THE EFFECT OF THREE DEHYDRATING PROCESSES ON THE ACCEPTABILITY OF WHOLE EGGS SCRAMBLED FOR VOLUME FOOD SERVICE

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

DORIS ANN JANEK

1967

ABSTRACT

THE EFFECT OF THREE DEHYDRATING PROCESSES ON THE ACCEPTABILITY OF WHOLE EGGS SCRAMBLED FOR VOLUME FOOD SERVICE

by Doris Ann Janek

The objectives of this investigation were to evaluate the effect of spray-drying, freeze-drying, and foam-spray-drying on the coagulative properties and palatability characteristics of scrambled whole eggs and to compare the scrambled eggs cooked by two volume food service methods: in a half-counter pan in an institutional deck oven and in a skillet on an institutional range unit. Frozen whole eggs for the control and for drying were obtained from a common source. Six replications of scrambled eggs were prepared from each of the four types of processed eggs and cooked by each of the two methods and evaluated by objective and subjective methods.

The following statistical differences were indicated from the subjective evaluations of the scrambled eggs. At the 5 per cent level of probability, the panel preferred the color of the spray-dried scrambled eggs over the color of the freeze-dried scrambled eggs. The flavor scores for the frozen scrambled eggs and for freeze-dried scrambled eggs were significantly higher, at the 5 per cent level of

probability, than the flavor scores for the foam-spray-dried scrambled eggs. For each of the factors of aroma, color, coagulation, moistness, texture, and flavor, the skillet-cooked scrambled eggs were preferred over the oven-cooked scrambled eggs at the 0.1 per cent level of probability. Highly significant positive correlation coefficients were present between scores for aroma and flavor; between scores for color and flavor; between scores for coagulation and each of the factors of moistness, texture, and flavor; between scores for moistness and each of the factors of tenderness, texture, and flavor; between scores for tenderness and each of the factors of texture and flavor. Positive correlations, significant at the 5 per cent level of probability, were indicated between syneresis scores and each of the factors of coagulation, moistness, and texture.

The objective measurements of percentage of syneresis and the two shear press measurements of the tenderness of the scrambled eggs were statistically analyzed. The shear press measurements for maximum force and area-under-the-curve for the skillet-cooked scrambled eggs were significantly higher, at the 0.1 per cent level of probability, than those for the oven-cooked scrambled eggs. The percentage of syneresis for the skillet-cooked scrambled eggs was significantly greater, at the 5 per cent level of probability, than the percentage of syneresis for the oven-cooked scrambled eggs. A highly significant positive correlation was calculated between maximum force and area-under-the-curve. A significant positive correlation was calculated between area-under-the-curve measurements of tenderness of the scrambled eggs and percentages of syneresis. Highly significant positive correlation coefficients were indicated between each of the average scores for coagulation, texture, and flavor and each of the two shear press measurements of maximum force and area-under-the-curve.

Time-temperature data for the scrambled eggs cooked by each method indicated that the scrambled eggs received sufficient heat to exceed the requirements for the destruction of Salmonella organisms. The oven-cooked scrambled eggs required approximately an hour to reach the desired end point temperature of $75\pm1^{\circ}C.$, whereas the skillet-cooked scrambled eggs reached $78\pm1^{\circ}C.$ in approximately 7 min. A negative correlation coefficient, at the 1 per cent level of probability, indicated that as cooking times for the scrambled eggs increased, flavor scores decreased. A positive correlation coefficient between maximum temperatures at 1.3 cm. and flavor scores was significant, at the 1 per cent level of probability.

THE EFFECT OF THREE DEHYDRATING PROCESSES ON THE ACCEPTABILITY OF WHOLE EGGS SCRAMBLED FOR VOLUME FOOD SERVICE

By

Doris Ann Janek

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

1967

346335
10/10/67

ACKNOWLEDGMENTS

Without the advice, guidance, and patience of Miss Doris Downs, this study would have been an impossible task to complete. To her, the author is greatly indebted and expresses heartfelt gratitude and appreciation.

The author is also indebted to the many persons who supplied encouragement and support during the period of this study. Miss Katherine Hart deserves special mention for her continuing interest and support throughout the past two years of the graduate program.

Special thanks are given to Dr. Grace Miller for her assistance in reading the manuscript and to Dr. Frances Magrabi for her assistance in the statistical analyses of the data. Sincere gratitude is extended to Dr. Pearl Aldrich, to Dr. Kaye Funk, and to Miss Joanne Wolfe for their suggestions and encouragement.

Grateful acknowledgments are offered to Miss Gisele Charlebois, Dr. Mary Coleman, Mrs. Elizabeth Davey, Sister M. Marcel DeJonckheere, Sister Ancilla Domenci, Dr. Theodore Irmiter, Miss Mary Morr, and Miss Joanne Wolfe for their faithful attendance on the taste panel.

* * * * * * * * *

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	4
Processing of Eggs	4
Microbiological aspects of processing eggs .	5
Frozen eggs	7
Dried eggs	8
Effect of dehydration on eggs	12
Methods of Evaluating Processed Eggs	15
Subjective evaluation	15
Objective measurements	17
Use of Dried Eggs in Volume Food Service	20
EXPERIMENTAL PROCEDURE	22
Preliminary Investigation	22
Selecting cooking methods	22
Development of formula and preparation schedules	26
Determining evaluation techniques	28
Design of Experiment	29
Procurement and Storage of Materials	31
Eggs	32
Remaining materials	36
Preparation of Scrambled Eggs	36
Preparation of ingredients	37
Mixing procedure	38
Cooking methods	39
Evaluation of Scrambled Eggs	44
Subjective evaluation	44
Objective measurements	45
Analysis of data	50
RESULTS AND DISCUSSION	52
Subjective Evaluation of Scrambled Eggs	52
Analyses of scores for aromatic and visual factors	53
Analyses of scores for taste factors	57
Variance due to serving order	61

Page

Variance among replications 63
Correlation coefficients between scores for sensory factors 63
Objective Evaluation of Scrambled Eggs 67
Analysis of syneresis measurements 68
Analysis of shear press measurements of tenderness 70
Color measurements 72
pH measurements 74
Correlation coefficients for combinations of objective measurements and between selected objective measurements and subjective evaluations 74
Cooking Times and Temperatures of Scrambled Eggs 77
Oven-cooked scrambled eggs 77
Skillet-cooked scrambled eggs 81
Correlation coefficients for combination of flavor and time-temperature data 82

SUMMARY AND CONCLUSIONS 84

LITERATURE CITED 90

APPENDICES 96

LIST OF TABLES

Table		Page
1.	Schedule for preparation and evaluation of scrambled eggs prepared by two volume food service methods of cooking from four types of processed whole eggs	30
2.	Formula for scrambled eggs prepared by two methods of cooking from four types of processed whole eggs	37
3.	Analyses of variance of scores for aromatic and visual factors of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods	54
4.	Average scores and standard deviations for aromatic and visual factors for scrambled eggs	55
5.	Analysis of variance of scores for taste factors of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods of cooking	57
6.	Average scores and standard deviations for taste factors for scrambled eggs	58
7.	Analyses of variance of the effect of serving order on the scores for sensory factors of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods .	62
8.	Correlation coefficients for selected combinations of sensory factors evaluated in scrambled eggs	64
9.	Analyses of variance of syneresis, maximum force, and area-under-the-curve for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods	68

Table Page

10. Averages and standard deviations of syneresis, maximum force, and area-under-the-curve measurements of scrambled eggs 69

11. Average x and y values from color measurements of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods 73

12. Averages and standard deviations of pH values for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods 74

13. Correlation coefficients for combinations of objective measurements of scrambled eggs and between objective measurements and subjective evaluations 75

14. Averages and standard deviations of total cooking times and maximum temperatures for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods 80

15. Correlation coefficients for flavor and cooking time and temperatures of scrambled eggs 83

16. Palatability scores for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods 100

17. Values of shear press measurements, percentages of syneresis, and pH for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods 102

18. Color determinations for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods 104

19. Time-temperature data for oven-cooked scrambled eggs prepared from four types of processed whole eggs 106

20. Time-temperature data for skillet-cooked scrambled eggs prepared from four types of processed whole eggs 107

LIST OF FIGURES

Figure		Page
1.	Apparatus and equipment used in cooking scrambled eggs in a skillet on an institutional range unit and in a half-counter pan in an institutional oven	40
2.	Typical Allo-Kramer shear press curves for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods	71
3.	Average cooking times and temperatures (at 1.3 cm.) of oven-cooked and skillet-cooked scrambled eggs prepared from four types of processed whole eggs and average oven temperatures during cooking	78
4.	Average temperatures at 1.3 cm. and at 0.2 cm. during oven-cooking and skillet-cooking scrambled eggs prepared from four types of processed whole eggs	79

LIST OF APPENDICES

Appendix Page

A. Instructions and Evaluation Sheet used in Subjective Evaluation of Scrambled Eggs . . . 96

B. Tables of Palatability Scores, Objective Measurements, and Time-temperature Data for Individual Replications of Scrambled Eggs 99

INTRODUCTION

The purpose of this investigation is two-fold. The primary objective is to determine the effect of freeze-drying, spray-drying, and foam-spray-drying on the coagulative properties and palatability characteristics of whole eggs as exhibited in scrambled eggs. The secondary objective is to compare the effect of two volume food service methods for cooking scrambled eggs: baked in a half-counter pan in an institutional deck oven and cooked in a skillet on an institutional range unit. This investigation is a segment of a master project to evaluate the effect of various dehydration processes on eggs.

Although eggs were first commercially dried in China in the early 1900's, problems of palatability, performance, and microbiological safety have limited the use of dried eggs. The baking industry, the Armed Forces, and the commercial mix manufacturers currently consume the majority of dried eggs. Dried eggs are also stored for use as a governmental surplus commodity. However, advanced technical knowledge and improved standards are encouraging increased utilization of dried eggs in volume food services and possibly in homes.

Eggs are necessary ingredients in many products prepared for volume feeding, therefore large quantities of eggs must be readily available. Dried eggs require less storage space, are lighter in weight, and require less labor to use in many items than either shell or frozen eggs. Dried eggs offer additional advantages over frozen eggs of being ready for immediate use and of not occupying valuable freezer space.

Scrambled eggs contain a large amount of protein and provide good media for examining the coagulative properties. Since the flavor of the scrambled eggs is neither diluted nor masked by other ingredients, they are also a good product to evaluate subjectively. However, scrambled eggs are difficult to prepare in volume food service and pose problems of achieving the desirable amount of coagulation by various cooking methods and of maintaining optimum palatability characteristics and microbiological safeness of the scrambled eggs throughout preparation and service.

The effect of pasteurization and dehydration on eggs became a subject for increased research in the years following World War II. The Food and Drug Administration recently passed regulations requiring that liquid, frozen, and dried egg products be pasteurized. The development of freeze-drying and foam-spray-drying processes and improvements in the spray-drying process have encouraged further inquiries into the effect of these processes on the functional properties and palatability characteristics of eggs. A drying process which would yield dried eggs similar to shell or frozen eggs in performance and palatability would offer a convenience product to the food service industry and to homemakers.

REVIEW OF LITERATURE

New and improved processing methods have increased the variety and quality of dried eggs available for use in volume food service kitchens. The development of new drying processes and innovations in existing spray-drying processes have encouraged research to determine the applicability of these processes to eggs (22). This review attempts to compile past and current developments concerned with the effect of processing on whole eggs, the methods of evaluating processed eggs, and the use of dried eggs in volume food service.

Processing of Eggs

Processing and storage do not improve the quality of a food, therefore the initial quality of the eggs must be high for an acceptable processed product (30). Shell eggs which are frozen or dried must be of low bacterial count (9). After reaching an egg processing plant, the shell eggs are cleaned, inspected, broken, separated, blended, and homogenized under strict sanitary conditions (23). The eggs are then either frozen or dried to maintain optimum quality (7, 30).

Microbiological aspects of processing eggs

Although microbiological contamination of eggs occasionally develops from ovule infection, microbial growth in shell eggs usually results from external factors such as shell contamination, improper handling, and inadequate processing (41). Shell eggs produced under sanitary conditions which maintain the eggs' natural defenses of cuticle, shell, membrane, and albumen inhibitory proteins during storage and handling procedures are relatively free from bacteria upon reaching consumers or egg processing plants (41).

Removing eggs from shells renders them highly susceptible to bacterial infections and loss of quality, therefore only shell eggs of high quality should be processed under precautionary conditions (9). If ingested in sufficient quantities, Salmonella, the bacteria of primary concern in eggs, can cause salmonellosis, a communicable foodborne gastroenteritis (9). Some dried eggs were processed under unsanitary conditions and handled improperly during World War II and were responsible for outbreaks of salmonellosis (22, 25).

Temperatures similar to those used for pasteurizing milk kill Salmonella organisms (28). Milk is pasteurized by heating every particle to either 61.6^{o}C. and holding for 30 min. or by flash-heating the milk to 71.7^{o}C. and holding for 15 sec. at that temperature (28). A commercial technique for pasteurizing whole eggs and other processed egg products was developed after the war period (22).

Since July 1, 1966, the Food and Drug Administration has required that all processed egg products involved in interstate commerce be pasteurized by flash-heating to 60°C. and holding at this temperature for an interval of 3.5 to 4 min. to kill any *Salmonella* organisms present (11, 26). Whole eggs processed in England are submitted to a pasteurization procedure of 64°C. for 2.5 min. (41). Forsythe and Ayres reported that a recommendation had been made to the British egg industry by British researchers that whole eggs be pasteurized at 65°C. for 2.5 min. because at this time-temperature combination both *Salmonella senftenberg* and an enzyme, alpha-amylase, are destroyed (24).

Miller and Winter reported that pasteurizing liquid whole egg for 4 min. at 60 to 61°C. reduced the standard plate and coliform bacteria by more than 99 per cent and found no significant differences in subjective evaluations of flavor, texture, tenderness, and moisture of scrambled eggs prepared from shell eggs, frozen eggs, and pasteurized frozen eggs (52). Sugihara *et al.* evaluated pasteurization effects on whole eggs and found that pasteurizing had no appreciable effect on viscosity, foaming power, or cake volume (63).

Chemical additives can lower the resistance of microorganisms to heat. Lategan and Vaughan attempted to decrease the heat resistance of Salmonella typhimurium by the addition of various chemicals to liquid eggs (45). They found that the most effective additives were beta-propiolactone, ethylene oxide, and butadiene dioxide, each of which could be added to the liquid eggs to lower the pH value of 5.5, which allowed for pasteurization at the low temperature of 55°C. (45).

Frozen Eggs

Frozen foods have increased in variety and quality as a result of knowledge of freezing effects and development of improved freezing equipment. The consumption of frozen egg products has grown due to the increased convenience over shell eggs for use by food manufacturers, bakers, and food service organizations (52, 56). Regulations of the Food and Drug Administration now require that all processed egg products which travel in interstate commerce be pasteurized (11, 26). Pasteurizing eggs before freezing has helped decrease the possibility of microbiological contamination and insured a processed egg product with longer shelf life than unpasteurized eggs (52). After the eggs are pasteurized, they are packaged and flash-frozen to temperatures of -29 to -56°C. for 72 hr. (23).

Dried eggs

The first commercial application of drying to eggs began in China around the turn of the century (7). The availability of low-cost dried eggs imported from China hindered American commercial operations until the passage of protective tariff laws and the development of spray-drying and tunnel-drying in this country during the 1920's (25). During World War II, demands for large quantities of dried foods plus advanced knowledge of controlled heat and drying procedures enabled large scale production of dried egg products (25).

Improper drying conditions and unsanitary factors in some egg drying plants during World War II produced dried eggs which were unsatisfactory in palatability and initiated prejudices against dried eggs (25). Problems with functional properties, stability, palatability, and microbiological safeness decreased the acceptance of the dried eggs, and also stimulated research to investigate possibilities for improving drying processes (7). At present, most dried whole eggs are produced by spray-drying, but the development of freeze-drying and foam-spray-drying has encouraged research on the effect of these processes on eggs (22, 55).

Removal of glucose from whole eggs prior to drying extends shelf life and aids in maintaining optimum palatability and functional properties in dried eggs (5, 25, 34, 61). Either yeast fermentation of whole eggs or adding the enzyme glucose oxidase and a catalyst to eggs prior to drying is used to remove glucose (7). Kline et al. compared the two methods, enzyme treatment and yeast fermentation, for removal of glucose and found no differences according to consumer preference tests and stability tests (39).

Dawson et al. determined that adding sucrose or lactose to eggs prior to drying improved the flavor ratings and delayed deterioration of flavor and functional properties in dried eggs stored at high temperatures (16). Ziemba reported that adding sucrose prior to drying eggs improved the retention of whipping ability of the dried eggs (65). Bate-Smith and Hawthorne showed that adding sucrose to eggs before drying exerted a stabilizing effect on the dried egg by retarding the Maillard reaction (5). Kline et al. studied the effect of substituting low-dextrose equivalent corn sirup solids for sucrose in the eggs prior to drying and reported that corn sirup solids were as effective as sucrose in maintaining flavor and chemical stability of the dried eggs (40).

Spray-drying. The ability to control heat was instrumental in the improvement of spray-drying equipment during the 1920's (25). In spray-drying, liquid eggs are sprayed in fine particles into regulated streams of hot air and the dried eggs are collected and cooled (7). Van Arsdel reported that problems appeared in spray-formation, contact of spray with the hot air, and effective separation of the powder from the hot humid air of the interior of the drier (64). Atomizing pressures of up to 5000 lb. per square inch are used on liquid whole egg (7). Bergquist reported that whole eggs and yolks were more impervious to physical damage during drying than egg albumen (7).

Freeze-drying. Freeze-drying, also known as lyophilization or sublimation drying, is essentially the removal of moisture by sublimation of ice from frozen foods (36, 64). A high vacuum maintained inside the drier creates a difference in water vapor pressure between the product exterior and the frozen interior, resulting in transportation of water from the interior to the exterior of the food particle (64). After blast-freezing the liquid eggs to -56°C., they are loaded onto trays and set on shelves which are hollow platens through which circulating liquids provide the heat necessary to evaporate the frozen water from the egg (30). Extreme care in temperature control maintains the surface temperature of the egg particles below 60°C. (55).

In addition to retaining most of the original color, structure, and flavor of the food, conduction of freeze-drying at low temperatures prevents heat damage to proteins (55). Problems associated with freeze-drying include non-enzymatic browning, oxidation of lipids, and storage problems (30). Low moisture content of freeze-dried foods helps resolve the problems of darkening and deteriorating color and undesirable flavors which are often linked with non-enzymatic browning (30). Exclusion of light and oxygen in packaging helps prevent oxidative deterioration (30).

Harper and Tappel postulated that freeze-dried eggs would be superior to spray-dried eggs because of the benefits of freeze-drying (36). Rolfes et al. compared freeze-dried, spray-dried, shell, and frozen whole eggs and determined that the effect of spray-drying was more detrimental to egg proteins, although some damage by freeze-drying resulted in a slight loss of functional properties which was attributed to the breakdown of the natural fat emulsion of the shell eggs (59).

Foam-spray-drying. Modification of the spray-drying technique to produce improved dried eggs was begun in the 1920's (7). Hanrahan and Webb reported that the injection of air into the fluid prior to atomization increased surface area and lowered the density of the foam-spray-dried product (33). After injecting nitrogen or oxygen under pressure or compressed air into the liquid eggs, the foamed eggs are dried with spray-drying equipment to produce dried eggs with greater dispersibility and solubility than spray-dried eggs (23, 33). However, foam-spray-dried eggs are more hygroscopic than spray-dried eggs (33).

Effect of dehydration on eggs

The quality characteristics which determine the acceptability of dried eggs are pH, flavor, color, and functional properties (7, 46).

pH. Knowles reported that drying whole eggs resulted in an increase in alkalinity (41). The pH values of 7.2 and 7.6 of the eggs increased to 7.6 and 8.6 after drying, respectively (41). During storage the pH decreased because of the glucose amino acid reaction and the reaction of free fatty acids (41). Salwin *et al*. indicated that a range of 7.0 to 9.0 was suitable for reconstituted dried eggs (60). Under drying or cooking conditions of high heat and high pH, formation of a green color was attributed to a reaction between the sulfur compounds present and egg proteins in the whole egg (60).

Flavor. Various types of off-flavor can occur in dried eggs. Bate-Smith *et al*. categorized these as "storage," resulting from storage at moderate temperatures; "burnt," resulting from high temperatures during drying or storage; "fishy," characteristic of dried eggs stored at moderate heat for long periods of time; and "acid," found in samples with a low pH (4).

Scrambled eggs have been used as a medium for evaluating changes in flavor (15, 16, 61). Dawson *et al*. reported that off-flavors which were detected in scrambled eggs prepared from deteriorated dried eggs were not apparent in cakes made from the eggs until the scrambled eggs prepared from the deteriorated eggs were almost inedible (15). Dawson _et al_. studied the effect of adding carbohydrates prior to spray-drying whole eggs and found that the functional properties and flavor of the whole spray-dried eggs were acceptable in sponge cakes and baked custards, but the unaccustomed sweetness reduced the acceptability of scrambled eggs (16). Ziemba reported that storage off-flavor in dried eggs could be attributed to a reaction between glucose and the amine group of the lipid, cephalin (65).

Color. The intensity and concentration of the carotenoid pigments in the yolk determine the color of the whole egg (21). Some of the causes of darkening of dried eggs after processing are related to aldehyde-amine reactions, destruction of carotenoid pigments, and oxidative chemical changes (46). Lightbody and Fevold reported that dried egg color is not a reliable index of vitamin content but that it is useful in determining the amount of deterioration that has occurred (46).

Coagulation and texture. Careful control of drying temperatures is necessary to prevent denaturation of the egg protein and loss of functional properties of the whole egg (7). When high protein foods such as eggs are heated, the proteins coagulate and become insoluble (20, 56). Coagulation is a form of denaturation resulting in a precipitation of protein (31). Kauzmann defined denaturation as a process, or sequence of processes, in which the spatial arrangement of the polypeptide chains within the molecule is changed from that of native protein to a more disordered arrangement resulting from the rupture of certain molecule bonds which stabilized the native protein structure (38). Meyer described denaturation as a transformation which results in the unfolding of the protein molecule (51). Denaturation may also be induced by other means than heat, including mechanical action or adding agents such as acids, alkalies, alkaloids, and heavy metal salts (51).

Some factors affecting egg protein coagulation are the rate and amount of heating, concentration of protein, and the presence of other ingredients (48). The rate at which a protein product coagulates is dependent upon the degree and rate of heat received and increases until a maximum amount of coagulation has been achieved (48). Heating beyond this point results in syneresis and curdling (31). Coagulation of various food products made from eggs vary because of the rate of heating, ingredients, and dilution of protein. The endothermic nature of coagulation results in a temperature rise that is rapid until the protein begins to coagulate and then the temperature either remains constant or rises slowly (48). Scrambled eggs coagulate at an internal temperature range of 80.5 to 83.0°C., whereas baked custards coagulate in a range from 86 to 92°C. (47, 48). The difficulty in cooking scrambled eggs to definite temperatures has limited their use as a medium for evaluating the degree of coagulation (15).

Miller *et al*. compared baked custards made from shell, frozen, and spray-dried eggs and found that custards made from spray-dried eggs were less firm than custards made from shell or frozen eggs (53). Dawson *et al*. reported that dried eggs which were stored at 44°C. lost the coagulative properties necessary to produce a firm custard (15). Schlosser *et al*. found that custards made from spray-dried eggs which had been stored at 4.4 or 21°C. had texture qualities similar to custards made from shell eggs (61). Stuart *et al*. compared the effect of high drying temperatures and storage changes on the solubility of dried eggs and determined that high drying temperatures were more detrimental to the coagulative ability of the eggs than were storage changes (62).

Methods of Evaluating Processed Eggs

The quality of products prepared with dried eggs can be evaluated through selected subjective means and/or objective measurements (1).

Subjective evaluation

Subjective evaluation is determined by sensory human evaluation of quality characteristics. Although many factors can be measured objectively, some, such as flavor can be most successfully measured by taste-testing (11, 44).

Dawson *et al*. defined a taste panel as a "small number of well chosen members who serve essentially as a well chosen laboratory instrument. As with any laboratory instrument, the precision of the results depends on the precision of the tool and the conditions under which the tool is used" (12). Harper defined sensory evaluation as a form of "diagnosis" based on cues (35).

Dawson and Dochterman compared ranking and scoring procedures and determined that differences in acid concentration were detected by both methods of evaluation, although scoring showed the degree of differences that existed between the acid concentrations (14). Multiple comparison methods can be utilized to detect smaller differences than triangle methods and also give information about the importance of differences (12).

Selection of taste panel members should be based on their health, age, and ability to discriminate (13). The ability of taste panel members to be objective, precise, and consistent can be increased through careful selection and adequate training sessions to familiarize members with the product being evaluated and with the means of evaluation (6). To insure the proper evaluation of characteristics, the researcher should define them for the taste panel members (44). Matz defined texture as "those perceptions which constitute the evaluation of a food's physical characteristics by the skin or muscle senses of the buccal cavity, excepting the senses of temperature or pain" (50). Aroma is regarded as the ability of the olfactory receivers in the nose to perceive an aromatic quality of food (54). Flavor is defined by Amerine *et al*. as the sensation perceived by the receptors on the tongue (1).

Objective measurements

Objective or instrumental measurements of food quality are most effective if they can be correlated with sensory evaluations (1). Comparisons of subjective and objective measurements should be determined on identical samples, with sufficient replications, similar conditions for all evaluations, and knowledge of variation between the two methods (1).

Color. Color is a characteristic of light, measured in terms of intensity and wave length (10, 44, 49). According to MacKinney and Little, color instruments can be divided into five groups: visual colorimeters, comparators, spectrophotometers, tristimulus photoelectric colorimeters, and other instruments (49).

The spectrophotometer is recognized as the basic instrument in the standardization of color (49). A spectrophotometer measures the amount of reflection of light from an object's surface at wave lengths varying from 380 to

770 mμ. The x and y values are obtained through a computing form and are plotted on a chromaticity diagram (44). The tristimulus values are x, y, and z and when taken together furnish a specification of the color which can be duplicated by mixing together the amounts of three standard lights specified by the values (10). Disadvantages of the spectrophotometer include the long length in calculating time, the small amount of sample evaluated, and difficulty in evaluating a uniform unaltered sample (49).

Measurement of texture. Measurement of texture, the kinesthetic characteristics, deals with sensations of feel through finger or mouth (44). Basic principles involved in the many instruments devised to measure texture are compression, shearing, cutting, tensile strength, and shear pressure which are interpreted in pounds of force (44).

In 1951, Kramer developed a multipurpose basic unit which could be altered to cut, compress, shear, and penetrate many types of foods through utilization of various sample assemblies (42). The shear press consisted of five main parts: a sample cell, a test cylinder, a power cylinder, a control valve, and an electrically operated hydraulic pump (42). Further modifications have increased ease in operation and provided electrical indicators and recording systems for permanent records of the pounds of force required to measure the selected attributes of each sample (17).

The standard shear compression cell on the shear press has been utilized for measuring the maturity of vegetables and fruits and the firmness or hardness of raw and cooked foods (44). Bailey _et al_. reported that correlation coefficients between Kramer shear press readings determined with the standard cell block and sensory evaluations of tenderness of beef steak were either significant or approaching significance (3). Gruber and Zabik found very highly significant correlations between shear press measurements using the standard shear compression cell and sensory evaluations of texture and tenderness of butter cakes (32). Endres, in a study of the effect of drying processes on the gel strength of eggs in baked egg and milk slurries, reported significant correlations between the shear press measurements of maximum force and area-under-the-curve using the upper assembly of the fixed blade cell (19). Kramer and Hawbecker used two types of extrusion cells on the shear press to measure rheological properties of gels and emphasized the possibility of obtaining information from the shape and pattern of the time-force curve (43). Funk _et al_. measured angel cakes of three degrees of toughness on the shear press, using the piston from the succulometer cell and the fixed blade assembly of a standard shear compression cell to measure compressibility, a specially designed attachment to measure tensile strength, and the standard shear compression cell to measure tenderness (29). They reported significant correlations between each shear press measurement and sensory evaluations of cell size, cell distribution, cell wall thickness, tenderness, and moistness, except between the tensile strength measurement and evaluations of cell distribution.

Use of Dried Eggs in Volume Food Service

Since dried eggs have both the shell and water removed, their use in volume feeding requires less labor than shell eggs and their availability for immediate use provides convenience over using frozen eggs, which require thawing (8, 27). One of the major concerns with the use of dried eggs in volume feeding is their microbiological safety (47). Although the eggs are pasteurized prior to drying, they must be handled with caution during storage and reconstitution to prevent recontamination (8). For storage prior to opening, dried eggs refrigerated at 1 to 10°C. keep best (58). After containers of dried eggs are opened, the unused powder should be refrigerated in tightly closed containers to prevent adsorption of moisture and flavors from other foods and to deter microbial growth (58). In many recipes, dried eggs need not be reconstituted, but can be mixed in with the other dried ingredients (27). The dried eggs can be reconstituted by adding water in the correct proportions and used as shell or frozen eggs, however precautions should be taken to prevent bacterial contamination (8).

The United States Department of Agriculture recommended that dried eggs be used as an ingredient only in foods which are to be thoroughly cooked and that dried eggs not be used in egg milk drinks, uncooked salad dressings, cream puddings, soft custards, ice creams, omelets, or scrambled eggs which are cooked on top of the stove (58). Longrée *et al*. studied time-temperature relationships in scrambled eggs made from dried whole eggs cooked by two volume food service methods and reported that scrambled eggs cooked in the oven to internal temperatures of 80 to 82^{o}C. exceeded the requirements set forth by Angelotti *et al*. (47). Angelotti *et al*. determined that *Salmonella* organisms were destroyed by heating every food particle to a temperature of 66^{o}C. and holding at that temperature for at least 12 min. (2).

EXPERIMENTAL PROCEDURE

Whole eggs from a common source were frozen and then portions of the frozen eggs were spray-dried, freeze-dried, and foam-spray-dried and a portion was kept frozen for use as a control in evaluating the effect of the dehydration processes on the coagulative properties and palatability characteristics of the whole eggs. Scrambled eggs were prepared from each of the four types of processed eggs by two volume food service methods of cooking, skillet and oven, and evaluated subjectively and objectively.

Preliminary Investigation

Cooking methods were selected, a formula and preparation schedules were developed, and evaluation techniques were determined during a preliminary investigation. Institutional equipment was used when feasible.

Selecting cooking methods

Scrambled eggs may be prepared by a variety of cooking methods in volume feeding. For this investigation, a method for cooking scrambled eggs in the oven and a method for cooking scrambled eggs on a direct source of heat were desired. Scrambled eggs cooked in the oven would supposedly be heated thoroughly enough to destroy any microorganisms present, however, scrambled eggs cooked on top of the stove were on a list of food items which should not be prepared from dried eggs because the scrambled eggs might not be sufficiently cooked to destroy microorganisms (8, 47, 58).

Oven method. The upper deck of a two-deck Hotpoint roasting and baking oven, Model No. HJ225, with an air-cushion bottom was used throughout the study. A Minneapolis Honeywell controller, Model No. R7161B, which replaced the normal thermostats, was adjusted to regulate the upper oven temperature at $176 \pm 2^{\circ}C$. and the bottom oven at $204 \pm 2^{\circ}C$. Another study in the laboratory involved the use of the bottom deck oven on some of the days that scrambled eggs were prepared, therefore the bottom oven was always heated because of the possible influence on the temperature of the top oven.

An apparatus was devised to facilitate the recording of temperatures at two depths in the mixture during the oven-cooking of scrambled eggs in a half-counter pan. Thermocouple holders which could be adjusted to raise or lower the thermocouples to record temperatures at various depths in the mixture were inserted into metal blocks attached to a U-shaped bar which clamped to the sides of the half-counter pan. One of two thumbscrews in each metal block secured the thermocouple holder and the other affixed the metal block to the U-shaped bar.

Scrambled eggs which were oven-cooked without a rack under the pan coagulated too rapidly and layered excessively. Elevating the half-counter pan of scrambled eggs approximately 0.45 in. with a wire rack increased cooking time, allowed for more even coagulation, and decreased the layering.

A standard procedure was developed for stirring the oven-cooked scrambled eggs at selected temperatures and time intervals. The scrambled eggs were stirred at 60, 65, 70, and 72°C., and thereafter at approximately 3-min. intervals until the scrambled eggs reached 74 to 76°C. Oven-cooking the scrambled eggs to temperatures higher than 76°C resulted in off-colored and rubbery scrambled eggs with excessive syneresis.

Griddle method. Attempts were made to standardize a procedure for cooking scrambled eggs on a General Electric griddle, Model No. CG20A. The griddle was coated with a lecithin aerosol spray[1] instead of with fat to prevent introducing another flavor and enable control of the seasoning used.

Several problems were encountered in cooking scrambled eggs on the griddle, including difficulty in controlling the griddle area covered by the scrambled eggs, developing a standard pouring and stirring procedure, uneven coagulation

---

[1]Food Release, lecithin, a vegetable product with an aerosol propellant packed for United Institutional Distributors Corporation.

and browning of the scrambled eggs, and the lack of a method of positioning thermocouples to record time-temperature data as the scrambled eggs were cooking. As a result of these problems, the griddle method of cooking scrambled eggs was abandoned and a method was developed for cooking scrambled eggs in a skillet.

Skillet method. Scrambled eggs were cooked in a Teflon 10-in. skillet heated on a General Electric range unit, Model No. CR44. During heating of the range unit for 90 min. prior to use, surface temperatures cycling from 150 to 180^{o}C. were recorded on the potentiometer chart by using two thermocouples with flat heads: one was positioned at the center of the width and 4 in. from the front edge of the range surface and the other set in the center of the width and 12 in. from the front edge of the range surface to record temperatures where the skillet was placed during the cooking period. The latter thermocouple was placed in the skillet to measure the skillet temperature during the 2 min. heating interval prior to adding the scrambled egg mixture to the skillet. The thermocouple was removed immediately before the scrambled egg mixture was added to the skillet.

Temperatures at two depths in the skillet-cooked scrambled eggs were obtained by positioning four thermocouples in the skillet. The temperature of the skillet-cooked scrambled eggs increased rapidly and the time between printouts of temperatures for each thermocouple was 90 to 100 sec., therefore two thermocouples at each depth allowed for the recording of temperatures every 40 to 50 sec.

After the scrambled egg mixture was heated in the skillet for 2 min., stirring according to a standardized procedure was begun. The scrambled egg mixture was stirred continuously until it reached 77 to 79^{o}C. The skillet-cooked scrambled eggs were cooked to a higher temperature than was used for the oven-cooked scrambled eggs, because at 75^{o}C. the scrambled egg mixture in the skillet was partially fluid and did not coagulate to a servable consistency until the temperature reached 77 to 79^{o}C.

Development of formula and preparation schedules

A formula was adapted from one-fourth of the proportions of eggs, liquid, and salt in a quantity recipe[2] for scrambled dried whole eggs. Water was substituted for the milk in the original recipe to prevent introducing an additional flavor to the scrambled eggs. The recipe proportion of 3.7 tsp. (18 ml.) liquid to one egg was altered to 2.9 tsp. (14 ml.) due to the excessive moistness of scrambled eggs prepared from the original recipe.

---

[2]Lenore M. Sullivan's Recipe File, copyright 1944, Iowa State College Press.

A difference in the dimensions of the skillet and the half-counter pan necessitated preparing two quantities from the formula to achieve an equal depth of the mixture in both containers. Instead of applying fat to the interiors of the half-counter pan and skillet, they were sprayed with a flavorless lecithin spray which prevented sticking.

The scrambled eggs were mixed on the Hobart Kitchen Aid mixer, Model No. K5-A, using the paddle attachment. Although planetary revolutions of 130 to 160 per minute were satisfactory for mixing the frozen eggs, the paddle threw the dried eggs out of the bowl and necessitated a reduction to 62 revolutions per minute. A procedure was developed which allowed for the reconstitution of each of the processes of dried eggs and mixing of scrambled eggs from each of the four types of processed eggs.

The minutes required to cook scrambled eggs in the oven and in the skillet were observed and used to develop two daily preparation schedules which allowed for subjective evaluation of the scrambled eggs immediately after preparation. Although scrambled eggs cooked in the oven were served first on half of the days, preparation of oven-cooked scrambled eggs was always begun first because of the longer time required for cooking the eggs.

Determining evaluation techniques

Methods for evaluating the scrambled eggs subjectively and objectively were selected. The scrambled eggs were evaluated by a taste panel immediately after cooking. Samples of the scrambled eggs were reserved for selected objective measurements.

Subjective evaluation. During two sessions for training the taste panel, scrambled eggs were served on heated china plates in heated stainless steel serving assemblies[3] to each taste panel member for subjective evaluation. In the first training session, the judges detected an aftertaste from the first sample of the scrambled eggs which impaired the evaluation of the second sample. Therefore, in the second training session and for each of the observations during the data collection period, the judges were asked to condition their mouths before evaluating each sample of scrambled eggs by eating unsalted crackers and drinking water containing lemon juice.[4] The conditioning water was prepared by adding 2 tsp. of lemon juice to each quart of water.

Objective measurements. The percentage of syneresis, pH, and color of the scrambled eggs were measured with standard

---

[3]Dri-Heat Food System, Inc., Chicago 6, Illinois.

[4]ReaLemon, reconstituted lemon juice, a trademark of ReaLemon Co., Chicago 9, Illinois.

methods and equipment. Various means of measuring the tenderness of the scrambled eggs were considered.

Scrambled eggs were cooked to three end point temperatures, 69, 72, and 75°C., and measured for tenderness in four forms: unaltered, cubed by a French-fry cutter, forced through a sieve, and ground with the grinder attachment of a Hobart Kitchen Aid mixer, Model No. K-4. Differences in the tenderness of the scrambled eggs cooked to the three end point temperatures were detected when measured with the Precision Universal penetrometer, using the flat disc, and also when measured with the Allo-Kramer shear press, using the standard shear compression cell. However, the latter instrument detected greater differences among the samples and was selected for measuring the tenderness of the scrambled eggs. The differences in tenderness of the unaltered samples were evident in the shear press curves, therefore the scrambled eggs were presented for measurements in unaltered form.

Design of Experiment

Six replications of scrambled eggs were prepared from each of the four types of processed eggs and cooked by each of the two methods according to a randomized schedule of the process of egg, the method of cooking, and the serving order (Table 1). Scrambled eggs which were prepared from each of the four processes of eggs and cooked by one

Table 1. Schedule for preparation and evaluation of scrambled eggs prepared by two volume food service methods of cooking from four types of processed whole eggs (1 was served first, 2 was served second)

	Method of Cooking							
	Oven				Skillet			
	Process of Egg				Process of Egg			
Replication Number	Frozen	Spray-dried	Freeze-dried	Foam-spray-dried	Frozen	Spray-dried	Freeze-dried	Foam-spray-dried
1		2			1			
				2				1
	2						1	
			1			2		
2		2				1		
				1			2	
	2							1
			2		1			
3			2				1	
	1					2		
		1						2
				1	2			
4	1				2			
		1					2	
				2		1		
			1					2
5		2			1			
	2						1	
			2					1
				2		1		
6				1	2			
	1							2
		1					2	
			1			2		

method were served at least once on the same day with the scrambled eggs prepared from each of the four processes of egg and cooked by the other method. Two samples were prepared on three days of each week, resulting in forty-eight observations.

Immediately after the scrambled eggs were cooked by either method, samples of the scrambled eggs were submitted to eight taste panel members for subjective evaluation of aroma, color, syneresis, coagulation, moistness, tenderness, texture, and flavor of the scrambled eggs. An evaluation sheet is included in Appendix A. Objective measurements of syneresis, pH, color, and tenderness were determined for samples of scrambled eggs from each preparation. During the heating periods for the equipment and the cooking periods of the scrambled eggs, time-temperature data of the scrambled eggs, the oven, and the range surface were collected.

Procurement and Storage of Materials

Prior to the beginning of data collection, the ingredients required for preparation of the scrambled eggs were acquired and stored in the laboratory. The materials necessary for subjective evaluation were also purchased.

Eggs

Shell eggs from a common lot were purchased from a commercial processor[5] and equal portions were processed by each of four methods: freezing, spray-drying, freeze-drying, and foam-spray-drying. The shell eggs varied in age from one to two weeks and in grades from A to C. After the shell eggs were machine-broken under USDA supervision, the whole eggs were strained through stainless steel screens (0.014-in. perforations) and churned to produce homogeneity. A refractometer was used to check the whole eggs during stirring and when necessary liquid yolk was added to adjust the solids to 25.5 per cent. On a basis of 31.5 ± 0.5 per cent carbohydrate and 1.5 ± 0.25 per cent salt in the whole egg solids, liquid corn sirup and salt were added to the blended whole egg.

Freezing. After pasteurizing the whole eggs at 60 to 61°C. for 3.5 to 4 min., the whole eggs were frozen in 30-lb. containers and held at -30°C. until further processing or shipment. One-fourth of the frozen whole eggs was alloted for use as the control and equal amounts of the remaining eggs were spray-dried, freeze-dried, and foam-spray-dried.

Spray-drying. The frozen whole eggs were thawed, blended, and then spray-dried[6] in a pilot plant spray-dryer under

---

[5]Seymour Foods Co., Topeka, Kansas.

[6]Ibid.

atomizing pressures of 2000 lb. Intake temperatures ranged from 149 to 163°C. and exhaust temperatures varied from 66 to 71°C. The egg solids were strained through 16-mesh USBS screens, cooled to 29°C., packed in polyethylene-lined drums, and held at 20.6°C, until packaging.

Freeze-drying. The frozen eggs for freeze-drying were shipped to the processor[7] and maintained at -30°C. For 48 hr. before the eggs were freeze-dried, they were tempered at 14.4°C. After mixing, the thawed eggs were portioned into 10-lb. batches and placed in dryer pans in a Vacudyne sublimator. After freezing the eggs to -29°C. under a pressure of 100 microns, the eggs were vacuum-dried. During the 15.5-hr. drying cycle, the eggs did not reach a temperature above 50°C. At the end of the drying cycle, the vacuum in the chamber was broken with air and the eggs were removed. After the eggs reached 25°C., they were sealed in 5-gal. containers until final packaging.

Foam-spray-drying. The metal containers of frozen eggs were packed in dry ice and shipped to Michigan State University for foam-spray-drying by a modification of the process developed by Blakely and Stine.[8] The eggs were partially thawed

---

[7]Armour Grocery Products Company, Bellwood, Illinois.

[8]Food Science Department, Michigan State University, East Lansing, Michigan.

and heated to 54°C. in a water bath which was maintained at 60°C. Prior to drying, nitrogen gas was injected into the eggs under pressures of 900 to 1000 lb. The eggs were then foam-spray-dried using a co-current horizontal inverted tear-drop dryer equipped with two No. 62 nozzles with No. 20 spinners. The eggs were dried under an atomization pressure of 850 lb. Inlet temperatures ranged from 124 to 127°C. and exhaust temperatures varied from 79 to 82°C.

Packaging the eggs. The dried whole eggs were packaged[9] in laminated-foil pouches which consisted of three layers: polyethylene terephthalete (0.005-in. thickness), foil aluminum (0.001-in. thickness), and polyethylene (0.002-in. thickness). After drawing 27-in. vacuum on the dried eggs in the package, the eggs were purged with nitrogen twice and sealed on the third purging. The spray-dried and freeze-dried whole eggs were packaged in 1-lb. units and the foam-spray-dried whole eggs were packaged in 6-oz. units, because of the low density of the foam-spray-dried eggs.

Storing and repackaging eggs. Eggs which were processed by the three dehydration methods and by freezing were stored at approximately -23°C. in laboratory freezers. Three weeks before data collection began, 16 lb. of each process of dried egg were blended in a 20-qt. mixing bowl on a Hobart

---

[9] Jianas Brothers, Kansas City 5, Missouri.

mixer, Model No. A-200. Portions of the dried eggs which were adequate for one replication were heat-sealed in plastic pouches and stored at approximately -23^{o}C. The quantity of foam-spray-dried eggs was sealed in two packages because of the low density of the dried egg.

A 10-gr. sample of each process of blended dried egg was removed and sealed for moisture determination. From each 10-gr. sample of dried eggs, three samples of 2 gr. each were weighed into tared aluminum pans, dried for 6 hr. in a vacuum oven at a vacuum of 29 in. and temperatures of 70 to 80^{o}C., and then reweighed. The percentage of actual solids in the dried eggs was determined by dividing the weight of the egg before drying into the weight of the egg after the drying period.

The 30-lb. can of frozen whole egg was refrigerated at approximately 2^{o}C. for 48 hr. and reached temperatures of 1 to 2^{o}C. and a chunky consistency. Portions of egg adequate for one observation were weighed into 1-qt. plastic packages which were placed in 1-qt. plastic-coated paper containers. The plastic packages were closed with plastic-covered wires, the lids were placed on the paper containers, and the packaged eggs were then refrozen at approximately -23^{o}C.

Remaining materials

The remaining ingredients were obtained and stored in the laboratory. Two containers of the lecithin aerosol spray and a 1-lb. container of salt were obtained from the Michigan State University Food Stores and stored at room temperature. The distilled water, at room temperature, was obtained daily from a Barnstead still, Model No. 92235.

The materials used to aid in subjective evaluation were purchased from a grocery store. Two 1-lb. packages of unsalted crackers were purchased and two crackers were heat-sealed in cellophane pouches and stored at room temperature. The lemon juice used in subjective evaluation was purchased from a common lot and refrigerated.

Preparation of Scrambled Eggs

Scrambled eggs were prepared from each of the four types of processed whole eggs and cooked by each of the two cooking methods, using a standardized procedure developed in preliminary investigations in the laboratory. Quantities of ingredients for scrambled eggs prepared by the two methods of cooking from the four types of processed eggs are indicated in Table 2. The amounts of dried egg and water were calculated to equal the solids content of frozen whole eggs, 34.4 per cent.

Table 2. Formula for scrambled eggs prepared by two methods of cooking from four types of processed whole eggs

Method of Cooking	Process of Egg	Ingredients: Whole Eggs Gr.	Distilled Water Gr.	Salt Gr.
Oven	Frozen	1360	400	10.4
	Spray-dried	474	1286	10.4
	Freeze-dried	472	1288	10.4
	Foam-spray-dried	474-475*	1285-1286*	10.4
Skillet	Frozen	1027	302	7.9
	Spray-dried	358	971	7.9
	Freeze-dried	356	973	7.9
	Foam-spray-dried	358	971	7.9

*Differences in quantities in the foam-spray-dried eggs occurred because of the differences in moisture content in packages.

Preparation of ingredients

Frozen eggs were removed from the freezer and refrigerated for 20 hr. prior to use. Two hours before mixing, the frozen eggs were removed from the refrigerator, placed in a stainless steel bowl, and allowed to reach room temperatures of 23 to 25°C. The packages of dried eggs were removed from the freezer and placed at room temperature for one hour before mixing.

The amount of salt needed for each observation was weighed into scoops on a 120-gr. capacity Torsion dial balance, Model No. DLT2-1, covered with coded Saran wrap, and set aside until needed.

Before weighing, the calculated total amount of water for reconstituting the egg and for the scrambled egg formula was divided and the two equal amounts of distilled water were weighed on a 5-kg. capacity Toledo dial scale, Model No. 4020, into pre-weighed beakers which were then covered with coded Saran wrap and set aside until needed. Immediately before mixing the scrambled eggs, the amount of egg needed was weighed into a pre-weighed 5-qt. stainless steel mixer bowl on the 5-kg. dial scale.

Mixing procedure

Each of the eight treatments of scrambled eggs was mixed on the Hobart Kitchen Aid mixer, Model No. K5-A, according to a procedure developed during the preliminary investigation. The mixer was set on speed 1 and connected to a powerstat which adjusted the planetary revolutions of the mixer to approximately 62 per minute. The powerstat was connected to an electric timer which controlled the number of seconds for each mixing period.

A mixing procedure for the frozen and dried eggs was developed. The bowl containing the frozen egg was placed in the raised position on the mixer, the water and salt were added, and the ingredients were blended for 90 sec. For mixing the scrambled eggs from each of the three processes of dried eggs, the bowl containing the dried egg was placed in the raised position on the mixer, one-half of the total amount of water was added, and the ingredients were mixed for 30 sec. The sides of the bowl and the paddle were then scraped with a rubber spatula to loosen any undispersed powder. After the scrambled egg mixture was blended for an additional 30 sec., the bowl and the paddle were again scraped, and the remaining half of the water was added. Following a third mixing period of 30 sec., the bowl and paddle were again scraped, the pre-weighed salt was added, and the scrambled egg mixture was blended for 90 sec.

Immediately after mixing, the scrambled egg mixture was strained through a weighed household strainer (16 wires per linear in.). The scrambled egg mixture to be cooked in the oven was strained into a 4.5-qt. capacity half-counter pan and the mixture to be cooked in the skillet was strained into a porcelain-enameled measuring pitcher. The strainer containing any remaining residue was weighed. A 30-ml. sample of the raw scrambled egg mixture was placed in a beaker, covered with coded Saran wrap, and refrigerated for later pH and color evaluations.

<u>Cooking methods</u>

The scrambled eggs were prepared from each of the four processes of whole eggs and cooked by two methods: baked in a half-counter pan in an institutional deck oven and cooked in a skillet on an institutional range unit. Figure 1 shows the arrangement of apparatus and equipment used in cooking the scrambled eggs.

Figure 1. Apparatus and equipment used in cooking scrambled eggs in a skillet on an institutional range unit and in a half-counter pan in an institutional oven.

Oven-cooking. Two hours before the beginning of the cooking of the scrambled eggs in the oven, the temperature controllers for both of the two deck ovens were turned on, the grids were set on high, and the dampers pulled half-way out. Thirty minutes after the beginning of the heating period, the grids were turned to medium. Oven temperatures were recorded on a Minneapolis Honeywell-Brown Electronik potentiometer with a chart speed of 1 in. per 6 min. and a printout every 90 to 100 sec.

During the preliminary investigation, an apparatus was specially fabricated to record temperatures of the scrambled eggs during cooking in the oven. One thermocouple was positioned over the center of the pan and recorded temperature at 1.3 cm. from the bottom of the scrambled egg mixture. The other thermocouple was positioned to the side of the center thermocouple to record temperature at 0.2 cm. from the bottom of the scrambled egg mixture. The positions of the thermocouples were checked daily.

After the scrambled egg mixture was strained into the half-counter pan, the apparatus was clamped into place. A caliper reading of the depth of the scrambled egg mixture was taken next to the thermocouple in the center. If a depth greater than 2.8 cm. was measured, a portion of the liquid was removed to adjust the height of the scrambled egg mixture to 2.8 cm. The half-counter pan of scrambled eggs was then set on the wire rack on the deck of the oven, the door closed, and the beginning of baking time for the oven-cooked scrambled eggs marked on the potentiometer chart.

When the temperature at the center of the scrambled egg mixture reached 60°C., the oven door was opened and the scrambled egg mixture was stirred with a wooden spatula[10] which had been sprayed with the lecithin aerosol spray. During stirring of the scrambled egg mixture, the sides of the pan were scraped and then the spatula was moved across the bottom of the pan parallel to the sides of the half-counter pan six times. The spatula was also pushed under the thermocouples during each stirring period, which took 40 to 50 sec. The scrambled egg mixture was stirred when the center of the mixture reached 65, 70, and 72°C. After the stirring at 72°C., the scrambled egg mixture was stirred at every other printout for the center thermocouple or approximately every 3 min. After the scrambled egg mixture attained a temperature of 74 to 76°C., the half-counter pan of scrambled eggs was removed from the oven.

Skillet-cooking. Scrambled eggs were cooked in a 10-in. Teflon skillet on an institutional range unit. Temperatures of the scrambled eggs were obtained by positioning thermocouples over the center of the scrambled egg mixture in the skillet. Two thermocouples recorded temperatures at each of

[10]A spatula made of selected hardwood copyrighted in 1964 by Nevco and imported from Yugoslavia.

two depths: 1.3 and 0.2 cm. from the bottom of the skillet. The position of all thermocouples was checked daily.

The empty skillet was sprayed with lecithin and placed on a range unit and heated for 2 min. The scrambled egg mixture was then poured into the heated skillet, the beginning of cooking time for the skillet-cooked scrambled eggs was recorded on the potentiometer, and an interval timer was started for 2 min. The thermocouples were adjusted over the center of the skillet and a caliper reading was taken of the depth of the scrambled egg mixture at the center of the skillet. After 2 min., the scrambled egg mixture was stirred continually. First the scrambled egg mixture was loosened from around the side of the skillet, then the spatula was moved around the skillet at approximately 2 in. from the side of the skillet. The spatula was then moved around and under the thermocouples in the center of the scrambled egg mixture and back to the side. The pattern of stirring in concentric circles was alternately reversed and repeated until a temperature of 77 to 79^{o}C was recorded on the potentiometer chart. The skillet was then removed from the range unit and the scrambled eggs were immediately transferred to a half-counter pan which was preheated to 55 to 60^{o}C.

Evaluation of Scrambled Eggs

Immediately after removal from the source of heat, samples of scrambled eggs were removed for syneresis, pH, and color determinations and the half-counter pan of scrambled eggs was set into another preheated half-counter pan on a General Electric warming unit, Model No. GR11A, set at 3. The temperature of the bottom half-counter pan cycled from 65 to 70°C.

Subjective evaluation

Scrambled eggs were served to each of the eight panel members on white china plates in stainless steel serving assemblies which helped retain the temperature of the scrambled eggs during the serving and evaluation period. Each assembly consisted of a heated plate suspended over a heated metal pellet in a heated stainless steel bottom unit and covered with a heated cover unit. The pellets were preheated for 3 hr. to temperatures ranging from 115 to 120°C. in a General Electric warming unit, Model No. GR11A, set at 7. The stainless steel bottoms were heated in a range oven for 3 hr. to temperatures ranging from 50 to 60°C. A Hobart Kitchen Aid dishwasher, Model No. E36608, set on the plate warmer cycle, was used to warm the plates to temperatures varying from 55 to 65°C. and the stainless steel tops to a range of 60 to 70°C.

The scrambled eggs were portioned with a number 30 dipper and placed on each coded plate, which was then covered with the heated top. The remaining eggs in the half-counter pan were covered and refrigerated at approximately 2^{o}C. The scrambled eggs were served immediately to the taste panel for subjective evaluation.

Each of the eight members of the taste panel was seated at an assigned place under infrared lighting for each evaluation throughout the study. In addition to the unsalted crackers and water containing lemon juice for conditioning their mouths before judging each sample, glasses of tap water at room temperature were provided for the judges to use during the evaluations of the scrambled eggs.

The judges evaluated each sample of scrambled eggs for factors of aroma, color, syneresis, coagulation, moistness, tenderness, texture, and flavor of the scrambled eggs. Descriptive terms for each factor were chosen when applicable or for a score lower than fair. The first sample of scrambled eggs and the evaluation sheet were removed before serving the second sample. The instructions to the judges and an evaluation sheet are located in Appendix A.

<u>Objective measurements</u>

Samples of the scrambled eggs were prepared for measurements of syneresis, pH, color, and tenderness of the scrambled eggs.

Syneresis determination. Immediately after the scrambled eggs were removed from the source of heat, three samples were transferred with a number 30 dipper to three screen-covered petri-dishes for syneresis determination. An interval timer was started for 60 min. and the samples of scrambled egg and dishes were covered with a large bowl. The plastic petri-dishes and wire screens, 16 wires per linear inch, were pre-weighed on a Mettler top-loading precision balance, Model No. P1000. One hour after placing the sample of scrambled eggs on the screen, the bowl covering the samples was removed and each petri-dish with screen and scrambled eggs was weighed. The screens and scrambled eggs were removed from the top of the petri-dishes and each petri-dish containing any liquid drained from the scrambled eggs was weighed. The percentage of syneresis was determined by dividing the weight of the scrambled egg sample into the amount of liquid drained from each scrambled egg sample and multiplying the result by 100. Data from triplicate samples of the scrambled eggs were averaged for each replication.

Slurry preparation. Immediately after the scrambled eggs were removed from the source of heat, a number 8 dipper of the scrambled eggs was placed in a pre-weighed blender jar, which was then covered. Thirty to forty minutes later, the scrambled eggs were adjusted to 100 gr. and 50 gr. of distilled water was added. The scrambled eggs and water were blended for 2 min. at high speed on a Waring blender, Model No. PB5A, the sides of the jar scraped with a rubber spatula, and the slurry was blended for an additional minute. The resulting slurry of scrambled eggs was used for both pH and for color determinations.

pH determination. The pH values of single samples of the uncooked scrambled egg mixture and the cooked scrambled egg slurry were determined on a Beckman Zeromatic pH meter. The samples of scrambled eggs ranged in temperature from 16 to 20°C. Samples of the distilled water used in each replication of scrambled eggs were also evaluated for pH at 23 to 25°C.

Color evaluation. Ten ml. of the scrambled egg slurry was poured into each of three glass cells (2.7 cm. diameter by 2.7 cm. height) with flat bottoms of uniform optical properties. Stirring through the mixture with a small wooden spatula removed any air bubbles from the bottom of the cell. The optical cells were covered with Saran wrap which was secured with rubber rings. A sample of the uncooked scrambled egg mixture was also evaluated for color. Samples were refrigerated until evaluated.

The color of the scrambled egg samples was determined on a Bausch and Lomb Spectronic-20 colorimeter using the reflectance attachment. Prior to the period of data collection, the per cent reflectance at each wave length was determined using a block of magnesium carbonate as a pure-white standard. The reference settings from the calibration were used throughout the period of data collection. Each optical cell of scrambled egg mixture or slurry was placed in a light shield, set over the aperture, and the per cent reflectance recorded at each wave length on the Bausch and Lomb Trichromatic Coefficient Computing Form for Illuminant C. Before taking each reading, the bottom of the glass cell was wiped with lint-free tissue to remove any condensation. Values for x and y were determined on all samples of scrambled eggs. For each replication, the three x and y values for the cooked scrambled egg slurry were averaged and the x and y values for the uncooked scrambled eggs were based on a determination from one sample. The x and y values were plotted on a chromaticity diagram.

Shear press tenderness measurement. Three 100-gr. samples of the scrambled eggs which had been refrigerated for 1 hr. were weighed onto wax paper on a Mettler top-loading precision balance. After the wax paper was folded over each sample of scrambled eggs, the three samples were placed on a tray, covered with another tray, and again refrigerated. After a 3 to 3.5-hr. chilling period, the tenderness of each sample of scrambled eggs was measured on the Allo-Kramer shear press. The temperatures of the scrambled eggs ranged from 4 to 8^{o}C. during the measurements of tenderness of the scrambled eggs.

Each sample of scrambled eggs was placed in the standard shear compression cell which was composed of moveable stainless steel blades which meshed precisely with grids in the top and bottom of the sample box. For the determination of tenderness of the scrambled eggs, a 100-lb. ring, a range of 100, and downstroke speed of 30 sec. were used. The cell was positioned on the shear press and the pounds of force required to shear the scrambled eggs were recorded as a time-force curve by a Varian Associates electronic indicator, Model No. E2EZ, which was attached directly to the proving ring dynamometer. The cell and sample box were rinsed between each evaluation and as much of the excess water removed as possible.

The highest peak of the time-force curve which resulted from the maximum pounds of force required to shear and compress the scrambled eggs was recorded as a measure of tenderness of the scrambled eggs. The area-under-the-curve of the time-force curve was calculated according to a method described by Funk et al. and was recorded as a measure of tenderness of the scrambled eggs (29). The area covered by each time-force curve was not handled and was weighed immediately after being carefully cut from the graph paper. The area was carefully cut with sharp scissors along the line formed by the electronic indicator and weighed on a Mettler balance, Model No. 2. The weight of the paper in milligrams was multiplied by a factor of 174.2 which converted the weight of the time-force curve to an area of square centimeters. The averages for each replication of scrambled eggs for both maximum force and area-under-the-curve were calculated from values for three samples of scrambled eggs.

Analysis of data

The data obtained for all of the evaluations of the scrambled eggs were analyzed using statistical programs available for the CDC 3600 Computer at Michigan State University. The AOV routine was used to calculate the analysis of variance of the subjective data and of the objective measurements of syneresis, maximum force, and area-under-the-curve for the scrambled eggs. The data were analyzed for statistical differences due to variances between the two methods of cooking scrambled eggs, among the four types of processed whole eggs, and among the eight treatment combinations of scrambled eggs. The Studentized range test was used to determine the location of the significant differences indicated by the analysis of variance (18). Correlation coefficients for all combinations of the data were calculated using the BASTAT routine.

Numbers of 5, 4, 3, 2, and 1 were assigned to the subjective evaluations of excellent, good, fair, poor, and unacceptable, respectively, for the purpose of analyzing the data. The eight scores of each factor were averaged for each replication and the average score for each factor was used as the basis for the analysis of the subjective data. The average value for each objective measurement for each replication was used as the basis for analysis of the objective measurements.

RESULTS AND DISCUSSION

The objectives of this study were to evaluate the effect of spray-drying, freeze-drying, and foam-spray-drying on the coagulative properties and palatability characteristics of scrambled whole eggs prepared by two volume food service methods of cooking: in an institutional deck oven and in a skillet on an institutional range unit. Scrambled eggs were prepared according to a standardized procedure and evaluated by subjective and objective methods. Time-temperature data of the scrambled eggs were collected during cooking and the temperatures of the oven and range surface were recorded prior to, and during, the cooking periods.

The data from six replications of each variable were statistically analyzed to determine differences due to the four types of processed eggs and the two methods of cooking the scrambled eggs.

Subjective Evaluation of Scrambled Eggs

The taste panel of eight members subjectively evaluated the scrambled eggs for each of eight factors: aroma, color, coagulation, syneresis, moistness, tenderness, texture, and flavor. The taste panel used a scale of five quality terms: excellent, good, fair, poor, and unacceptable. After the eggs were evaluated by the judges, numbers of 5, 4, 3, 2, and 1 were respectively assigned to the quality terms for the purpose of analyzing the data. The judges were asked to check descriptive terms on the evaluation sheet for each factor evaluated as fair or lower. Average taste panel scores for each factor for each replication of scrambled eggs are located in Table 16, Appendix B.

Analyses of scores for aromatic and visual factors

Scores for aroma and for the visual factors of color, coagulation, and syneresis of the scrambled eggs were statistically analyzed. The results of analyses of variance of scores for aromatic and visual factors of the scrambled eggs are shown in Table 3 and the average scores and standard deviations are located in Table 4. Significant differences which existed among scores for replications for each of the aromatic and visual factors will be discussed later.

Variance among egg processes. Analyses of variance of scores for aroma and for each of the visual factors of the scrambled eggs disclosed that the only significant difference which was due to the type of processing was for color (Table 3). Analyses of variance of aroma, syneresis, and coagulation indicated no significant differences among egg processes (Table 3).

Table 3. Analyses of variance of scores for aromatic and visual factors of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods

Source of Variance	D.F.	Mean Square Values			
		Aroma	Color	Syneresis	Coagulation
Total	47				
Replication	5	0.6756**	0.2418**	0.1001***	0.2625**
Process	3	0.1079	0.1545*	0.0285	0.0938
Cooking Method	1	7.8062***	36.9064***	0.0344	21.9569***
Method x Process	3	0.0236	0.0779	0.0189	0.0205
Error	35	0.0726	0.0542	0.0162	0.0739

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.
***Significant at the 0.1 per cent level of probability.

Comparisons of average color scores for the scrambled eggs prepared from each of four types of processed eggs indicated that the color of the scrambled spray-dried eggs was more desirable, at the 5 per cent level of probability, than the color of the scrambled freeze-dried eggs. No other significant differences due to type of processing were detected among the color scores of the scrambled eggs.

Variance between methods of cooking. Analyses of variance of the scores for aroma and for each visual factor indicated very highly significant differences between the two methods of cooking scrambled eggs for each of the factors of aroma, color, and coagulation and no significant differences for

Table 4. Average scores and standard deviations for aromatic and visual factors for scrambled eggs (scores based on a scale of 5 to 1)[a]

Factor	Method of Cooking	Process of Egg: Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	Average for Method of Cooking	Process Differences at 5% Level of Significance[c]
Aroma	Oven	2.63 ± 0.31	2.40 ± 0.37	2.38 ± 0.34	2.41 ± 0.53	2.46	NONE
	Skillet	3.35 ± 0.44	3.32 ± 0.32	3.19 ± 0.43	3.19 ± 0.26	3.26[b]	NONE
	Average	2.99	2.86	2.79	2.80		NONE
Color	Oven	2.14 ± 0.30	2.15 ± 0.17	2.01 ± 0.38	2.02 ± 0.35	2.08	NONE
	Skillet	3.71 ± 0.19	4.09 ± 0.10	3.69 ± 0.34	3.84 ± 0.28	3.83[b]	NONE
	Average	2.92	3.11	2.85	2.93		FD F FSD SD (FD F FSD underlined together; F FSD SD underlined together)
Syneresis	Oven	3.98 ± 0.10	4.17 ± 0.19	4.13 ± 0.08	4.15 ± 0.10	4.11	NONE
	Skillet	4.15 ± 0.15	4.18 ± 0.20	4.15 ± 0.21	4.17 ± 0.22	4.16	NONE
	Average	4.06	4.17	4.14	4.16		NONE
Coagulation	Oven	1.92 ± 0.32	2.12 ± 0.26	2.03 ± 0.39	2.07 ± 0.33	2.03	NONE
	Skillet	3.34 ± 0.19	3.54 ± 0.17	3.29 ± 0.43	3.37 ± 0.30	3.39[b]	NONE
	Average	2.63	2.83	2.66	2.72		NONE

[a]Scores: 5 = excellent, 4 = good, 3 = fair, 2 = poor, and 1 = unacceptable.

[b]The two methods of cooking were significantly different at the 0.1 per cent level of probability.

[c]Processes of eggs underlined are not significantly different.

syneresis (Table 3). The panel preferred the aroma, color, and coagulation of the skillet-cooked scrambled eggs to the oven-cooked scrambled eggs. The average scores for syneresis were in the good range for scrambled eggs cooked by each method.

The average score for aroma of the skillet-cooked scrambled eggs, 3.26, was fair and significantly higher at the 0.1 per cent level from the average aroma score for the oven-cooked scrambled eggs, 2.46, which was poor (Table 4). The panel marked descriptive terms of unpleasant, musty, and sulphury more frequently for the oven-cooked scrambled eggs than for the skillet-cooked scrambled eggs. Comments of "sweetish" and "weak egg" were added for eggs cooked by each method.

The average score for color for the skillet-cooked scrambled eggs, 3.83, was almost in the good range and was significantly higher at the 0.1 per cent level of probability than the average score for color of the oven-cooked scrambled eggs, 2.08, which was poor. The panel more often marked descriptive terms of dark yellow, browning, and uneven color for the oven-cooked scrambled eggs than for the skillet-cooked scrambled eggs.

The average score for the coagulation of the skillet-cooked scrambled eggs, 3.39, was fair and was significantly higher at the 0.1 per cent level of probability from the average score for coagulation of the oven-cooked scrambled eggs, 2.03, which was evaluated as poor (Table 4). The panel more often marked descriptive terms of underdone, lumpy, layered, and uneven coagulation for the oven-cooked scrambled eggs than for the skillet-cooked scrambled eggs.

Analyses of scores for taste factors

Scores for the taste factors of moistness, tenderness, texture, and flavor of the scrambled eggs were submitted to analyses of variance (Table 5). The averages of scores and standard deviations for the scrambled eggs are located in Table 6. Significant differences which existed among replications for scores of moistness, tenderness, and texture will be discussed later.

Table 5. Analyses of variance of scores for taste factors of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods of cooking

Source of Variance	D.F.	Mean Square Values			
		Moistness	Tenderness	Texture	Flavor
Total	47				
Replication	5	0.3520*	0.8866***	0.5909***	0.2611
Process	3	0.1249	0.0134	0.1379	0.4181*
Cooking Method	1	16.5004***	0.1617	21.3571***	9.3602***
Method x Process	3	0.1922	0.1232	0.0623	0.0560
Error	35	0.1340	0.0785	0.0664	0.1135

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.
***Significant at the 0.1 per cent level of probability.

Table 6. Average scores and standard deviations for taste factors for scrambled eggs (scores based on a scale of 5 to 1)[a]

Factor	Method of Cooking	Process of Egg: Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	Average for Method of Cooking	Process Differences at 5% Level of Significance[c]
Moistness	Oven	2.24±0.41	2.63±0.36	2.63±0.38	2.72±0.60	2.55	NONE
	Skillet	3.74±0.21	3.77±0.18	3.77±0.50	3.62±0.40	3.73[b]	NONE
	Average	2.99	3.20	3.19	3.17		NONE
Tenderness	Oven	3.23±0.48	3.33±0.48	3.40±0.24	3.47±0.50	3.36	NONE
	Skillet	3.54±0.39	3.54±0.19	3.51±0.60	3.31±0.33	3.47	NONE
	Average	3.39	3.44	3.45	3.39		NONE
Texture	Oven	1.79±0.35	2.05±0.28	2.10±0.31	1.84±0.45	1.95	NONE
	Skillet	3.27±0.20	3.41±0.08	3.24±0.48	3.19±0.54	3.28[b]	NONE
	Average	2.53	2.73	2.67	2.51		NONE
Flavor	Oven	2.27±0.32	1.96±0.10	2.26±0.48	1.92±0.29	2.10	NONE
	Skillet	3.24±0.23	2.98±0.19	2.99±0.66	2.74±0.41	2.98[b]	NONE
	Average	2.75	2.46	2.62	2.33		FSD SD FD F

[a]Scores: 5 = excellent, 4 = good, 3 = fair, 2 = poor, and 1 = unacceptable.

[b]The two methods of cooking were significantly different at the 0.1 per cent level of probability.

[c]Processes of eggs underlined are not significantly different.

Variance among egg processes. Analyses of variance of scores for taste factors for the scrambled eggs showed that the only significant difference which was related to the processing of eggs was for flavor (Table 5). Analyses of variance for moistness, tenderness, and texture scores for the scrambled eggs indicated no significant differences due to egg processes (Table 5).

The average score for flavor of scrambled eggs prepared from each of the processes was in the poor range on the evaluation sheet. The presence of dextrins in the dried eggs and frozen eggs could have been detected and would account for the low flavor scores. However, comparisons of the average scores for scrambled eggs from each of the four processes disclosed that the taste panel evaluated the flavor of the foam-spray-dried scrambled eggs significantly lower, at the 5 per cent level of probability, than the flavor of the frozen and freeze-dried scrambled eggs (Table 6). The taste panel marked the descriptive term of sweet for scrambled eggs prepared from each of the processes of eggs and also commented on the "unpleasant," "disagreeable," and "undesirable" flavor of the scrambled eggs.

Variance between methods of cooking. Analyses of variance of the scores for each taste factor of moistness, texture, and flavor for the scrambled eggs disclosed very highly significant differences which could be attributed to the two methods of cooking scrambled eggs (Table 5). The taste panel preferred the moistness, texture, and flavor of the skillet-cooked scrambled eggs to those cooked in the oven (Table 6). Analysis of variance of tenderness scores for the scrambled eggs showed no significant differences which could be attributed to the method of cooking (Table 5).

The average score for moistness for the skillet-cooked scrambled eggs, 3.73, was fair and was significantly different at the 0.1 per cent level of probability from the average score for the oven-cooked scrambled eggs, 2.55, indicating a rating of poor (Table 6). The panel frequently marked the oven-cooked scrambled eggs as wet and attributed the moistness to undercooking.

The average score for texture for the skillet-cooked scrambled eggs, 3.28, was fair and was significantly different at the 0.1 per cent level of probability from the average score for oven-cooked scrambled eggs. 1.95, which was unacceptable, although the average score was almost in the poor range (Table 6). The panel marked descriptive terms of uneven and curdlike for the texture of the oven-cooked scrambled eggs and often added comments of "gummy," "mushy," and "sticky."

The averages of the flavor scores for both methods of cooking scrambled eggs indicated that the taste panel significantly preferred the flavor of the skillet-cooked scrambled eggs over the oven-cooked scrambled eggs, at the

0.1 per cent level of probability (Table 6). The average of 2.98 for the flavor of the skillet-cooked scrambled eggs was poor, but was almost in the fair range. The average score for flavor for the oven-cooked scrambled eggs, 2.10, indicated that the long cooking period in the oven resulted in lower scores. The panel frequently marked the descriptive term of strong egg flavor for oven-cooked scrambled eggs and sweet was frequently marked for scrambled eggs cooked by both methods. Additional comments of "fishy," "perfumery," and "stale" were used to describe the flavor of both oven-cooked and skillet-cooked scrambled eggs.

Variance due to serving order

The analyses of variance of serving order of the scrambled eggs were calculated by combining replications 1 and 4, replications 2 and 5, and replications 3 and 6 to make three replications (Table 7). The analyses of variance of scores of scrambled eggs disclosed no significant differences which could be attributed to the order of serving for the factors of aroma, syneresis, coagulation, moistness, tenderness, texture, and flavor of the scrambled eggs, but did disclose a significant difference in color scores according to the order of serving the scrambled eggs. The colors of the scrambled eggs which were served first were significantly preferred, at the 5 per cent level of probability, over the color of the scrambled eggs served second.

Table 7. Analyses of variance of the effect of serving order on the scores for sensory factors of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods

Source of Variance	D.F.	Mean Square Values							
		Aroma	Color	Syneresis	Coagulation	Moistness	Tenderness	Texture	Flavor
Total	47								
Replication	2	0.0515	0.0684	0.0117	0.0203	0.0020	0.0550	0.0049	0.0216
Process	3	0.1079	0.1545	0.0285	0.0938	0.1249	0.0134	0.1379	0.4181*
Cooking Method	1	7.8062***	36.9064***	0.0344	21.9569***	16.5004***	0.1617	21.3571***	9.3602***
Serving Order	1	0.1535	0.3014*	0.0307	0.0587	0.5742	0.0166	0.0819	0.0316
Method x Process	3	0.0236	0.0779	0.0189	0.0205	0.1922	0.1232	0.0623	0.0560
Error	37	0.1531	0.0721	0.0274	0.1027	0.1587	0.1906	0.1402	0.1407

*Significant at 5 per cent level of probability.
**Significant at 1 per cent level of probability.
***Significant at 0.1 per cent level of probability.

Variance among replications

Analyses of variance of the sensory evaluations disclosed significant differences among replications of scrambled eggs for all factors except flavor (Tables 3 and 5). However, combining the replications for the analyses of the effect of serving order showed no significant differences among replications of the scrambled eggs (Table 7).

The scrambled eggs were difficult to replicate and although precautions were taken and a standardized procedure was followed, variations could have occurred. Significant differences among replications might be attributed to variation in individual judge's evaluations from day to day, to differences in the amount of heat received by the scrambled eggs, to differences in the cooking times, to changes in the eggs between serving and tasting, and to human errors of the investigator. The lower scores for the factors toward the end of the data collection period may have indicated panel fatigue. The severe weather at times during the investigation may also have influenced the judges' evaluations. The analyses of the objective measurements of the scrambled eggs disclosed no significant differences among replications.

Correlation coefficients between scores for sensory factors

Correlation coefficients were computed for selected combinations of the scores from the subjective evaluations of the scrambled eggs and are located in Table 8.

Table 8. Correlation coefficients for selected combinations of sensory factors evaluated in scrambled eggs

Combination of Factors	Correlation Coefficients
Aroma / Flavor	0.7868**
Color / Flavor	0.8407**
Syneresis / Coagulation	0.2931*
Syneresis / Moistness	0.3068*
Syneresis / Tenderness	0.2805
Syneresis / Texture	0.2979*
Coagulation / Moistness	0.9335**
Coagulation / Tenderness	0.3269*
Coagulation / Texture	0.9536**
Coagulation / Flavor	0.8487**
Moistness / Tenderness	0.4672**
Moistness / Texture	0.9316**
Moistness / Flavor	0.8195**
Tenderness / Texture	0.4422**
Tenderness / Flavor	0.3446*
Texture / Flavor	0.8619**

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.

A highly significant correlation, at the 1 per cent level of probability, was found between the aroma and flavor scores for the scrambled eggs. As the scores for aroma increased or decreased, the scores for flavor also increased or decreased, illustrating the interrelationship of the olfactory and taste senses.

Correlating the color scores with the flavor scores of the scrambled eggs resulted in a highly significant coefficient. The scores for color and for flavor of the scrambled eggs increased together.

Significant correlations, at the 5 per cent level of probability, were found between syneresis scores and scores for each of the factors of coagulation, moistness, and texture. The panel evaluated the scrambled eggs as having less syneresis as the scores for the other factors increased. The correlation coefficient computed between syneresis scores and tenderness scores of the scrambled eggs was not significant.

Highly significant correlation coefficients for the comparisons of coagulation scores with each of the factors of moistness, texture, and flavor of the scrambled eggs indicated that the coagulation scores of the scrambled eggs increased at a highly significant rate as the scores for each of the other factors increased. Correlations which were significant at the 5 per cent level of probability were computed between coagulation and tenderness and between coagulation and syneresis, disclosing that as the scores for coagulation of the scrambled eggs increased, the scores for the other factors also increased.

Comparing the scores for moistness of the scrambled eggs with scores for coagulation, tenderness, texture, and flavor produced significant correlations, at the 1 per cent level of probability, indicating that as the panel's evaluation of moistness of the scrambled eggs increased, their evaluations of the other factors also increased. A significant correlation between moistness and syneresis of the scrambled eggs, at the 5 per cent level of probability, indicated that the scores for these factors increased together.

Significant correlations at the 1 per cent level of probability between tenderness scores of the scrambled eggs and the scores for texture and moistness showed that as the scores for tenderness of the scrambled eggs increased, the scores for the other factors also increased. Comparing tenderness scores of the scrambled eggs with scores for flavor and coagulation disclosed a significant correlation, at the 5 per cent level of probability, between the factors indicating that the scores increased together. The correlation coefficient computed between the tenderness scores and syneresis scores of the scrambled eggs was not significant.

Comparison of texture scores with scores for coagulation, moistness, tenderness, and flavor of the scrambled eggs yielded highly significant correlations, at the 1 per cent level of probability, showing that the scores for texture of the scrambled eggs increased as the scores for the other factors increased. A significant correlation, at the 5 per cent level of probability, was also computed between texture scores and syneresis scores of the scrambled eggs, indicating that the panel's evaluation of texture of the scrambled eggs increased with a corresponding increase in the panel's evaluation of absence of syneresis in the scrambled eggs.

Positive correlation coefficients were computed between flavor scores and scores for aroma, color, coagulation, moistness, and texture. A highly significant relationship was found between the flavor of the scrambled eggs and each of the other factors. Comparison of flavor scores with tenderness scores disclosed a significant correlation, at the 5 per cent level of probability, indicating that the scores of the scrambled eggs increased together.

Objective Evaluation of Scrambled Eggs

Portions of the scrambled eggs were evaluated objectively for syneresis, tenderness, color, and pH. The percentages of syneresis and the two shear press measurements of the scrambled eggs were submitted to three-way analyses of variance. The Studentized range test was used to locate the significant differences shown by the analyses of variance (18). The x and y values of the raw and cooked eggs were determined on a Bausch and Lomb Spectronic 20 colorimeter and plotted on a chromaticity diagram. The pH values of the raw and cooked scrambled eggs were determined with a Beckman pH meter. Correlation coefficients were computed for selected combinations of the objective measurements. Values for each of the objective measurements for each of the six replications of scrambled eggs are located in Tables 17 and 18 in Appendix B.

Analysis of syneresis measurements

Analysis of variance of the percentages of syneresis for the scrambled eggs are shown in Table 9. The percentages of syneresis ranged from 0.34 to 0.67 for oven-cooked scrambled eggs and from 0.60 to 1.02 for skillet-cooked scrambled eggs (Table 10).

Table 9. Analyses of variance of syneresis, maximum force, and area-under-the-curve for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods

		Mean Square Values		
Source of Variance	D.F.	Percentage of Syneresis	Maximum Force	Area-under-the-curve
Total	47			
Replication	5	0.1036	20.2167	1.0829
Process	3	0.1594	2.0293	0.1245
Cooking Method	1	0.5132*	3462.3356***	156.2745***
Process x Method	3	0.1872	4.2076	0.2887
Error	35	0.1025	11.0368	0.7469

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.
***Significant at the 0.1 per cent level of probability.

Significant differences existed at the 5 per cent level of probability between the methods of cooking scrambled eggs, but differences in the amount of syneresis of the scrambled eggs among the four types of processed eggs were not significant. Comparison of the averages of the percentage

Table 10. Averages and standard deviations of syneresis, maximum force, and area-under-the-curve measurements of scrambled eggs

Measurement	Method of Cooking	Process of Egg: Frozen	Spray-dried	Freeze-dried	Foam-spray-dried	Average for Method of Cooking	Significant Process Differences
Syneresis (%)	Oven	0.67±0.41	0.34±0.20	0.54±0.37	0.58±0.21	0.53*	NONE
	Skillet	0.60±0.41	0.74±0.21	0.60±0.30	1.02±0.37	0.74	NONE
	Average	0.63	0.54	0.57	0.80		NONE
Maximum Force (lb.)	Oven	12.11±1.57	13.58±3.16	12.31±4.52	13.86±3.22	12.97***	NONE
	Skillet	30.56±3.60	29.39±4.82	29.72±2.26	30.14±3.58	29.95	NONE
	Average	21.33	21.49	21.01	22.00		NONE
Area-under-the-curve (sq. cm.)	Oven	2.35±0.47	2.79±0.84	2.59±1.16	2.89±0.91	2.66***	NONE
	Skillet	6.36±0.91	6.11±1.21	6.29±0.48	6.31±0.83	6.26	NONE
	Average	4.35	4.45	4.44	4.60		NONE

*Significantly different at the 5 per cent level of probability.
***Significantly different at the 0.1 per cent level of probability.

of syneresis from the skillet-cooked scrambled eggs was significantly greater at the 5 per cent level of probability than the amount from the oven-cooked scrambled eggs. Skillet-cooked scrambled eggs had the highest average amount of syneresis indicating that a greater amount of coagulation had occurred in the skillet-cooked scrambled eggs than in the oven-cooked scrambled eggs.

Analyses of shear press measurements of tenderness

The tenderness of the scrambled eggs was measured using the standard shear compression cell on the Allo-Kramer shear press. Typical time-force curves for each variable of scrambled eggs are illustrated in Figure 2. The highest peak of the time-force curve from each evaluation was recorded as the maximum pounds of force required to shear the scrambled eggs and the area-under-the-curve was calculated by multiplying the weight of the time-force curve by 174.2 (29).

Analysis of maximum force measurement. An analysis of variance for tenderness of the scrambled eggs as measured by maximum force is shown in Table 9. A very highly significant difference existed between the two methods of cooking the scrambled eggs, but there were no significant differences in the tenderness of the scrambled eggs due to the four types of processed eggs (Tables 9 and 10). A greater amount of force required to shear the skillet-cooked

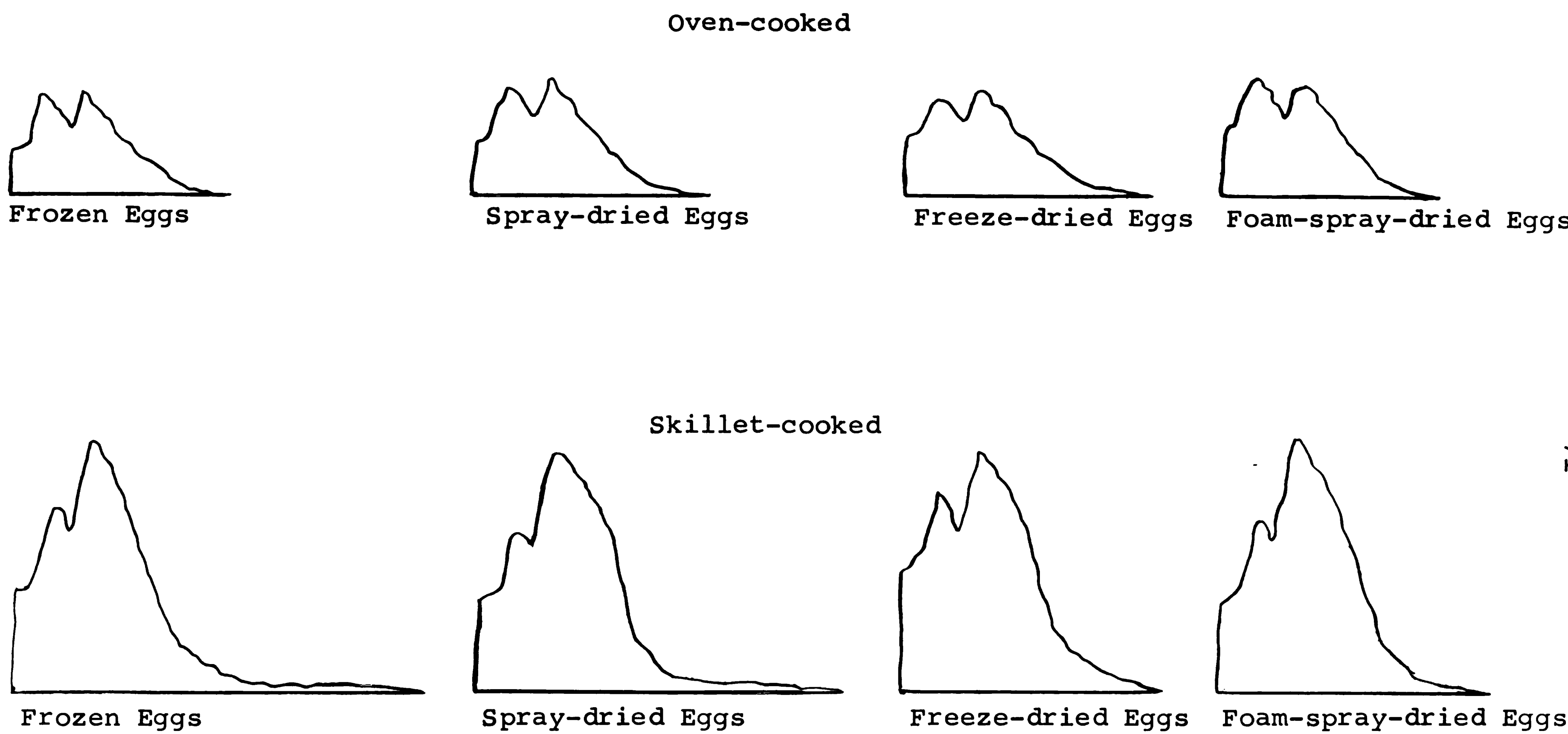

Figure 2. Typical Allo-Kramer shear press curves for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods.

scrambled eggs indicated that the skillet-cooked scrambled eggs were less tender than the oven-cooked scrambled eggs.

<u>Analysis of area-under-the-curve measurements</u>. Analysis of variance of the measurements of area-under-the-curve is shown in Table 9. A very highly significant difference existed between the two methods of cooking scrambled eggs, but there were no significant differences among area-under-the-curve measurements according to the four types of processed eggs (Tables 9 and 10). The skillet-cooked scrambled eggs were less tender than the oven-cooked scrambled eggs.

<u>Color measurements</u>

The averages and standard deviations for the x and y values of the color of the raw and cooked scrambled eggs are reported in Table 11. The standard deviations from the average x and y values were within 0.001 and 0.008 of the measurements shown in Table 11.

The average x and y values for the scrambled eggs prepared from each type of processed eggs and cooked by each method were plotted on a chromaticity diagram to identify the color of the raw scrambled egg mixture and of the cooked scrambled eggs.

The color of the raw scrambled egg mixture prepared from the spray-dried eggs was yellowish-orange and the raw scrambled egg mixtures prepared from frozen, freeze-dried, and foam-spray-dried eggs were yellow. The oven-cooked

Table 11. Average x and y values from color measurements of scrambled eggs prepared from four types of processed whole eggs and cooked by two methods

Color Measurement	Method of Cooking	Process of Egg: Frozen	Spray-dried	Freeze-dried	Foam-spray-dried
x Value					
Raw	Oven	0.385	0.380	0.378	0.376
Mixture	Skillet	0.383	0.379	0.381	0.377
y Value					
Raw	Oven	0.393	0.382	0.386	0.382
Mixture	Skillet	0.387	0.388	0.389	0.386
x Value					
Cooked	Oven	0.365	0.359	0.358	0.357
Eggs	Skillet	0.361	0.359	0.358	0.357
y Value					
Cooked	Oven	0.382	0.376	0.380	0.373
Eggs	Skillet	0.382	0.380	0.380	0.376

scrambled eggs prepared from the frozen eggs were yellow in color as compared to oven-cooked scrambled eggs prepared from the spray-dried, freeze-dried, and foam-spray-dried eggs which were greenish-yellow in color. The skillet-cooked scrambled eggs prepared from each type of processed egg were greenish-yellow in color and therefore showed a greater color change from the raw scrambled eggs than did the oven-cooked scrambled eggs. The subjective evaluation of the color of the scrambled eggs indicated that the panel preferred the color of the skillet-cooked scrambled eggs.

pH measurements

The pH values of the raw scrambled egg mixture and the cooked scrambled eggs are reported in Table 12.

Table 12. Averages and standard deviations of pH values for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods

pH Measurement	Method of Cooking	Process of Egg			
		Frozen	Spray-dried	Freeze-dried	Foam-spray-dried
Raw Mixture	Oven	7.8±0.14	8.3±0.16	8.3±0.08	8.3±0.05
	Skillet	7.7±0.08	8.4±0.16	8.3±0.18	8.4±0.12
Cooked Mixture	Oven	8.3±0.15	8.3±0.09	8.4±0.13	8.4±0.08
	Skillet	8.3±0.08	8.5±0.15	8.4±0.12	8.6±0.11

The average pH values of the raw scrambled egg mixture prepared from the frozen eggs were lower than the average pH values of the raw scrambled egg mixture prepared from the dried eggs. The average pH values for the cooked scrambled eggs were all 8.3 or higher, ranging to 8.6.

Correlation coefficients for combinations of objective measurements and between selected objective measurements and subjective evaluations

Correlation coefficients of selected combinations of the objective measurements and between selected combinations of the objective measurements and the subjective evaluations of the scrambled eggs are presented in Table 13.

Table 13. Correlation coefficients for combinations of objective measurements of scrambled eggs and between objective measurements and subjective evaluations

Combinations	Correlation Coefficients
Maximum Force / Area-under-the-curve	0.9926**
Maximum Force / Syneresis	0.2869
Area-under-the-curve / Syneresis	0.2890*
Objective Syneresis / Subjective Syneresis	-0.0597
Maximum Force / Coagulation	0.8946**
Maximum Force / Tenderness	0.0802
Maximum Force / Texture	0.8574**
Maximum Force / Flavor	0.7630**
Area-under-the-curve / Coagulation	0.8856**
Area-under-the-curve / Tenderness	0.1013
Area-under-the-curve / Texture	0.8462**
Area-under-the-curve / Flavor	0.7530**

*Significant at the 5 per cent level of probability.
**Significant at the 1 per cent level of probability.

Objective measurements of maximum force, area-under-the-curve, and syneresis were each compared with each other. A highly significant correlation, at the 1 per cent level of probability, between the shear press measurements of maximum force and area-under-the-curve of the scrambled eggs indicated that as the maximum force increased, the area-under-the-curve also increased. Significant correlations, at the 5 per cent level of probability, between area-under-the-curve and percentage of syneresis of the scrambled eggs indicated that as the tenderness of the scrambled eggs decreased, the percentage of syneresis increased.

Correlation coefficients computed between maximum force and percentage of syneresis were not significant.

Combinations of correlation coefficients between objective measurements and subjective evaluations as shown in Table 13 were selected to determine if a relationship existed between objective and subjective methods of measurement. The correlation coefficient computed between the objective measurement of syneresis and the subjective measurement of syneresis of the scrambled egg was not significant.

Combination of the shear press measurements of maximum force and area-under-the-curve with the subjective evaluations of coagulation, tenderness, texture, and flavor of the scrambled eggs produced significant correlations, at the 1 per cent level of probability, between each of the two shear press measurements and coagulation, texture, and flavor of the scrambled eggs. Since the panel scores for texture and coagulation of the scrambled eggs increased as the shear press measurements increased, this indicates that the less tender eggs were preferred and the more tender eggs were under-cooked. Significant correlations between flavor and shear press measurements of the scrambled eggs indicated that the flavor scores of the scrambled eggs increased as the shear press measurements increased.

Cooking Times and Temperatures of Scrambled Eggs

Time-temperature data which were recorded during the cooking of scrambled eggs are summarized in Figures 3 and 4. A potentiometer recorded the relationships between cooking times and temperatures of the scrambled eggs, the length of cooking times, and maximum temperatures for each of the observations of the scrambled eggs. Averages and standard deviations of total cooking times and maximum temperatures for the scrambled eggs are shown in Table 14. Time-temperature data for individual replications are shown in Tables 19 and 20 in Appendix B.

Oven-cooked scrambled eggs

Internal temperatures of the oven-cooked scrambled eggs increased rapidly until the scrambled eggs reached 70 to 72°C. (Figures 3 and 4, Table 14). In that range, coagulation began and the temperature fluctuated from 70 to 73°C. and increased slowly, illustrating the theory that coagulation is an endothermic reaction (48). Temperatures recorded at 1.3 cm. in the oven-cooked scrambled eggs rose more rapidly than temperatures at 0.2 cm. in the scrambled eggs until temperatures of 65 to 70°C. were reached and then the temperatures at 0.2 cm. exceeded the temperatures at 1.3 cm. (Figure 3).

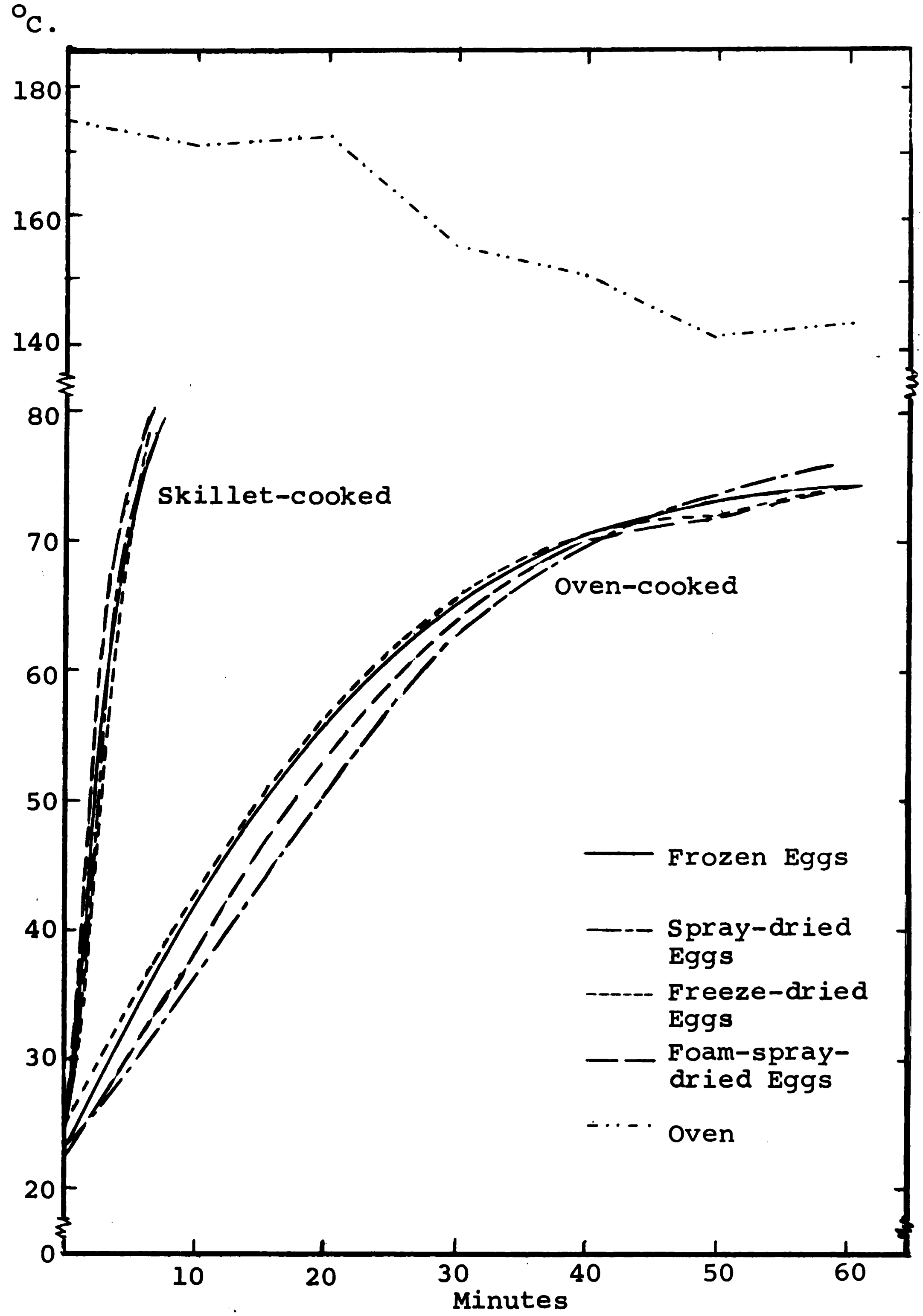

Figure 3. Average cooking times and temperatures (at 1.3 cm.) of oven-cooked and skillet-cooked scrambled eggs prepared from four types of processed whole eggs and average oven temperatures during cooking.

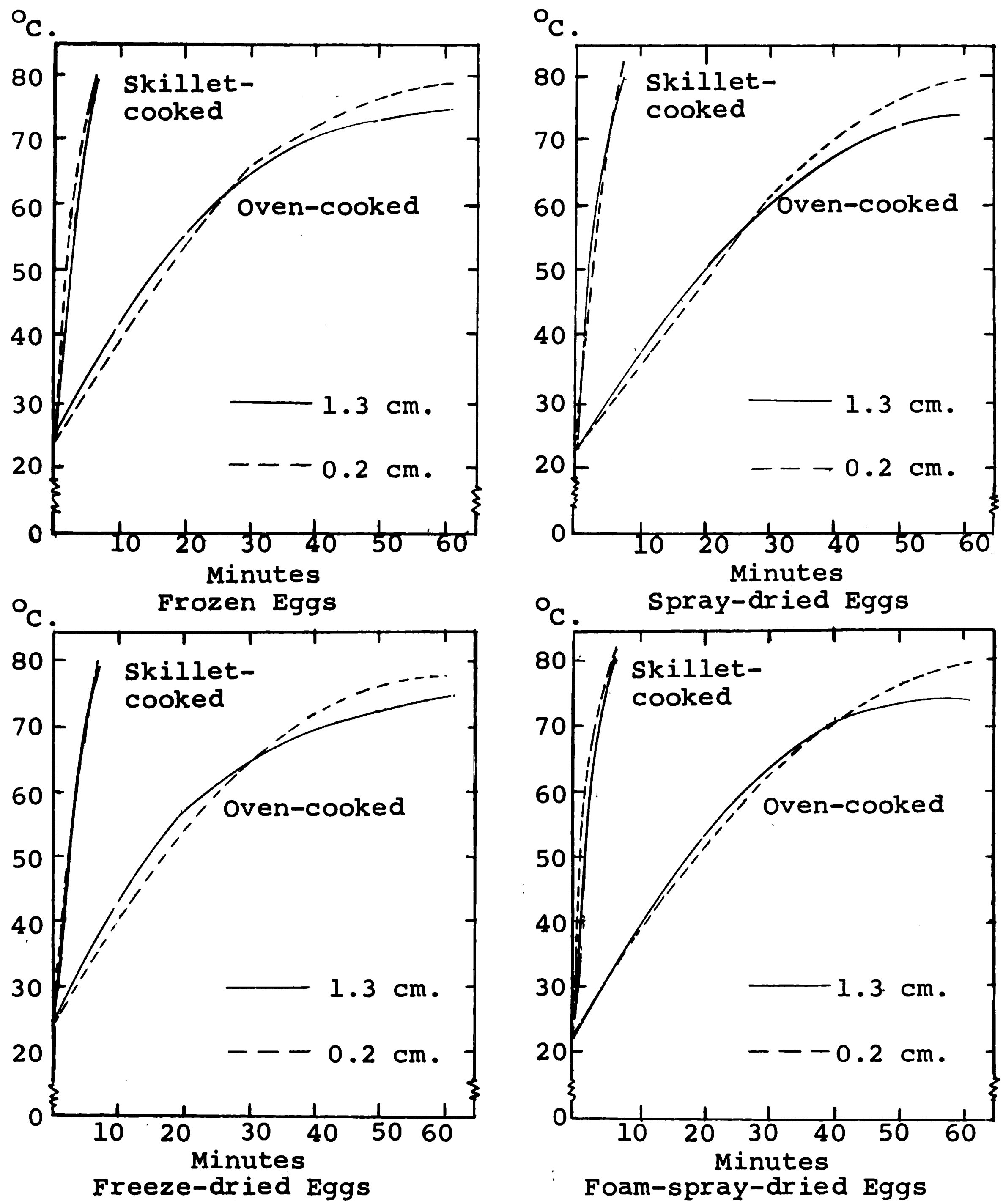

Figure 4. Average temperatures at 1.3 cm. and at 0.2 cm. during oven-cooking and skillet-cooking scrambled eggs prepared from four types of processed whole eggs.

Table 14. Averages and standard deviations of total cooking times and maximum temperatures for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods

Measurement	Method of Cooking	Process of Egg			
		Frozen	Spray-dried	Freeze-dried	Foam-spray-dried
Total Cooking Time (min.)	Oven	61.83±3.31	59.17±4.26	61.33±3.98	61.00±3.95
	Skillet	7.00±0.63	7.50±0.84	7.00±0.89	6.50±0.84
Maximum °C. at 1.3 cm.	Oven	74.67±1.86	76.50±1.76	74.33±1.21	74.33±1.21
	Skillet	78.00±1.10	79.33±1.03	78.33±1.51	79.83±1.17
Maximum °C, at 0.2 cm.	Oven	78.83±1.33	80.00±1.10	78.50±1.38	80.33±1.97
	Skillet	80.00±1.41	83.00±1.55	79.67±1.86	81.33±1.63

The average cooking time for the oven-cooked scrambled eggs from the frozen, freeze-dried, and foam-spray-dried eggs was 61 min. and the average cooking time for the spray-dried scrambled eggs cooked in the oven was 59 min. (Table 14). The differences in cooking times might be attributed to variations in oven cycling and to the loss of heat during the stirring periods when the oven door was open and shut.

The averages of the maximum temperatures of the oven-cooked scrambled eggs recorded at 1.3 cm. were: frozen eggs, 74.67°C.; spray-dried eggs, 76.50°C.; and of the freeze-dried and foam-spray-dried eggs, 74.33°C. (Table 14). Although the oven-cooked scrambled eggs were to be removed from the oven at 75°C., some of the scrambled eggs did not reach this temperature after 61 min. and were removed at a lower temperature. The temperatures of all of the oven-cooked scrambled eggs remained above 62°C. for at least 30 min., which would be sufficient to destroy Salmonella organisms (28) (Table 19, Appendix B).

Skillet-cooked scrambled eggs

The temperatures of the skillet-cooked scrambled eggs rose much faster than the oven-cooked scrambled eggs due to the direct source of heat (Figures 3 and 4, Table 14). The temperatures of the skillet-cooked scrambled eggs did not stabilize at a plateau around 70°C. as did the

oven-cooked scrambled eggs, but continued to rise rapidly. Skillet-cooked scrambled eggs reached average maximum temperatures at 1.3 cm. of 78.00°C. for frozen eggs, 79.33°C. for spray-dried eggs, 78.33°C. for freeze-dried eggs, and 79.83°C. for foam-spray-dried eggs. The recorded temperatures for all skillet-cooked scrambled eggs remained above 72°C. for at least 15 sec. and, therefore met the requirements for destruction of Salmonella organisms (28) (Table 20, in Appendix B).

The average cooking times for the skillet-cooked scrambled eggs were: frozen, 7.0 min.; spray-dried eggs, 7.5 min.; freeze-dried eggs, 7.0 min.; and foam-spray-dried eggs, 6.5 min. (Table 14). Variations in the cooking times for the skillet-cooked scrambled eggs might be attributed to the differences in the cycling of the range unit.

Correlation coefficients for combinations of flavor and time-temperature data

Correlation coefficients computed between flavor and cooking time and between flavor and maximum temperature at 1.3 cm. are shown in Table 15.

A negative correlation coefficient significant at the 1 per cent level of probability between total cooking time and flavor scores showed that the panel scores for flavor increased with the decrease in cooking time, reflecting the panel preference for the scrambled eggs cooked in the skillet. Comparisons of flavor of the scrambled eggs and maximum temperatures at 1.3 cm., significant at the 1 per cent level of probability, indicated that the panel scores for flavor rose as the maximum temperatures of the scrambled eggs rose.

Table 15. Correlation coefficients for flavor and cooking time and temperatures of scrambled eggs

Combinations	Correlation Coefficients
Flavor / Cooking Time	-0.7930**
Flavor / Maximum Temperature at 1.3 cm.	0.6286**

**Significant at the 1 per cent level of probability.

SUMMARY AND CONCLUSIONS

The objectives of this investigation were to evaluate the effect of spray-drying, freeze-drying, and foam-spray-drying on the coagulative properties and palatability characteristics of scrambled whole eggs and to compare the scrambled eggs cooked by two volume food service methods: in an institutional deck oven and in a skillet on an institutional range unit. Whole eggs for a master project were obtained from a common source and frozen. Equal portions of the frozen eggs were spray-dried, freeze-dried, and foam-spray-dried and one portion was reserved for use as a control.

A standardized procedure using institutional equipment whenever feasible was developed to prepare scrambled eggs from each of the four processes of eggs. A formula containing only eggs, water, and salt was selected to eliminate the possible masking of flavor of the eggs or influencing coagulation by other ingredients. Two samples of scrambled eggs were prepared and evaluated on each day. The scrambled eggs were prepared according to a schedule which randomized the four types of processed eggs, the two methods of cooking, and the order of serving the two samples. The oven-cooked scrambled eggs were baked in a half-counter pan in an institutional deck oven and stirred at pre-selected temperatures and intervals until the scrambled eggs reached 74 to 76°C. The skillet-cooked scrambled eggs were cooked in a preheated skillet on a range unit. Two minutes after the scrambled egg mixture was poured into the skillet, it was stirred continually until the temperature of the scrambled eggs reached 77 to 79°C. The scrambled eggs were served to a taste panel for subjective evaluation of aroma, color, syneresis, coagulation, moistness, tenderness, texture, and flavor. Data were collected from six replications of each of the eight variables and submitted to statistical analyses.

The results indicated significant differences which were attributable to the processing of the eggs. At the 5 per cent level of probability, the taste panel preferred the color of the spray-dried scrambled eggs over the freeze-dried scrambled eggs and preferred the flavor of the scrambled eggs prepared from the frozen and freeze-dried eggs over the foam-spray-dried scrambled eggs. No significant differences were indicated among egg processes for the remaining subjective evaluations or for any of the objective evaluations.

Statistically significant differences were found between cooking methods. The taste panel scores for the aroma, color, coagulation, moistness, texture, and flavor of the skillet-cooked scrambled eggs were significantly higher, at the 0.1 per cent level of probability, than the scores for the oven-cooked scrambled eggs. The two shear press measurements of maximum force and area-under-the-curve each showed a very highly significant difference in the tenderness of the scrambled eggs: the oven-cooked scrambled eggs were more tender than the skillet-cooked eggs. The percentage of syneresis of the skillet-cooked scrambled eggs was significantly higher, at the 5 per cent level of probability, than the amount from the oven-cooked scrambled eggs.

Correlation coefficients were computed for selected combinations of subjective evaluations and for selected combinations of subjective evaluations with objective measurements. Comparisons of the factors which were subjectively evaluated showed significant positive correlations, at the 1 per cent level of probability, between scores for aroma and flavor; between scores for color and flavor; between scores for coagulation and for each of the factors of moistness, texture, and flavor; between scores for tenderness and each of the factors of texture and moistness; and between scores for texture and flavor. Significant positive correlations, at the 5 per cent level of probability, were indicated between subjective evaluations of syneresis and each of the factors of coagulation, moistness, and texture. Significant correlations, at the 1 per cent level of probability, were indicated between scores for each of the factors of coagulation, texture, and flavor and each of the two shear press measurements of maximum force and area-under-the-curve.

Positive correlation coefficients were shown between certain objective measurements. Correlations between maximum force and area-under-the-curve measurements were significant at the 1 per cent level of probability. The shear press measurement of area-under-the-curve correlated significantly, at the 5 per cent level of probability, with objectively measured syneresis.

Statistically significant differences were detected among replications for average taste panel scores for all factors except flavor, whereas no significant differences were shown among the six replications in the analyses of objective measurements. These findings might indicate that scrambled eggs, which are difficult to consistently prepare and present to a panel, should be subjectively evaluated only for flavor. However, significant differences among replications did not evolve from analyses in which the six replications were combined into three replications to facilitate analyzing for the effect of serving order. A significant difference, at the 5 per cent level of probability, due to the order of serving the scrambled eggs was found only for the subjective evaluation of color: the scrambled eggs which were served first received significantly higher color scores, at the 5 per cent level of probability, than were received by those which were served last.

Measurements of pH and of color of the scrambled eggs were not statistically analyzed. The pH values of the raw frozen scrambled eggs were lower than the pH values of the raw dried scrambled egg mixtures. The pH values for all cooked scrambled eggs ranged from 8.3 to 8.6. Color determinations indicated that the raw spray-dried scrambled egg mixture was yellowish-orange as compared to the yellow color of the raw scrambled egg mixtures from each of the other processes. Oven-cooked scrambled eggs prepared from the spray-dried, freeze-dried, and foam-spray-dried eggs were greenish-yellow in color as compared to those prepared from the frozen eggs which were yellow. All of the skillet-cooked scrambled eggs were greenish-yellow in color.

The oven-cooked scrambled eggs required approximately an hour to reach the desired end point temperature of $75 \pm 1^{\circ}$C., whereas the skillet-cooked scrambled eggs reached $78 \pm 1^{\circ}$C. in approximately 7 min. Internal temperatures for all of the oven-cooked scrambled eggs increased rapidly until 70 to 72°C., then the temperatures rose slowly. The temperatures of the skillet-cooked scrambled eggs increased rapidly and did not reach a plateau as did the oven-cooked scrambled eggs. The recorded time-temperature data for the scrambled eggs cooked by each method indicated that the scrambled eggs received sufficient heat to meet the requirements for the destruction of Salmonella organisms. A negative correlation coefficient, at the 1 per cent level of probability, indicated that as cooking times for the scrambled eggs increased, flavor scores decreased. A positive correlation coefficient between maximum temperatures at 1.3 cm. and flavor scores was significant at the 1 per cent level of probability.

Results from this study point to the need for further research in the following areas: (1) an investigation of the drying processes on whole eggs without the addition of dextrins prior to drying, (2) a comparison of the palatability of scrambled eggs prepared by other volume food service methods of cooking, (3) further investigation into sensory evaluation techniques to determine the interrelationship among factors, (4) developing a method for objectively measuring the tenderness of scrambled eggs, as well as other foods, at serving temperatures, and (5) studies to assess the palatability and microbiological safety of scrambled eggs held for typical periods on steam counters or in serving units.

LITERATURE CITED

1. Amerine, M. A., R. M. Pangborn, and E. B. Roessler. Principles of Sensory Evaluation of Food. N.Y.: Academic Press. 1965.

2. Angelotti, R., M. J. Foter, and K. H. Lewis. Time-temperature effects on salmonellae and staphylococci in foods. II. Behavior at warm holding temperatures. Amer. J. Public Health. 51: 83, 1961.

3. Bailey, M. E., H. B. Hedrick, F. C. Parrish, and H. D. Nauman. L. E. E.-Kramer shear force as a tenderness measure of beef steak. Food Tech. 16 (12): 99, 1962.

4. Bate-Smith, E. C., J. Brooks, and J. R. Hawthorne. Dried egg--methods for the preparation, examination, and storage of spray-dried whole egg. J. Soc. Chem. Ind. 62: 97, 1943.

5. Bate-Smith, E. C., and J. R. Hawthorne. The nature of the reaction leading to the loss of solubility of dried egg protein. J. Soc. Chem. Ind. 64: 297, 1945.

6. Bennet, G., B. M. Spahr, and M. L. Dodds. The value of training a sensory test panel. Food Tech. 10: 205, 1956.

7. Bergquist, D. G. Eggs. In Van Arsdel, W. B., and M. J. Copley, eds.: Food Dehydration. II. Products and Technology. Westport, Conn.: The AVI Publishing Co., Inc., 1964.

8. Blair, E. Dried eggs. Vol. Feed. Mgmt. 25: 60, 1965.

9. Bowmer, E. J. Salmonellae in food--a review. J. Food and Milk Tech. 28: 74, 1965.

10. Davidson, H. R., and H. Hemmendinger. Fundamentals of color measurement. Color Eng. 1 (2): 19, 1963.

11. Davis, A. L. War on Salmonella. Food Proc. 25: 25, 1965.

12. Dawson, E. H., J. L. Brogdon, and S. McManus. Sensory testing of differences in taste. I. Methods. Food Tech. 17: 1125, 1963.

13. Dawson, E. H., J. L. Brogdon, and S. McManus. Sensory testing of differences in taste. II. Selection of taste panel members. Food Tech. 17: 1251, 1963.

14. Dawson, E. H., and E. F. Dochterman. A comparison of sensory methods of measuring differences in food qualities. Food Tech. 5: 79, 1951.

15. Dawson, E. H., D. E. Shank, J. M. Lynn, and E. A. Wood. Effect of storage on flavor and cooking quality of spray-dried whole egg. U.S. Egg and Poult. Mag. 51: 154, 1945.

16. Dawson, E. H., E. A. Wood, and E. H. McNally. Spray-dried eggs improved with carbohydrates. Food Ind. 19: 483, 1947.

17. Decker, R. W., T. N. Yeatman, A. Kramer, and A. P. Sidwell. Modifications of the shear-press for electrical indicating and recording. Food Tech. 11: 343, 1957.

18. Duncan, D. B. Multiple range tests for correlated and heteroscidastic means. Biometrics. 13: 164, 1957.

19. Endres, J. A. The effect of drying processes on the color and gel strength of baked whole egg and milk slurries. M. S. thesis. Michigan State University, 1965.

20. Feeney, R. E., and R. M. Hill. Protein chemistry and food research. In Chichester, C. O., E. M. Mrak, and G. F. Stewart, eds.: Advances in Food Research. N. Y.: Academic Press. 10: 23, 1960.

21. Forsythe, R. H. Chemical and physical properties of eggs and egg products. Cereal Science Today. 8: 309, 1963.

22. Forsythe, R. H. Recent advances in egg processing technology and egg products. Baker's Digest. 38: 52, 1964.

23. Forsythe, R. H. Eggs. In Matz, S. M. ed.: Bakery Technology and Engineering. Westport, Conn.: The AVI Publishing Co., Inc. 1960.

24. Forsythe, R. H., and J. C. Ayres. Should egg pasteurization requirements be changed? Poult. Proc. and Mktg. 68: 28, 1962.

25. Forsythe, R. H., and T. Miyahara. The use of modern egg solids in baking. Baker's Digest 33 (2): 57, 1959.

26. Foster, E. M. Salmonella challenges food industry. Food Eng. 38 (12): 107, 1966.

27. Fowler, S. F., B. B. West., and G. S. Shugart. Food for Fifty, 4th ed. N. Y.: John Wiley and Sons. 1967.

28. Frazier, W. C. Food Microbiology. N. Y.: McGraw-Hill Book Co. 1958.

29. Funk, K., M. E. Zabik, and D. M. Downs. Comparison of shear press measurements and sensory evaluation of angel cakes. J. Food Sci. 30: 729, 1965.

30. Goldblith, S. A., M. Karel, and G. Lusk. Freeze-dehydration of foods. Food Tech. 17: 139, 1963.

31. Griswold, R. M. The Experimental Study of Foods. Boston, Mass.: Houghton Mifflin Co. 1962.

32. Gruber, S. M., and M. E. Zabik. Comparison of sensory evaluation and shear-press measurements of butter cakes. Food Tech. 20: 968, 1966.

33. Hanrahan, F. P., and B. H. Webb. USDA develops foam-spray-drying. Food Eng. 33 (8): 37, 1961.

34. Hanson, H. L., and L. Kline. Consumer-type appraisal of whole egg powders stabilized by glucose removal and by acidification. Food Tech. 8: 372, 1954.

35. Harper, R. The psychologist's role in food-acceptance research. Food Tech. 16 (10): 70, 1962.

36. Harper, J. C., and A. L. Tappel. Freeze-drying of food products. In. Mrak, E. M., and G. F. Stewart, eds.: Advances in Food Research. N. Y.: Academic Press 7: 171, 1957.

37. Joslin, R. P., and B. E. Procter. Some factors affecting the whipping characteristics of dried whole egg powders. Food Tech. 8: 150, 1954.

38. Kauzmann, W. Some factors in the interpretation of protein denaturation. In Anfinsen, Jr., C. B., M. L. Anson, K. Bailey, and J. T. Edsall, eds.: Advances in Protein Chemistry. N. Y.: Academic Press. 14: 1, 1959.

39. Kline, L., T. T. Sonada, and H. L. Hanson. Comparison of the quality and stability of whole egg powders desugared by the yeast and enzyme methods. Food Tech. 8: 343, 1954.

40. Kline, L., T. T. Sugihara, and J. J. Meehan. Properties of yolk containing solids with added carbohydrates. J. Food Sci. 29: 693, 1964.

41. Knowles, N. R. The preservation of eggs. In Hawthorne, J. M., and J. M. Leitch, eds.: Recent Advances in Food Science. London: Butterworth's. 1962.

42. Kramer, A., G. J. Burkhardt, and H. P. Rogers. The shear press: a device for measuring food quality. The Canner. 112 (1): 34, 1951.

43. Kramer, A., and J. V. Hawbecker. Measuring and recording rheological properties of gels. Food Tech. 20: 209, 1966.

44. Kramer, A., and B. A. Twigg. Fundamentals of Quality Control for the Food Industry. Westport, Conn.: The AVI Publishing Co., Inc. 1962.

45. Lategan, P. M., and R. H. Vaughan. The influence of chemical additives on the heat resistance of Salmonella typhimurium on the liquid whole egg. J. Food Sci. 29: 339, 1964.

46. Lightbody, H. D., and J. L. Fevold. Biochemical factors influencing the shelf life of dried whole eggs and means for their control. In Mrak, E. M., and G. F. Stewart, eds.: Advances in Food Research. N. Y.: Academic Press. 1: 149, 1950.

47. Longrée, K., J. C. White, B. Y. Sison, and K. Cutlar. Scrambled eggs made with whole egg solids. J. Am. Dietet. A. 41: 213, 1962.

48. Lowe, B. Experimental Cookery from the Chemical and Physical Standpoint. 4th ed. N. Y.: John Wiley and Sons, Inc. 1955.

49. MacKinney, G., and A. C. Little. Color of Foods. Westport, Conn.: The AVI Publishing Co., Inc., 1962.

50. Matz, S. A. Food Texture. Westport, Conn.: The AVI Publishing Co., Inc., 1962.

51. Meyer, L. H. Food Chemistry. N. Y.: Reinhold Publishing Co. 1960.

52. Miller, C., and A. R. Winter. The functional properties and bacterial content of pasteurized and frozen whole eggs. Poult. Sci. 29: 88, 1950.

53. Miller, G. A., E. M. Jones, and P. J. Aldrich. A comparison of the gelation properties and palatability of shell eggs, frozen whole eggs, and whole egg solids in standard baked custards. Food Res. 24: 584, 1959.

54. Moulton, D. G. Physiological aspects of olfaction. J. Food Sci. 30: 908, 1965.

55. Nair, J. H. New developments in drying food stuff. Cornell Hotel and Restaurant Quarterly. 5 (5): 39, 1964.

56. Parkinson, T. L. Effect of heat and other factors on whole egg and its constituents. J. Sci. Food and Agr. 17: 233, 1966.

57. Present and Potential Use of Egg Products in the Food Manufacturing Industry: USDA Mktg. Research Rpt. No. 608, 1963.

58. Quantity Recipes Using Dried Whole Egg Solids. USDA AMS Bull. PA-437, March 1963.

59. Rolfes, T., P. Clements, and A. R. Winter. Physical and functional properties of lyophilized whole egg, yolk, and white. Food Tech. 9: 569, 1955.

60. Salwin, H., I. Block, and J. H. Mitchell, Jr. Dehydrated stabilized egg: importance and determination of pH. Food Tech. 7: 447, 1953.

61. Schlosser, G. C., M. S. March, and E. H. Dawson. Flavor and cooking quality of stabilized dried whole egg solids. Poult. Proc. 67 (9): 8, 1961.

62. Stuart, L. S., E. Grewe, E. E. Dicks. Solubility of spray-dried whole egg powder. U.S. Egg and Poult. Mag. 48: 489, 1942.

63. Sugihara, T. F., K. Ichichi, and L. Kline. Heat pasteurization of liquid whole egg. Food Tech. 20: 1076, 1966.

64. Van Arsdel, W. B. Food Dehydration. Vol I. Principles. Westport, Conn.: The AVI Publishing Co., Inc. 1963.

65. Ziemba, J. V. Egg solids to the forefront. Food Eng. 27: 77, 1955.

APPENDIX A

INSTRUCTIONS AND EVALUATION SHEET

USED IN SUBJECTIVE EVALUATION OF SCRAMBLED EGGS

Name: ______________________________

Institution Administration
Project 719 1966-67
Downs and Janek

INSTRUCTIONS TO TASTE PANEL MEMBERS FOR EVALUATING SCRAMBLED EGGS

Please follow the following instructions when evaluating the two samples of scrambled eggs which will be served, one at a time, during each taste period.

1. Do not smoke, chew gum, or partake of food or beverages during the 30 minutes before the taste panel time.

2. Sit at the same place in the room for each evaluation.

3. Before tasting each sample, eat one soda cracker and then clear the mouth with the conditioning water (marked L). If water is desired during the evaluation of a sample, use water from the unmarked glass. Extra crackers are on the table for those wishing more than one before evaluating each sample.

4. Check to see that numbers on the plates match those on the score cards.

5. As you evaluate each characteristic, check the space which best fits your overall judgment for that characteristic (excellent, good, fair, poor, or unacceptable). Also, please mark at least one term describing the reason for evaluating a product "fair", "poor", or "unacceptable." If an appropriate term is not listed check other and write a brief description in the "comment" column.

6. Since facial or vocal expressions may influence the scoring of other taste panel members, please remain quiet until all panelists are through evaluating.

7. Evaluate the aroma of the sample immediately on removal of the cover. Evaluate visual characteristics without disturbing the sample, and then evaluate the characteristics of taste.

8. Check to make sure you have checked eight spaces on the score sheet and have marked the descriptive terms as directed above.

9. Replace the cover and take your first sample, fork, and score sheet to the table. Return to your place, and await the arrival of the second sample, which should be evaluated according to the above procedure.

10. Students should record the time they are here each day.

11. You may leave the room after evaluating the second sample.

THANK YOU!

Institution Administration
Project 719 1966-67

Sample No. ______

EVALUATION SHEET FOR SCRAMBLED EGGS

Judge: ____________________
Date: ____________________

	FACTORS	Excellent*	Good	Fair	Poor	Unacceptable	Descriptive Terms		Comments
Olfactory	AROMA						__ Musty __ Strong Egg __ Foreign __ Lacking	__ Sulphury __ Unpleasant __ Other	
Visual	COLOR						__ Too Light __ Dark Yellow __ Uneven __ Browning	__ Greenish __ Pinkish __ Grey __ Other	
	SYNERESIS						__ Slight __ Moderate __ Excessive	__ Other	
	COAGULATION						__ Uneven __ Stiff __ Porous __ Lumpy	__ Layered __ Underdone __ Too Done __ Other	
Taste	MOISTNESS						__ Sl. dry __ Dry __ Sl. wet __ Wet	__ Uneven __ Other	
	TENDERNESS						__ Sl. tough __ Tough __ Leathery __ Rubbery	__ Other	
	TEXTURE						__ Grainy __ Rubbery __ Compact	__ Curdlike pieces __ Uneven __ Other	
	FLAVOR						__ Strong Egg __ Foreign __ Bitter __ Sweet	__ Flat __ Sulphury __ Other	

*An excellent scrambled egg is a light-yellow mass of slightly moist "scrambles" which are tender and evenly coagulated and are pleasing in aroma, flavor and appearance. There should be no visible syneresis in scrambled eggs of high quality

APPENDIX B

TABLES OF PALATABILITY SCORES, OBJECTIVE MEASUREMENTS, AND TIME-TEMPERATURE DATA FOR INDIVIDUAL REPLICATIONS OF SCRAMBLED EGGS

Table 16. Palatability scores[a] for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods[b]

Process of Egg	Method of Cooking	Replication Number	Characteristics: Aroma	Color	Syneresis	Coagulation	Moistness	Tenderness	Texture	Flavor
Frozen	Oven	1	3.00	2.50	4.13	2.25	2.38	3.38	2.13	2.75
		2	2.50	2.00	4.00	1.38	2.63	3.00	1.50	1.88
		3	3.00*	2.29*	3.86*	2.14*	2.86*	4.14	2.29*	2.43*
		4	2.43*	2.29*	4.00*	1.86*	2.29*	2.86*	1.43*	2.43*
		5	2.25	1.63	4.00	1.75	2.00	3.13	1.63	2.00
		6	2.63	2.13	3.88	2.13	2.25	2.88	1.75	2.13
Frozen	Skillet	1	4.13	3.88	4.13	3.38	3.50	4.13	3.38	3.13
		2	3.25	3.63	4.38	3.13	3.88	3.50	3.13	3.38
		3	3.50	3.88	4.25	3.63	3.88	3.75	3.63	3.38
		4	3.00*	3.86*	4.14*	3.43*	3.72*	3.00*	3.14*	3.57*
		5	3.38	3.50	4.00	3.13	3.50	3.25	3.25	3.00
		6	2.88	3.50	4.00	3.38	4.00	3.63	3.13	3.00
Spray-dried	Oven	1	2.50	2.38	4.25	2.38	3.25	4.00	2.38	2.13
		2	3.00	2.25	4.25	2.00	2.25	3.63	2.00	2.00
		3	2.50	2.00	4.25	2.38	2.88	3.50	2.25	2.00
		4	2.00*	2.00*	4.00*	1.71*	2.43*	3.00*	1.57*	1.86*
		5	2.00	2.00	3.88	2.00	2.50	3.25	2.00	1.88
		6	2.38	2.25	4.38	2.25	2.50	2.63	2.13	1.88
Spray-dried	Skillet	1	3.38	4.13	4.25	3.38	3.88	3.75	3.50	2.88
		2	3.63	4.13	4.38	3.63	3.88	3.75	3.38	3.25
		3	3.71*	4.00*	4.43*	3.57*	3.43*	3.57*	3.43*	3.00*
		4	2.86*	4.00*	4.00*	3.29*	3.71*	3.29*	3.29*	2.71*
		5	3.25	4.00	4.00	3.38	3.88	3.50	3.50	2.88
		6	3.13	4.25	4.00	3.63	3.88	3.38	3.38	3.13

Freeze-dried	Oven	1	3.00	2.50	4.25	2.13	2.88*	3.75	2.50	3.00
		2	2.38	1.75	4.13	1.50	2.38	3.50	2.00	1.75
		3	2.13	1.63	4.13	1.63	2.13	3.38	1.63	1.75
		4	2.43*	2.29*	4.14*	2.29*	3.00*	3.14*	2.00*	2.57*
		5	2.00	1.63	4.00	2.13	2.38	3.50	2.13	2.25
		6	2.38	2.25	4.13	2.50	3.00	3.13	2.38	2.25
Freeze-dried	Skillet	1	3.38	4.00	4.38	3.50	4.25	4.38	3.63	3.38
		2	3.71*	4.00*	4.14*	3.29*	3.71*	3.57*	3.29*	3.43*
		3	3.13	3.63	4.38	3.38	4.00	3.50	3.38	3.38
		4	2.43*	3.14*	3.86*	2.57*	3.00*	2.71*	2.43*	1.86*
		5	3.13	3.50	4.13	3.13	3.38	3.00	3.00	2.50
		6	3.38	3.88	4.00	3.88	4.25	3.88	3.75	3.38
Foam-spray-dried	Oven	1	3.13	2.13	4.13	2.38	3.38	3.88	2.63	2.38
		2	2.29*	2.43*	4.29*	2.57*	3.57*	4.00*	2.00*	2.00*
		3	2.50	1.88	4.25	1.88	2.38	3.50	1.75	1.88
		4	1.57*	1.43*	4.00*	1.71*	2.14*	2.57*	1.29*	2.00*
		5	2.25	2.00	4.13	2.00	2.50	3.38	1.75	1.75
		6	2.75	2.25	4.13	1.88	2.38	3.50	1.63	1.50
Foam-spray-dried	Skillet	1	3.50*	4.25*	4.00*	3.25*	4.00*	3.75*	3.63*	3.00*
		2	3.13	4.00	4.50	3.50	3.75	3.13	3.25	2.50
		3	3.50	3.88	4.38	3.38	3.63	3.25	3.38	3.00
		4	2.86*	3.43**	4.00*	2.86*	2.86*	2.86*	2.14*	2.29*
		5	3.00	3.75	4.00	3.50	3.88	3.25	3.25	2.63
		6	3.13	3.75	4.13	3.75	3.63	3.63	3.50	3.00

[a]Palatability scores: 5 = excellent, 4 = good, 3 = fair, 2 = poor, 1 = unacceptable.

[b]Each figure represents the average of eight taste panel members' scores unless otherwise designated.

*The figure represents the average of seven taste panel members' scores.

**The figure represents the average of six taste panel members' scores.

Table 17. Values for shear press measurements, percentages of syneresis, and pH for scrambled eggs prepared from four types of processed whole eggs and cooked by two methods

			Measurements				
			Shear Press[a]		Syneresis[a]	pH[b]	
Process of Egg	Method of Cooking	Replication Number	Maximum Force (lb.)	Area-under-the-curve (sq. cm.)	Percentage Drainage	Raw Mixture	Cooked Eggs
Frozen	Oven	1	11.50	2.40	0.44	7.7	8.1
		2	9.67	1.54	0.75	7.8	8.2
		3	13.00	2.73	1.40	8.0	8.5
		4	11.50	2.09	0.21	7.7	8.4
		5	12.83	2.63	0.74	7.8	8.4
		6	14.17	2.72	0.48	7.6	8.3
Frozen	Skillet	1	27.50	5.74	0.63	7.6	8.1
		2	26.83	5.46	0.21	7.7	8.2
		3	28.17	5.86	1.06	7.8	8.3
		4	35.50	7.72	0.32	7.7	8.3
		5	31.50	6.12	0.25	7.7	8.3
		6	33.83	7.25	1.11	7.6	8.3
Spray-dried	Oven	1	19.00	4.19	0.21	8.2	8.3
		2	9.67	1.70	0.71	8.6	8.3
		3	14.00	3.20	0.32	8.4	8.5
		4	11.33	2.38	0.19	8.3	8.5
		5	13.67	2.72	0.41	8.2	8.4
		6	13.83	2.54	0.20	8.2	8.4
Spray-dried	Skillet	1	28.17	6.17	0.68	8.3	8.3
		2	26.17	5.35	0.38	8.6	8.6
		3	23.50	4.52	1.04	8.5	8.7
		4	28.17	8.03	0.68	8.3	8.4
		5	28.17	5.81	0.91	8.2	8.4
		6	34.33	6.78	0.72	8.2	8.5

Freeze-dried	Oven	1	9.00	1.56	0.11	8.2	8.3
		2	8.83	1.59	0.99	8.2	8.5
		3	7.83	1.56	0.62	8.2	8.2
		4	16.00	3.57	0.81	8.3	8.5
		5	13.17	3.23	0.61	8.4	8.5
		6	19.00	4.08	0.09	8.3	8.4
Freeze-dried	Skillet	1	29.50	6.38	0.89	8.3	8.3
		2	30.17	6.69	0.66	8.3	8.3
		3	30.33	6.39	0.43	8.2	8.5
		4	27.50	5.85	0.83	8.3	8.4
		5	33.50	6.83	0.70	8.4	8.6
		6	27.33	5.60	0.09	8.4	8.5
Foam-spray-dried	Oven	1	18.50	4.08	0.93	8.3	8.3
		2	11.33	2.59	0.71	8.4	8.4
		3	10.00	1.67	0.53	8.3	8.4
		4	15.17	3.32	0.47	8.4	8.5
		5	16.00	3.55	0.29	8.4	8.5
		6	12.17	2.15	0.54	8.3	8.5
Foam-spray-dried	Skillet	1	31.00	6.42	1.33	8.2	8.4
		2	35.67	7.55	1.37	8.3	8.6
		3	32.50	6.90	0.75	8.5	8.6
		4	26.67	5.37	0.84	8.4	8.7
		5	28.33	6.01	0.54	8.4	8.7
		6	26.67	5.57	1.27	8.5	8.6

[a]Values based on averages of three determinations for this measurement.

[b]Values based on one determination for this measurement.

Table 18. Color determinations for scrambled eggs prepared from four types of processed whole eggs cooked by two methods

Process of Egg	Method of Cooking	Replication Number	Color Determinations: Raw Mixture[a] x Value	Raw Mixture[a] y Value	Cooked Scrambled Eggs[b] x Value	Cooked Scrambled Eggs[b] y Value
Frozen	Oven	1	0.387	0.395	0.368	0.383
		2	0.391	0.394	0.372	0.389
		3	0.384	0.390	0.365	0.380
		4	0.388	0.395	0.362	0.379
		5	0.380	0.398	0.383	0.380
		6	0.382	0.385	0.360	0.382
Frozen	Skillet	1	0.384	0.390	0.360	0.382
		2	0.375	0.385	0.362	0.380
		3	0.391	0.397	0.360	0.383
		4	0.384	0.379	0.360	0.379
		5	0.384	0.377	0.361	0.383
		6	0.380	0.393	0.360	0.383
Spray-dried	Oven	1	0.375	0.381	0.357	0.376
		2	0.381	0.390	0.363	0.381
		3	0.388	0.361	0.358	0.375
		4	0.375	0.388	0.361	0.380
		5	0.377	0.384	0.357	0.371
		6	0.384	0.390	0.356	0.374
Spray-dried	Skillet	1	0.384	0.393	0.358	0.375
		2	0.380	0.389	0.359	0.377
		3	0.380	0.386	0.356	0.381
		4	0.374	0.388	0.359	0.382
		5	0.379	0.389	0.357	0.378
		6	0.378	0.381	0.364	0.386

Freeze-dried	Oven	1	0.384	0.394	0.361	0.378
		2	0.377	0.378	0.366	0.382
		3	0.387	0.381	0.367	0.386
		4	0.372	0.382	0.359	0.377
		5	0.364	0.395	0.361	0.377
		6	0.382	0.387	0.359	0.381
Freeze-dried	Skillet	1	0.368	0.388	0.359	0.380
		2	0.382	0.380	0.355	0.379
		3	0.385	0.390	0.362	0.382
		4	0.384	0.390	0.357	0.380
		5	0.387	0.393	0.356	0.381
		6	0.381	0.393	0.359	0.378
Foam-spray-dried	Oven	1	0.367	0.375	0.358	0.374
		2	0.382	0.388	0.356	0.375
		3	0.375	0.383	0.359	0.372
		4	0.378	0.383	0.355	0.371
		5	0.380	0.385	0.354	0.371
		6	0.374	0.378	0.357	0.375
Foam-spray-dried	Skillet	1	0.374	0.379	0.360	0.380
		2	0.377	0.389	0.358	0.377
		3	0.378	0.387	0.355	0.377
		4	0.378	0.382	0.356	0.376
		5	0.371	0.385	0.359	0.376
		6	0.382	0.395	0.356	0.372

[a] Value based on one determination for this measurement.

[b] Value based on three determinations for this measurement.

Table 19. Time-temperature data for oven-cooked scrambled eggs prepared from four types of processed whole eggs

Process of Egg	Replication Number	Time-Temperature Data: Maximum Temperature °C. at 1.3 cm.	°C. at 0.2 cm.	Total Cooking Time (min.)	Minutes Cooked Over 62°C.
Frozen	1	73	77	61	39
	2	74	79	65	40
	3	78	79	57	33
	4	73	78	66	40
	5	75	79	60	34
	6	75	81	61	34
Spray-dried	1	79	80	57	30
	2	77	79	57	31
	3	77	80	54	32
	4	77	79	59	30
	5	75	80	66	32
	6	74	82	62	31
Freeze-dried	1	75	77	56	32
	2	76	77	66	40
	3	74	78	66	38
	4	73	79	61	37
	5	73	80	59	34
	6	75	80	60	34
Foam-spray-dried	1	75	79	57	32
	2	76	79	56	30
	3	75	81	60	32
	4	73	82	65	36
	5	73	78	63	32
	6	74	83	65	36

Table 20. Time-temperature data for skillet-cooked scrambled eggs prepared from four types of processed whole eggs

Process of Egg	Replication Number	Time-Temperature Data			
		Maximum Temperature		Total Cooking Time (min.)	Minutes Cooked Over 72°C.
		°C. at 1.3 cm.	°C. at 0.2 cm.		
Frozen	1	78	80	7	2.75
	2	77	81	8	2.50
	3	78	82	7	2.25
	4	78	78	6	1.50
	5	80	79	7	1.75
	6	77	80	7	2.00
Spray-dried	1	80	84	9	3.00
	2	79	82	7	2.25
	3	78	82	8	2.50
	4	79	81	7	2.50
	5	81	84	7	2.25
	6	79	85	7	3.00
Freeze-dried	1	79	78	6	1.25
	2	80	80	7	1.50
	3	80	80	6	1.75
	4	77	81	8	2.50
	5	77	77	8	1.75
	6	77	82	7	2.50
Foam-spray-dried	1	80	81	7	2.50
	2	82	83	6	1.75
	3	79	79	6	2.50
	4	80	80	6	2.00
	5	79	83	8	2.50
	6	79	82	6	2.50