ABSTRACT

A COMPARISON OF FROZEN, SPRAY-DRIED, FOAM-SPRAY-DRIED AND FREEZE-DRIED ALBUMEN IN SOFT MERINGUES

By

Karen Johnson Morgan

The primary objective of this study was to compare the quality characteristics of soft meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen. For this purpose, three lemon meringue pies were prepared, according to standardized procedures, for each of the six replications of each albumen process. A carrageenan stabilizer was added to all meringues. Meringues were evaluated 2 to 3 hr after preparation for pies designated as fresh and after a 20 to 22 hr refrigerated holding period for pies designated as held.

Objective measurements of albumen temperature, whipping times, specific gravity, foam stability and pH were determined for unbaked meringues. Time-temperature relationships were continuously recorded during baking. Percentages of evaporation and drainage were calculated in a manner similar to evaporation and drip losses of meat, respectively. Tenderness and height were objectively measured on fresh and held baked

meringues while color was determined only on fresh meringues and bead counts were determined only on held baked meringues. A trained taste panel evaluated fresh meringues for color and appearance, shrinkage, slippage and drainage, texture, tenderness, flavor and general acceptability.

Statistical analyses of the data showed no significant differences due to albumen process for albumen temperature, specific gravity and foam stability; however, the pH of spray-dried albumen was significantly higher ($P \leq 0.001$) than the pH of albumen processed by the other methods. Ranked in order of increasing average whipping times needed to obtain specific gravities of 0.24 to 0.22 were meringues prepared from frozen, freeze-dried, foam-spray-dried and spray-dried albumen.

The average maximum temperature of 85.3°C recorded from meringues prepared from foam-spray-dried albumen was significantly higher ($P \leq 0.05$) than similar temperatures of 78.3, 78.0 and 78.3°C recorded for meringues prepared from frozen, spray-dried, and freeze-dried albumen, respectively.

Percentages of drainage and evaporation did not differ significantly among albumen processes for fresh and held meringues. However, held meringues showed lower percentages of drainage than fresh meringues while percentages of evaporation were greatest for held meringues.

No significant differences were found among processes for Allo-Kramer shear press measurements of tenderness, expressed as maximum force and area-under-the-curve, color measurements, height and beading count. Sensory evaluations showed no significant differences among process for evaluation of color and appearance, slippage and drainage, texture, tenderness, flavor and general acceptability while evaluations of shrinkage varied significantly ($P \leq 0.05$). All meringues were evaluated as acceptable.

A second objective was to determine the effect of stabilizer on quality characteristics as determined by objective measurements and for this purpose meringues were prepared from spray-dried albumen with and without added stabilizer. Statistical analysis of the results indicated stabilizer significantly decreased drainage ($P \leq 0.01$) and increased tenderness ($P \leq 0.05$). Other objective measurements of specific gravity, foam stability, pH, evaporation, shrinkage and color indicated stabilizer had no significant effect on quality characteristics of the meringues.

The results of this investigation indicated acceptable meringues can be prepared with frozen, spray-dried, foam-spray-dried and freeze-dried albumen; however, whipping time must be adjusted to yield meringues of equal specific gravity and hence equal acceptability.

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Karen Johnson Morgan

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INTRODUCTION

Primary objectives of food service systems are the production and service of food of the highest quality attainable. Meringued pies can aid or deter fulfillment of these objectives. When properly prepared, a delicately browned, tender meringue on top of a filling in a crisp crust is very appetizing. If spray-dried, foam-spray-dried and/or freeze-dried albumen can be used for meringue production they could provide conveniences such as improved keeping quality, time economy and reduced storage space. In fulfilling these objectives the food service operator must predict the quantities of menu items needed to serve an undetermined number of people. When a day's production of a menu item exceeds the quantity served, the food may be held at refrigerated temperatures until the following day.

Stabilizers are often used as a special precaution to prevent liquid from draining from a meringue. A stabilized meringue is stiffer and drier than an unstabilized meringue and there is less accumulation of liquid between the filling and the meringue; thus meringue quality may be improved by the addition of minute quantities of stabilizers.

The primary purpose of this study was to compare the quality characteristics of soft meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen. For this purpose, three lemon meringue pies were prepared for each of the six replications of each albumen process. A carrageenan stabilizer was added to all meringues. Quality characteristics were evaluated 2 to 3 hr after preparation and after a 20 to 22 hr refrigerated holding period. A secondary objective of the study was to determine the effect of a carrageenan stabilizer on the stability of soft meringues. For this purpose, meringues were prepared from spray-dried albumen with and without added stabilizer.

Standardized procedures were utilized in preparation, objective measurements and subjective evaluations. The meringues were whipped to a specific gravity between 0.24 and 0.22 before being spread to a constant depth on lemon pie base and baked at 163°C. Five types of objective tests, which included height measurements, evaporation and drainage, tenderness, color and beading, were used. A 7-member taste panel evaluated seven quality characteristics of the meringues using a 7-point scale.

Data were analyzed statistically for significant differences attributable to albumen process, replication and stabilizer. Results obtained in this study were compared with those from an angel cake study to ascertain general trends attributable to processing of egg albumen.

REVIEW OF LITERATURE

Nature of Proteins

Proteins compose a major part of egg albumen. Denaturation and/or coagulation of albumen involves some type of change in the native protein. Thus to gain an understanding of the process of denaturation and/or coagulation, one must first understand the structure of protein.

Protein structure (Watson, 1965)

Proteins are immensely complex macromolecules that are polymers containing approximately twenty different amino acids linked by polypeptide bonds. A complete analysis of a given protein involves not only the quantity of each amino acid, but also the sequence in which the amino acid residue appears (primary structure), the interaction of the carbonyl groups with the imino groups which leads to the formation of helices (secondary structure), the three-dimensional folding of the polypeptide chains (tertiary structure), and the aggregation of two or more chains into the gross structural unit of the protein (quaternary structure).

The number of chains and the sequence of amino acids within them constitute the primary structure of proteins.

Polypeptides are linear molecules formed by the condensation of the nitrogen containing amino acids which are linked together with peptide bonds in a regular order. When several polypeptide chains are present in the same molecule, they are often held together by secondary forces. In other cases, disulfide bonds (S-S) between certain amino acid side groups keep them together. Disulfide bonds are also important in helping a single chain to maintain a rigid shape.

The protein secondary structure is polypeptide chains which are usually arranged in helical configurations and held together by secondary bonds. These bonds are between the carbonyl groups of first and fourth amino acids in the chain and result in the twisting of the molecule to form a helix.

The three-dimensional form of a protein is its tertiary structure. If each monomer group is in identical orientation within a polymeric molecule, each monomer forms the same group of the secondary bond as every other monomer. However, practically no proteins exist in the form of a simple helix for many reasons. The most important reason for this is the diverse chemical nature of the amino acid side groups. Two other reasons are: 1) some amino acids, for example proline, does not contain an amino group, thus regular hydrogen bonding must be interrupted, and 2) disulfide bridges are formed between cysteine residues. Thus, the tertiary structure of many irregular polymers is a compromise between the tendency of the regular chain to form a regular helix and the tendency of the irregular chain to twist the chain into a configuration that maximizes the strength of the secondary bonds. The three-dimensional configuration represents the energetically most favorable arrangement of the polypeptide chain. Each specific sequence of amino acids takes up the particular "native" arrangement that makes possible a maximum number of favorable contacts between it and its normal environment.

Hydrolysis of the protein changes it from a hydrophilic to a hydrophobic molecule. There is a strong tendency for nonpolar groups to arrange themselves so that they are not in contact with the water molecules because such a contact requires a considerable input of free energy. Water insoluble side groups are, therefore, found stacked next to each other in the interior of hydrolyzed protein, and the external surface contains groups that mix readily with water. Van der Waals bonding arises from a nonspecific attractive force originating when two atoms come fairly close to one another. In addition to attractive forces, repulsive forces are also important in stabilizing the structural configuration of proteins. It is based not upon the existence of permanent charge separations, but rather upon the induced fluctuating charges caused by the nearness of molecules. Van der Waals forces are effective bonding forces at physiological temperatures when several atoms in a given molecule are bonded to several atoms in another molecule. Van der Waals interactions are less important between polar molecules, however, because such molecules can acquire a lower energy state by forming other types of bonds. Hydrogen bonds are "links" formed when a hydrogen atom covalently bound to another atom is shared with a third atom that has a free pair of electrons. Since the natural medium of protein-protein interactions is aqueous, all polar groups on the surface of the molecule will be hydrogen bonded to water.

Denaturation and/or coagulation

There is presently no precise definition or explanation for the denaturation or coagulation processes. Some authors use these two terms interchangably; others define and discuss only one of the terms.

Mechanism theories. Feeney *et al*. (1960) has defined denaturation as "that change in the protein which causes an alteration in the physical and/or biological properties without breaking a primary chemical bond." Haurowitz (1963) and Meyer (1960) defined denaturation similarly: an alteration of protein chain conformation; during this alteration the peptide chains may become unfolded, refolded, or changed to some other formation due to the action of a denaturing reagent. Scherage (1961) described denaturation as "the process in which a protein or polypeptide is transformed from an ordered to a disordered state without rupture of covalent bonds." Colvin (1964) indicated recent research has established protein denaturation occurs in systems which do not contain long polypeptide chains, and "changes grouped under denaturation may be regarded as the result of phase changes or of transconformations in any high polymer and that the phenomena are not restricted in principle to proteins."

Lowe (1955) believed coagulation was closely related to denaturation and was the process of rendering proteins insoluble. Chick *et al*. (1910) defined coagulation as a reaction between the proteins and water (denaturation) and involved the separation of the altered proteins (precipitation). Macleod *et al*. (1937) stated in the first stage of coagulation the protein is modified by the process of hydrolysis which changes the protein from a hydrophilic to a hydrophobic colloid; however, coagulation actually occurs when the denatured protein is precipitated.

Causes. Heat, mechanical action, freezing, and dehydration are the most common causes of denaturation in food preparation. Heat denaturation occurs during cooking; often it is desired before the food is eaten as in the case of the coagulation of egg proteins. Mechanical action, such as stirring or whipping, may cause the formation of interfacial areas which result in surface denaturation. Mechanical denaturation can be desirable as in the case of egg white foams (Feeney *et al*., 1960).

Effect of pH. Chick *et al*. (1912-1913) reported acids hastened the heat coagulation process whereas alkalies prevented the coagulation process. The influence of acid on the coagulation rate of albumen is dependent on the quantity of acid added to the albumen (Chick et al., 1910). In a more recent study, Cunningham et al. (1964) found at pH values below 2.2, egg white forms a cloudy, milklike gel which remains stable until neutralized. The surface tension of egg white is not greatly altered by acid treatment; however, the viscosity of the system changes with both time and pH. Below pH 8.0 the viscosity of egg white falls gradually until a minimum is reached around pH 4.0. Further addition of acid causes a drastic increase in viscosity. By electrophoretic studies, Cunningham et al. (1964) showed the ovomucin (immobile fraction) was insolubilized and precipitated from egg white between pH 8.0 and 5.0. Below pH 4.0 the conalbumin fraction was gradually immobilized and at pH 3.0 failed to migrate. In a very acid medium (pH 1.0) the electrophoretic mobility of lysozyme was reduced by about 50%.

Composition of Albumen

Several researchers have studied the composition of egg albumen. From these studies Sweetman et al. (1959) and Romanoff et al. (1949) reported albumen contained 87.8 and 87.9% water, 10.8 and 10.6% protein, 0.0 and 0.03% fat, 0.0 and 0.9% carbohydrate, and 0.6 and 0.6% ash, respectively.

Albumen is found in four concentric layers within the egg according to Parkinson (1966), Sweetman et al. (1959), and Romanoff et al. (1949). The layer next to the yolk is dense and continuous with the chalazae. The second layer is thin, while the third and largest in volume is thick and jellylike. The fourth, or outer layer of albumen, is thin.

Romanoff et al. (1949) established that the concentric layers of albumen differ in chemical composition. The percentage of water in the four layers is as follows: outer liquid, 88.8%; middle dense, 87.6%; inner liquid, 86.4%; and liquid next to yolk, 84.3%. Since the dry matter of the albumen consists chiefly of protein, the percentage of protein therefore increases from the outermost to the innermost layer. Romanoff et al. (1949) also reported the percentage of minerals increases from the outermost to the innermost layer.

Albumen proteins

The difficulty in purifying proteins has resulted in a variety of postulations as to the actual number of proteins present in albumen. Romanoff et al. (1949) reported albumen contained five major proteins; Evans et al. (1956) separated the protein fractions by paper electrophoresis and found albumen consisted of four major proteins. With the use of improved techniques, Meyer (1960) and Feeney et al. (1960) both reported there are seven identified proteins in egg white. The findings of Feeney et al. (1960) on the composition of albumen are presented in Table 1.

Table 1. Principal constituents of albumen.

Constituent	Approx. amount (%)	Approx. isoelectric point	Unique properties
Ovalbumin	54.0	4.6	Denatures easily.
Conalbumin	13.0	6.0	Complexes iron.
Ovomucoid	11.0	4.3	Resistant to denaturation.
Lysozyme	3.5	10.7	Antimicrobial.
Ovomucin	1.5	?	Least soluble.
Flavo-protein	0.8	4.1	Binds riboflavin.
Avidin	0.05	9.5	Binds biotin.
Unidentified proteins	8.0		Mainly globulins.
Others	8.0		Primarily glucose and salts.

Information on the different proteins found in albumen has been reported by Meyer (1960) and Feeney et al. (1960). Ovalbumin, the most abundant of the egg white proteins, is readily denatured and precipitated by heat and a number of denaturation reagents. The second albumen protein, conalbumin, is an iron-binding protein and antibacterial agent. When this protein is denatured, it loses its iron-binding activity; however, the iron complex of this protein is very resistant to denaturation by heat and by enzyme attack. Ovomucoid is distinguished from ovalalbumin and conalbumin by its stability to heat. In many animal species this protein acts as an antienzyme for trypsin, diminishing the protease activity of the enzyme. The fourth protein, lysozyme, is a basic protein with an unusually high percentage of histidine, lysine, and arginine. Lysozyme is quite stable to heat, cold, and many denaturation reagents; however, it is unstable to alkali. Some proteases such as trypsin and papain do not attack it. The fifth protein component of egg white, ovomucin, is a poorly characterized fraction and probably never has been obtained in the pure state. Ovomucin is a mucoprotein which forms very viscous solutions, and these only under alkaline conditions. It is reputed to be the main component of the "mucin fibers" of egg white and hence is responsible for the physical structure of the thick white. Approximately four times as much ovomucin is found in the thick white as in the thin white. Avidin, the sixth protein, is present in egg white in relatively small amounts and has the unique function of binding the B vitamin, biotin, to make it unavailable to many species of bacteria and animals. It is another agent in the antibacterial defenses of the egg. The seventh albumen protein, flavo-protein, is distinctive in that the flavin moiety of the protein is riboflavin. Feeney et al. (1960) reported there are at least five uncharacterized proteins in albumen of which several probably belong to the globulins.

A few attempts have been made to determine the distribution of some of the individual proteins in the various layers of albumen. In an early study, Hughes (1936) defined only three layers of albumen and found the proportional amounts of protein in each as follows:

Table 2. Principal proteins in various layers of albumen.

Protein	Outer liquid (%)	Dense (%)	Inner liquid (%)
Ovalbumin	94.4	89.2	89.3
Ovoglobulin	3.7	5.6	9.6
Ovomucin	1.9	5.2	1.1

These data suggest that the albumen layers differ in protein content. These results have been substantiated by electrophoretic studies (Frampton et al., 1947).

Albumen pH

The first chemical change observed in an egg after it is laid is a rapid rise in the pH of the white. Feeney et al. (1960) reported the initial pH of the white to be about 7.6; while Griswold (1962) and Sweetman et al. (1959) reported a value of 7.9. The rate at which the pH rises is dependent upon the temperature of storage and the carbon dioxide content of the air since the rise in pH is accompanied by the escape of carbon dioxide through the pores of the shell (Feeney et al., 1960). Under the usual holding conditions, the pH of the white rises to approximately 8.5 in less than 24 hr. The pH then continues to rise, but much more slowly, until it is somewhere around 9.0 to 9.5 (Sweetman et al., 1959).

Processing Of Albumen

Processing albumen for experimental or commercial use involves exposing it to several treatments which may or may not affect the physical and functional properties of the albumen. Processes of concern in this thesis are those in which the albumen is exposed to freezing, spray-drying, foam-spray-drying and freeze-drying. Techniques used in the freezing and the spray-drying processes have been reviewed by Brown (1964). Endres (1965) reviewed the techniques used in the freeze-drying process and Wolfe (1967), the techniques used in the foam-spray-drying process.

Effect of processing on proteins

Freezing can damage proteins either by surface action or dehydration. Feeney *et al*. (1960) postulated ice crystal formation causes rupture of physical structures and denatures protein either by surface phenomena at the ice solution interfaces or by removing water essential for normal structure. Feeney *et al*. (1960) also stated the drying processes may cause undesirable surface denaturation of egg proteins if faulty drying techniques, including use of too high a drying temperature or too severe a shear force, are used.

Effect of processing on pH

Changes in pH result when albumen is subjected to drying processes. Hill *et al*. (1965) reported that a spray-dried albumen sample which reconstituted at pH 9.0 may have had a pre-drying pH of 6.0 to 8.5. Since carbon dioxide is almost completely lost during the adjustment of albumen to pH levels below 5.5, little pH change results from spray-drying these samples. However, at intermediate pH levels (6.0 to 7.5), the carbon dioxide is incompletely evolved during pH adjustment and is further expelled during the drying process. Hence, the pH of a reconstituted albumen with a pre-drying pH of 6.0 to 7.5 is higher than the original liquid sample. Since the carbonate buffering system of egg white above pH 7.5 exists mostly as carbonate and bicarbonate ions, less extensive pH changes occur in albumen spray-dried at 8.0 to 10.0 (Hill *et al*., 1965).

Hill *et al*. (1965) also reported spray-drying albumen below 6.5 altered the ability of the reconstituted powder to heat coagulate when readjusted to pH 8.8. These proteins produced a flocculated coagulum rather than the gel-like coagulum formed by albumen dried at pH 8.5. Hill *et al*. (1965) concluded that spray-drying albumen at pH 8.5 produced a powder which yielded larger volume angel cakes and had less protein damage and greater heat coagulability than other samples dried through pH 4.0 to 10.0.

Foam Formation

Lowe (1955) defined a foam as dispersed gaseous phase in which the dispersing medium is often a liquid. All liquids which contain substances capable of either positive or negative adsorption at the air-liquid interface will form foams because surface tension at the interface is thus lowered. Rahn (1932) stated that most colloids depress the surface tension of solutions, and "to them applies the law of Gibbs and Thomson which states that substances which cause a depression of surface tension will accumulate in the surface." If the foam is to be stable, the material in the film must be viscous enough to resist thinning to the point where it ruptures. The longer whipping is continued, the more finely divided the air bubbles become and the more rigidity the foam structure develops. Partial protein coagulation occurs during whipping, thus permanently modifying protein properties (Lowe, 1955). In recent studies, Colvin (1964) indicated that this aggregation was a marked function of the protein concentration and was partly due to a reaction between sulfhydryl and disulfide bonds. After the beating is discontinued, liquid begins to drain from the interfaces until the structure weakens at some point and the adjacent bubble or bubbles collapse. With this breakdown, more liquid is released for drainage.

Albumen foams

Upon being beaten, egg white readily forms a stiff and fairly permanent foam, in which minute air bubbles are suspended (Romanoff, et al., 1949). According to Lowe (1955) and Griswold (1962) a liquid must have a low surface tension, a low vapor pressure, and a tendency to form a semi-rigid surface film in order to produce a stable foam. The surface tension of liquid naturally causes it to form a minimum surface area. Thus, to allow for the great expansion in volume which must occur during foam production, the surface tension of the albumen must be low. Too rapid evaporation during foam formation causes drying before the liquid albumen can be divided and stretched into large foam volume; therefore, low vapor pressure is necessary to allow for slow evaporation. Finally the ability to form a semi-rigid surface film is necessary for the incorporation of air bubbles to produce a stable foam. The particles of denatured protein which are adsorbed at the liquid/gas interface form this semi-rigid surface film in the albumen foam.

Function of proteins. By chemical fractionation of egg white into its principal protein constituents MacDonnell et al. (1955) showed the contribution of each to the performance of albumen in the preparation of angel cakes. MacDonnell et al. (1955) reported the function of the individual proteins could be postulated as follows: The globulins are extremely good foamers; they are of particular importance in forming a meringue and batter with a large volume, small bubbles, and very smooth texture. The ovomucin is not a foamer but has the property of stabilizing the egg white foam in a short whipping time, presumably because of its very rapid coagulation at the surface of the bubbles. The other proteins of the albumen merely furnish heat-denaturable bulk which on baking coagulates to form the supporting matrix of the cake.

Effect of processing. Freezing, pasteurization, drying, and high temperature storage have been reported to affect the functional properties of albumen. Miller *et al*. (1943) reported albumen which had been frozen whipped more rapidly and produced a more stable foam than fresh albumen. Musil *et al*. (1957) found shell eggs subjected to five months storage at below freezing temperatures produced foams of good volume and stability.

In early studies, Wilkin *et al*. (1947), Slosberg *et al*. (1948), and Payawal *et al*. (1946) found albumen was deleteriously affected when it was subjected to temperatures as low as 41°C for sufficient periods of time for pasteurization. Consequently, the albumen was characterized by prolonged beating time, decreased stability, and loss of leavening power. Slosberg *et al*. (1948) have attributed these changes in the functional properties of pasteurized albumen to protein denaturation. Clinger *et al*. (1951), using the pasteurization method developed by Winter *et al*. (1946), reported albumen heated at 57°C for 4 min required a significant increase in both whipping speed and time to produce foams comparable to those from fresh albumen. Siedeman et al. (1963), also employing the technique of Winter et al. (1946), studied the relationship between pasteurization and pH. They found heating albumen at 58°C for 3 min with pH values varying between 7.0 and 9.5 brought about a significant increase in the whipping time of the albumen. Albumen with a pH near 8.75 whipped faster than albumen with higher or lower pH. After pasteurization for 3 min at 60°C and above, Siedeman et al. (1963) noted a decrease in whipping rate of the albumen regardless of the pH level used.

In a more recent series of studies, Kline et al. (1966) found foaming power of albumen may be damaged during pasteurization but this could be minimized by (a) mechanical treatment during processing leading to a thinner product, (b) use of acceptable whipping aid additives, and probably (c) mechanical or other thinning before heat process. They concluded a thinner product probably resulted in a better performing pasteurized product. Angel cakes with excellent texture and volume were obtained from albumen pasteurized at 60 to 61°C for 3.5 to 4 min with the pH adjusted to 7 and addition of aluminum salts to the liquid albumen (Cunningham et al., 1965).

Hill et al. (1965) studied the influence of egg white pH prior to spray-drying upon some properties of the resulting product. They found spray-drying albumen at pH 8.5 produced a powder which yielded larger volume angel cakes and had less protein damage and greater heat coagulability than other samples dried at pH 4.0 to 10.0.

Ayres *et al.* (1949) reported a satisfactory whipping rate for foams prepared from dried albumen which had been held under high temperature storage at 48.9°C for 20 days, 54.4°C for 8 days, or 57.2°C for 4 days. Storage of dried albumen containing 3 to 6% moisture at 50°C for periods up to 120 days had no significant effect on its whipping properties (Banwart *et al.*, 1956).

In a comprehensive review of egg dehydration, Bergquist (1964) stated that the foaming ability of albumen is almost always adversely affected by dehydration. Studying the effect of lyophilization on albumen, Rolfes *et al.* (1955) reported spray-drying reduced the foaming ability of albumen but freeze-drying did not have this effect. In contrast, Joslin *et al.* (1954) and Carlin *et al.* (1953) found spray-dried and pan-dried albumen retained satisfactory whipping properties.

Effect of physical conditions. Because the surface tension of albumen decreases as the temperature increases, most researchers agree the temperature of albumen affects the volume and stability of the resultant foam. Barmore (1935), St. John *et al.* (1930-1931), Miller *et al.* (1943), Lowe (1955), and Griswold (1962) reported greater volume is obtained when albumen is at room temperature than at refrigerator temperature. St. John _et al_. (1930-1931) also found that egg whites warmed to 30°C produced foams of increased volume but decreased stability. Henry _et al_. (1933) indicated that beating egg whites at temperatures from 15 to 25°C had no effect on the stability of the foam; while at 10°C the stability of the foam was only slightly less.

The length of beating time for the albumen affects the volume, stiffness, texture, and stability of the foam produced. Both Henry _et al_. (1933) and Sweetman _et al_. (1959) found volume and stability of foam increased with the beating time to a point; however, as the beating time was further increased volume and stability decreased. Maximum foam stability is obtained before maximum foam volume; therefore, maximum foam volume is obtained only with a decrease in foam stability.

Effect of added ingredients. The volume and stability of albumen foam can be affected by the addition of various substances. Hanning (1945), Lowe (1955), Sechler (1959), and Griswold (1962) found salt decreased foam stability and increased the whipping time required to reach a characteristic foam.

When sugar is added during the beating of egg whites, foam formation is delayed because sugar retards the denaturation of albumen. Thus the beating period must be extended to obtain the desired foam formation (Griswold, 1962;

Romanoff et al., 1949; Sweetman et al., 1959). Hanning (1945) characterized an albumen foam with sugar as one that is less stiff, more plastic, and more stable than one without sugar.

The addition of acid to egg whites increases foam stability, but increases the time necessary for beating (Henry et al., 1933; Barmore, 1934; Bailey, 1935; Lowe, 1955; Sweetman et al., 1959; Griswold, 1962). Romanoff et al. (1949) stated that acid apparently produces an irreversible change in the protein concentrated at the liquid-air interface, because the addition of enough base to completely neutralize the acid does not cause the foam to break down.

Researchers are not in complete agreement on the effect of adding water to albumen. Romanoff et al. (1949) stated there is a direct linear relationship between the volume of foam and the amount of water added. They found that if the proportion of water in the mixture does not exceed 40% by volume, the stability of the foam is nearly as great as obtained from undiluted albumen, although the structure of the foam from water-containing samples appeared to be more porous. However, Sweetman et al. (1959) concluded the addition of water up to 40% volume did not increase the foam volume and did not affect its stability. In contradiction, Henry et al. (1933) found that water added to albumen in amounts up to 40% by volume increases the volume of the foam but decreased its stability.

Angel Cakes

Franks *et al*. (1969) studied the performance and palability of frozen, foam-spray-dried, freeze-dried, and spray-dried egg albumen in angel cakes. In this study the whipping times for the frozen and reconstituted albumen were established to obtain foams of the same specific gravity. The researchers found cakes with foam-spray-dried albumen had the largest volume while cakes with spray-dried albumen had the smallest volume. Shear press measurements of tenderness expressed as area-under-the curve, compressibility, and tensile strength revealed no significant differences attributable to processing. However, shear press measurements of tenderness expressed as maximum force showed cakes with foam-spray-dried and freeze-dried albumen to be tougher than cakes with spray-dried or frozen albumen. Objective measurements of tenderness were negatively correlated with tenderness scores, thus, more force was required to shear or compress cakes which scored low in tenderness. Franks *et al*. (1969) found freeze-dried albumen produced cakes which scored poorest in the palatability characteristics of texture, tenderness and moisture. Frozen albumen was found to produce a cake of superior flavor. All cakes were judged by the taste panel as acceptable.

Soft Meringues

The effect of processing, physical conditions, and added ingredients on foam formation or meringue preparation have previously been discussed. The concern of this portion of the review of literature is the characteristics of acceptable baked soft meringues and possible causes of deviations from the standard.

Characteristics of soft meringues

An acceptable soft meringue is fine-textured, tender, cuts easily without tearing, has a delicate, slightly sweet flavor, and does not show leakage or beading (Hughes, 1962). Common deviations from this standard product are beading and leakage, the latter subsequently resulting in slippage and soaking of the crust. Beading is the term designating the formation of small droplets of syrup on the surface of a baked meringue (Godston, 1950). The term "leakage" means the amount of liquid that collects at the filling-meringue interface of a meringued pie (Griswold, 1962). This liquid may become a lubricating film that may cause the meringue to slip from the filling when the pie is tipped. The liquid may also cause soakage of the crust.

Lowe (1955) stated that the factors in obtaining a desirable meringue are: (1) extent of beating the egg white, (2) optimum proportion of sugar to egg white, (3) time of adding the sugar, (4) method of adding the sugar, (5) use of a stabilizer, (6) temperature of the filling, and (7) baking temperature and time.

Effect of beating. Griswold (1962) and Briant et al. (1954) reported meringues had more tender crusts when the egg whites were beaten at high speed throughout the beating period than when the beating was started at a low speed and finished at high speed. In contradiction, Godston (1950) reported medium speed whipping generally yielded a finer cell structure and better meringue than did high speed whipping. Briant et al. (1954) and Niles (1936) emphasized that underbeating egg whites adversely affected the stability of the meringue and leakage resulted.

Effect of sugar. The amount of sugar for a desirable meringue varies with the fineness of the sugar (Richetta, 1940). Lowe (1955) reported that in general, desirable sweetness and texture are obtained by using 2 tbsp of finely granulated sugar per egg white. Richetta (1940) also advised the use of 2 tbsp sugar per egg white and reported that too little sugar tended to produce a less tender, less fluffy meringue, and one lacking in sweetness; too much sugar produced a gummy crust or a crust containing sugar crystals. Griswold (1962) recommended 2.5 tbsp sugar per egg white and stated the superior appearance and greater ease of cutting of meringues containing 2.5 tbsp of sugar more than offset their slightly greater leakage as compared with meringues made with 2 tbsp sugar per egg white. Gillis et al. (1956) found no significant relation between proportion of sugar and leakage of meringue.

According to Lowe (1955) and Gillis et al. (1956) difficulties with leakage of the meringue may occur if the egg whites are overbeaten before the sugar is added. By using a hot sugar syrup, Felt et al. (1956) and Godston (1950) found more stable meringues were produced.

Effect of stabilizer. Stabilizers are often used as a special precaution to prevent liquid from draining from the meringue. A stabilized meringue is stiffer and drier than an unstabilized meringue and is more attractive because the accumulation of liquid between the filling and meringue may be lessened or eliminated (Anon., 1953). Felt et al. (1956), Godston (1950) and Glabau (1948) found the use of a "vegetable gum stabilizer" in the meringue decreased the amount of liquid collected between the filling and meringue. Glabau (1948) also reported the foam structure was much finer and more stable when a stabilizer was used than when none was employed. He indicated the quantity of seepage or liquid which is obtained from a meringue when it is allowed to stand is directly related to the quantity of stabilizing material used. In addition, he also concluded that the amount of added stabilizer was directly related to the rigidity of meringues as shown by the resistance to shearing with a modified MacMichael apparatus. Glicksman (1962) reported meringues can be stabilized effectively with carrageenan additives.

Effect of temperature of filling. The amount of leakage and beading is affected by temperature of the filling when the pies are meringued. Felt *et al*. (1956) found as the filling temperature decreased, the amount of leakage increased. Hester *et al*. (1949) concluded a desirable degree of coagulation of the egg white in the meringue is an important factor in preventing leakage and beading. Leakage was greatest when the meringue was placed on a cold (15°C) filling instead of a hot (55 to 60°C) filling prior to baking. These experimenters maintained the meringues baked on cold bases were not adequately coagulated. According to Hester *et al*. (1949), the appearance of amber beads of liquid on the surface of meringues may be due to overcoagulation of the protein with a subsequent loss of some of the absorbed liquid. They found that beads were especially noticeable when meringues were spread on hot filling.

Baking time and temperature. There is some controversy in literature as to the ideal oven temperature for baking meringues. Godston (1950) recommended that meringued pies prepared in large quantity be baked at 219 to 232°C with the oven door open to allow the steam to escape and "toast" the meringue to eliminate the liquid layer. Hester et al. (1949) baked meringued pies at 163°C for about 10 min, 190°C for about 7 min, and 219°C for about 4.5 min. They found the most leakage with pies baked at 219°C. However, they found there was less stickiness and greater tenderness when pies were baked at the higher temperature. Gillis et al. (1956) considered the best meringued pies to be those baked at 163°C for 18 min. Felt et al. (1956) found the meringued pies baked at 190°C were more stable than ones baked at 163°C and 219°C.

Methods of Assessing Quality

Various methods of objectively and subjectively assessing quality may be applicable to soft meringue, however certain precautions should be taken in using these methods. Amerine et al. (1965) stressed the samples for both tests should be as identical as possible, there should be sufficient replications, one individual should conduct each objective test throughout the investigation, and the same individuals should participate on all panels from which the data are averaged for comparison with the objective tests.

Objective measurements

Objective measurements of food quality are extremely useful to supplement subjective measurements (Amerine et al., 1965). Objective measurements are preferred to sensory evaluations when they furnish a precise measurement of food quality because they can be used repeatedly without the danger of human error and/or fatigue.

Drainage and slippage measurements. Felt et al. (1956) measured the angle at which meringue slipped from simulated pies. The cooled, crustless pies were placed on a platform which could be tilted mechanically. The pies were slowly tilted and the angle at which the meringue slipped from the filling was determined and called the "slippage angle." As the meringues slipped from the fillings, they were caught on a screen. The liquid that passed through the screen was collected in a can and weighed. The pies were tilted to an angle of 50^{o} to collect the liquid from the pie. Felt et al. (1956) found the ease of slippage of the meringues increased as the amount of liquid increased.

Tenderness measurement. No reports of objective measurements of meringue tenderness were found in the literature. However, the Allo-Kramer shear press has been used by many investigators to measure tenderness of various foods. Tenderness measurements of meat (Boyle, 1968), angel cake (Funk et al., 1965; Brown, 1964), custards (Wolfe, 1967), and cream puffs (Charlebois, 1968) by the Kramer shear press have proven reliable and precise. Charlebois (1968) reviewed the techniques of using the shear press.

Color measurement. Felt et al. (1956) used the color of the meringue, rather than a definite baking time, to indicate the end point of the baking period. Meringues were baked until they matched a specific color plate of Ridgway. Plate XV, 15' Y-O f was used as a standard for the "light" meringues; plate XV, 15' Y-O b, for the "medium" meringues; and plate XV, 17' Y-O i, for the "dark" meringues.

No other reports of objective measurements of the color of baked meringues were found in the literature. Photoelectric tristimulus colorimeters have been used successfully to measure the color of many foods such as tomato juice (Robinson et al., 1952), citrus juice (Huggart et al., 1966), cauliflower and spinach (Boggs et al., 1949) and custards (Wolfe, 1967; Longree et al., 1961). Endres (1965) found the Gardner colorimeter produced highly significant correlations among the a_L values, b_L values, panel preference scores for color, and panel difference scores for color of baked whole egg-milk slurries. In a study by Wolfe (1967), the sensory evaluation of color of baked custards correlated with the Hunter L (lightness) values at the 5% level of probability and with the Hunter b_L (yellowness) values at the 0.1% level of probability.

Time-temperature relationships. In the investigation by Felt et al. (1956) the tip of a thermocouple was placed at the interface of the filling and meringue of cream pies to indicate the temperature during baking. The investigators studied the effect of filling temperature on protein coagulation as indicated by the temperature at the filling-meringue interface.

Investigating the microbiological aspects of soft meringues, Mallmann et al. (1963) used three thermocouples to obtain readings on the protentiometer for the center of the filling, center of the meringue, and interface between the two. Meringues were placed on warm and hot fillings and the effect of each on the maximum temperatures reached was determined.

Sensory evaluation

The concensus among researchers indicates the desirability of employing subjective as well as objective measurements in the evaluation of food quality. Subjective evaluations provide information essential for product improvement, quality maintenance and the development of new products (Amerine et al. 1965).

Types of sensory tests. Lowe et al. (1947) classified subjective tests into two categories: preference or acceptance tests and psychometric or difference tests. Preference tests measure the degree of acceptance of a food, and when conducted with large numbers of the population, permit the determination of consumer acceptance of a product. Psychometric tests are used for determining the quantitative differences in food quality characteristics. On the other hand, Amerine et al. (1965) classified sensory tests into eight categories. The classification included difference, rank order, scoring, descriptive, hedonic scaling, acceptance, preference tests, and other methods. According to Griswold (1962) and Lowe (1955), scoring tests are probably the most frequently used methods of evaluating the quality of food.

Taste panel selection and training. Dawson et al. (1951) and Lowe (1955) stated that candidates considered for a panel should exhibit intelligence, comprehension, concentration, motivation toward sensory testing, and be available for the entire period of the experiment. They should also be able to detect fine differences in specific attributes of foods and give reproducible judgments in testing the same samples at different times (Dawson et al., 1951; Griswold, 1962).

Amerine et al. (1965) emphasized careful selection and training of judges are essential to achieve maximum discriminability. They noted "there is considerable controversy in the literature on the value of a sensory panel that has been selected and trained." They further stated any method of selection should include a preliminary training period designed to acquaint the tasters with the quality factors involved in the product to be tested.

Dawson *et al*. (1951) emphasized the importance of panel members working under controlled conditions, such as odor free, air-conditioned, well-lighted rooms free from distractions. The panel should be large enough to counteract unusual variations which might affect day to day comparisons. Small, highly sensitive panels usually give more reliable results than large, less sensitive groups (Amerine *et al*., 1965).

Samples and score card. The number of samples to be tested at one session and the proper preparation of the samples to be tested are other important factors of sensory testing (Dawson *et al*., 1963; Griswold, 1962). According to Griswold (1962), more samples can be evaluated in one session if the flavor is bland than if it is strong. The samples should be prepared and served as uniformly as possible with their actual identity concealed by coding (Dawson *et al*., 1963). The instructions given to the panel members, especially regarding scoring, should be clear and precise (Kramer *et al*., 1962).

Boggs *et al*. (1949) stated 10 scale intervals are usually sufficient. The trend in the literature appears to be the use of 9, 10, or 11 gradations, although the scale often varies with different foods (Lowe, 1955). Griswold (1962) advised including descriptive adjectives or phrases arranged in a graduated series to which numerical scores can be given. Extensive preliminary work on the part of the research worker and the judging panel may be necessary for the development of an acceptable grading chart.

EXPERIMENTAL PROCEDURE

Design Of Experiment

To determine the effects of freezing, spray-drying, foam-spray-drying and freeze-drying on foaming ability and foam stability, and on the color and palatability of soft meringues, six replications of a standard soft meringue formula were prepared and baked for each albumen process. Standard whipping procedures for each type of process were developed in preliminary investigations so that all had a specific gravity of 0.24 to 0.22. The temperature and humidity of the laboratory were recorded for each preparation day.

Three pies were prepared for each replication. One pie was used for objective measurements 2 to 3 hr after preparation; a second pie was used for objective measurements 20 to 22 hr after preparation; and a third pie was used for determination for time-temperature relationships and sensory evaluation. Nine pies were prepared each day, thus three different albumen processes were used each preparation day. Pies were baked two days of each week. A rotation schedule was used in this investigation to randomize the preparation and evaluation of pies.

Procurement Of Ingredients

Whenever possible, ingredients for the meringue and filling were obtained from a common lot. Unbaked pie crusts and pie filling mix were purchased commercially. Albumen and sugar were packaged separately for each replication and stored until needed; other ingredients were weighed or measured just prior to preparation.

Ingredients for meringues

The procurement, processing, packaging, and storage of the frozen and spray-dried albumen were outlined by Zabik et al. (1968). The same procedures for the freeze-dried and foam-spray-dried albumen were reported by Charlebois (1968). The frozen albumen was thawed by placing the 30-lb tins under cold running water, subdivided into appropriate amounts, and placed in polyethylene pouches inside cardboard containers. During this repackaging, the temperature of the albumen did not exceed 4 to 5°C. The albumen was then re-frozen and held at -23°C for 6 to 7 months prior to use. The package of the three types of dried albumen were opened and quantities of each type dry blended for 5 min by using a KitchenAid mixer, model K5-A. The albumens were then portioned into 45 g amounts using a 5-kg capacity torsion balance, heat sealed in heat sealable polyester bags, and held at -23°C until needed.

All sugar used in this investigation was placed in the 12-qt bowl of the Hobart mixer, model A-200, and dry blended for 5 min. The 244 g of sugar needed for each replication were weighed on the 5-kg capacity torsion balance and then stored in closed polyethylene bags at room temperature.

The carrageenan, 402,[1] weighed on a Mettler balance, model H15, to the nearest 0.0001 g, and salt, weighed on a Mettler balance, model P100, to the nearest 0.01 g, used in this investigation were weighed just prior to preparation.

Ingredients for crusts and filling

Unbaked pie crusts[2] in aluminum foil pie pans, 9 x 1 in, were purchased commercially. The pie crusts, separated with a sheet of waxed paper, were placed in polyethylene bags in the quantities needed for each day of preparation before they were frozen and stored at -23°C.

Lemon flavored pie filling mix[3] was obtained from a common lot. Packages of filling were opened just prior to preparation. Sugar from the same common lot as used for the meringues was weighed into 400 g lots for each replication and stored in closed polyethylene bags at room temperature. Fresh eggs were purchased weekly from a local market to provide the yolks needed.

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[1]Viscarin brand, Marine Colloids, Inc., Springfield, New Jersey.

[2]Michigan State University Union Food Service.

[3]My-T-Fine, R. J. Reynolds Foods, Inc., New York, New York.

Method Of Preparation And Baking

Formula and procedures for the preparation of the filling and meringues were developed during preliminary investigation. Baking times and temperatures for crusts and meringues were also determined.

Crusts and filling

Frozen crusts were removed from freezer and allowed to thaw for 10 min; each crust was pricked in several places and then all were placed in a 219°C Hotpoint deck oven, model HJ225, for approximately 10 min or until golden brown. After the pie crusts were removed from oven, they were cooled for approximately 30 min, randomly coded with letters and arrows, and stored in a cupboard until used the following day. The arrows were used to designate which part of the pie was nearest the front of the oven. The rotation schedules for sensory evaluation and objective measurements were based on the placement of these arrows.

Six 4-oz packages of lemon flavored filling mix, 12 egg yolks, 400 g sugar, and 3548 ml tap water were placed in the top part of a 12-qt stainless steel double boiler and blended with a large wooden spoon. The filling was cooked over boiling water until it reached a temperature of 82 to 84°C. The filling was then cooled in a bath of cold water to a temperature of 42 to 45°C. While the filling was cooling it was stirred vigorously every 5 min to prevent film formation on the surface. The filling was then placed in the crusts to a depth of 2.0 cm as measured with a vernier caliper from the bottom of the pan. The filled crusts were covered with inverted aluminum foil pie pans and allowed to cool to room temperature or until needed. Samples of the filling were reserved in 150 ml pyrex beakers for pH determination and in 600 ml pyrex beakers for viscosity determination. These beakers were covered with Saran and set aside for later testing.

Meringues

Preliminary investigations showed less drainage from meringues if a stabilizer was added to the formula. One-tenth of one per cent of the liquid albumen weight was found to be a satisfactory amount of stabilizer to use to minimize drainage and retain the quality characteristics of a soft meringue.

Reconstitution and defrosting of albumen. The moisture content of each type of dried albumen was determined according to the AOAC method 16.3 (b) and (a) (1955). Three 2 g samples of each type of dried albumen were weighed into tared aluminum foil dishes on a Mettler balance, model H15. The samples were dried to a constant weight (approximately 5 hr) in a vacuum oven at 90 to 100°C using 28 in of Hg. Using the moisture content data and the previously found percentage of solids from the liquid albumen, the formula for reconstitution of dried albumen was developed as shown in Table 3.

Table 3. Formulas used in the reconstitution of dried albumen.

	Dried Albumen (g)	Additions of distilled water 1 (ml)	2 (ml)	3 (ml)
Spray-dried	43.7	65	120	121
Foam-spray-dried	43.6	65	120	121
Freeze-dried	42.6	65	121	121

Prior to reconstitution each sample of dried albumen was allowed to warm to room temperature over a period of approximately 45 min. All dried albumen samples were reconstituted according to the technique used by Brown (1964). In this technique the required amount of dried albumen, weighed on a Mettler balance, model P1000, to the nearest 0.1 g, was placed in the bowl of a KitchenAid mixer, model K5-A, and 65 ml of distilled water were added through a long-stemmed funnel held just above the surface of the albumen. The albumen and water were blended using a paddle attachment for 30 sec at speed 1 (53 rpm). The bowl was then scraped and the second portion of water was added through the funnel; this mixture was blended for 30 sec at speed 1. The bowl was again scraped, the third portion of water added and the mixture was blended 30 sec at speed 1. The sides of the bowl were again scraped and blending was continued for an additional 60 sec at the same speed. After removal of the bowl from the mixer, the reconstituted albumen was allowed to stand for 15 min to assure complete hydration and was then poured through a fine gauge strainer to insure complete dispersion.

Frozen liquid albumen was allowed to defrost in a refrigerator at $5^{o}C$ for approximately 24 hr before being used.

Basic formula. The formula selected for this study was adapted from that followed by Mallmann *et al*. (1963) in which the ratio of sugar to egg albumen was based on the home recipe of 2 tbsp sugar per egg white. However, a stabilizer was included in the formula. The weights of the ingredients used for the soft meringues prepared in lots sufficient for three pies are listed in Table 4.

Table 4. Formula used in the preparation of soft meringues.

Ingredients	Amounts (g)
Liquid or reconstituted albumen	293.
Sugar	244.
Stabilizer	0.2930
Salt	1.87

Mixing procedure. The liquid or reconstituted albumen was weighed, using a 5-kg capacity torsion balance, into the 5-qt bowl of a KitchenAid mixer, model K5-A. The temperature of the albumen was adjusted to $25^{o}C \pm 1^{o}$. Using the whip attachment the albumen was whipped for 30 sec at speed 2 (67 rpm). The salt was added and whipping was continued for 45 sec at speed 2. The sugar and stabilizer were previously mixed together in the bowl of a KitchenAid mixer, model K4-B, for 3 min at speed 1 (34 rpm). The sugar-stabilizer mixture was added gradually to the albumen over a 1 min interval during which the 5-qt mixer was operating at speed 2 (67 rpm). After the sides of the bowl had been scraped, the mixture was whipped for 10 min at speed 2. Finally, the mixture was whipped at speed 4 (98 rpm) for the additional time needed to obtain a specific gravity between 0.24 and 0.22.

Preparation for baking. Before the pies were meringued, each filled crust was weighed on a Mettler balance, model P1000. The temperature of filling was determined. The filled crust was then placed in a metal frame and covered with meringue which was leveled to a depth of 1.91 cm with a metal spatula. This method was outlined by Mallmann *et al*. (1963). The meringued pies were then weighed. Samples of meringue were reserved in 150 ml pyrex beakers for later pH determination. Thermo Electric type 5A3110A protected iron-constantan thermocouples with 4 in immersion lengths from a 12-point Brown Electronic Potentiometer High Speed Multiple Point Recorder were placed in one pie from each lot to obtain the temperature at the interface of the meringue and filling and at a point midway between the filling and the meringue surface. The apparatus used to support the potentiometer leads was similar to that described by Elgidaily et al. (1968).

Baking and cooling. Each lot of three pies was placed, with arrows facing forward, in a 163°C oven, equipped with a Honeywell Versatronik controller. The pies were removed after the 34 to 36 min baking period, set on racks, and allowed to cool at room temperature for approximately 2 hr. The one pie from each lot designated for objective measurements after holding was then placed in a pie holder and refrigerated at 5°C. The other two pies were prepared for objective measurements and sensory evaluation.

Objective Measurements

To determine the effects of processing, objective measurements of soft meringues were performed. In addition, viscosity and pH measurements of the filling were made.

Filling

After completing the preparation of the pies, the viscosity of the filling was measured by using a Brookfield Synchro-Lectric viscometer, model RVT, mounted on a Helipath stand, model C. To measure the viscosity, the graduated 600 ml beaker containing approximately 400 ml of filling was placed so that the number 6 spindle was in the center and was immersed to the designated level. The spindle, operating at 20 rpm, was stopped after 15 sec and the reading was recorded. The spindle was then allowed to rotate for an additional 15 sec and a second reading was taken. The average of the two readings was multiplied by a factor of 5 to convert the average to poise. The pH of the filling, at room temperature, was measured with a Beckman Zeromatic pH meter.

Meringues

Objective measurements of soft meringues included specific gravity, foam stability, pH, evaporation, drainage, shrinkage, color, and tenderness. Specific gravity, foam stability, pH and color were measured by well established methods. The percentages of evaporation and drainage were determined in a manner similar to evaporation and drip losses of meat, respectively. Tenderness was evaluated using the Allo-Kramer shear press.

Specific gravity. The specific gravity of each foam mixture was determined according to the method of Platt et al. (1933). Their technique involved a comparison of the average weight of one-half cup of foam to the average weight of one-half cup of distilled water at 25°C. A serving spoon was used to dip the foam mixture samples. As each half-cup was filled with foam mixture and leveled with a metal spatula, care was taken not to destroy the foam structure. The specific gravity was computed by dividing the weight of the foam mixture by the average weight of the water. Two quotients were averaged to obtain the final reading for each replication of each process.

Foam stability. Foam stability was measured according to the technique described by Lowe (1955). The same half-cup of foam mixture used in the determination of specific gravity was inverted into a 100 mm diameter funnel placed over a 10 ml graduated cylinder. The funnel was tightly covered with Saran to prevent loss of any liquid through evaporation. The amount of drainage was read after 30 min. The drainage value for each replication represents an average of two readings.

Determination of pH. The pH of the meringue was determined by using a Beckman Zeromatic pH meter equipped with calomel and glass electrodes. The pH meter was standardized with a buffer of pH 7. The electrodes were carefully inserted into the center of the beaker of meringue which was at room temperature.

Evaporation, drainage and shrinkage measurements. Losses due to evaporation and drainage were determined using techniques similar to Funk et al. (1966). After the pies had cooled at room temperature for approximately 2 hr, the pie from each lot used for objective measurements on the day of preparation was weighed. Then the meringue on this pie was cut in half; one half of the meringue was carefully removed from the pie base by using a flexible metal spatula and was transferred to a 10-in layer cake pan. To determine shrinkage, the height of the meringue, which still remained on the pie, was measured at the center using a vernier caliper. After the height had been measured, the second half of the meringue was removed from the pie base and was transferred to the cake pan. The pie pan, crust, and filling were then weighed.

The percentage of evaporation was calculated from the difference between the unbaked and baked meringued pie using the formula:

$$\frac{\text{Weight of unbaked pie} - \text{Weight of baked pie}}{\text{Weight of unbaked meringue}} \times 100$$

The amount of drainage was determined by weighing the pan, crust and filling before the pie was meringued and after the meringue had been removed from the baked pie. To calculate the percentage of drainage, the following formula was used:

$$\frac{\text{Weight of baked pan, crust \& filling} - \text{Weight of unbaked pan, crust \& filling}}{\text{Weight of unbaked meringue}} \times 100$$

Tenderness. The rotation schedule shown in Figure 1 indicates the halves of each replication used for Allo-Kramer shear press and for Hunter color-difference meter determinations. This randomized order permitted testing on sections

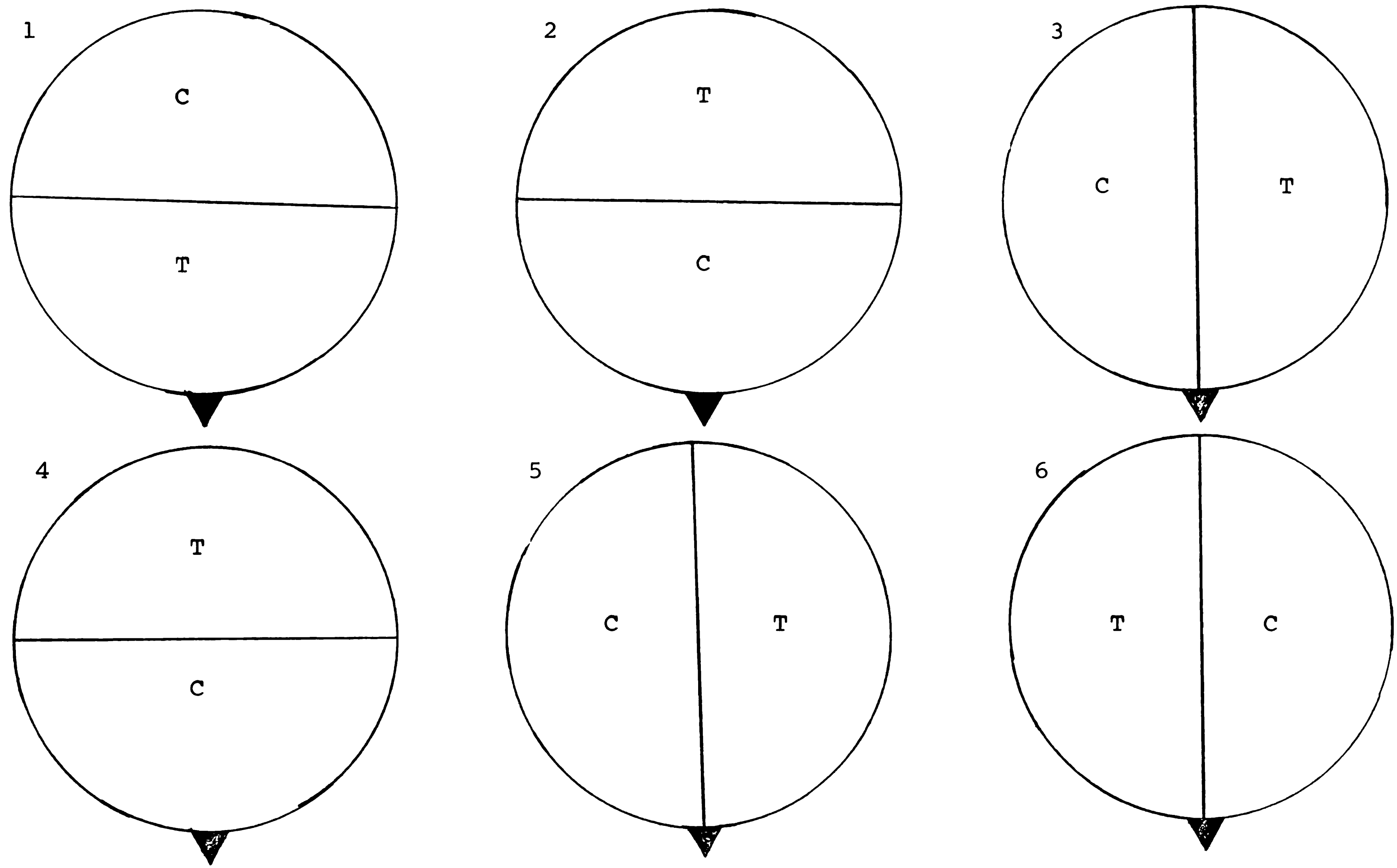

Figure 1. Rotation patterns used for objective measurements of tenderness (T) and color (C) of six replications of soft meringues.

of meringue baked in right- and left-oven positions and front- and back-oven positions.

The Allo-Kramer shear press, model SP12, was used to measure the tenderness of the meringues. Using a 5.39 cm square cutter, two samples were cut from the designated half and each was weighed on a Torbal balance, model PL-800, to the nearest 0.01 g. The sample was placed in the center of the standard shear compression cell. Using a 30 sec downstroke, 10 lb range, 25 lb pressure, and a 100 lb proving ring, the sample was sheared. The pounds of force required to shear the meringue sample were recorded on a time force curve by a Varian electronic indicator, model E2EZ. The maximum force per gram was calculated as:

$$\frac{\text{Maximum peak (\%) X Range (\%) X Ring}}{\text{Sample weight}}$$

The area of the complete graph curve was also used as an indication of meringue tenderness. Each curve was carefully cut out and weighed on a Mettler balance, model H15, to the nearest 0.0001 g. A conversion factor of 187.2 for changing gram weight to area had previously been determined by weighing multiple squares of varying known areas from random locations on similar chart paper according to the procedure outlined by Brown (1964).

<u>Color</u>. Color of the soft meringues was measured by a Hunter color-difference meter, model D-25. The instrument was

standardized with a white tile covered with an optical lens (L, 93.0; a_L, -0.6; b_L, -0.1) in preparation for determination of L (lightness), a_L+ (redness), and b_L+ (yellowness) values of the soft meringue samples.

The following procedure was used for the color analysis of all variables. The portion of the meringue previously designated for this color determination testing was cut in half. The cut piece of meringue was placed on a clear, flat piece of high quality plate glass (5 x 5 x 1/8 in) and was covered with a special optical lens (3 x 4 x 1/8 in). The glass, meringue, and optical lens were placed under the viewing area of the Hunter color-difference meter, and two sets of values were derived from different meringue positions by moving the glass supporting the meringue one quarter turn. This process was then repeated with the other quarter of meringue. Each value reported represents an average of four readings.

Sensory Evaluation

A taste panel consisting of seven judges subjectively scored the soft meringue samples for color and appearance, shrinkage, slippage and drainage, texture, tenderness, flavor and general acceptability, using a 7-point scale. A score of 1 indicated unacceptable quality and a score of 7 showed excellent quality. Descriptive terms aided the judges in their evaluations. A copy of the score card as well as as the instructions given to the judges appear in the Appendix, Figures 5 and 6.

The panel was trained at two preliminary sessions. A room with special lighting and in which all conditions except temperature and humidity could be kept constant was used throughout the study. A glass of lemon water (2 tsp lemon juice per qt of water) at room temperature was provided for the panelists to use between the evaluation of three samples served at each session.

The pieces of pie were assigned to the judges according to the predetermined positions indicated in Figure 2. The serving of the pieces of pie for the six replications of each variable was rotated so that the judges evaluated pieces of pie which were baked in six different positions.

After being out of the oven for approximately two hours, the pies were prepared for sensory evaluation as follows: (1) the pie was marked for cutting into 7 pieces with a pie marker; (2) pieces of pie were cut with a sharp knife which had been dipped in lukewarm water before cutting each piece; (3) each piece of pie was placed on a white plate coded with a predetermined random number and the initials of each judge; (4) pieces of pie were served individually to the judges; after one sample had been evaluated, it was removed and the next sample was presented for evaluation.

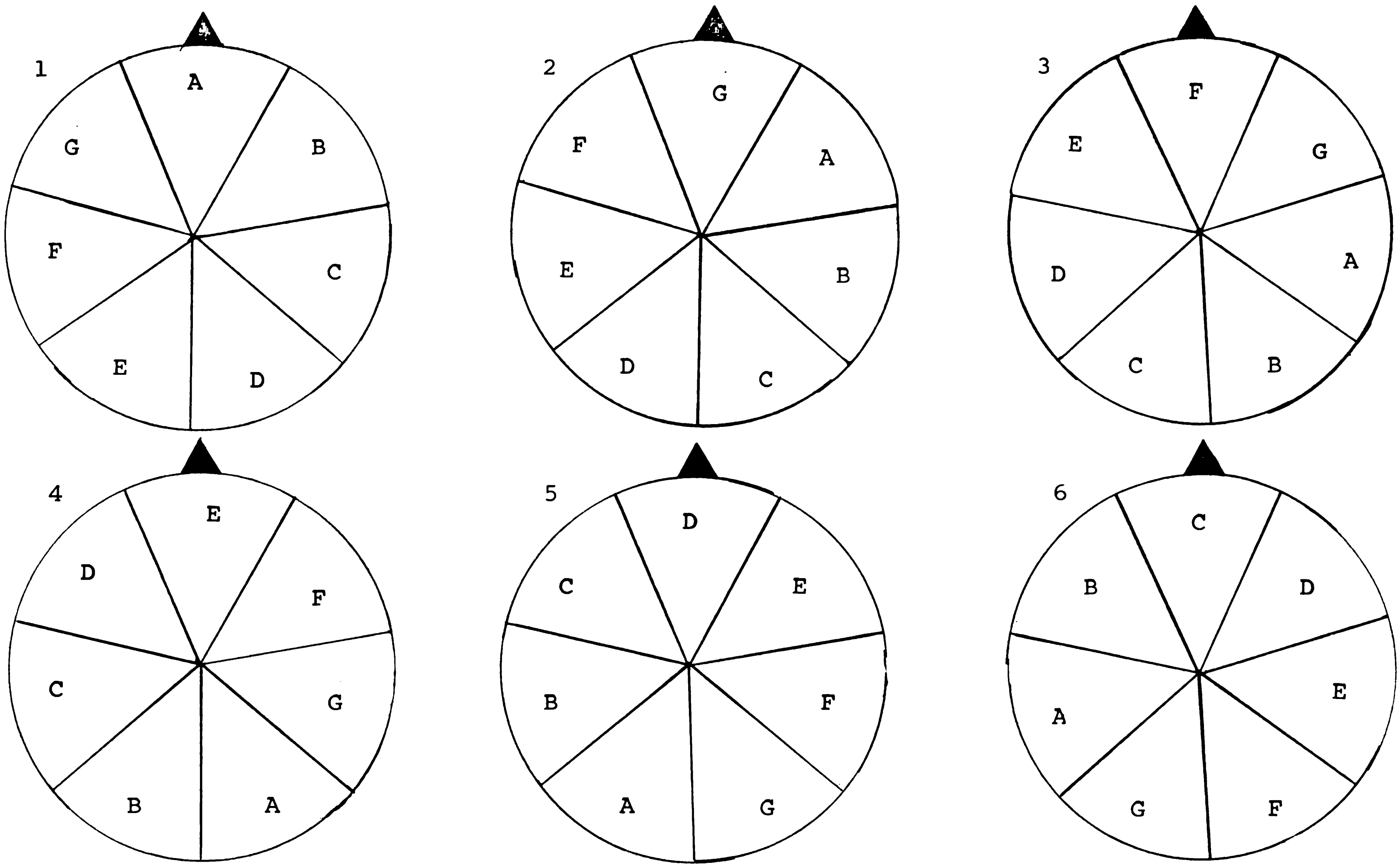

Figure 2. Six rotation patterns used for six replications of sensory evaluation of soft meringues by seven judges (A-G).

Effect Of Holding

To study the effect of holding meringued pies, one pie from each lot was refrigerated at $5^{o}C$ after it had cooled at room temperature for approximately 2 hr. All the objective measurements performed on the freshly baked pies, except color determination, were repeated after a 20 to 22 hr refrigerated holding period. In addition to these objective tests, beads of moisture which accumulated on the surface of the meringue were counted. Each value reported for number of beads represents an average of two countings.

Meringues Without Stabilizer

A second series of pies was prepared from spray-dried albumen without the addition of a stabilizer to demonstrate the effect of the stabilizer. Six replications were made for this part of the investigation; two replications were prepared on each of three separate days.

The same preparation, baking, cooling, and holding procedures used for the meringues with stabilizer were followed for those without stabilizer with the exception of blending the stabilizer with the sugar. These pies were submitted to identical objective measurements as those prepared with stabilizer. No sensory evaluations were performed on the meringues without stabilizer.

Analyses of Data

All data from objective and subjective evaluations were analyzed using statistical routines for the CDC 3600 computer at Michigan State University. Time-temperature relationships recorded during baking were averaged.

Statistical procedures

The data obtained from the objective measurements and sensory evaluations of meringues prepared with added stabilizer were analyzed for variance due to albumen process and replication using an AOV Routine for the CDC 3600 computer. To minimize variance due to judges, scores of all judges for palatability characteristic were averaged for each replication. Duncan's multiple range test (Duncan, 1957) was used to pinpoint further the source of the significant differences.

Correlation coefficients for all possible combinations of data were determined using a BaStat Routine for the computer. Means and standard deviations were also obtained by using a BaStat Routine.

Sensory evaluation data were also analyzed for variances due to judge, albumen process,replication and first order interactions using an AOV Routine for the calculations. The second order interaction mean square term was used as the error variance for testing significant differences.

Data obtained from objective measurements of stabilized meringues prepared with spray-dried albumen were compared with similar data on unstabilized meringues prepared with spray-dried albumen using the test statistic (Dixon et al., 1957)

$$Z = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\sigma_1^2}{N_1} - \frac{\sigma_2^2}{N_2}}}$$

Time-temperature relationships

During baking, the time-temperature relationships were recorded by a recording potentiometer for one pie from each lot to obtain the temperature at the interface of the meringue and filling and at a point midway between the filling and the meringue surface. At 4 min intervals, the temperature for each of the two points recorded from the 6 pies with each type of egg process were averaged. Average maximum temperatures at the two points were also determined.

RESULTS AND DISCUSSION

The primary objective of this study was to compare the quality characteristics of soft meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen. For this purpose, three lemon meringue pies were prepared for each of the six replications of each albumen process. A carrageenan stabilizer was added to all meringues. Quality characteristics were evaluated 2 to 3 hr after preparation for pies designated as fresh and after a 20 to 22 hr refrigerated holding period for pies designated as held. A secondary objective of the study was to determine the effect of stabilizer on the quality characteristics of soft meringues and for this purpose, meringues were prepared from spray-dried albumen with and without added stabilizer. Standardized procedures were utilized in the preparation, subjective evaluations and objective measurements. Data were analyzed statistically for differences attributable to albumen process, replication and stabilizer.

Environmental Conditions And Lemon Filling

Because room temperature and humidity may affect the quality characteristics of soft meringues, these data were recorded for each day during which pies were prepared.

The viscosity, pH and temperature of the filling may also affect quality characteristics (Felt et al., 1956; Hester et al., 1949), hence, these data were determined.

Room temperature and relative humidity

Room temperature ranged from 24 to 32°C and the relative humidity ranged from 43 to 72% on the eight days during which meringues were prepared. These data, assigned to the appropriate replications, are presented in the Apendix, Table 22.

Lemon pie filling

The quantity of filling needed for all pies prepared during each day of the experiment was from a common batch. The prepared filling was poured into baked shells and randomly assigned to albumen process. For each batch of room temperature filling, the viscosity and pH were determined while temperatures of the filling were recorded to the nearest 0.5° just before the meringue was spread on the pies. Mean values for viscosity, and temperature and ranges for pH are presented in Table 5 while the values assigned to the appropriate replication are presented in the Appendix, Table 23.

Analyses of variance were computed for viscosity, pH and temperature of the filling. Results of the analyses are summarized in Table 6.

Table 5. Means and standard deviations for filling viscosity and temperature and pH ranges for six replications of soft meringues prepared from albumen processed by four methods.

Measurement	Albumen Process			
	Frozen	Spray-dried	Foam-spray-dried	Freeze-dried
Viscosity (poise)	201.17±10.61	205.83±13.48	210.75±8.18	204.50±14.14
pH	3.4-3.5	3.4-3.5	3.4-3.5	3.4-3.5
Temperature (°C)	29.2±2.8	29.5±2.6	29.5±1.5	29.5±2.1

Table 6. Analyses of variance for filling viscosity, pH and temperature for six replications of soft meringues prepared from albumen processed by four methods.

Source of Variance	Degrees of Freedom	Mean Squares		
		Viscosity	pH	Temperature
Total	23			
Process	3	94.872	0.002	0.1667
Replication	5	346.919**	0.005	11.2667*
Error	15	71.430	0.002	3.2667

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

Filling viscosity. Average filling viscosity was 201.17, 205.83, 210.75 and 204.50 poises for pies prepared with frozen, spray-dried, foam-spray-dried and freeze-dried albumen, respectively. When analyzed on the basis of egg process, filling viscosity did not differ significantly. However, significant differences ($P \leq 0.01$) existed among replications. Perhaps the end cooking temperature for the filling, ranging from 82 to 85°C, caused some variation in the viscosity of the different batches. Although the same routine was followed in preparation of the pies, differences in cooling and/or gelation time may have occurred thus affecting the viscosity of the filling.

Filling pH. The pH of the lemon filling ranged from 3.4 to 3.5. The differences were not significant.

Filling temperature. Average filling temperatures for pies prepared with frozen, spray-dried, foam-spray-dried and freeze-dried albumen were 29.2, 29.5, 29.5 and 29.5°C, respectively. When analyzed on the basis of process, filling temperature did not differ significantly. Nevertheless, significant differences ($P \leq 0.05$) were found among the replications which ranged from 25 to 33°C. These variations probably reflect differences in cooling time necessitated by the preparation schedule as well as differences in room temperature.

Unbaked Meringues

The albumen temperature was recorded before meringue preparation began. Whipping time, specific gravity, foam stability and pH of the unbaked meringues were determined. Averages and standard deviations or ranges for these data are presented in Table 7 while values for each replication are found in the Appendix, Table 24. Analyses of variance for albumen temperature, whipping time, specific gravity, foam stability and pH are summarized in Table 8.

Table 7. Means and standard deviations for albumen temperature, whipping time, specific gravity and foam stability and pH ranges of unbaked meringues prepared from albumen processed by four methods.

	Albumen Process			
Characteristics	Frozen	Spray-dried	Foam-spray-dried	Freeze-dried
Albumen temperature (°C)	25.4±0.4	25.5±0.4	25.3±0.4	25.2±0.3
Whipping time (min)	13.54±0.41	16.08±1.51	16.00±2.50	13.92±0.67
Specific gravity	0.23±0.01	0.23±0.01	0.24±0.01	0.23±0.01
Foam stability (ml)	0.10±0.20	0.08±0.16	0.29±0.44	0.03±0.04
pH	6.3	6.7-6.8	6.2-6.3	6.2-6.3

Table 8. Analyses of variance for albumen temperature, whipping time, specific gravity, foam stability and pH of unbaked meringues prepared from albumen processed by four methods.

Source of Variance	Degrees of Freedom	Mean Squares				
		Albumen temperature	Whipping time	Specific gravity	Foam stability	pH
Total	23					
Process	3	0.122	10.84**	0.000	0.0818	0.3215***
Replication	5	0.310*	4.88*	0.000	0.1384*	0.0048*
Error	15	0.088	1.41	0.000	0.0419	0.0012

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

Albumen temperature

Albumen temperatures, before meringue preparation began, were 25.4, 25.5, 25.3 and 25.2°C for meringues prepared with frozen, spray-dried, foam-spray-dried and freeze-dried albumen. According to the analyses of variance, the temperatures did not differ significantly when analyzed on the basis of albumen process; however, significant differences ($P \leq 0.05$) existed among replications. The temperature of all albumen was adjusted to 25 to 26°C.

Whipping time

Ranked in order of increasing average whipping times of 13.54, 13.92, 16.00 and 16.08 min were meringues prepared from frozen, freeze-dried, foam-spray-dried and spray-dried albumen. The analyses of variance showed significant differences due to process ($P \leq 0.01$) and replication ($P \leq 0.05$). Further analysis showed frozen albumen required significantly less ($P \leq 0.01$) whipping time than spray-dried and foam-spray-dried albumen; furthermore, freeze-dried albumen required significantly less ($P \leq 0.01$) whipping time than spray-dried albumen and significantly less ($P \leq 0.05$) whipping time than foam-spray-dried albumen.

The findings of this investigation are in agreement with reports of previous research. In a comprehensive review of egg dehydration, Bergquist (1964) stated the foaming ability of albumen is usually adversely affected by dehydration.

Rolfes et al. (1955) reported spray-dried albumen had reduced foaming abilities but freeze-dried albumen had satisfactory foaming properties. However, Joslin et al. (1954) and Carlin et al. (1953) found spray-dried and pan-dried albumen retained satisfactory whipping properties. In a more recent study, Zabik et al. (1969), who used constant whipping times, found foam-spray-dried albumen to have the highest specific gravity, indicating decreased foaming ability, followed by freeze-dried albumen. Spray-dried and frozen albumen had equivalent and lowest specific gravities. Perhaps contradictions of this study with the investigation of Zabik et al. (1969) can be attributed to variation in processing techniques. Franks et al. (1969) reported the time required to whip albumen from the same common lot as albumen used in this investigation to a controlled specific gravity increased in the same order as reported for this experiment. Therefore, the results of this study support the conclusions of Franks et al. (1969) in that whipping times for albumen processed by the four methods require adjustment for production of foams of the same aeration.

Specific gravity

All meringues were whipped to a specific gravity of 0.24 to 0.22 by adjusting the total whipping time. Hence, no significant differences attributable to egg process or replication existed.

Foam stability

Ranked in order of decreasing stability as indicated by volume of drainage, were meringues prepared with freeze-dried, spray-dried, frozen and foam-spray-dried albumen. When analyzed for variances due to processing, no significant differences existed. In contradiction, Zabik et al. (1969) reported foam stability of foam-spray-dried albumen to be less than that of albumen processed by the other methods when the albumen was whipped for a constant time.

Significant differences ($P \leq 0.05$) in foam stability existed among replications. The significant correlation coefficient, $r = 0.48$, between room temperature and volume of drainage indicated foam stability decreased as shown by an increase in the amount of drainage as the room temperature increased. The correlation coefficient calculated for specific gravity and volume of drainage showed no significant relationship.

Meringue pH

Meringues prepared with spray-dried albumen had a significantly higher ($P \leq 0.001$) pH of 6.7 - 6.8 than the pH of 6.2 - 6.3 for meringues prepared with the other three types of processed albumen. In a study on the foaming ability of albumen processed by the same methods, Zabik et al. (1969) reported spray-dried albumen had had a higher pH than albumens processed by the three other methods;

however, the pH of freeze-dried and foam-spray-dried albumen was also higher than that of frozen albumen. Hill *et al.* (1965) reported changes in pH of albumen subjected to spray-drying.

Time-temperature Relationships

Potentiometer leads were placed at the meringue-filling interface and at a point midway between the meringue-filling interface and the meringue surface. Mean progressive time-temperature relationships from data obtained during baking were plotted (Figures 3 and 4).

Rates of temperature rise recorded at the meringue-filling interface were most rapid during the first 8 min of baking. For the remainder of the baking period, the temperature at the meringue-filling interface continued to rise at a constant, but reduced, rate. Throughout the baking period, temperatures recorded from meringues prepared from foam-spray-dried albumen exceeded those recorded from meringues prepared from albumen processed by the three other methods (Figure 3). Dips in the curves during the last few minutes of baking are probably due to the averaging process. When a pie was removed from the oven, temperatures were not included in the calculations of the average time-temperature data.

Rates of temperature rise recorded at a point midway between the meringue-filling interface and the meringue

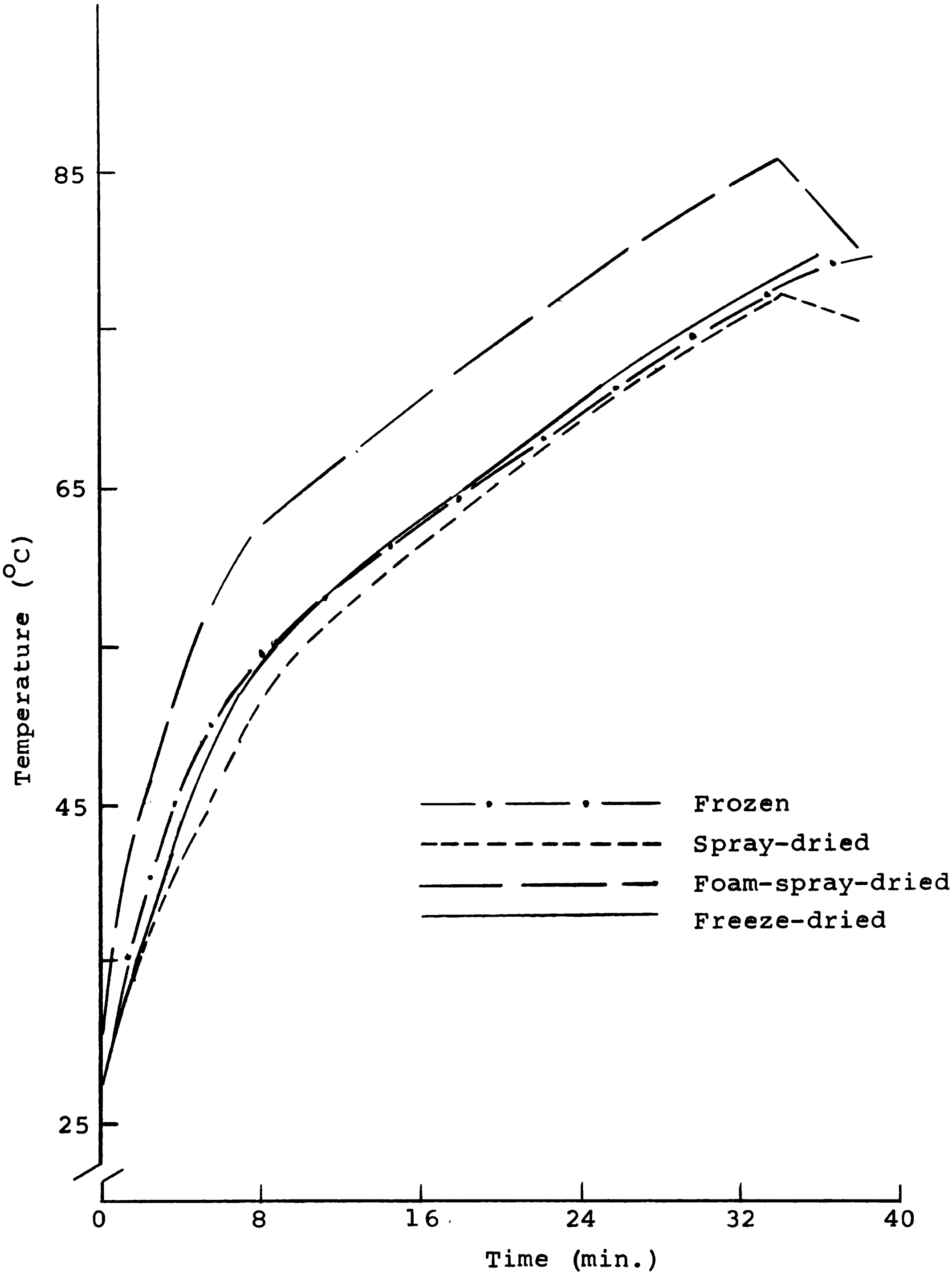

Figure 3. Mean time-temperature relationships at the filling-meringue interface.

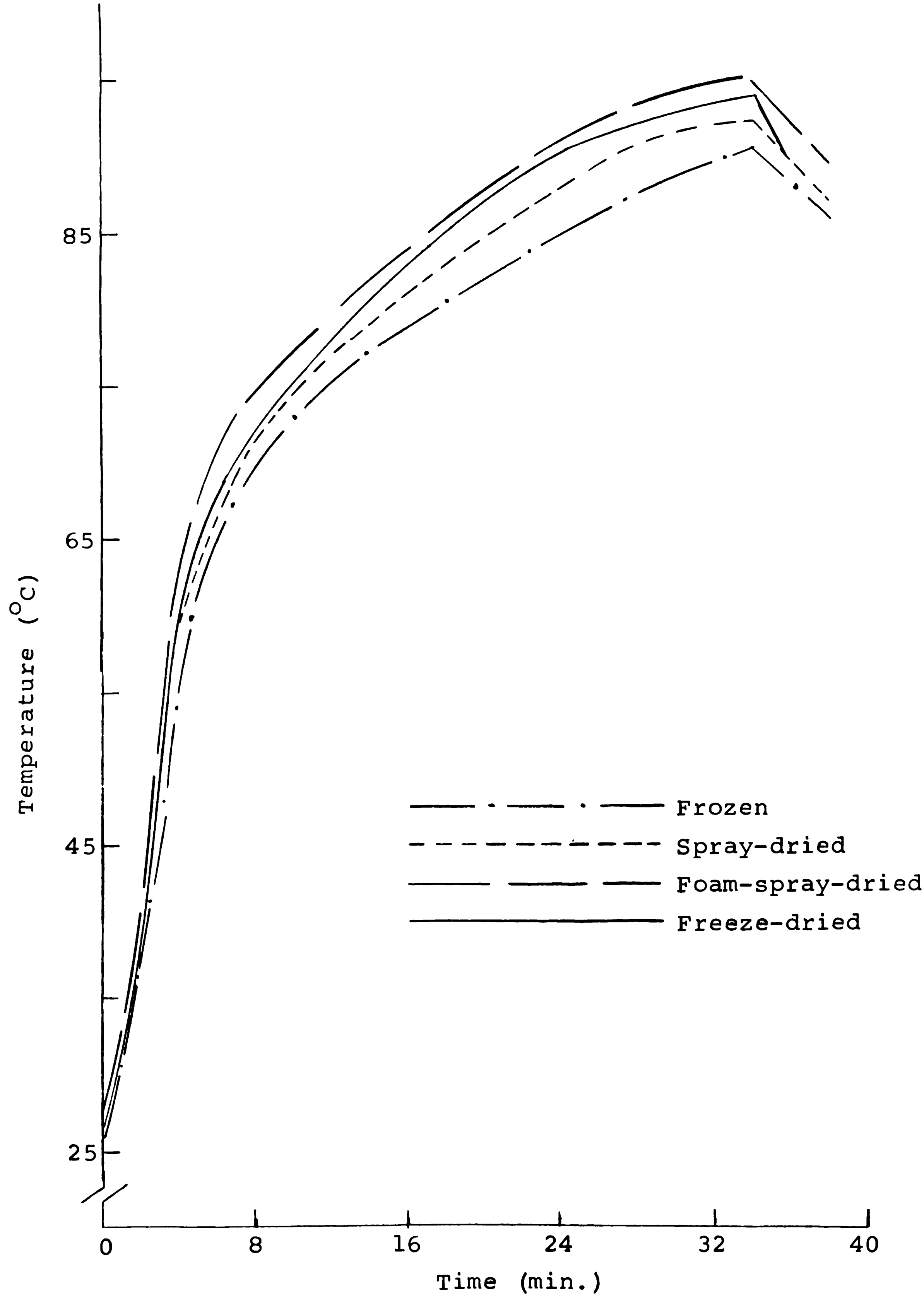

Figure 4. Mean time-temperature relationships recorded from a point midway between the meringue-filling interface and the top meringue surface.

surface exceeded those recorded at the interface of the meringue and filling throughout the baking period. Again, the most rapid rates of temperature rise were recorded during the first few minutes of baking. Temperatures recorded for all albumen processes were similar during the first few minutes of baking. Ranked in order of increased temperatures during the remainder of the baking period were meringues prepared with foam-spray-dried, freeze-dried, spray-dried and frozen albumen (Figure 4). The dips or irregularities in the curves during the last few minutes of baking reflect changes in oven temperature which occurred when the door was opened to check surface browning of the pies. The change in oven temperature may have cooled the meringue to the depth of the potentiometer lead placement, or perhaps only the 4-in immersion length of the potentiometer lead used in this investigation was affected by the oven temperature change.

Average maximum temperatures recorded at the interface of filling and meringue were 78.3 ± 5.8, 78.0 ± 4.4, 85.3 ± 5.6 and $78.3 \pm 2.8^{\circ}C$ for meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen, respectively, while average maximum temperature recorded within the meringues were 93.0 ± 7.5, 98.0 ± 8.7, 98.3 ± 5.2 and $98.6 \pm 6.1^{\circ}C$ for the same order of albumen processes. Results of the analyses of variance, showing significant differences due to process among interface temperatures, are summarized in Table 9.

Further analysis showed meringues prepared with foam-spray-dried albumen had a significantly higher ($P \leq 0.05$) average maximum interface temperature than the same temperature for meringues prepared with the other three types of processed albumen. The maximum interface temperature was correlated with filling temperature, however the correlation coefficient was not significant.

Table 9. Analyses of variance for average maximum temperatures recorded from meringues prepared from albumen processed by four methods.

		Mean Squares	
Source of Variance	Degrees of Freedom	Interface Temperature	Meringue Temperature
Total	23		
Process	3	76.0000*	42.1250
Replication	5	31.5250	66.7917
Error	15	20.4917	43.5417

*Significant at the 5 per cent level of probability.

Average baking times and standard deviations for meringues prepared with frozen, spray-dried, foam-spray-dried and freeze-dried albumen were 35.3 ± 2.13, 34.7 ± 1.55, 35.0 ± 1.10 and 36.0 ± 2.19 min, respectively. All pies remained in the oven until they were lightly browned. These findings are not in agreement with Hester _et al_. (1949) or Gillis _et al_. (1956) who reported baking meringued pies at

$163^{o}C$ for 10 and 18 min, respectively. Perhaps these differences can be attributed to the differences in equipment used in baking the meringues. In this investigation a controller was used to regulate the oven temperature to $\pm$ $2^{o}C$.

Objective Measurements Of Baked Meringues

Objective measurements of baked soft meringues included percentage of evaporation and drainage, height measurements, tenderness, color and beading counts. Percentages of evaporation and drainage, height measurements and tenderness were performed on both fresh and held meringues. Only fresh meringues were subjected to color determination, while beading was counted on only held meringues.

Percentage of evaporation and drainage

Percentages of evaporation and drainage for six replications of each albumen process of fresh and held meringues are presented in the Appendix, Table 25. Mean percentages and standard deviations are presented in Table 10.

Analyses of variance were computed for percentages of evaporation and drainage to determine differences due to processing and replication. Results of the analyses, indicating significant differences, are summarized in Table 11.

Evaporation. Meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen lost an average

Table 10. Means and standard deviations for percentages of evaporation and drainage of fresh and held soft meringues prepared from albumen processed by four methods.

Measurement	Process			
	Frozen	Spray-dried	Foam-spray-dried	Freeze-dried
Evaporation, fresh	20.9±2.1	20.6±1.9	20.5±1.3	21.2±1.5
Evaporation, held	21.8±2.4	21.2±2.6	21.3±1.9	22.3±1.4
Drainage, fresh	12.9±5.0	11.8±5.4	10.4±4.0	9.9±2.6
Drainage, held	10.3±6.5	10.1±4.0	9.0±3.6	6.1±2.9

Table 11. Analyses of variance for percentages of evaporation and drainage of fresh and held soft meringues prepared from albumen processed by four methods.

Source of Variance	Degrees of Freedom	Mean Squares			
		Evaporation fresh	Evaporation held	Drainage fresh	Drainage held
Total	23				
Process	3	0.6361	1.4678	11.3767	22.2371
Replication	5	4.2487	10.5677*	32.5060	6.3464
Error	15	2.6004	2.3488	14.9720	24.3891

*Significant at the 5 per cent level of probability.

of 20.9, 20.6, 20.5 and 21.2%, respectively, during baking and the subsequent cooling period after baking. The percentages of evaporation showed no significant differences among process or replication.

Evaporation increased during the refrigerated holding period with meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen showing averages of 21.8, 21.2, 21.3 and 22.3%, respectively. Again, no significant differences attributable to processing were found. However, significant differences ($P \leq 0.05$) existed among replications. Standard deviations indicate more variance among replications of meringues prepared with spray-dried and frozen albumen than among meringues prepared with foam-spray-dried and freeze-dried albumen.

A highly significant correlation coefficient, $r = 0.60$, existed between percentage of evaporation for fresh meringues and filling temperatures. These data indicate that as the temperature of the filling increased, the percentage of evaporation increased.

Drainage. No significant differences attributable to process or replication existed for percentages of drainage of fresh or held soft meringues. Fresh meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen had average drainages of 12.9, 11.8, 10.4, and 9.9%, respectively; held meringues had average drainages of 10.3, 10.1, 9.0 and 6.1%, respectively. All types of processes showed less average percentage drainage after holding. Perhaps part of the decrease in percentage of drainage could be attributed to evaporation during holding. In a discussion of foams, Glabau (1948) indicated sugar may be present in a meringue as a syrup or as dry sugar within the cellular walls. Perhaps during baking, the sugar in solution separated from the meringue and then during the holding period, dry sugar absorbed liquid which had previously drained from the meringues. There was no significant correlation coefficient between the filling temperature and the percentage of drainage.

Height measurements

Height measurements, as an indication of shrinkage, for six replications of each albumen process of fresh and held meringues are presented in the Appendix, Table 26. Mean values and standard deviations are presented in Table 12.

Table 12. Means and standard deviations for height measurements of fresh and held meringues prepared from albumen processed by four methods.

Height (cm)	Process			
	Frozen	Spray-dried	Foam-spray-dried	Freeze-dried
Fresh	1.85±0.03	1.87±0.08	1.87±0.05	1.87±0.08
Held	1.78±0.13	1.74±0.09	1.78±0.07	1.76±0.05

To determine differences in height due to processing and replication, data were subjected to analyses of variance.

No significant differences attributable to process or replication were found. However, comparison of means revealed meringues prepared from spray-dried, foam-spray-dried and freeze-dried albumen decreased significantly ($P \leq 0.05$) in height after being held for 20 to 22 hr under refrigeration. Such a decrease was not found in the meringues prepared from frozen albumen, however, the large standard deviation indicates the measurement of height varied considerably.

Tenderness

Allo-Kramer measurements of tenderness, expressed as maximum force and area-under-the-curve, for six replications of each albumen process of fresh and held meringues are presented in the Appendix, Table 27. Mean values and standard deviations are presented in Table 13.

Analyses of variance were computed for maximum force and area-under-the-curve values to determine differences in tenderness due to process and replication. The results, presented in Table 14, show the only significant difference ($P \leq 0.01$) existed among replications of held meringues. These data agree with that reported by Franks *et al.* (1969) in that no significant differences were found in tenderness values, expressed as maximum force and area-under-the-curve, for angel cakes prepared from albumen processed by the same methods.

Table 13. Means and standard deviations for tenderness measurements, expressed as maximum force and area-under-the-curve, of fresh and held soft meringues prepared from albumen processed by four methods.

Tenderness Measurement	Process			
	Frozen	Spray-dried	Foam-spray-dried	Freeze-dried
Maximum force, fresh (lb. force/g)	0.232±0.043	0.228±0.029	0.233±0.057	0.232±0.015
Maximum force, held (lb. force/g)	0.207±0.045	0.206±0.033	0.182±0.038	0.189±0.023
Area-under-the-curve, fresh (cm^2)	2.991±0.612	3.183±0.453	3.279±0.626	3.409±0.588
Area-under-the-curve held (cm^2)	2.726±0.324	2.754±0.447	2.730±0.374	2.794±0.289

Table 14. Analyses of variance for tenderness measurements, expressed as maximum force and area-under-the-curve, of fresh and held soft meringues prepared from albumen processed by four methods.

Source of Variance	Degrees of Freedom	Tenderness measurements: Maximum force fresh	Maximum force held	Area-under-the-curve fresh	Area-under-the-curve held
Total	23				
Process	3	0.0000	0.0946	0.1859	0.0059
Replication	5	0.0021	0.3359**	0.3009	0.2210
Error	15	0.0013	0.0545	0.3386	0.1023

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

Tenderness, expressed as maximum force, was correlated with the percentage of evaporation. While no significant relationship was shown between these factors for fresh meringues, the correlation coefficient, r = 0.72, between the percentage of evaporation of held meringues and maximum force was very highly significant. This significant relationship suggested tenderness decreased as the amount of moisture present in the meringue decreased.

Color

Analyses of variance for Hunter color difference measurements showed no significant differences attributable to process or replication existed. Color measurements for six replications of meringues prepared from albumen processed by four methods are presented in the Appendix, Table 28, while mean values and standard deviations are presented in Table 15.

Table 15. Means and standard deviations for color measurements of soft meringues prepared from albumen processed by four methods.

Color Measurement	Process Frozen	 Spray-dried	 Foam-spray-dried	 Freeze-dried
Hunter L	82.09±2.33	81.54±3.85	81.51±2.45	80.44±2.46
Hunter a_L+	3.37±1.04	3.48±1.79	3.47±1.56	4.61±1.15
Hunter b_L+	19.92±1.78	19.53±2.44	19.50±1.53	20.31±1.73

Hunter color difference meter showed meringues prepared from frozen albumen to be the lightest in color followed by spray-dried, foam-spray-dried and freeze-dried. For Hunter a_L+ value, meringues prepared from freeze-dried albumen had highest mean redness values followed by spray-dried, foam-spray-dried and frozen. Meringues prepared from freeze-dried albumen were most yellow, as indicated by Hunter b_L+ values, followed by frozen, spray-dried and foam-spray-dried albumen.

Beading

As an indication of the meringue stability, beads or droplets of moisture which accumulated during holding were counted. According to the analyses of variance, there were no significant differences attributable to process or replication. Table 26 in the Appendix shows average beading counts for six replications of soft meringues prepared from albumen processed by four methods.

Average beading counts were 42 ± 42, 28 ± 16, 21 ± 8 and 64 ± 96 for held meringues prepared with frozen, spray-dried, foam-spray-dried and freeze-dried albumen. The high standard deviations indicate this measurement lacks the desired precision to objectively measure meringue stability.

Subjective Evaluation Of Baked Meringues

Surface color and appearance, shrinkage, slippage and drainage, texture, tenderness, flavor and general acceptability were evaluated by a 7-member taste panel using a 7-point rating scale. Data were analyzed for variance and simple correlation coefficients of appropriate combinations of data were derived.

Analyses of meringue attributes

Average quality characteristic scores of seven judges for six replications of soft meringues prepared from albumen processed by four methods are presented in the Appendix, Table 29; grand mean scores and standard deviations for subjective evaluations are shown in Table 16. Results of the analyses of variance are summarized in Table 17. Significant differences were pursued further using Duncan's multiple range (Duncan, 1957).

Table 16. Grand mean scores and standard deviations for quality characteristics of soft meringues prepared from albumen processed by four methods.

Quality Characteristics	Albumen Process			
	Frozen	Spray-dried	Foam-spray-dried	Freeze-dried
Color and Appearance	4.9±0.6	4.5±0.9	4.9±0.6	5.3±0.4
Shrinkage	5.1±0.7	5.7±0.5	5.9±0.5	6.1±0.3
Slippage and Drainage	5.4±0.5	5.3±1.0	5.6±0.5	5.9±0.3
Texture	5.4±0.4	5.1±0.5	5.0±0.5	5.5±0.5
Tenderness	4.8±0.6	5.1±0.4	4.9±0.7	5.1±0.4
Flavor	5.2±0.6	5.0±0.5	5.0±0.5	5.1±0.3
General Acceptability	5.0±0.5	4.8±0.5	4.9±0.4	5.2±0.2

Color and appearance. Average scores for color and appearance were 4.9, 4.5, 4.9 and 5.3 for meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen, respectively. Comments by the judges indicated some of the meringues were too pale, unevenly browned and/or beaded. Amerine *et al*. (1965) stated consumers expect foods to have a certain color, and deviation from this color may influence acceptability. Perhaps the color of the flat-surfaced meringues in this study did not meet the subjective standards of the judges. The same meringues were used for sensory evaluation and for time-temperature data. The apparatus used to support

Table 17. Analyses of variance of scores for quality characteristics of soft meringues prepared from albumen processed by four methods.

		Mean Squares						
Source of Variance	Degrees of Freedom	Color and Appear.	Shrink.	Slip. and Drain.	Tex.	Tend.	Flavor	Gen. Accept.
Total	23							
Process	3	0.7517	1.0833*	0.3349	0.3078	0.1267	0.0717	0.1671
Replication	5	0.3827	0.1667	0.4648	0.2687	0.4977	0.1467	0.1154
Error	15	0.4007	0.2993	0.3512	0.2364	0.2323	0.2687	0.2114

*Significant at the 5 per cent level of probability.

the potentiometer leads apparently prevented browning in some areas thus resulting in unevenly browned appearance of some meringues. Analyses of variance showed no significant differences attributable to process or replication.

A highly significant negative correlation coefficient, $r = -0.61$, existed between color and appearance scores and Hunter L values indicating that taste panel scores decreased as Hunter L values increased. A high Hunter L value indicated a light colored meringue. Thus judges showed a preference for more browned meringues. A highly significant correlation coefficient, $r = 0.56$, and a significant correlation coefficient, $r = 0.52$, existed between color and appearance scores and Hunter a_L+ values and Hunter b_L+ values, respectively, indicating that as the amount of redness (a_L+) and yellowness (b_L+) increased, the judges gave higher scores for color.

<u>Shrinkage</u>. To evaluate the attribute of shrinkage judges were instructed to examine the piece of pie to see if the meringue adhered to the pastry and covered the top of the filling. Analyses of variance showed a significant difference among process ($P \leq 0.05$) in shrinkage scores. Further analysis showed meringues prepared from frozen albumen had a significantly lower ($P \leq 0.05$) average shrinkage score than meringues prepared from freeze-dried albumen. Approximately one-third of the judges' comments indicated the meringues prepared from frozen albumen did not cover the filling.

Perhaps overcoagulation during preparation or baking resulted in shrinkage. Lowe (1955) suggested baking times of 18 to 25 min at an oven temperature of 160°C because longer baking times at lower temperatures caused shrinkage when the pie was removed from the oven. However, meringues prepared with frozen albumen were baked for about the same time as the meringues prepared with the other three types of albumen.

Shrinkage scores correlated significantly, $r = 0.48$, with color and appearance scores. Although shrinkage was not to be evaluated as part of the appearance, these data suggest shrinkage probably influenced the judges' color and appearance scores.

Slippage and drainage. To evaluate slippage and drainage the judges were instructed to visually determine how much liquid was present between the filling and meringue and to tilt the plate on which the piece of pie was placed to determine if meringue would slip from filling. Meringues prepared from all four types of albumen received average of good to very good for this attribute indicating a very small amount of drainage. No significant correlation existed between slippage and drainage scores and percentage of drainage of fresh meringues.

Texture. The texture of a standard meringue was defined as having many small even-sized air cells with thin cell walls. Ranked in order of decreasing texture scores were meringues prepared from freeze-dried, frozen, spray-dried and foam-spray-dried albumen. There were no significant differences attributable to process for the texture scores. These findings are not in agreement with those of Franks *et al*. (1969) who divided texture of angel cakes into two parts for evaluation. For distribution and cell size, angel cakes prepared from spray-dried albumen received the best average score followed by frozen and foam-spray-dried albumen; freeze-dried albumen received the lowest average score for distribution and cell size. Ranked in decreasing order of scores for cell wall thickness were angel cakes prepared from foam-spray-dried, spray-dried, frozen and freeze-dried albumen.

Tenderness. The judges were instructed to evaluate tenderness by how easily the meringue was cut, removed from fork and masticated. Meringues prepared from freeze-dried and spray-dried albumen were scored as being the most tender followed by foam-spray-dried and frozen albumen. There were no significant differences due to process among average tenderness scores. These findings are not in agreement with Franks *et al*. (1969) who found angel cakes prepared from frozen albumen to be the most tender and those prepared from freeze-dried albumen to be the least tender.

The attribute of tenderness received some of the lowest scores for all four types of albumen. Most comments by the judges indicated the meringues were sticky and clung to the fork. Briant *et al*. (1954) found that when egg whites were beaten at high speed the surface of the meringue was rated more tender than when egg whites were beaten at medium, then high speed. Investigating the effect of oven temperature on meringue tenderness and stickiness, Hester _et al._ (1949) reported meringues baked at 163°C received significantly lower ($P \leq 0.01$) scores than meringues bakes at 218°C. Perhaps the speed of beating or baking temperature influenced the tenderness scores in this investigation.

The sensory evaluation of tenderness data are in agreement with the objective measurement of tenderness; however, only the data of this investigation are available to assess the validity of the shear press to measure this characteristic of soft meringues. Furthermore, there was no significant correlation coefficient between tenderness scores and shear press readings.

Flavor. The flavor for a standard meringue was defined as being delicate, bland and slightly sweet. Judges' comments pertaining to flavor indicated some meringues were too sweet, eggy, salty, powdery and/or flat. Average flavor scores were 5.2, 5.0, 5.0 and 5.1 for meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen. The ranking of these scores is in agreement with the findings of Franks _et al_. (1969).

General acceptability. Meringues prepared from freeze-dried albumen were scored as being most acceptable followed by those prepared from frozen, foam-spray-dried and spray-dried albumen. However, all were judged acceptable. These data agree with that of Franks et al. (1969) who found angel cakes prepared from the same types of processed albumen to be acceptable.

As general acceptability scores increased, color and appearance, shrinkage, slippage and drainage and flavor scores increased. Very highly significant correlation coefficient, $r = 0.69$, between general acceptability and color and appearance average scores, and very highly significant correlation coefficient, $r = 0.69$, between general acceptability and flavor average scores emphasize that the appearance and flavor of a food are important characteristics contributing to its acceptability.

Significant correlation coefficients of objective measurements and/or subjective evaluations are summarized in Table 18. A summary of correlation coefficients pertinent to this investigation appears in the Appendix, Table 31.

Analysis of taste panel member data

To determine variations among the scoring of judges, sensory data were subjected to three-way analysis of variance. The results, presented in Table 19, show significant differences due to albumen process in scores for color and appearance ($P \leq 0.001$), shrinkage ($P \leq 0.001$), slippage and drainage ($P \leq 0.01$), and texture ($P \leq 0.05$) while the

Table 18. Significant correlation coefficients for soft meringue attributes as determined by objective measurements and/or subjective evaluations.

Relationship	Correlation Coefficient
Color and appearance scores / Hunter L	-0.61**
Color and appearance scores / Hunter a_L	0.56**
Color and appearance scores / Hunter b_L	0.52*
Shrinkage scores / Color and appearance scores	0.48*
General acceptability scores / Color and appearance scores	0.69***
General acceptability scores / Shrinkage scores	0.61**
General acceptability scores / Slippage and drainage scores	0.78***
General acceptability scores / Flavor scores	0.69***

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

analysis of variance based on mean scores showed significant difference ($P \leq 0.05$) only in shrinkage scores. However, the large number of degrees of freedom for the error mean square used in the three-way analysis of variance increases the power of the analyses.

Significant differences ($P \leq 0.001$) attributable to judge were found for each of the seven quality characteristics of the meringues. These data are shown in Table 20. Examination of the individual scores showed two judges, designated as F and G, evaluated five of the seven

Table 19. Analyses of variance for determining significant differences among judges.

Source of Variance	Degrees of Freedom	Mean Squares						
		Color & Appearance	Shrinkage	Slippage & Drainage	Texture	Tenderness	Flavor	General Accept-ability
Total	167							
Process (P)	3	4.8631***	9.0536***	2.3016**	2.2758*	0.9107	0.5456	1.0377
Judge (J)	6	5.1032***	14.8571***	12.1508***	4.8155***	12.9008***	15.7063***	7.5139***
P X J	18	1.4233*	0.6693	0.5794	0.6276	0.7765	1.1243	0.9266
Replication (R)	5	2.3203*	1.4774*	3.4667***	1.9060	2.6774***	1.0488	0.9345
P X R	15	2.3679***	1.6393***	2.0349***	1.4615	1.3440**	1.4266	1.0520
J X R	30	0.7675	0.5857	0.5722	0.6560	0.8246*	0.8183	0.5901
Error	90	0.7669	0.4772	0.5183	0.8300	0.4876	0.8775	0.5964

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

Table 20. Means and significant differences among judges for evaluation of quality characteristics of soft meringues prepared from albumen processed by four methods.

Quality Characteristics	Judge A	B	C	D	E	F	G	Significant Difference[1] Additional at P = 0.001	P = 0.01	P = 0.05
Color and Appearance	4.2	5.3	5.5	5.0	5.2	4.7	4.6	BCE > A	C > GF	BE > AG
Shrinkage	5.8	6.1	7.0	5.9	5.0	4.7	5.0	ABCD > EFG		
Slippage & Drainage	5.7	6.3	5.9	6.0	5.8	4.7	4.4	ABCDE > FG	B > A	B > E
Texture	5.3	5.3	5.9	5.2	5.3	4.4	5.0	C > F	ABDE > F C > G	G > F C > ABDE
Tenderness	5.3	5.5	5.6	5.5	4.8	3.9	4.0	ABCDE > FG	BCD > E	A > E
Flavor	4.5	5.6	6.1	5.0	5.7	3.8	4.8	BCDEG > F BCE > A CE > G C > D	BE > G	A > F BE > D
General Acceptability	4.6	5.4	5.8	5.0	5.2	4.1	4.6	BCDE > F BC > A G C > D		C > E > AG > F

[1]Values underscored by the same line are not significantly different (Duncan, 1957).

characteristics lower than the other judges; however, variations among judges existed for evaluation of all quality characteristics. The judge designated as C evaluated six of the seven characteristics higher than other judges.

Significant interaction ($P \leq 0.05$) between albumen process and judges was demonstrated only for color and appearance of the meringues. The data indicated a preference for meringues prepared with freeze-dried albumen. Judges also indicated a preference for meringues prepared with freeze-dried albumen in their evaluations of shrinkage, slippage and drainage, texture and the general acceptability.

Significant differences due to replication were noted for color and appearance ($P \leq 0.05$), shrinkage ($P \leq 0.05$), slippage and drainage ($P \leq 0.001$) and tenderness ($P \leq 0.001$), thus indicating judges were not consistent in scoring among replications for these quality characteristics. Furthermore, the significant differences shown in replication and egg process interaction for color and appearance ($P \leq 0.001$), shrinkage ($P \leq 0.001$), slippage and drainage ($P \leq 0.001$) and tenderness ($P \leq 0.01$) substantiate this conclusion. Tenderness evaluations showed significant differences ($P \leq 0.05$) in judge and replication interaction.

Judges apparently experienced difficulties in consistently evaluating the characteristics of color and appearance, shrinkage, slippage and drainage, and tenderness. Uneven browning as previously mentioned, probably affected color and appearance scores. Perhaps training sessions for the judges were inadequate in number and/or scope or perhaps the descriptive terms used on the score card did not adequately describe the meringues.

Meringues Without Stabilizer

To demonstrate the effect of stabilizer on quality characteristics of soft meringues, six replications of meringues prepared from spray-dried albumen without added stabilizer were subjected to objective measurements. The results of these objective measurements are presented in the Appendix, Table 30. Means, standard deviations and statistical analyses for comparing these data with similar data from soft meringues without stabilizer are shown in Table 21.

Environmental conditions and lemon filling

The room temperature for days during which soft meringues without stabilizer were prepared ranged from 24 to 27°C while the relative humidity ranged from 46 to 69%. These data recorded for each pie appear in the Appendix, Table 30.

Viscosity readings recorded for the lemon pie filling averaged 178.3 poises, pH values were 3.5 and temperature averaged 27.3°C, respectively. These data, assigned to the appropriate replication are presented in the Appendix, Table 30.

Table 21. Means, standard deviations or ranges and statistical comparison of means of objective measurements of soft meringues prepared from spray-dried albumen with and without added stabilizer.

Measurement or Evaluation	Spray-dried Albumen With Stabilizer	Spray-dried Albumen Without Stabilizer	Z Value
Albumen temperature (°C)	25.5±0.4	25.2±0.2	1.66
Specific gravity	0.23±0.01	0.24±0.01	0.623
Foam stability (ml)	0.08±0.16	0.10±0.04	0.896
pH	6.7-6.8	6.7	0.0
Whipping time (min)	16.08±1.51	14.67±1.11	1.855
Maximum temperature interface (°C)	78.0±4.4	76.9±3.5	0.479
Maximum temperature meringue (°C)	98.0±8.7	93.3±5.6	1.12
Baking time (min)	34.7±1.6	34.0±0.0	1.11
Evaporation, fresh (%)	20.6±1.9	19.2±1.1	1.56
Evaporation, held (%)	21.2±2.6	21.1±1.4	0.083
Drainage, fresh (%)	11.8±5.4	20.1±2.5	3.428**
Drainage, held (%)	10.1±4.0	14.6±5.5	1.62
Height, fresh (cm)	1.87±0.08	1.87±0.43	0.0
Height, held (cm)	1.74±0.09	1.77±0.11	0.515
Beading	28±16	10±3	2.708*
Maximum force, fresh (lb. force/g)	0.228±0.029	0.260±0.035	1.739
Maximum force, held (lb. force/g)	0.206±0.033	0.243±0.028	0.206
Area-under-the-curve, fresh (cm^2)	3.183±0.453	3.514±0.405	1.68
Area-under-the-curve, held (cm^2)	2.754±0.447	3.253±0.190	2.52*
Hunter L	81.54±3.85	82.38±2.34	0.457
Hunter a_L	3.48±1.79	3.05±1.09	0.503
Hunter b_L	19.53±2.44	19.52±1.82	0.008

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

Unbaked meringues

No significant differences were found in albumen temperature, whipping time, specific gravity, foam stability and pH between meringues prepared from spray-dried albumen with and without added stabilizer. It should be noted the average room temperature for days during which meringues without stabilizer were prepared was lowered than for days during which meringues with stabilizers were prepared. Perhaps the lower room temperature affected the foam stability less than the higher room temperature, thereby indicating a decrease in the noticable influence of the stabilizer.

Average total whipping times were 16.08 ± 1.51 and 14.67 ± 1.11 min for meringues prepared with and without added stabilizer, respectively. This finding is in agreement with that of Glabau (1948) who suggested that a "vegetable gum stabilizer" increased whipping times to acquire meringues of equal specific gravity. Glabau (1948) employed the same whipping times for meringues with and without stabilizer and found meringues with added stabilizer had higher specific gravity than those without added stabilizer. According to his report, the use of stabilizer increased foam stability of meringues.

Time-temperature relationships

Plotting of data showed time-temperature curves for meringues prepared with and without stabilizer were very similar. Initial temperatures recorded from the interface of the filling and meringue reflected the 2^{o}C lower filling temperature of pies used for meringues without stabilizer. However, the initial temperature did not affect baking time. Average baking time for meringues with stabilizer was 34.7$\pm$1.6; whereas those prepared without stabilizer had an average baking time of 34.0$\pm$0.0. Statistical analysis showed no significant differences between meringues prepared with and without stabilizer for maximum temperature at the filling-meringue interface and at a point midway between the interface and meringue surface.

Evaporation and drainage

No significant differences were found between the percentages of evaporation of 20.6 and 19.2% incurred during baking of meringues with and without added stabilizer indicating the use of stabilizer did not prevent moisture losses by evaporation. Also, when the meringues were held at refrigerated temperatures, no significant differences existed in percentages of evaporation of 21.2 and 21.1% for meringues prepared with and without stabilizer, respectively.

Percentages of drainage decreased significantly ($P \leq 0.01$) in fresh meringues when stabilizer was used. Meringues prepared with and without stabilizer had drainage losses of 11.8 and 20.1%, respectively. This finding is in agreement with those of Glicksman (1962), Felt *et al.* (1956), Anon. (1953), Godston (1950) and Glabau (1948). When the meringues were held for 20 to 22 hr, drainage losses of 10.1 and 14.6% for meringues with and without stabilizer, respectively, did not differ significantly.

Held meringues with and without stabilizer had lower percentages of drainage than fresh meringues while fresh meringues had lower percentages of evaporation than held meringues. This phenomenon has been discussed previously.

Height and beading

There were no significant differences in the height of fresh and held meringues prepared with and without added stabilizer. Statistical analysis showed a significant difference ($P \leq 0.05$) for number of beads with the lowest number noted for meringues without added stabilizer. However, as previously stated, the reliability of these data is questionable.

Tenderness

Fresh and held meringues prepared with and without stabilizer had similar average shear-press values when expressed as maximum force. Comparison of means for tenderness, expressed as area-under-the-curve, for meringues prepared with and without stabilizer showed no significant differences for fresh meringue; however, there was a significant difference for held meringues. Held meringues prepared without stabilizer received higher average readings, expressed as area-under-the-curve, than held meringues prepared with stabilizer added. These findings are not in agreement with Glabau (1948) who concluded that added stabilizer caused more rigid meringues as shown by resistance to shearing with a modified MacMichael apparatus.

Color

No significant differences were found for any of the three color values as determined with the Hunter color difference meter for meringues prepared with and without added stabilizer.

SUMMARY AND CONCLUSIONS

The primary objective of this study was to compare the quality characteristics of soft meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen. For this purpose, three lemon meringue pies were prepared for each of the six replications of each albumen process. All ingredients were from common lots.

All meringues, prepared according to standardized procedures, contained added stabilizer; were whipped to a specific gravity of 0.24 to 0.22; were spread to a constant depth on the pie shells previously filled to a constant level; and were baked at 163°C for 34 to 36 min. During baking time-temperature relationships were continuously recorded at the meringue-filling interface and at a specified point within the meringue. Quality characteristics were evaluated 2 to 3 hr after preparation for pies designated as fresh and after a 20 to 22 hr refrigerated holding period for pies designated as held.

Objective measurements of albumen temperature, whipping times, specific gravity, foam stability and pH were determined for the unbaked meringue. Percentages of evaporation and drainage were calculated. The measurements of baked meringues were tenderness using an Allo-Kramer shear press, color of fresh meringues using a Hunter color-difference meter, height and bead counts of moisture accumulating on the surface of held meringues. A taste panel evaluated fresh meringues for color and appearance, shrinkage, slippage and drainage, texture, tenderness, flavor and general acceptability.

Data from objective measurements and sensory evaluations were analyzed statistically for variance. Appropriate correlation coefficients were determined.

Analyses of the data showed no significant differences attributable to albumen process for albumen temperature, specific gravity and foam stability; however significant differences ($P \leq 0.001$) existed in the pH of the albumen. Significant differences among replications were found in measurements of albumen temperature, foam stability and pH. The significant correlation coefficient, $r = 0.48$, between room temperature and volume of drainage indicated foam stability decreased as the room temperature increased. Whipping times differed significantly due to process ($P \leq 0.01$) and replication ($P \leq 0.05$). Ranked in order of increasing average whipping times of 13.54, 13.92, 16.00 and 16.08 min were meringues prepared from frozen, freeze-dried, foam-spray-dried and spray-dried albumen; standard deviations indicated the greatest variation in whipping times for foam-spray-dried followed by spray-dried, freeze-dried and frozen albumen.

Throughout the baking period, temperatures recorded from the filling-meringue interface of meringues prepared from foam-spray-dried albumen exceeded those recorded from meringues prepared from albumen processed by the three other methods. Rates of temperature rise recorded from a point midway between the meringue-filling interface and the meringue surface exceeded those recorded at the meringue-filling interface throughout the baking period. The average maximum temperature of 85.3°C recorded from meringues prepared from foam-spray-dried albumen was significantly higher ($P \leq 0.05$) than similar temperatures of 78.3, 78.0 and 78.3°C recorded for meringues prepared from frozen, spray-dried and freeze-dried albumen, respectively.

Drainage of 12.9, 11.8, 10.4 and 9.9% for meringues prepared from frozen, spray-dried, foam-spray-dried and freeze-dried albumen, respectively, were not significantly different. After holding, decreased values of 10.3, 10.1, 9.0 and 6.1% were shown for the respective processes. Percentages of evaporation for fresh and held meringues did not differ significantly among processes, however, significant differences ($P \leq 0.05$) were found among replications of held meringues.

Comparison of means revealed meringues prepared with spray-dried, foam-spray-dried and freeze-dried albumen decreased significantly ($P \leq 0.05$) in height after being held; however, the decrease in height measurements of meringues prepared with frozen albumen was not significant.

Allo-Kramer shear press measurements of tenderness, expressed as maximum force and area-under-the-curve, showed significant differences due to process ($P \leq 0.01$) only among maximum force values of replications of held meringues. The correlation coefficient, $r = 0.72$, between percentages of evaporation of held meringues and maximum force values of tenderness of held meringues was very highly significant thereby suggesting tenderness decreased as the amount of moisture present in the meringue decreased.

While no significant differences existed in color measurements, the values showed fresh meringues prepared from frozen albumen to be lightest in color followed by spray-dried, foam-spray-dried and freeze-dried albumen. Meringues prepared from freeze-dried albumen had highest redness values followed by spray-dried, foam-spray-dried and frozen albumen while meringues prepared from freeze-dried albumen were most yellow followed by frozen, spray-dried and foam-spray-dried albumen.

Beading counts did not differ significantly among process; however, the high standard deviations indicate this measurement lacks the desired precision to objectively measure meringue stability.

Sensory evaluations showed no significant differences among processes or replications for color and appearance, slippage and drainage, texture, tenderness, flavor and general acceptability. Comments on color and appearance evaluations suggested the panelists preferred more browning than was apparent on most of the pies while small amounts of drainage were evident in all of the pies evaluated. All pies showed good to very good texture while tenderness scores indicated all meringues were evaluated as medium to good in this attribute. The correlation coefficients between tenderness scores and shear press measurements were not significant. The flavor of meringues on all pies was good to very good. Ranked in order of general acceptability were meringues prepared with freeze-dried, frozen, foam-spray-dried and spray-dried albumen; however, all meringues were scored as good. Shrinkage scores differed significantly ($P \leq 0.05$) with the greatest amount of shrinkage indicated for meringues prepared from frozen albumen followed by spray-dried, foam-spray-dried and freeze-dried albumen.

Analyses of the taste panel member data showed significant differences ($P \leq 0.001$) among judges for all attributes evaluated. The analyses also indicated judges experienced difficulties in consistently evaluating the characteristics of color and appearance, shrinkage, slippage and drainage and tenderness.

The results of this investigation were compared with the results of a study on angel cakes using albumen processed by the same methods. Although the formula for angel cakes results in a system different from meringues, some general trends were evident. Whipping times showed the same rank order. Tenderness measurements showed no significant differences due to processing in either the meringues or angel cakes. Sensory evaluations of texture, flavor and general acceptability of the two products showed no significant differences due to process; however, judges evaluated tenderness of angel cakes as significantly different among process. In general, the results of this investigation support the conclusion of Franks et al. (1969) in that albumen processed by four methods can be used to produce equally acceptable products when whipping times are adjusted to yield foams of the same specific gravity.

A second objective of the study was to determine the effect of stabilizer on the quality characteristics as determined by objective measurements of soft meringues and for this purpose, meringues were prepared from spray-dried albumen with and without added stabilizer. Without stabilizer, meringues had a significantly higher ($P \leq 0.01$) percentage of drainage, significantly lower ($P \leq 0.05$) beading counts and were significantly tougher ($P \leq 0.05$) when held, as indicated by area-under-the-curve values, than meringues prepared with stabilizer. Other objective measurements indicated the addition of stabilizer had no significant effect on the quality characteristics of the meringues.

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APPENDIX

Please follow these instructions when evaluating the three soft meringues 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 preceding the taste panel time.
2. Sit at the same place in the taste panel room for each evaluation period.
3. Since facial or verbal expressions may influence the scoring of other taste panel members, please remain quiet during the evaluation period.
4. Check to make sure the number on the plate containing the sample agrees with the one on the score sheet.
5. Before tasting each sample, clear your mouth with the water in the glass.
6. As you evaluate each factor, compare it with the "standard" description and then check the space which best fits your overall judgment for that factor. If you mark Medium, Poor, Very Poor or Unacceptable, also mark the descriptive term or phrase which best describes the reason you chose the score for the particular factor being evaluated. If an appropriate term or phrase is not listed, write a brief description of it on the back of the score sheet.
7. During the evaluation period taste only the meringue, <u>do not</u> taste or evaluate the filling or crust.
8. Evaluate the factors for the soft meringues in the following order and way:
   a. Evaluate the overall <u>COLOR</u> and <u>APPEARANCE</u> of the meringue and determine if there are any beads of moisture present.
   b. For <u>SHRINKAGE</u> - Check to see if the meringue adheres to the pastry and covers the top of the filling.
   c. For <u>SLIPPAGE</u> and <u>DRAINAGE</u> - Visually examine the area between the meringue and filling to determine if much liquid is present there. Feel with your fingers the back of the crust to determine if it is dry. Tilt the plate to about a 30° angle to determine if meringue will slip from filling.
   d. With a fork tear off a portion of the meringue. Examine the upper half of the exposed area to evaluate the <u>TEXTURE</u> of the meringue.
   e. Remove a bite-size portion by cutting through the meringue with side of the fork; base your evaluation of <u>TENDERNESS</u> and <u>STICKINESS</u> on how easily the meringue is cut, removed from fork and masticated.
   f. Remove another bite-size portion and determine the <u>FLAVOR</u> from eating the removed portion which is to be <u>only</u> the meringue part of the pie.
   g. Evaluate the <u>GENERAL ACCEPTABILITY</u> by taking all the above factors into consideration.
9. Check to be sure you have marked <u>seven</u> spaces and have also indicated the descriptive terms or phrases as directed in No. 6 above.

Figure 5. Instructions for evaluating soft meringues.

Name ______________________ Date ______________ Sample No. ____________

For any characteristic scored 4 or below check the deviation which caused the lower score.

CHARACTERISTICS OF STANDARD MERINGUE	Excel-lent 7	Very good 6	Good 5	Medium 4	Poor 3	Very poor 2	Unaccept-able 1	DEVIATIONS FROM STANDARD CHARACTERISTICS
Color and Appearance: Pale Golden Brown; No beading								Too Dark ___ Too Pale ___ Uneven browning ___ Beading ___
Shrinkage: Meringue adheres to pastry and covers top of filling								Meringue pulled away from crust ___ Meringue does not cover filling ___
Slippage & Drainage: Very little liquid between meringue & filling; crust is dry								Large amount of liquid ___ Meringue slips easily from pie ___ Crust is soaked ___
Texture: Even; many small air cells; thin cell walls								Uneven ___ Air cells too large ___ Thick cell walls ___
Tenderness & Stickiness: Cuts easily with fork and does not cling to fork; easily masticated								Is not cut easily with fork ___ Clings to fork ___ Rubbery or chewy ___ Sticky or gummy ___
Flavor: Delicate; bland; slightly sweet								Too sweet ___ Too salty ___ Eggy flavor ___ Off flavor ___(describe)
Overall Rating; General Acceptability								Comment: ___________

Figure 6. Soft meringue score card.

Table 22. Room temperature and relative humidity assigned to six replications of soft meringues prepared from albumen processed by four methods.

Egg Process	Replication	Room Temperature (°C)	Relative Humidity (%)
Frozen	1	27	72.0
	2	24	59.5
	3	27	47.0
	4	27	51.0
	5	32	62.0
	6	32	56.0
Average		28	58.0
Spray-dried	1	24	72.0
	2	27	59.5
	3	29	66.0
	4	32	51.0
	5	32	62.0
	6	29	43.0
Average		29	59.0
Foam-spray-dried	1	27	72.0
	2	24	47.0
	3	29	66.0
	4	27	51.0
	5	32	56.0
	6	29	43.0
Average		28	56.0
Freeze-dried	1	27	59.5
	2	27	47.0
	3	29	66.0
	4	27	62.0
	5	32	56.0
	6	29	43.0
Average		29	56.0

Table 23. Filling viscosity, pH and temperature for six replications of lemon meringue pies.

Egg process	Replication	Filling Viscosity (poise)	Filling pH	Filling Temperature (°C)
Frozen	1	210.0	3.5	31.5
	2	195.0	3.5	25.0
	3	212.5	3.5	26.5
	4	207.5	3.5	29.0
	5	185.0	3.4	32.0
	6	197.0	3.5	30.0
Average		201.2		29.2
Spray-dried	1	210.0	3.5	29.5
	2	195.0	3.5	27.0
	3	220.0	3.4	30.0
	4	207.5	3.5	26.0
	5	185.0	3.4	33.0
	6	217.5	3.4	31.0
Average		205.8		29.5
Foam-spray-dried	1	210.0	3.5	28.0
	2	212.5	3.5	30.0
	3	220.0	3.4	29.0
	4	207.5	3.5	28.0
	5	197.0	3.5	32.0
	6	217.5	3.4	30.0
Average		210.8		29.5
Freeze-dried	1	195.0	3.5	30.0
	2	212.5	3.5	26.0
	3	220.0	3.4	29.0
	4	185.0	3.4	32.0
	5	197.0	3.5	31.0
	6	217.5	3.4	29.0
Average		204.5		29.5

Table 24. Albumen temperature, whipping times, specific gravity, foam stability and pH for six replications of unbaked meringues prepared from albumen processed by four methods.

Egg Process	Replication	Albumen Temperature (°C)	Whipping Time (min)	Specific Gravity	Foam Stability (ml)	pH
Frozen	1	25.5	13.75	0.24	0.0	6.3
	2	25.5	13.75	0.24	0.0	6.3
	3	25.5	13.75	0.24	0.0	6.3
	4	26.0	13.75	0.22	0.0	6.3
	5	25.0	13.25	0.24	0.5	6.3
	6	25.0	13.00	0.22	0.1	6.3
Average		25.4	13.54	0.23	0.1	
Spray-dried	1	25.5	15.75	0.24	0.0	6.8
	2	26.0	18.75	0.24	0.0	6.8
	3	26.0	15.75	0.22	0.0	6.7
	4	25.5	15.75	0.23	0.0	6.7
	5	25.0	14.25	0.23	0.4	6.7
	6	25.0	16.25	0.24	0.05	6.7
Average		25.5	16.08	0.23	0.08	
Foam-spray-dried	1	25.5	14.75	0.22	0.0	6.3
	2	25.0	19.75	0.24	0.0	6.3
	3	26.0	15.75	0.24	0.05	6.2
	4	25.5	18.25	0.24	0.0	6.3
	5	25.0	13.25	0.24	0.7	6.3
	6	25.0	14.25	0.24	1.0	6.2
Average		25.3	16.00	0.24	0.29	
Freeze-dried	1	25.5	13.75	0.24	0.0	6.3
	2	25.5	15.25	0.24	0.0	6.3
	3	25.0	13.25	0.23	0.0	6.2
	4	25.0	13.25	0.22	0.05	6.2
	5	25.0	13.75	0.24	0.1	6.3
	6	25.0	14.25	0.24	0.0	6.2
Average		25.2	13.92	0.23	0.03	

Table 25. Percentages of evaporation and drainage for six replications of fresh and held soft meringues prepared from albumen processed by four methods.

		Percentages			
		Evaporation		Drainage	
Egg Process	Replication	Fresh	Held	Fresh	Held
Frozen	1	19.4	19.5	3.8	-1.5
	2	18.5	20.4	15.9	17.6
	3	19.1	19.2	10.7	8.4
	4	23.2	23.0	14.0	11.9
	5	22.1	23.9	17.5	13.0
	6	22.9	24.6	15.6	12.4
Average		20.9	21.8	12.9	10.3
Spray-dried	1	20.4	19.5	10.0	13.2
	2	19.0	20.3	14.9	11.0
	3	23.7	21.4	2.4	8.5
	4	18.4	18.7	18.0	13.7
	5	21.8	26.0	11.3	2.7
	6	20.3	21.2	14.2	11.2
Average		20.6	21.2	11.8	10.1
Foam-spray-dried	1	20.6	20.1	11.8	10.3
	2	19.7	22.7	12.7	2.4
	3	21.3	19.4	2.8	11.8
	4	18.4	20.2	12.3	8.7
	5	22.2	24.3	9.1	8.5
	6	20.7	20.9	13.8	12.1
Average		20.5	21.3	10.4	9.0
Freeze-dried	1	19.7	21.4	12.3	8.4
	2	19.4	20.2	12.8	7.8
	3	22.0	22.0	9.7	8.5
	4	23.4	23.5	5.6	1.0
	5	21.5	24.1	9.2	4.6
	6	21.3	22.3	9.6	6.3
Average		21.2	22.3	9.9	6.1

Table 26. Height measurements of fresh and held meringues and beading counts of held meringues for six replications of soft meringues prepared from albumen processed by four methods.

Egg Process	Replication	Height (cm) Fresh	Height (cm) Held	Beading Held
Frozen	1	1.85	1.90	65
	2	1.80	1.60	7
	3	1.90	1.95	107
	4	1.85	1.80	60
	5	1.85	1.70	9
	6	1.85	1.75	6
Average		1.85	1.78	42
Spray-dried	1	1.80	1.70	32
	2	1.80	1.70	47
	3	1.80	1.75	26
	4	1.95	1.90	4
	5	1.90	1.65	15
	6	1.95	1.75	42
Average		1.87	1.74	28
Foam-spray-dried	1	1.85	1.80	23
	2	1.95	1.70	14
	3	1.80	1.75	32
	4	1.90	1.85	20
	5	1.85	1.70	9
	6	1.85	1.85	26
Average		1.87	1.78	21
Freeze-dried	1	1.85	1.75	24
	2	1.80	1.80	14
	3	1.75	1.80	22
	4	1.90	1.70	256
	5	1.95	1.80	4
	6	1.95	1.70	61
Average		1.87	1.76	64

Table 27. Tenderness measurements, expressed as maximum force and area-under-the-curve, for six replications of fresh and held soft meringues prepared from albumen processed by four methods.

Egg Process	Replication	Maximum Force (lb. force/g) Fresh	Maximum Force (lb. force/g) Held	Area-under-the-curve Fresh	Area-under-the-curve Held
Frozen	1	0.199	0.139	3.772	2.939
	2	0.186	0.219	2.078	2.322
	3	0.227	0.169	3.173	3.164
	4	0.216	0.229	2.462	2.387
	5	0.260	0.228	3.201	2.724
	6	0.304	0.260	3.258	2.818
Average		0.232	0.207	2.991	2.726
Spray-dried	1	0.215	0.164	2.920	2.471
	2	0.197	0.177	2.659	2.004
	3	0.227	0.197	3.033	2.771
	4	0.239	0.217	3.164	3.005
	5	0.210	0.252	3.342	3.099
	6	0.278	0.226	3.978	3.173
Average		0.228	0.206	3.183	2.754
Foam-spray-dried	1	0.194	0.157	2.340	2.275
	2	0.330	0.180	4.193	2.949
	3	0.185	0.169	3.127	2.668
	4	0.185	0.151	3.136	2.434
	5	0.251	0.255	3.707	3.323
	6	0.251	0.179	3.164	2.733
Average		0.233	0.182	3.279	2.730
Freeze-dried	1	0.232	0.170	3.108	2.415
	2	0.239	0.170	3.426	2.696
	3	0.204	0.191	2.406	2.668
	4	0.226	0.176	3.716	2.855
	5	0.246	0.230	3.726	3.286
	6	0.243	0.195	4.072	2.846
Average		0.232	0.189	3.409	2.794

Table 28. Hunter colorimeter average readings for six replications of soft meringues prepared from albumen processed by four methods.

Egg Process	Replication	Color Values L	a_L	b_L
Frozen	1	79.60	4.25	20.58
	2	84.53	3.00	18.32
	3	84.80	1.85	17.23
	4	79.33	4.40	22.00
	5	82.23	2.60	20.63
	6	82.05	4.13	20.78
Average		82.09	3.37	19.92
Spray-dried	1	86.65	0.58	16.53
	2	84.05	3.60	17.80
	3	79.08	4.48	21.43
	4	83.53	2.30	17.93
	5	76.25	5.60	22.68
	6	79.65	4.33	20.78
Average		81.54	3.48	19.53
Foam-spray-dried	1	81.83	3.48	19.88
	2	80.63	3.43	19.03
	3	84.63	1.70	17.78
	4	82.58	3.08	18.53
	5	77.28	6.35	22.23
	6	82.08	2.75	19.53
Average		81.51	3.47	19.50
Freeze-dried	1	82.43	4.40	19.73
	2	84.38	2.48	17.28
	3	79.65	4.88	21.60
	4	77.83	5.35	21.50
	5	78.88	5.80	21.80
	6	79.48	4.73	19.95
Average		80.44	4.61	20.31

Table 29. Average quality characteristic scores of seven judges for six replications of soft meringues prepared from albumen processed by four methods.

Egg Process	Repli- cation	Color and Appearance	Shrinkage	Slippage and Drainage	Texture	Tenderness	Flavor	General Accepta- bility
Frozen	1	5.7	6.2	6.0	5.8	5.8	6.2	6.0
	2	4.7	4.3	5.1	5.0	4.6	5.3	4.7
	3	5.0	5.4	5.6	5.1	4.0	5.3	5.0
	4	5.0	4.6	5.3	5.0	5.0	5.1	4.7
	5	5.1	5.1	5.7	5.7	4.6	5.0	5.0
	6	4.0	4.8	4.7	5.7	4.8	4.5	4.7
Average		4.9	5.1	5.4	5.4	4.8	5.2	5.0
Spray-dried	1	3.0	5.2	4.2	5.2	5.5	4.5	4.0
	2	3.9	4.9	3.9	5.3	4.9	4.7	4.4
	3	5.1	6.1	5.9	5.3	5.3	5.0	5.4
	4	4.4	5.9	5.9	5.0	5.3	4.7	4.6
	5	5.3	6.1	6.1	4.1	5.3	5.4	5.1
	6	5.1	6.0	5.9	5.6	4.3	5.9	5.1
Average		4.5	5.7	5.3	5.1	5.1	5.0	4.8
Foam-spray-dried	1	4.8	4.8	4.7	4.5	4.8	4.7	4.3
	2	5.6	6.1	5.9	4.7	4.1	4.9	4.9
	3	4.7	6.0	5.3	5.9	5.4	4.3	4.7
	4	5.1	6.0	5.7	5.3	5.0	4.9	5.3
	5	5.3	6.2	6.0	4.5	6.0	5.8	5.5
	6	4.0	6.0	5.9	5.1	4.3	5.3	4.9
Average		4.9	5.9	5.6	5.0	4.9	5.0	4.9
Freeze-dried	1	5.1	5.6	5.9	5.7	4.9	5.4	5.3
	2	5.4	6.4	5.4	5.1	4.9	5.0	4.9
	3	5.9	6.0	5.9	5.4	5.4	4.6	5.1
	4	5.6	6.0	5.7	4.7	5.1	5.4	5.0
	5	5.3	6.2	6.2	5.8	5.7	5.0	5.3
	6	4.7	6.1	6.0	6.1	4.6	5.3	5.4
Average		5.3	6.1	5.9	5.5	5.1	5.1	5.2

Table 30. Objective measurements for six replications of soft meringues prepared from spray-dried albumen without stabilizer added.

Measurement or Evaluation	Replication						
	1	2	3	4	5	6	Average
Room temperature (°C)	24	24	27	27	27	27	26
Relative humidity (%)	46	46	69	69	48	48	54.3
Viscosity (poise)	195	195	185	158	183	183	178.7
Filling pH	3.5	3.5	3.5	3.5	3.5	3.5	
Filling temperature (°C)	27	24	27	26	31	29	27.3
Albumen temperature (°C)	25	25	25	26	25	25	25.1
Specific gravity	0.24	0.24	0.23	0.23	0.24	0.24	0.24
Foam stability (ml)	0.0	0.0	0.0	0.025	0.1	0.0	0.021
Albumen pH	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Whipping time (min)	14.25	16.75	15.25	14.25	13.75	13.75	14.67
Maximum temperature interface (°C)	75.0	80.0	70.5	78.0	79.0	79.0	76.92
Maximum temperature meringue (°C)	98.0	89.0	97.0	85.0	99.0	91.5	93.25
Baking time (min)	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Evaporation, fresh (%)	18.0	19.3	20.0	17.9	20.2	19.5	19.2
Evaporation, held (%)	21.5	21.2	23.6	17.8	21.4	20.9	21.1
Drainage, fresh (%)	23.2	16.3	17.7	23.2	18.8	21.1	20.1
Drainage, held (%)	13.2	12.9	6.5	24.1	14.7	15.9	14.6
Height, fresh (cm)	1.90	1.90	1.90	1.90	1.80	1.80	1.87
Height, held (cm)	1.80	1.75	1.75	1.80	1.75	1.75	1.77
Beading	16	9	8	8	10	7	10
Maximum force, fresh (lb. force/g)	0.226	0.236	0.257	0.234	0.339	0.266	0.260
Maximum force, held (lb. force/g)	0.241	0.231	0.215	0.281	0.246	0.246	0.243
Area-under-the-curve, fresh (cm^2)	3.070	3.389	3.520	3.295	4.278	3.529	3.514
Area-under-the-curve, held (cm^2)	3.613	3.182	3.323	3.164	3.061	3.173	3.253
Hunter L	83.65	85.43	80.03	84.00	80.28	80.90	82.38
Hunter a_L	2.13	1.63	4.38	2.58	3.85	3.70	3.05
Hunter b_L	18.20	16.73	21.25	19.68	21.23	20.05	19.36

Table 31. Summary of correlation coefficients for soft meringues as determined by objective measurements and/or subjective evaluations.

Relationship	Correlation Coefficient
Room temperature / Foam stability	0.48*
Specific gravity / Foam stability	0.16
Filling temperature / Maximum interface temperature	0.26
Filling temperature / Percentage of evaporation, fresh	0.60**
Filling temperature / Percentage of drainage, fresh	-0.36
Tenderness, maximum force, fresh / Percentage of evaporation, fresh	0.20
Tenderness, maximum force, held / Percentage of evaporation, held	0.72***
Color and appearance scores / Hunter L	-0.61**
Color and appearance scores / Hunter a_L	0.56**
Color and appearance scores / Hunter b_L	0.52*
Shrinkage scores / Color and appearance scores	0.48*
Slippage and drainage scores / Percentage of drainage, fresh	-0.23
Tenderness scores / Tenderness, maximum force, fresh	-0.39
Tenderness scores / Tenderness, area-under-the-curve, fresh	-0.03
General acceptability scores / Color and appearance scores	0.69***
General acceptability scores / Shrinkage scores	0.61**
General acceptability scores / Slippage and drainage scores	0.78***
General acceptability scores / Flavor scores	0.69***