases. Thus, a series of experiments were carried out with eggs whose pH had been adjusted to 7.7. The results of these experiments can be seen in Figure 2.

These results pointed out that even with the higher levels of Ovazyme and hydrogen peroxide the desugaring rate is much slower and at the end of 3 hours did not reach the desired glucose level of 0.008%. It is evident from these data that the pH of the eggs did become an important factor at a point somewhere between 7.2 and 7.7. This indicated that some of the difficulty that had been encountered during the interaction study might have been due to a shift in the pH of the eggs. The pH of the egg solutions was checked, and the pH of these supposedly at 7.2 was found to be approximately 7.5-7.6. A readjustment of the pH of these eggs immediately prior to beginning the experiments caused the glucose level to reach the desired range. The results of these experiments may be seen in Figure 3. Curve 1 is typical of those obtained with eggs whose pH was approximately 7.5. Lowering the pH of these eggs to 7.2 yielded Curve 2. It might be noted that at 150 minutes the level of glucose on Curve 2 appears to have increased from the value at 120 minutes. However, the variation in the glucose analysis is $\pm$ 0.003%; and this change, due to experimental error, is not significant.

D. Effect of 140°F. On Desugaring Process

In an attempt to combine the desugaring and cooking processes employed in the production of freeze dehydrated scrambled eggs a short series of experiments was performed to determine the effect of a temperature of 140°F. on the rate and degree of glucose removal from liquid whole eggs.

The results of this work are shown in Figure 4. These curves indicate that this high temperature had a very pronounced deleterious effect on the desugaring process and would require very high uneconomical levels of Ovazyme to drive the interaction, if at all possible, to completion. Therefore, a temperature of 140°F. becomes impractical in the desugaring process.

E. Effect Of 120°F. And Higher Levels Of Ovazyme And Hydrogen Peroxide

The previous results with 140°F. led to a series of experiments to investigate the effect of a temperature greater than 110°F. and higher Ovazyme and hydrogen peroxide levels on the desugaring rate. A 2x2x2 factorial design was used with two replications. The treatments were; temperature (110°F. and 120°F.), Ovazyme level (0.66 and 1.00 ml. per 500 g. of eggs) and hydrogen peroxide level (40 and 60 ml. per 500 g. of eggs). The pH was 7.2. The responses were measured at 0, 30, 60, 90, 120, and 150 minutes of incubation.

An analysis of the data showed that significant differences in treatments existed only at 30 and 60 minutes. The higher temperature had a negative effect on the desugaring rate, the higher Ovazyme a positive effect and interaction was present between the Ovazyme level and the temperature. These results indicated that increasing the temperature to 120°F. and utilizing higher levels of Ovazyme would not have a positive effect on the desugaring rate. However, it appears that higher levels of Ovazyme and hydrogen peroxide would increase the rate of glucose removal.

F. The Effect Of Additional Catalase

These experiments were performed to determine if the addition of more catalase and thus the production of more oxygen would have an effect on the Ovazyme - hydrogen peroxide system. Other factors considered were levels of Ovazyme and hydrogen peroxide. The catalase used was beef liver catalase which has a different effect on the production of oxygen than does fungal catalase. Beef liver catalase instantaneously decomposes all of the hydrogen peroxide while the fungal catalase decomposes hydrogen peroxide at a much slower rate. The constants in these experiments were: pH (7.2); temperature (110°F.); the lump addition of Ovazyme and the log addition of hydrogen peroxide. The variables were: level of Ovazyme (0.33 and 0.66 ml. per 500 g. of eggs); hydrogen peroxide (20 and 40 ml. per 500 g. of eggs); and beef liver catalase levels (activity added was equal to 50% and 100% of the fungal catalase activity that was in the added Ovazyme).

The analysis of the data showed that after 30 minutes increasing the level of Ovazyme was the only factor that had any significant effect on lowering the level of glucose in the eggs. These results indicated that the level of glucose oxidase in the Ovazyme had the major effect on the rate of glucose removal. It might be noted that the hydrogen peroxide level was close to significance.

G. Studies Utilizing Crystalline Glucose Oxidase And Catalase In Lieu Of Ovazyme

The data obtained from the previous experiments led to the acquisition of crystalline glucose oxidase and fungal catalase for the purpose of studying the effect of various levels of these enzymes and hydrogen peroxide on the rate of glucose removal from eggs. For this series of experiments the constant conditions were: temperature (110°F.); pH (7.2); lump addition of glucose oxidase and catalase; and a two hour logarithmic addition of hydrogen peroxide. The response was measured as percent of glucose remaining after 0, 30, 60, 90, 120, and 150 minutes. Two replications of each of the variables. These were: glucose oxidase (0.5, 1.0, and 1.5 units of activity per gram of egg); fungal catalase (0.33, 0.66, and 1.0 unit per gram of egg); and hydrogen peroxide (20, 40, and 60 ml. of a 3% solution per 500 grams of eggs). The activity of the enzymes was used in order to relate the levels to the level of activity of each enzyme in Ovazyme.

The results of this series of experiments can be seen in Figure 5. The statistical analysis of the data revealed that the glucose oxidase and hydrogen peroxide levels had

a significant effect in lowering glucose levels. The levels of catalase did not significantly affect glucose level over the ranges studied. Some interactions were significant at the 60 minute time, but interpretation was difficult because the replication effect was also significant at this point. At each time period the highest level of both the glucose oxidase and hydrogen peroxide yielded the best desugaring rates. Thus, it can be seen from the curves in Figure 5 that 1.0 to 1.5 units of glucose oxidase and 20 to 40 ml. of hydrogen peroxide produced the best rates. The effect of the level of catalase, as mentioned, was not significant.

Based on the findings of this study the following conditions are recommended for the most rapid desugaring of liquid whole eggs for the production of freeze dried scrambled eggs.

1. Incubation temperature: 110°F. with the range of 105 to 112°F.

2. Level of Ovazyme: 600 ml. per 1000 pounds of liquid whole eggs to be added at the beginning of the process.

3. Level of hydrogen peroxide: 0.8% of weight of eggs. U. S. Pharmacopoeia grade (30%).

4. Method of hydrogen peroxide addition: either the log decreasing or the continuous method should be used. This would call for 60% of the total amount to be added at the start of the process and the remainder to be added by using either the log decreasing or the continuous method.

5. Desugaring time: 2 hours.

Cooking Process - Time and Temperature

At the start of the cooking process, the temperature of the eggs ranged from 115°F. to 130°F. and that of the water bath was 150°F. to 168°F. The temperature of the eggs reached 155°F. within 13 minutes. At this point the eggs thicken and cause the surface to become wavy. At 156°F. a golden colored ring formed around the edge of the surface foam. Between 157°F. and 159°F. the foam began to rise and recede toward the stirrer. The critical temperature range in the cooking process was 160°F. to 162°F. In this temperature range a custard-like coagulum formed and the cooking process was completed.

The temperature of the water bath did not exceed 168°F. Cooking time for the 5 samples of eggs varied from 19 to 24 minutes with the average time being 22 minutes.

Details of the eggs and temperatures of both the eggs and water bath are shown in Figure 7.

Scrambled Egg Formula

A study was carried out to determine the effects of reducing the amount of water added to desugared eggs prior to cooking on the aroma, flavor and texture of freeze dried scrambled eggs. The treatments and the drying yields are shown below:

Treatments	Eggs	Water	Yield
1	100%	0%	26.4%
2	95	5	25.2
3	90	10	23.4
4	85	15	22.5
5	80	20	21.0
6*	75	25	20.1

*Current Formula

The criteria for the evaluation of four of the freeze-dried scrambled egg samples were appearance, aroma, flavor and texture. Three replicate panels were held and the average mean scores are given below:

	95% C.L.	Egg: Water 100:0	90:10	80:20	75:25
Appearance*	± .13	3.68	3.93	3.88	3.63
Aroma	± .34	7.24	7.10	7.31	7.09
Flavor	± .33	6.84	6.72	6.86	6.71
Texture	± .62	5.33	5.64	5.94	5.81

*On a 1 = not acceptable, 5 = acceptable scale. All others on a 1 = repulsive, 10 = excellent scale.

Statistical analysis of the scores revealed there are no significant formulation effects on aroma, flavor or texture. There did appear to be a significant (90%) effect on appearance. The 90:10 and 80:20 samples looked more acceptable than the 100:0 and the 75:25 samples.

The drying cycle for treatment 3 was 2 hours shorter than that of treatment 6, or 19-1/2 hours and 21 1/2 hours respectively. The estimated drying cycle for the other treatments were: #1 - 18 hours, #2 - 18-3/4 hours, #4 - 20 hours and 7 minutes and #5 - 20-3/4 hours.

The shortening of the drying cycle and the increase in yield would significantly affect the production cost of freeze dried scrambled eggs.

Dehydration Of Unfrozen Cooked Scrambled Eggs

The attempt to dehydrate unfrozen cooked scrambled eggs to determine the effect of freezing on the quality of freeze dried scrambled eggs was unsuccessful. As the vacuum reading in the drying chamber reached a level of 4000 microns the eggs puffed and overflowed the sides of the drying trays. The dried portions of the trays were too fluffy and fragile to make this process feasible.

Rehydration Of Freeze Dried Scrambled Eggs

The procedure used for the rehydration of stored samples of freeze dried scrambled eggs consisted of placing 2 ounces of dried product in a glass bowl and pouring 6 ounces of water (180 - 212°F.) over the eggs. A fork was used to insure complete contact of eggs and water to complete rehydration in 2 minutes.

With this method of adding water, and as described in LP/P. DES C-202-63, 5 March 1963, the freeze dried scrambled eggs are subjected to a wide variation in temperature during rehydration. Immediately, after water addition, the temperature of the product is about 160°F. This rapid heat loss subjected part of the dried eggs to a high temperature and part to a lower temperature, thus resulting in a lack of uniformity in texture. Dried eggs rehydrated at a high temperature tended to be rubbery and those rehydrated at lower temperatures were mushy.

A study investigating the temperature - texture correlation indicated that the texture of rehydrated freeze dried scrambled eggs can be significantly improved by adding the dried eggs to hot water in a warmed bowl. In this way the water heat loss is greatly reduced and the variation in temperature to which the eggs are subjected is minimized.

Storage Tests

The mean scores for the quality criteria of freeze dried scrambled eggs studied in the storage tests are shown in Tables XIII, XIV, and XV and plotted in Figures 8, 9, 10, and 11.

Statistical analyses of the data obtained from the storage tests revealed the following:

1. The geographical source of raw material had no significant effects on the quality of freeze dried scrambled eggs.

2. The quality of freeze dried scrambled eggs prepared from frozen eggs was significantly poorer than those prepared from Grade A and Grade B shell eggs. There were no significant differences in quality of freeze dried scrambled eggs prepared from Grade A and Grade B shell eggs.

3. Aroma and flavor of freeze dried scrambled eggs appear to be affected by time and temperature, the quality (defined as "mildness") decreased with an increase in these variables.

   A secondary factor influencing the aroma and flavor of freeze dried scrambled eggs was the type of eggs used to prepare the dried product. Scores for freeze dried scrambled eggs processed from frozen eggs fell consistently lower than those for the aroma and flavor of dried product prepared from Grade A and Grade B shell eggs.

   In the storage test, which involved summer eggs the rise in scores (Figures 8 and 9) after 6 months storage over those after 3 months storage (100°F.) is not readily understood. Since the stored product could not have improved with an increase in storage time, it might be assumed that the 3 month scores reflected the panel initial reaction to the product change, and the 6 month scores reflected panel acclimation to the change. This reaction was not observed in the subsequent evaluations of stored products (Figures 10 and 11).

4. The type of package greatly affected the appearance and texture of freeze dried scrambled eggs. The canned product possessed a better egg appearance and texture than the pouched product, but both were rated low because they lacked the continuity and curd of a typical fresh scrambled egg.

5. The different levels of headspace oxygen in both types of packaging had no effects on the quality of freeze dried scrambled eggs in any of the studies except one, which was probably due to package effect.

CONCLUSIONS

It is evident from the data collected from this study that the organoleptic characteristics of freeze dried scrambled eggs, as processed under the conditions mentioned in this report, were not comparable to those of scrambled eggs prepared from fresh frozen eggs. Throughout the many panel sessions held for the evaluation of stored freeze dried scrambled eggs the mean score for the reference sample was 8.0 for aroma, flavor and texture. Although the stored freeze dried eggs samples had mean scores which were lower than those of the reference for quality criteria, many of them could be classified as acceptable.

The mean scores for the aroma, flavor and, particularly, texture could have been higher by using the revised method for rehydration. Unfortunately, due to late time of the rehydration study, its use would have introduced a new variable in the last storage test that was already in progress.

Another important factor found to affect the quality of freeze dried scrambled eggs is overcooking. When liquid eggs are heated beyond the critical temperature of 162°F. or held at that temperature for periods extending beyond 25 minutes the quality, especially texture, of freeze dried scrambled eggs becomes poorer.

The raw material necessary for the production of freeze dried scrambled eggs should consist of either Grade A or Grade B shell eggs and may be obtained from any geographical location. The shell eggs should comply with the standards described in the publication mentioned in this report. Although no correlation was found between the analyses of the raw material and the quality of freeze dried scrambled eggs, they should meet the following requirements:

Liquid Whole Eggs

Total plate count, not more than	100,000 per gram
Coliform, less than	10 " "
Salmonella, less than	0.03 " "
Yeast and molds, less than	10 " "
Direct count, less than	500,000 " "
Egg solids, not less than	25.5%
pH, within the range of	7.2 - 7.8
Acidity of ether extract, not more than	1.5%

Freeze Dried Scrambled Eggs

Total plate count, not more than	1,000 per gram
Coliform, less than	10 " "
Salmonella, less than	0.03 " "
Yeast and molds, less than	10 " "
Moisture, not more than	1.5%
Salt, not more than	3.5%
Headspace oxygen, not more than	2.0%
Glucose, not more than	0.03%

The equipment and processes described in this report could be employed for the commercial production of freeze dried scrambled eggs. The production cost of the dried product can be minimized by: (1) utilization of modified formula for the scrambled egg mixture to increase the yield of dry product and decrease the drying cycle time, (2) use of Grade B shell eggs as the raw material, and (3) the efficient application of the various processing techniques described herein.

TABLE I.

MEAN SUMMARY - REGRADING AND WEIGHTS OF SHELL EGGS

Source	Purchase Grade	Net Wt/ Case lbs.	A %	B %	C %	CH %	L %	Inedibles %
Salina, Kansas	A	48.7	94.4	3.7	0.1	0.5	1.3	
	B	50.0	3.6	89.9	2.4	1.4	2.4	0.3
Sauk Center, Minnesota	A	48.5	97.1	2.1	0.1	0.7		
	B	50.2	4.9	93.4	0.05	1.1	0.4	0.05
Harrisonburg, Virginia	A	47.3	95.5	2.2		1.9	0.4	
	B	50.5	3.8	89.3	0.5	2.5	3.0	0.9
Douglas, Georgia	A	47.5	93.0	5.7		1.0	0.3	
	B	49.2	2.8	90.6	1.0	2.9	2.6	
Brownwood, Texas	A	48.1	90.4	4.0	0.1	3.3	2.1	0.1
	B	49.2	4.7	87.8	1.8	2.2	3.5	
Fresno, California	A*	46.8	79.2	18.0		1.1	1.7	
	B	49.3	4.5	91.2	0.3	2.0	2.0	

* First shipment of winter eggs contained 53.6% Grade A and 40.8% Grade B shell eggs.

TABLE II.

MEAN SUMMARY - CHEMICAL ANALYSES OF LIQUID WHOLE EGGS - PHASE I

Source	Egg Grade	Solids %	pH	Acidity of Ether Extract %	Free Ammonia mg/100gm.(1)
Salina, Kansas	A	26.3	7.5	1.17	1.5
	B	26.1	7.5	1.52	1.8
Sauk Center, Minnesota	A	25.3	7.4	1.68	2.1
	B	25.9	7.3	1.90	2.2
Harrisonburg, Virginia	A	25.8	7.6	1.73	2.3
	B	25.9	7.5	1.65	2.5
Douglas, Georgia	A	25.4	7.5	1.32	1.8
	B	25.7	7.7	1.49	1.8
Brownwood, Texas	A	25.6	7.5	1.67	2.0
	B	25.5	7.5	1.66	2.0
Fresno, California	A	25.8	7.5	1.47	2.1
	B	25.9	7.5	1.67	2.1

(1) Summer eggs only

TABLE III.

MEAN SUMMARY - CHEMICAL ANALYSES OF RAW LIQUID WHOLE EGGS BASED ON EGG PRODUCTION SEASON - PHASE I

Season	Solids %	pH	Acidity ml. of 0.05N Sodium Ethylate per ml. of Ether Extract %
Summer July & August	25.2	7.5	1.79
Winter February	25.3	7.5	0.73
Winter April	25.6	7.5	1.77

TABLE IV.

MEAN SUMMARY - CHEMICAL ANALYSES OF FROZEN EGGS - PHASE I

Source	Egg Grade	Sample	Solids %	pH	Acidity of Ether Extract %	Free Ammonia mg/100 gm.(1)
Salina, Kansas	B	Raw	26.2	7.5	1.74	2.1
		Pasteurized	25.3	7.6	1.35	2.4
		Frozen	23.6	8.0	1.65	2.4
		Thawed	25.3	7.3	1.70	2.7
		Repasteurized(1)	25.1	7.5	1.60	2.4
Sauk Center, Minnesota	B	Raw	25.9	7.3	1.71	1.8
		Pasteurized	25.2	7.6	1.32	2.1
		Frozen	24.3	8.1	1.83	2.4
		Thawed	25.1	7.6	2.07	2.4
		Repasteurized(1)	24.9	7.2	2.20	2.4
Harrisonburg, Virginia	B	Raw	26.1	7.7	1.43	2.1
		Pasteurized	25.0	7.6	1.43	2.1
		Frozen	23.8	7.9	1.83	2.4
		Thawed	25.1	7.5	1.73	2.4
		Repasteurized(1)	24.7	7.2	1.87	2.4
Douglas, Georgia	B	Raw	26.2	7.3	1.70	-
		Pasteurized	25.8	7.6	1.80	-
		Frozen	23.9	7.8	2.00	2.4
		Thawed	25.2	7.4	1.40	2.4
		Repasteurized(1)	25.0	7.4	1.60	2.4
Brownwood, Texas	B	Raw	25.3	7.5	1.72	2.4
		Pasteurized	24.2	7.5	1.91	1.5
		Frozen	22.2	7.8	1.63	1.8
		Thawed	25.1	7.4	1.78	2.4
		Repasteurized(1)	24.5	7.4	1.80	2.4
Fresno, California	B	Raw	25.4	7.5	1.74	1.8
		Pasteurized	24.5	7.7	1.56	2.4
		Frozen	24.0	7.9	1.87	2.4
		Thawed	23.9	7.6	2.01	1.8
		Repasteurized(1)	24.6	7.2	1.66	1.8

(1) Summer Eggs Only

TABLE V.

MEAN SUMMARY - CHEMICAL ANALYSES OF FREEZE DRIED EGGS - PHASE I

Source	Egg Grade	Moisture %	Salt %	Glucose %	Oxygen in Headspace %
Salina, Kansas	A	0.67	3.18	0.038	1.5
	B	0.48	3.17	0.064	1.6
Sauk Center, Minnesota	A	0.66	3.15	0.068	1.7
	B	0.75	3.13	0.045	1.4
Harrisonburg, Virginia	A	0.51	3.05	0.060	1.3
	B	0.69	3.20	0.042	1.4
Douglas, Georgia	A	0.62	3.28	0.047	1.4
	B	0.56	3.19	0.063	1.5
Brownwood, Texas	A	0.48	3.18	0.043	1.4
	B	0.55	3.15	0.056	1.4
Fresno, California	A	0.57	3.20	0.058	1.2
	B	0.51	3.16	0.066	1.5

TABLE VI.

CHEMICAL ANALYSES - LIQUID EGGS - PHASE II

Grade and Shipment	Sample	Solids %	Free Amino Acids Micromoles/gm.
B 1	Raw	25.2	25.7
	Pasteurized	25.0	27.5
	Desugared	25.0	19.6
B 3	Raw	27.0	25.9
	Pasteurized	25.3	26.8
	Desugared	25.4	17.9
B 5	Raw	25.7	27.0
	Pasteurized	25.5	26.5
A 1	Raw	24.2	12.5
	Pasteurized	24.9	13.1
	Desugared	25.0	11.1
A 2	Raw	24.3	19.6
	Pasteurized	24.0	19.3

TABLE VII.

CHEMICAL ANALYSES - FREEZE DRIED
SCRAMBLED EGGS - PHASE II

Grade and Shipment	Moisture %	Oxygen in Headspace Low Level %	Oxygen in Headspace High Level %	Glucose %
B 1	0.71	2.0	5.7	0.018
B 3	0.56	1.8	5.7	0.02
B 5	0.29	1.2	6.0	0.008
A 1	0.36	1.8	6.0	0.05
A 2	0.29	1.2	6.0	0.008

TABLE VIII.

BACTERIOLOGICAL ANALYSES OF RAW LIQUID WHOLE EGGS - PHASE I

Source	Egg Grade	Season	Total Plate count/gm.	Coliform /gm.	Salmonella /gm.	Mold /gm.	Yeast /gm.	Direct Count 1000/gm.
Salina, Kansas	A	Summer	7,700,000	1,300,000	∠.03	∠10	∠10	2,500,000
		Winter-1st ship.	90	∠10	∠.03	∠10	∠10	∠500
		" 2nd "	1,300	30	∠.03	∠10	∠10	20
	B	Summer	91,000	18,000	∠.03	∠10	∠10	200
		Winter-1st ship.	450	∠10	∠.03	∠10	∠10	1,600
		" 2nd "	1,600,000	∠10	∠.03	∠10	∠10	2,000
Sauk Center, Minn.	A	Summer	- - - - - - - - - - NO SAMPLE - - - - - - - - - -					
		Winter-1st ship.	350	∠10	∠.03	∠10	∠10	5,000
		" 2nd "	1,000	∠10	∠.03	∠10	∠10	∠500
	B	Summer	24,000,000	2,300,000	∠.03	∠10	∠10	3,000
		Winter-1st ship.	4,600,000	14,000	∠.03	∠10	∠10	5,000
		" 2nd "	2,300,000	∠10	∠.03	∠10	∠10	1,600
Harrisonburg, Va.	A	Summer	800	∠10	∠.03	20	∠10	800
		Winter-1st ship.	1,200	∠10	∠.03	∠10	∠10	∠500
		" 2nd "	1,000,000	∠10	∠.03	∠10	∠10	∠500
	B	Summer	18,000,000	1,000	∠.03	10	∠10	1,600
		Winter-1st ship.	4,300,000	∠10	∠.03	∠10	∠10	5,000
		" 2nd "	9,600,000	∠10	∠.03	10	∠10	200
Douglas, Georgia	A	Summer	- - - - - - - - - - NO SAMPLE - - - - - - - - - -					
		Winter-1st ship.	1,200	∠10	∠.03	∠10	∠10	∠500
		" 2nd "	2,000,000	∠10	∠.03	∠10	∠10	1,000
	B	Summer	2,000	∠10	∠.03	10	∠10	500
		Winter-1st ship.	14,000,000	∠10	.23*	∠10	∠10	1,200
		" 2nd "	10,000,000	∠10	∠.03	∠10	∠10	2,100

TABLE VIII CONTINUED

Source	Egg Grade	Season	Total Plate Count/gm.	Coliform /gm.	Salmonella /gm.	Mold /gm.	Yeast /gm.	Direct Count 1000/gm.
Brownwood, Texas	A	Summer	2,000	<10	<.03	<10	<10	800
		Winter-1st ship.	2,800,000	<10	<.03	<10	<10	400
		" 2nd "	8,500,000	<10	<.03	<10	<10	2,000
	B	Summer	4,100,000	31,000	<.03	40	10	600
		Winter-1st ship.	20	<10	<.03	10	<10	2,000
		" 2nd "	80	<10	<.03	<10	<10	<500
Fresno, California	A	Summer	840	<10	<.03	<10	<10	<500
		Winter-1st ship.	11,000,000	<10	<.03	<10	<10	1,000
		" 2nd "	7,000	<10	<.03	<10	<10	400
	B	Summer	- - - - - - - - - N O S A M P L E - - - - - - - - - - - -					
		Winter-1st ship.	40,000,000	<10	0.09	<10	<10	25,000
		" 2nd "	2,400,000	<10	<.03	30	<10	200

TABLE IX.

BACTERIOLOGICAL ANALYSES OF FREEZE DRIED EGGS - PHASE I

Source	Egg Grade	Season	Total Plate Count/gm.	Coliform /gm.	Salmonella /gm.	Mold /gm.	Yeast /gm.
Salina, Kansas	A	Summer	500	<10	<.03	40	<10
		Winter-1st ship.	10	<10	<.03	<10	<10
		" 2nd ship.	100	<10	<.03	<10	<10
	B	Summer	600	<10	<.03	<10	<10
		Winter-1st ship.	120	<10	<.03	<10	<10
		" 2nd "	250	<10	<.03	<10	<10
Sauk Center, Minnesota	A	Summer	50	<10	<.03	<10	<10
		Winter-1st ship.	100	<10	<.03	<10	<10
		" 2nd ship.	4,000	<10	<.03	<10	<10
	B	Summer	500	<10	<.03	80	<10
		Winter-1st ship.	50	<10	<.03	<10	<10
		" 2nd "	200	<10	<.03	<10	<10
Harrisonburg, Virginia	A	Summer	50	<10	<.03	10	<10
		Winter-1st ship.	<10	<10	<.03	<10	<10
		" 2nd "	200	<10	<.03	<10	<10
	B	Summer	400	<10	<.03	20	<10
		Winter-1st ship.	<10	<10	<.03	<10	<10
		" 2nd "	500	<10	<.03	10	<10
Douglas, Georgia	A	Summer	50	<10	<.03	10	<10
		Winter-1st ship.	31,000	50	<.03	<10	<10
		" 2nd "	200	<10	<.03	10	<10
	B	Summer	370	<10	<.03	<10	<10
		Winter-1st ship.	70	<10	<.03	<10	<10
		" 2nd "	100	<10	<.03	<10	<10

TABLE IX CONTINUED

Source	Egg Grade	Season	Total Plate Count/gm.	Coliform /gm.	Salmonella /gm.	Mold /gm.	Yeast /gm.
Brownwood, Texas	A	Summer	30	<10	<.03	10	<10
		Winter-1st ship.	200	<10	<.03	<10	<10
		" 2nd "	750	<10	<.03	<10	<10
	B	Summer	800	<10	<.03	30	<10
		Winter-1st ship.	8,000	<10	<.03	<10	<10
		" 2nd "	300	<10	<.03	<10	<10
Fresno, California	A	Summer	100	<10	<.03	<10	<10
		Winter-1st ship.	50	<10	<.03	<10	<10
		Winter-2nd ship.	<10	<10	<.03	10	<10
	B	Summer	1,000	<10	<.03	10	<10
		Winter-1st ship.	3,000	<10	<.03	<10	<10
		" 2nd "	<10	<10	<.03	30	<10

TABLE X.

BACTERIOLOGICAL ANALYSES OF SHELL EGGS
USED FOR PREPARING FROZEN EGGS - PHASE I

Source	Egg Grade	Season	Total Plate Count/gm.	Coliform /gm.	Salmonella /gm.	Mold /gm.	Yeast /gm.	Direct Count 1000/gm.
Salina, Kansas	B	Summer	14,000,000	4,700	.03	<10	<10	1,600
		Winter-1st ship.	<100	<10	<.03	10	<10	200
		" 2nd "	2,900,000	<10	<.03	<10	<10	200
Sauk Center, Minnesota	B	Summer	19,000,000	94,000	<.036	<10	<10	5,400
		Winter-1st ship.	140	90	<.03	<10	<10	<500
		" 2nd "	55,000	400	<.03	<10	<10	<500
Harrisonburg, Virginia	B	Summer	5,200	<10	<.03	<10	<10	1,000
		Winter-1st ship.	500	<10	<.03	<10	<10	<500
		" 2nd "	66,000	<10	<.03	<10	<10	<500
Douglas, Georgia	B	Summer	2,900	<10	<.03	<10	<10	1,000
		Winter-1st ship.	720	<10	<.03	<10	<10	<500
		" 2nd "	3,000,000	<10	<.03	<10	<10	<500
Brownwood, Texas	B	Summer	280	<10	<.03	<10	<10	14,450
		Winter-1st ship.	3,000	<10	<.03	<10	<10	<500
		" 2nd "	1,000	<10	<.03	<10	<10	<500
Fresno, California	B	Summer	160	<10	<.03	<10	<10	500
		Winter-1st ship.	2,000	<10	<.03	<10	<10	<500
		" 2nd "	3,600,000	<10	<.03	<10	<10	<500

TABLE XI

BACTERIOLOGICAL ANALYSES OF FREEZE DRIED EGG
PREPARED FROM FROZEN EGGS - PHASE I

Source	Egg Grade	Season	Total Plate Count/gm.	Coliform /gm.	Salmonella /gm.	Mold /gm.	Yeast /gm.
Saline, Kansas	B	Summer	20	<10	<.03	10	<10
		Winter-1st ship.	1,900	<10	<.03	<10	<10
		" 2nd "	6,000	<10	<.03	20	<10
Sauk Center, Minnesota	B	Summer	80	<10	<.03	<10	<10
		Winter-1st ship.	400	<10	<.03	<10	<10
		" 2nd "	5,000	<10	<.03	<10	<10
Harrisonburg, Virginia	B	Summer	4,000	<10	<.03	30	10
		Winter-1st ship.	200	<10	<.03	10	<10
		" 2nd "	15,000	<10	<.03	<10	<10
Douglas, Georgia	B	Summer	70	<10	<.03	<10	<10
		Winter-1st ship.	120	<10	<.03	<10	<10
		" 2nd "	50	<10	<.03	<10	<10
Brownwood, Texas	B	Summer	500	<10	<.03	10	<10
		Winter-1st ship.	160	<10	<.03	<10	<10
		" 2nd "	4,000	<10	<.03	<10	<10
Fresno, California	B	Summer	50	<10	<.03	<10	<10
		Winter-1st ship.	290	<10	<.03	<10	<10
		" 2nd "	1,000	<10	<.03	10	<10

TABLE XII.

BACTERIOLOGICAL ANALYSES - LIQUID AND FREEZE DEHYDRATED EGGS - PHASE II

Grade & Shipment	Sample	Total Plate Count/gm.	Coliform /gm.	Salmonella /gm.	Mold /gm.	Yeast /gm.	Direct Count 1000/gm
B 1	Raw	820,000	45,000	<.03	<10	<10	1,000
	Pasteurized	140	<10	<.03	<10	<10	<500
	Desugared	500	<10	<.03	<10	<10	<500
	Freeze Dried	250	<10	- -	<10	<10	- -
B 3	Raw	1,500,000	10	<.03	<10	50	5,500
	Pasteurized	190	<10	<.03	<10	<10	2,200
	Desugared	600	<10	<.03	<10	<10	4,000
	Freeze Dried	70	<10	- -	<10	<10	- -
B 5	Raw	150,000	30	<.03	50	<10	<500
	Pasteurized	20	10	<.03	<10	<10	<500
	Freeze Dried	<10	<10	- -	<10	<10	- -
A 1	Raw	350	<10	<.03	<10	<10	<500
	Pasteurized	300	<10	<.03	20	<10	<500
	Desugared	270	<10	<.03	<10	<10	<500
	Freeze Dried	4,000	<10	- -	<10	<10	- -
A 2	Raw	1,900	<10	<.03	<10	<10	<500
	Pasteurized	60	<10	<.03	<10	<10	<500
	Freeze Dried	<10	<10	- -	<10	<10	- -

TABLE XIII.

FREEZE DRIED SCRAMBLED EGGS STORAGE
TEST - 1963 SUMMER EGGS

Mean Panel Scores

FLAVOR

	0	3 months 40°F.	3 months 100°F.	6 months 40°F.	6 months 100°F.
Grade A Shell	7.11	6.82	5.31	6.41	5.86
Grade B Shell	6.80	6.67	5.44	6.21	6.05
Grade B Frozen	6.57	6.41	4.84	6.01	5.09
95% C.L.		±0.48		±0.80	

AROMA

	0	3 months 40°F.	3 months 100°F.	6 months 40°F.	6 months 100°F.
Grade A Shell	7.20	6.87	6.02	6.91	6.47
Grade B Shell	6.94	6.96	6.11	6.72	6.68
Grade B Frozen	7.19	6.77	5.74	6.53	5.89
95% C.L.		±0.36		±0.58	

TEXTURE

	0	3 months 40°F.	3 months 100°F.	6 months 40°F.	6 months 100°F.
Grade A Shell	6.30	6.22	5.70	5.95	5.69
Grade B Shell	6.28	6.34	5.48	6.13	5.95
Grade B Frozen	5.94	5.94	5.16	5.38	5.37
95% C.L.		±0.32		±0.60	

TABLE XIV.

FREEZE DRIED SCRAMBLED EGGS STORAGE TEST - 1964 WINTER EGGS

MEAN PANEL SCORES FOR BOTH SHIPMENTS

	FLAVOR				
		3 months		6 months	
	0	40°F.	100°F.	40°F.	100°F.
Grade A Shell	7.45	7.36	6.00	7.00	5.75
Grade B Shell	7.29	7.24	5.64	6.94	5.40
Grade B Frozen	7.09	6.29	5.91	6.37	5.41
95% C.L.		±0.22	±0.32	±0.14	

	AROMA				
		3 months		6 months	
	0	40°F.	100°F.	40°F.	100°F.
Grade A Shell	7.71	7.93	7.20	7.76	6.63
Grade B Shell	7.78	7.74	6.98	7.53	6.42
Grade B Frozen	7.74	7.83	6.95	7.46	6.47
95% C.L.		±0.12	±0.16	±0.08	

	TEXTURE				
		3 months		6 months	
	0	40°F.	100°F.	40°F.	100°F.
Grade A Shell	5.94	6.22	5.97	6.03	5.56
Grade B Shell	5.92	6.29	5.91	5.85	5.44
Grade B Frozen	5.16	5.41	4.32	5.11	4.53
95% C.L.		±0.26		±0.09	

TABLE XV.

FREEZE-DEHYDRATED EGGS - STORAGE TEST - PHASE II

Product	Significant Effect	Mean Scores			
		Appearance	Aroma	Flavor	Texture
		(1=Not acceptable 5=Acceptable)	(1 = Repulsive, 10 = Excellent)		
IV A-1	Package	can =3.25 pch =2.56			5.22 5.04
	Storage Temp		40°=7.54 70°=7.17 100°=6.80	6.10 5.84 5.52	
	Storage Time		3 mo=7.36 6 mo=6.97	6.00 5.64	
IV B-1	Package	can =3.57 pch =2.47			5.44 4.48
	Storage Temp		40°=7.43 70°=6.87 100°=6.42	6.50 5.99 5.42	5.12 5.06 4.69
IV B-3	Package	can =2.99 pch =2.40			5.42 4.60
	Storage Temp		40°=7.30 70°=6.97 100°=5.90	6.24 6.22 4.75	5.28 5.08 4.66
	Storage Time	3mo=2.90 6mo=2.50	7.18 6.26	6.06 5.41	5.21 4.80
	Pkg x Time	can 3mo=3.39 can 6mo=2.59 pch 3mo=2.40 pch 6mo=2.40			5.89 4.94 4.53 4.66
IV A-2	Package	can =2.80 pch =2.30			5.24 4.50
	Pkg x Temp	can 40°=2.36 can 70°=2.66 can100°=2.39 pch 40°=2.22 pch 70°=2.46 pch100°=2.23	7.26 7.06 5.55 7.08 6.74 6.21	6.16 6.41 4.35 5.56 6.26 4.94	
	Storage Temp		40°=7.17 70°=6.90 100°=5.90	5.86 6.33 4.64	5.01 5.05 4.56

TABLE XV CONTINUED

Product	Significant Effect	Mean Scores			
		Appearance	Aroma	Flavor	Texture
	Storage Time		3 mo=6.98 6 mo=6.32	5.88 5.34	
	Pkg x Oxygen				5.38 can- 2% 5.11 can- 5% 4.43 pch- 2% 4.58 pch- 5%
IV B-5	Package	can =2.87 pch =2.48			
	Time x Temp	40° 3mo=3.33 70° 3mo=2.61 100° 3mo=2.52 40° 6mo=2.48 70° 6mo=2.58 100° 6mo=2.53			
	Storage Temp		40°=6.82 70°=6.58 100°=5.73	6.24 6.07 4.89	5.43 5.21 4.77
	Storage Time		3mo=6.96 6mo=5.78	6.17 5.30	5.44 4.84

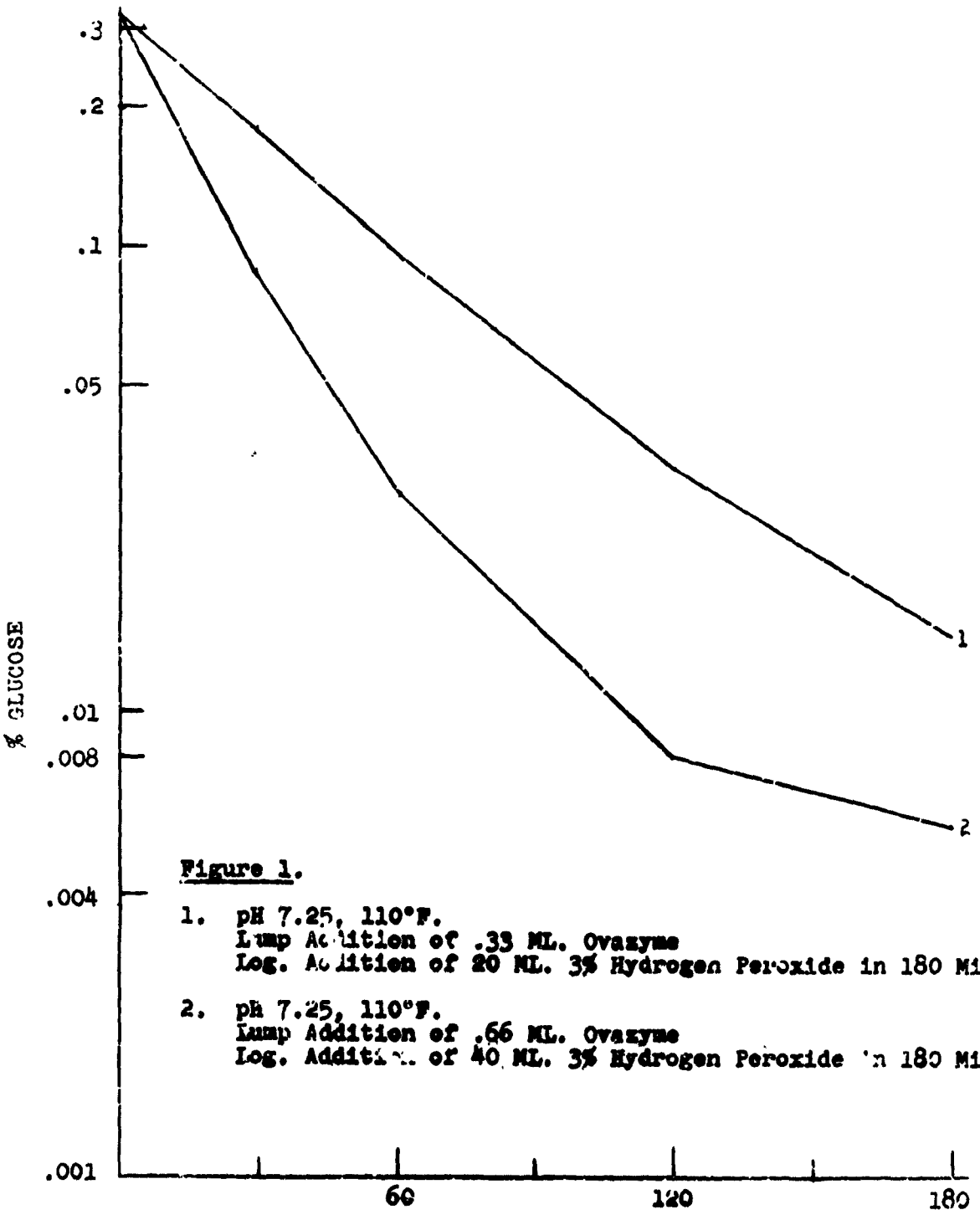


Figure 1.

1. pH 7.25, 110°F.
   Lump Addition of .33 ML. Ovazyme
   Log. Addition of 20 ML. 3% Hydrogen Peroxide in 180 Min.

2. pH 7.25, 110°F.
   Lump Addition of .66 ML. Ovazyme
   Log. Addition of 40 ML. 3% Hydrogen Peroxide in 180 Min.

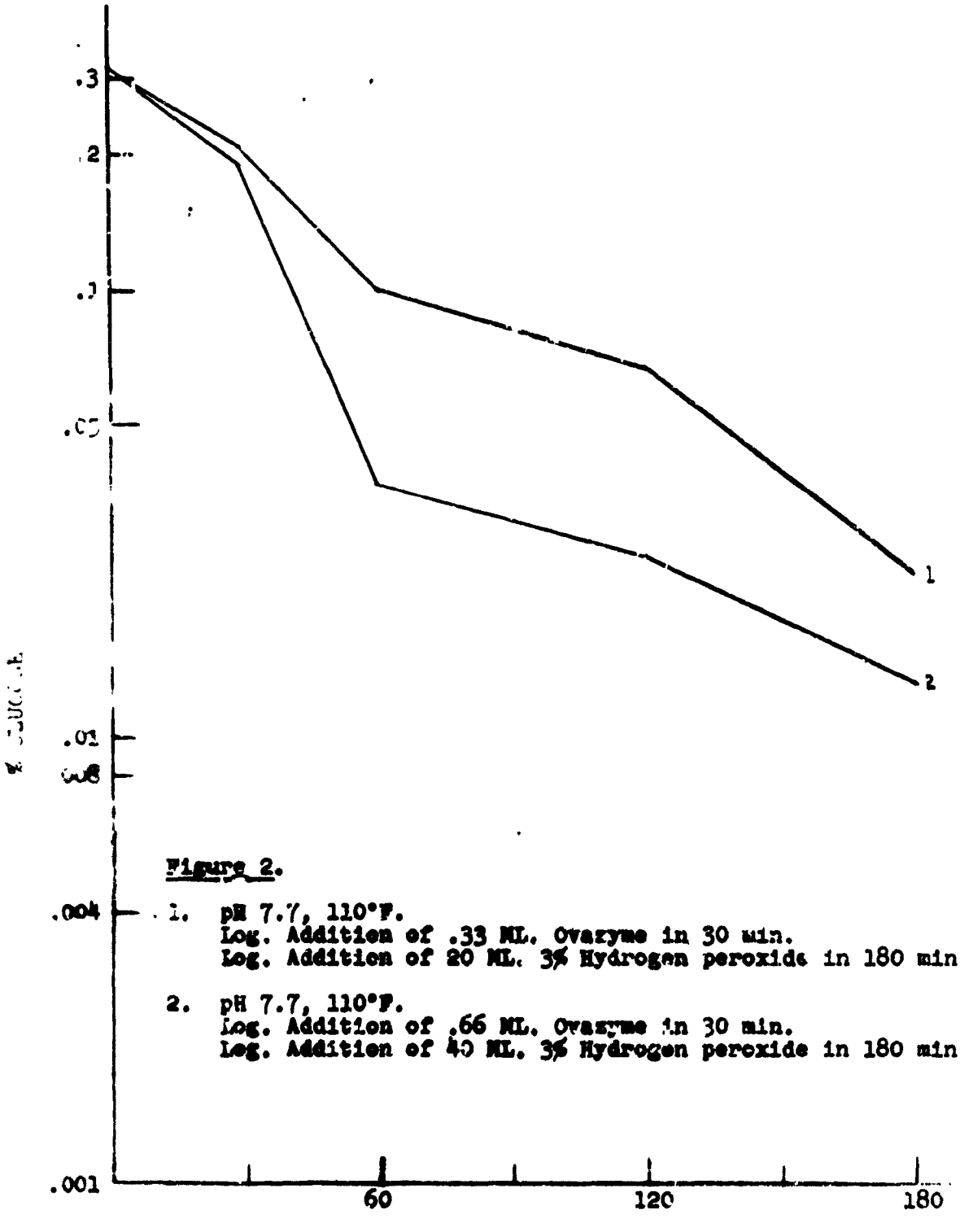


Figure 2.

1. pH 7.7, 110°F.
   Log. Addition of .33 ML. Ovazyme in 30 min.
   Log. Addition of 20 ML. 3% Hydrogen peroxide in 180 min.

2. pH 7.7, 110°F.
   Log. Addition of .66 ML. Ovazyme in 30 min.
   Log. Addition of 40 ML. 3% Hydrogen peroxide in 180 min.

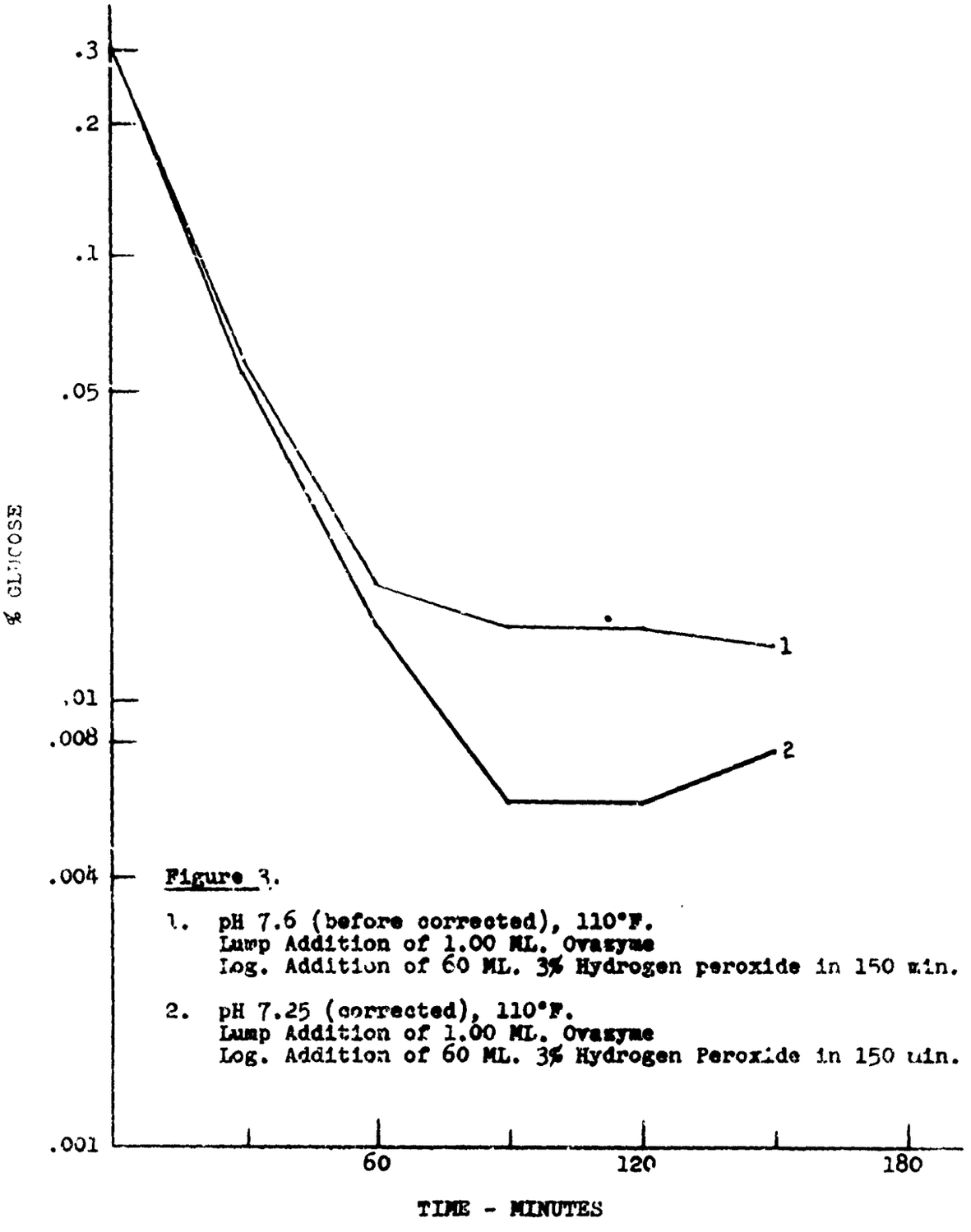


Figure 3.

1. pH 7.6 (before corrected), 110°F.
   Lump Addition of 1.00 ML. Ovazyme
   Log. Addition of 60 ML. 3% Hydrogen peroxide in 150 min.

2. pH 7.25 (corrected), 110°F.
   Lump Addition of 1.00 ML. Ovazyme
   Log. Addition of 60 ML. 3% Hydrogen Peroxide in 150 min.

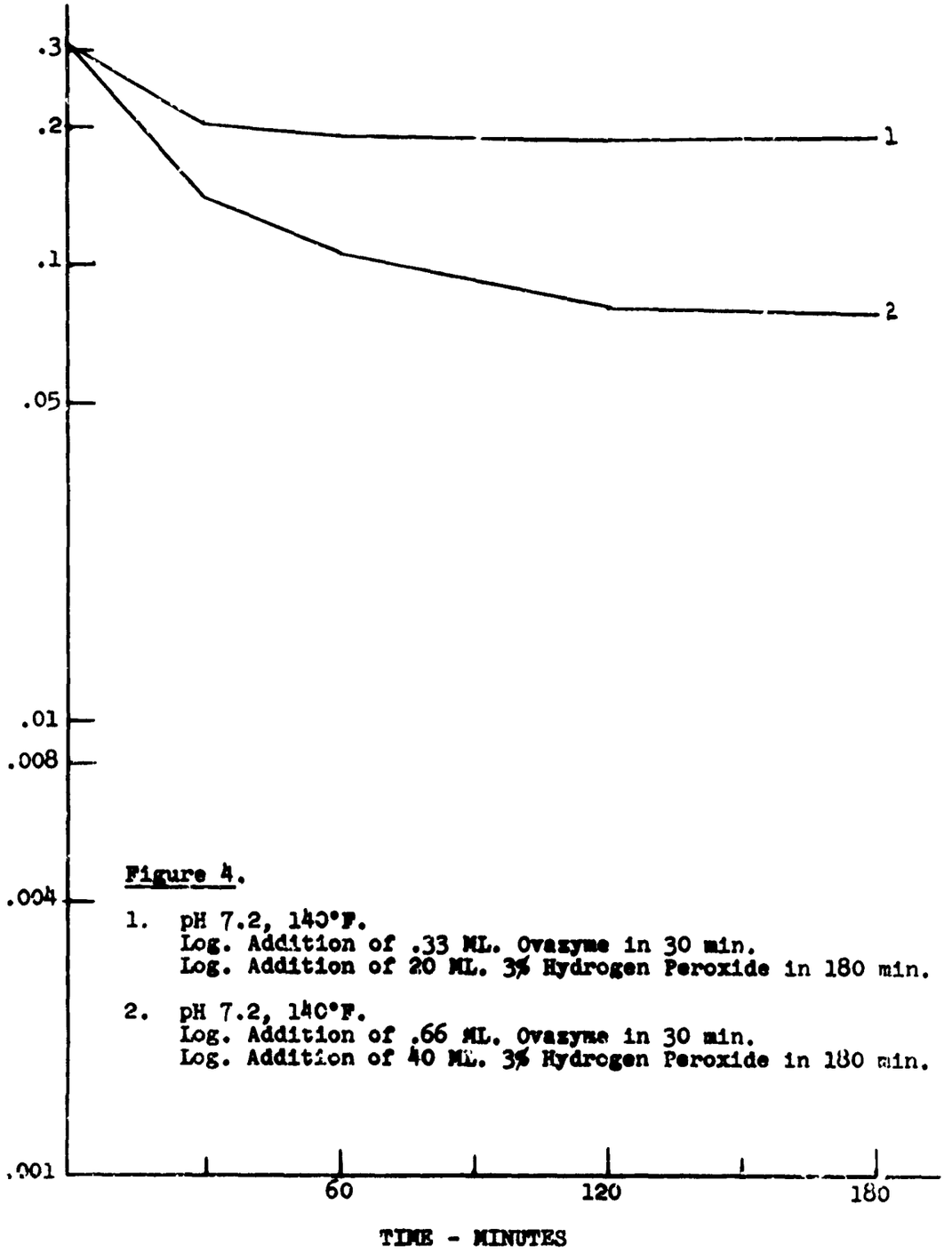


Figure 4.

1. pH 7.2, 140°F.
   Log. Addition of .33 ML. Ovazyme in 30 min.
   Log. Addition of 20 ML. 3% Hydrogen Peroxide in 180 min.

2. pH 7.2, 140°F.
   Log. Addition of .66 ML. Ovazyme in 30 min.
   Log. Addition of 40 ML. 3% Hydrogen Peroxide in 180 min.

CONDITIONS FOR FIGURE 5.

Curve 1.

pH 7.1
110°F.
Lump addition of 0.5 unit of glucose oxidase/gm. egg.
Lump addition of 0.66 unit of catalase/gm. egg.
Log. addition of 20 ML. 3% hydrogen peroxide in 120 min.

Curve 2.

pH 7.1
110°F.
Lump addition of 0.5 unit of glucose oxidase/gm. egg.
Lump addition of 1.00 unit of catalase/gm. egg.
Log. addition of 60 ML. 3% hydrogen peroxide in 120 min.

Curve 3.

pH 7.1
110°F.
Lump addition of 1.0 unit of glucose oxidase/gm. egg.
Lump addition of 0.33 unit of catalase/gm. egg.
Log. addition of 20 ML. 3% hydrogen peroxide in 120 min.

Curve 4.

pH 7.1
110°F.
Lump addition of 0.5 unit of glucose oxidase/gm. egg.
Lump addition of 0.33 unit of catalase/gm. egg.
Log. addition of 20 ML. 3% hydrogen peroxide in 120 min.

Curve 5.

pH 7.1
110°F.
Lump addition of 1.5 units of glucose oxidase/gm. egg.
Lump addition of 0.66 unit of catalase/gm. egg.
Log. addition of 40 ML. 3% hydrogen peroxide in 120 min.

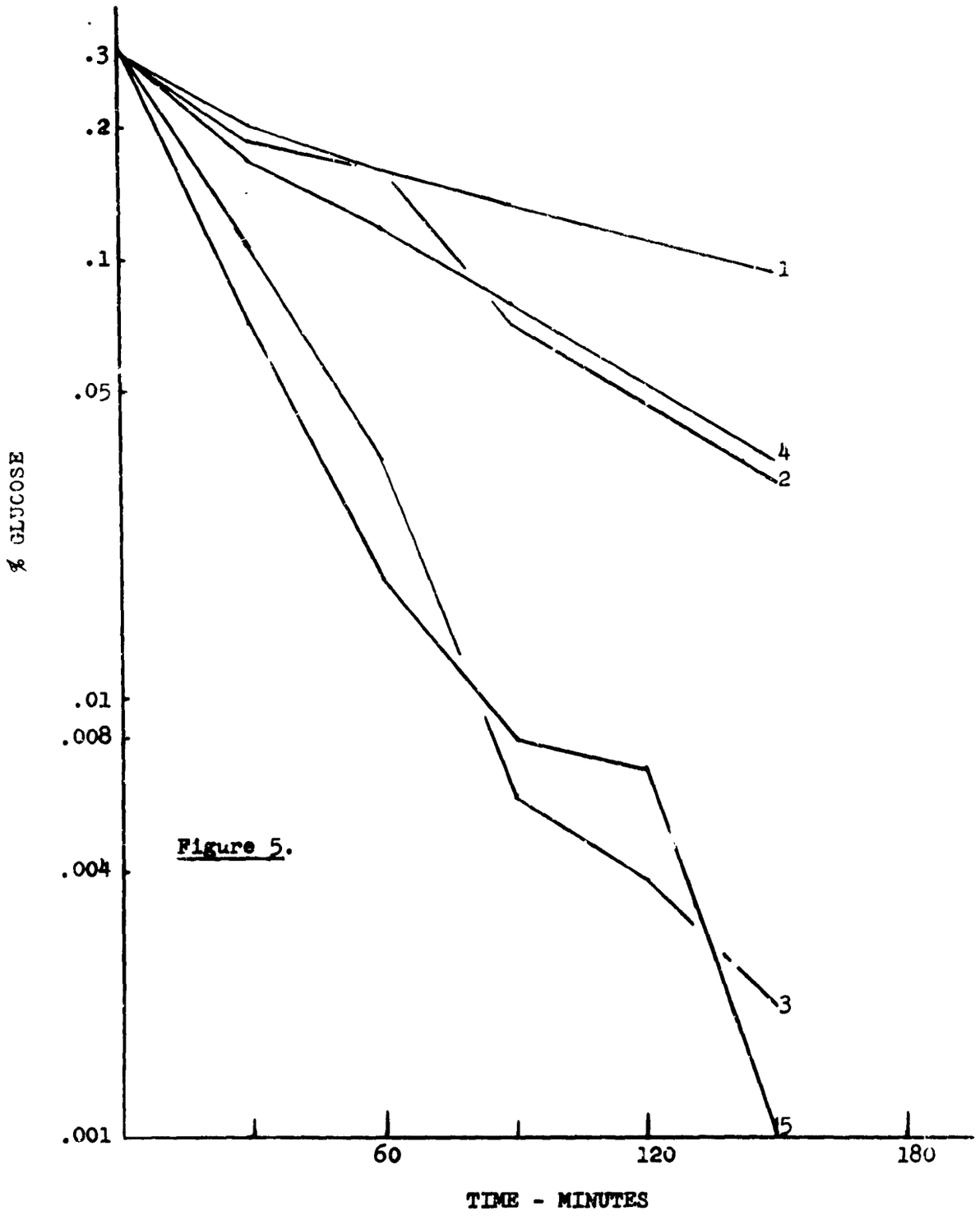
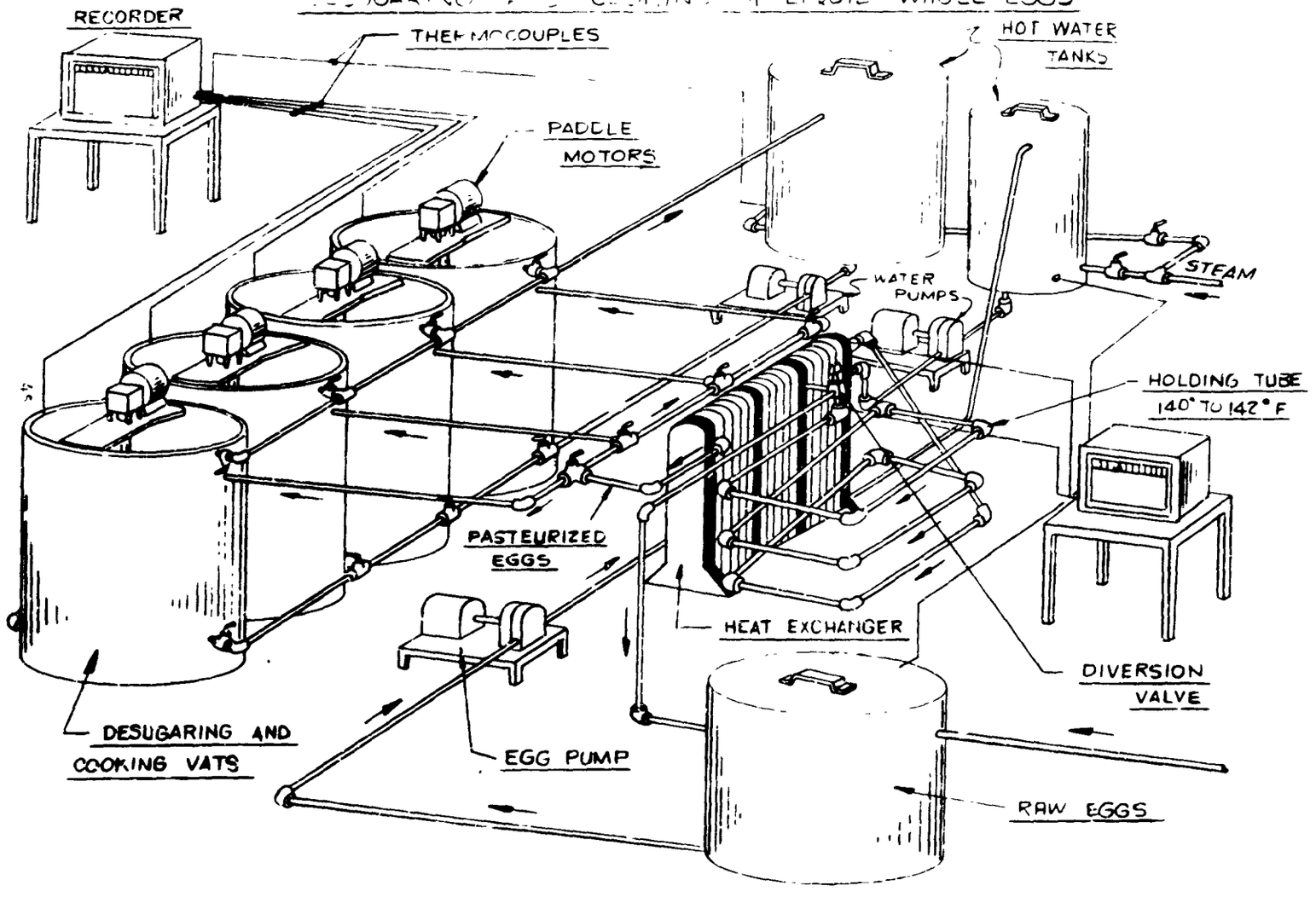


Figure 5.

FIGURE EQUIPMENT SETTING FOR PASTEURIZING, DESUGARING AND COOKING OF LIQUID WHOLE EGGS



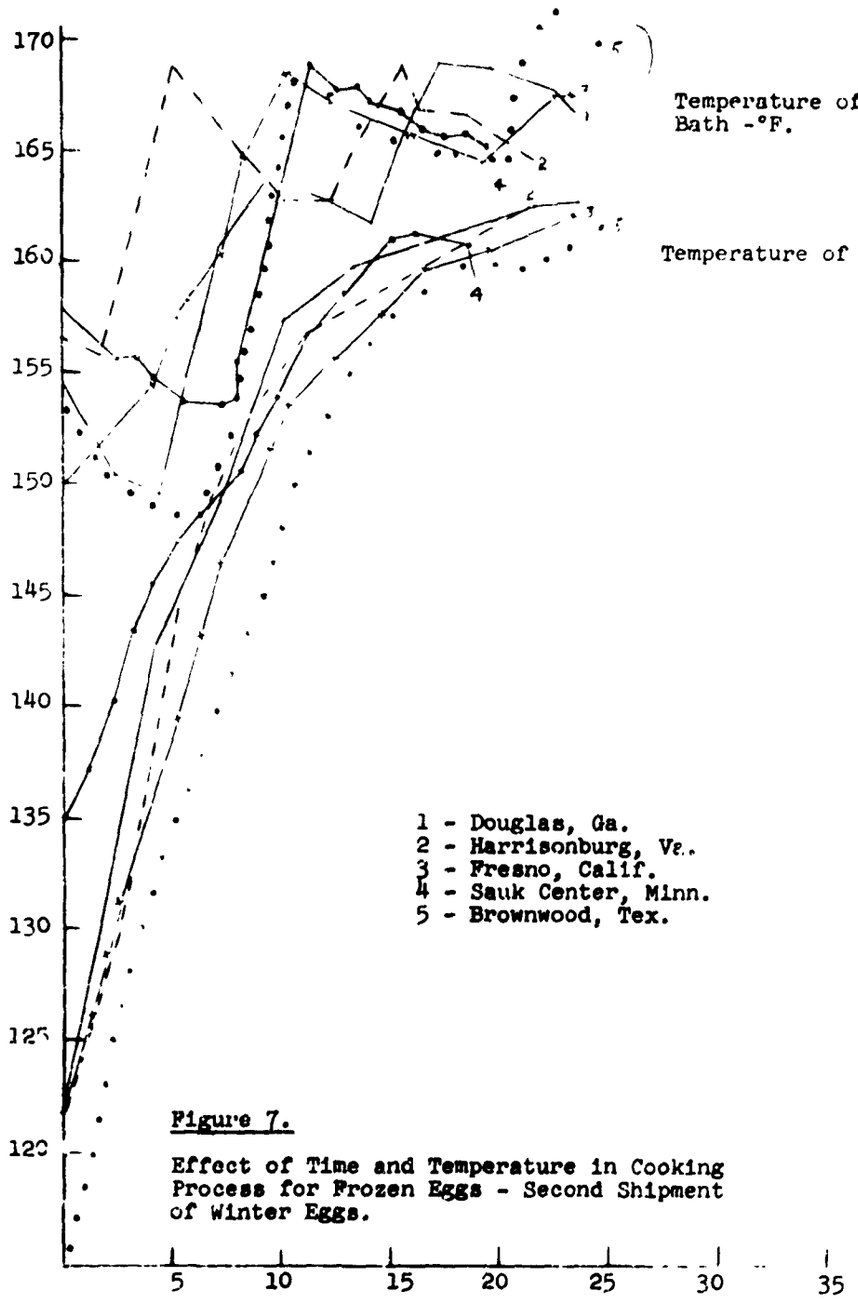
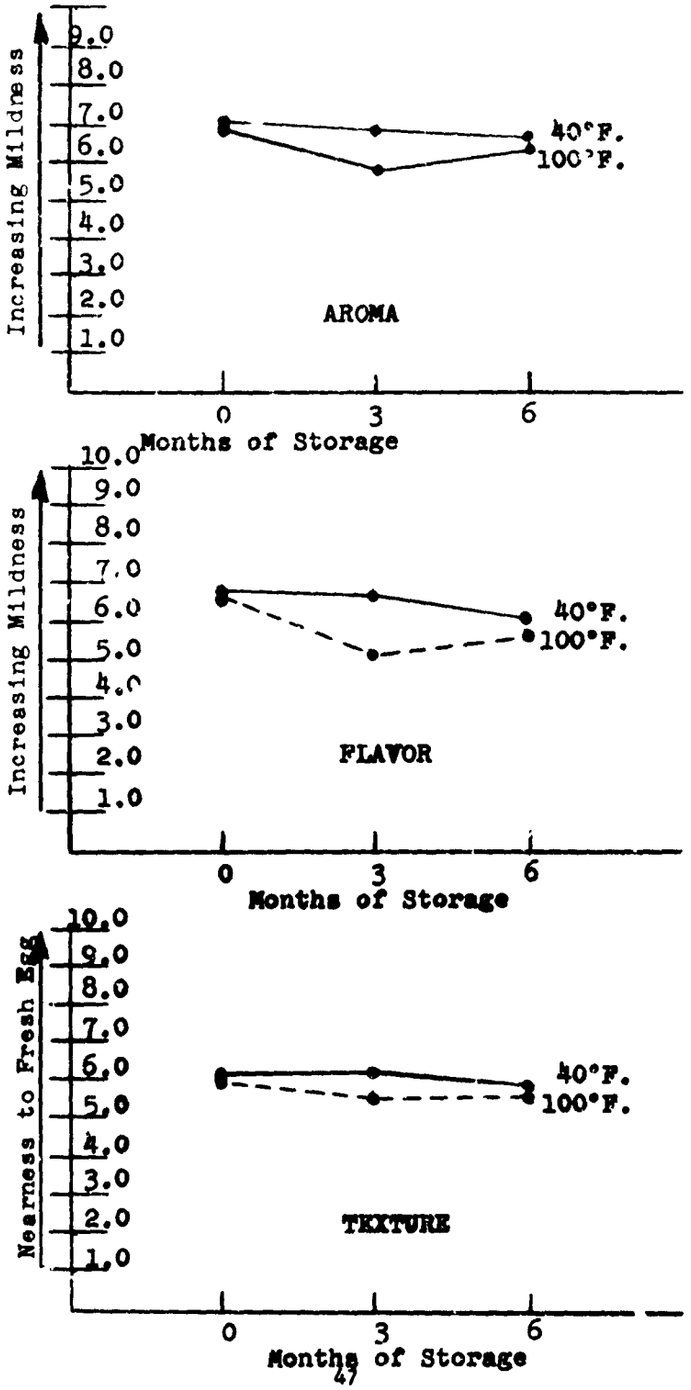


Figure 7.

Effect of Time and Temperature in Cooking Process for Frozen Eggs - Second Shipment of Winter Eggs.

EFFECT OF STORAGE TEMPERATURE ON QUALITY CRITERIA
OF FREEZE DEHYDRATED EGG SAMPLES STORED 6 MONTHS
AVERAGED OVER GRADES - SUMMER EGGS

Figure 8.



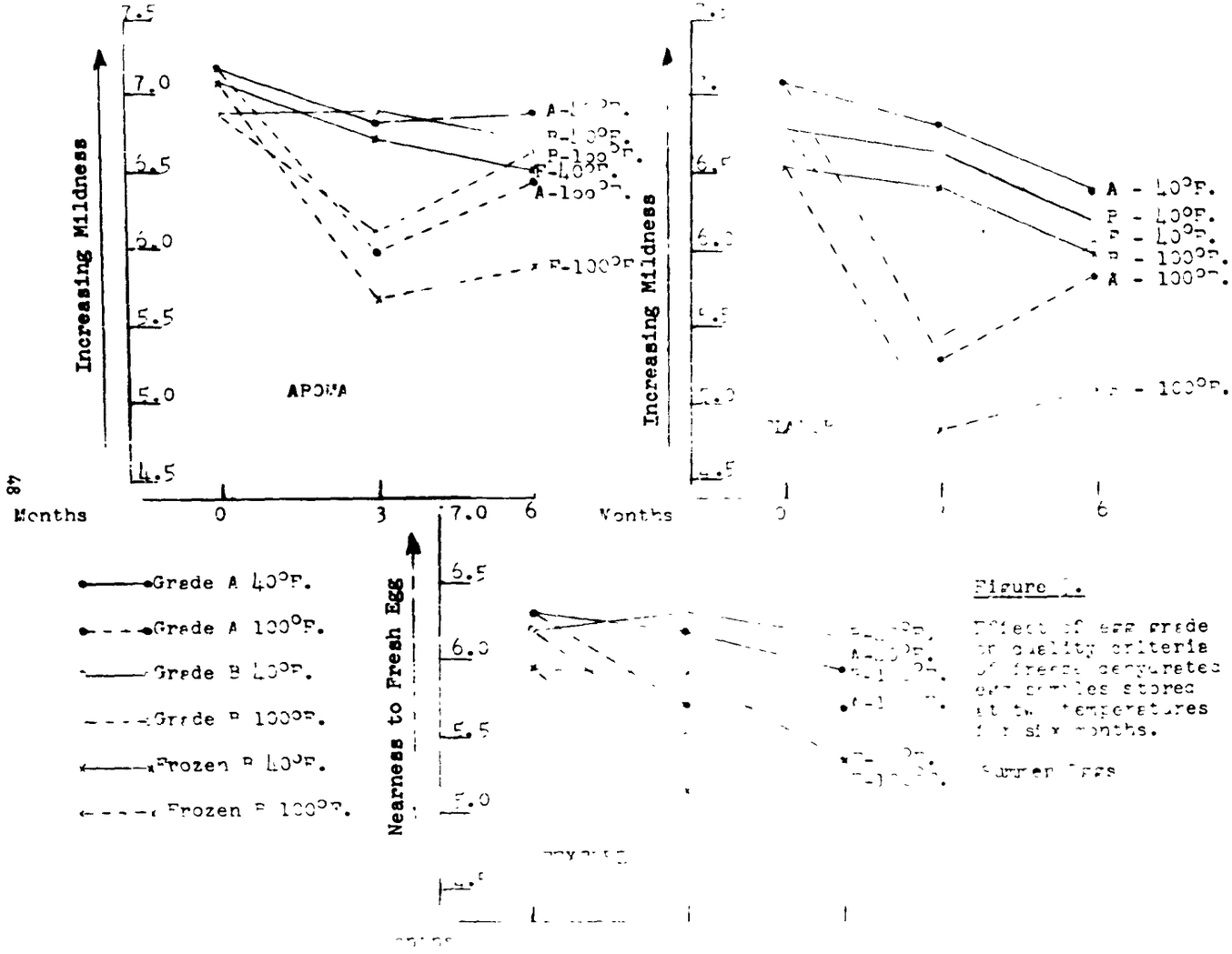


Figure 1.

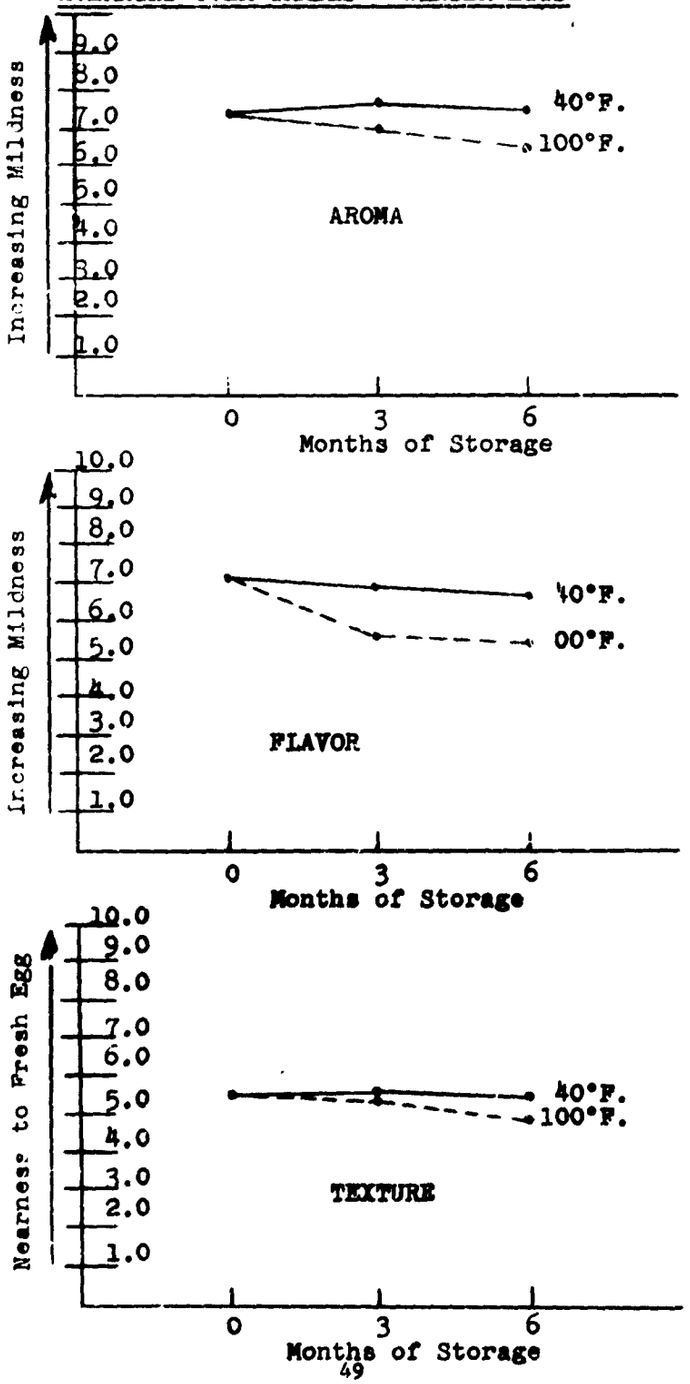
Effect of egg grade on quality criteria of freshly separated egg yolk mixes stored at two temperatures for six months.

Source Eggs

EFFECT OF STORAGE TEMPERATURE ON QUALITY CRITERIA
OF FREEZE DEHYDRATED EGG SAMPLES STORED 6 MONTHS

AVERAGED OVER GRADES - WINTER EGGS

Figure 10



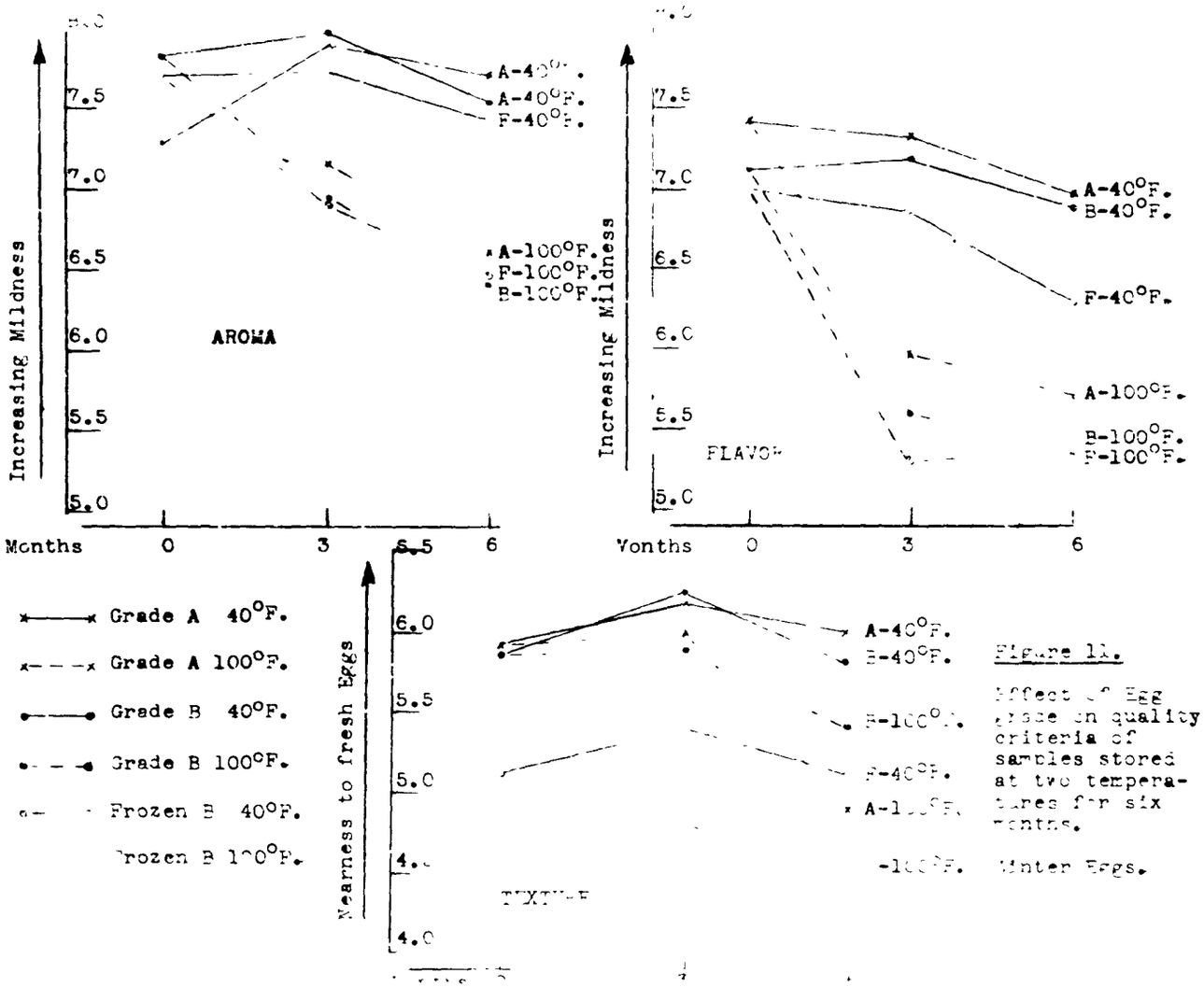


Figure 11.

Effect of Egg grade on quality criteria of samples stored at two temperatures for six months.

ABSTRACT (Continued)

trained panel initially and at the end of the storage period. Bacteriological and chemical data was obtained on the raw and processed eggs.

Geographical source of the eggs had no effect on the quality of the end product. There were no significant differences in the organoleptic criteria of the finished product produced from grade A or grade B table grade whole eggs. Finished product produced from grade B frozen egg was significantly poorer in organoleptic properties that from grades A and B eggs. Freeze-dried scrambled egg packed in cans kept better in storage than when packed in pouches. Oxygen level in headspace gas did not appear to affect flavor stability. Overcooking in the scrambling process and rehydration procedure had a deleterious effect on quality. Increasing the levels of enzyme preparation and hydrogen peroxide and raising the incubation temperature to 105°-112°F reduced the desugaring time to 2 hours.

Detailed recommendations are provided for raw materials, plant equipment and processing procedure.

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13 ABSTRACT

In the design of "Quick Serve Meals" as a military operational ration, there was a need for a quickly prepared egg product in the breakfast menus. A prototype scrambled, cooked, freeze-dried whole egg product was developed which possessed the appearance, aroma, flavor and texture similar to pan-fried scrambled egg, after rehydrating in hot water for 1 to 3 minutes. More complete information covering raw material and processing procedures was needed in order to produce a satisfactory product on a plant scale. The work covered in this report was carried out to investigate the raw material, processing methods and equipment necessary for the efficient production of freeze-dried scrambled eggs.

Summer and winter produced USDA table grades A and B shell eggs were obtained from 6 different geographical areas of the United States to provide for a random selection of eggs from major egg producing areas. In addition, table grade frozen egg prepared from table grade shell eggs was included in the study. The eggs were produced from predominately White Leghorn flocks. All eggs after receipt were held at 40°F until processed except that the frozen table grade egg was held at -10°F. The eggs were weighed, check graded, broken, homogenized, pasteurized, stabilized (desugared), precooked, frozen, freeze dried and vacuum and nitrogen treated before sealing in both cans and pouches. The packaged freeze dried eggs were stored at 38°-40°F and 100°F for six months. They were evaluated organoleptically for quality by a (Continued)

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Preparation methods	3					
Equipment	8					
Eggs	1		9			
Freeze-dried	0		0			
Scrambled	0		0			
Vacuum	1		9			
Storage stability			8			

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