A COMPARISON OF THE EMULSIFYING PROPERTIES AND THE PALATABILITY OF FROZEN, SPRAY-DRIED, FREEZE-DRIED AND FOAM-SPRAY-DRIED WHOLE EGGS IN CREAM PUFFS

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ABSTRACT

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by Gisele Charlebois

Cream puffs were prepared with frozen, spray-dried, freeze-dried and foam-spray-dried eggs to compare the emulsifying properties and palatability of the processed eggs. A taste panel evaluated the shape, exterior and interior appearance, cavity size, shell thickness, moistness, tenderness and flavor of the products. Measurements of tenderness, linear dimensions, volume, moisture losses and viscosity were determined and analyzed.

The panelists' scores for cream puffs were generally fair to good. Significant variations due to the types of processed eggs were found only in the scores for cavity size and tenderness. The cream puffs prepared with foam-spray-dried eggs had significantly* larger cavities than those in products prepared with either spray-dried or freeze-dried eggs, which were rated as poor. Cream puffs prepared with spray-dried eggs were scored significantly* tougher than those prepared with the other types of processed eggs.

Significant differences among the processed eggs were shown in analyses of data from the measurements of the viscosity of the batter and of the tenderness and moistness of the baked cream puffs. Batter containing foam-spray-dried eggs was significantly** thinner and the batter prepared with freeze-dried eggs was significantly** thicker than those prepared with the other three types of processed eggs. According to the shear press measurements of maximum force, cream puffs prepared with foam-spray-dried eggs were significantly* tougher than those prepared with spray-dried or freeze-dried eggs. Calculations of area-under-the-curve from the shear press measurements indicated that the cream puffs containing foam-spray-dried eggs were significantly** tougher than those containing each of the other types of eggs. Cream puffs prepared with freeze-dried eggs were significantly* moister than those prepared with frozen or foam-spray-dried eggs.

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*Significant at the 5 per cent level of probability.

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Dehydrated eggs offer many advantages over frozen and shell eggs. Dried eggs are lighter and require less storage space than frozen and shell eggs and do not need refrigeration until the seal on the container is broken. The composition of dried eggs is uniform, therefore eliminating the variables due to the differences in size, liquid content and proportion of albumen and yolk that are common with shell eggs. Furthermore, dehydrated whole eggs are always ready for use when needed and in the quantity needed (6). Production of dehydrated whole eggs having the functional properties and palatability characteristics of fresh eggs could benefit homemakers, volume food services and commercial users.

Although dried eggs have existed for a long time, they are primarily used in prepared mixes, by food companies, in bakeries, by the armed forces and as surplus food (17, 57, 78). Increased interest in improving the palatability, microbiological safeness and functional properties of dried eggs has prompted research to improve processing methods (15, 16, 24, 60). Spray-drying is the most commonly used method of drying eggs, however the development of freeze-drying and foam-spray-drying have encouraged the processing of eggs by these two relatively new methods (24, 33, 34).

The purpose of this investigation is to compare the emulsifying properties and palatability of frozen, spray-dried, freeze-dried and foam-spray-dried whole eggs in the preparation of cream puffs. Cream puffs were selected as the test product because they "are good examples of a batter in which the fat is emulsified" (47). The results of this investigation, which is a segment of a master project, may be helpful in assessing the quality of each type of processed eggs and in determining the feasibility of homemakers and volume food services using dehydrated eggs.

REVIEW OF LITERATURE

A critical test of the emulsifying property of whole eggs is their ability to emulsify the fat in the preparation of cream puff batter and to hold the emulsion during the baking of cream puffs. The extent to which processing alters the emulsifying function of eggs is therefore important. The literature was searched for information pertaining to the emulsifying properties of eggs, the effects of various methods of preservation on whole eggs, the function of the ingredients and procedures used in preparing cream puffs and the methods of assessing quality which are applicable to cream puffs.

Emulsifying Properties of Eggs

The components of eggs are primarily water, protein and fat with small quantities of minerals, vitamins and carbohydrates (47). Forsythe considered the properties of whole eggs as a combination of the chemical composition, nutritive value and pH of albumen and egg yolk (23). In thoroughly mixed whole egg the structure of both the albumen and yolk is destroyed and can no longer be identified. According to Forsythe, whole egg performs as an emulsifying agent more nearly like egg yolk than the albumen because of the relatively high proportion of the solids contributed by the yolk.

Albumen

The albumen, stated Feeney and Hill, is principally a solution of proteins and contains small amounts of minerals and carbohydrates (21). Most of the properties of albumen are those of the individual proteins in the mixture as well as their interaction products. Certain authors describe five, seven, eight or nine proteins, each having various unique properties in albumen (21, 31, 46, 47, 48). These proteins have high nutritive value and some have specific biological activities which suggest protection against harmful bacteria (21, 31). According to Lowe, the ability of egg proteins to expand and hold occluded gas, such as air or steam, is important in the successful preparation of such products as popovers, cream puffs, sponge and angel cakes, meringues and souffles (47). When deteriorated egg powders are used in these products, they are inferior to those made with fresh eggs and may be unacceptable.

Watts and Elliott combined each of three types of dried albumen and fresh albumen with egg yolks in preparing cream puffs (74). They found that cream puffs containing Chinese fermented and acid-treated spray-dried albumen were less than two-thirds the volume of those prepared with untreated vacuum-dried and fresh albumen.

According to Lowe, albumen is less efficient than egg yolk and whole eggs as an emulsifier (47). Nason compared cream puffs made with albumen with those made with egg yolks to show that the whole egg functions as an emulsifying agent (51). Cream puffs made with albumen were unable to puff because the albumen did not emulsify the fat sufficiently; while baking the steam escaped through the areas of melted fat and the baked product had a distinctly greasy crust. The cream puffs made with egg yolks did not puff because the yolks were less efficient than the whole eggs in giving extensibility to the gluten.

Egg yolk

The egg yolk is more concentrated, contains less water, more protein, more fat and its chemical composition is more complex than that of the albumen (23, 31). Romanoff and Romanoff described the egg yolk as a typical emulsion, a system of oil droplets suspended in an aqueous medium (59). The protein in egg yolk is a lyophilic colloid, which has a stabilizing effect. Consequently, egg yolk not only possesses emulsifying properties, but is also a good stabilizer. Forsythe pointed out that a microscopic examination of the yellow and white layers found in a cross section of a hard cooked egg yolk, indicated emulsions with quite varying globule sizes, thus giving an indication of the degree of emulsification in the various layers (23).

Egg yolk proteins are largely phosphoproteins associated with smaller amounts of water-soluble proteins

(21, 31, 47). According to Feeney and Hill, approximately one-third of the phospholipids present in the yolk are combined with phosphoproteins and called lipoproteins, which are responsible for the emulsifying properties of egg yolk (21). The two lipoprotein fractions which have been isolated from egg yolk are lipovitellin, which contains 17 to 18 per cent lipids and lipovitellinin, which contains 36 to 41 per cent lipids, mainly lecithin (21, 48). The lipids of egg yolk are present as an oil-in-water emulsion and include true fats and phospholipids such as lecithin and sterols (21, 31).

Sell *et al*. conducted a study to determine the emulsifying ingredient in egg yolk used to prepare mayonnaise (61). They reported that egg yolk was the stabilizing ingredient in mayonnaise because of its powerful emulsifying action and it was assumed that the phospholipid lecithin was the effective constituent of egg yolk in producing the emulsion in mayonnaise. In an attempt to prove this theory, they added lecithin to egg yolks, which resulted in mayonnaise with poor consistency. They then studied the effect of each of the major constituents of egg yolk on mayonnaise and demonstrated that no individual constituent of egg yolk was capable of producing the consistency derived from using whole egg yolk. They concluded that egg yolk owed its emulsifying action to an unstable complex containing both lecithin and protein, which they called lecitho-protein.

Preservation of Whole Eggs

Shell eggs undergo important physiochemical changes and may become contaminated with microorganisms during storage and marketing (21, 54). These changes, according to Griswold and Lowe, can be retarded with the use of cold storage in an atmosphere of high humidity and carbon dioxide and by other methods, including thermostabilization and oil treatment (31, 47). No method of preservation improves the original quality of eggs, which should be maintained prior to, during and after processing (47).

After the eggs are removed from their shells, they may be preserved by freezing and drying, however, various problems are encountered in the production, transportation and storage of frozen and dehydrated eggs. As a precautionary measure, a USDA law requires the pasteurization of all processed egg products involved in interstate commerce to kill any *Salmonella* organisms present (11, 26).

Frozen eggs

Freezing is one method of preserving the quality of whole eggs, maintaining their nutritive value and keeping the development of microorganisms at a minimum (31, 54). However, certain precautions are necessary in processing frozen whole eggs.

Although freezing does not appreciably alter the physical characteristics of albumen, it causes the gelation of untreated yolks (47, 59). According to Forsythe and Sweetman, the structure of frozen egg yolks is so broken down that the thawed product is a gelatinous rubbery mass resulting from dehydration and from the precipitation of the lecithovitellin complex (23, 65). This gelation renders the frozen egg yolk unsuitable for use because it is difficult to make it homogeneous. The early studies of Urbain and Miller implicated the lipoproteins in the gelation of egg yolks (70).

To prevent gelation during freezing, egg yolks and whole eggs are usually combined with salt, sugar, sirup or glycerine before freezing to increase the osmotic pressure and lower the freezing point of the liquid eggs (59, 69). Powrie et al. tested the effectiveness of sucrose and sodium chloride as inhibitors of gelation and the influence of urea on the viscosity of fresh egg yolk and of thawed yolk (56). Their experiment showed that both sucrose and salt were good inhibitors of gelation and that the addition of urea (0.166 mole per 100 gm. of yolks) did not appreciably increase the viscosity of fresh and thawed yolks except those that had been frozen at -14°C. Feeney et al. demonstrated that insolubilization of lipoproteins in egg yolk by freezing and thawing could be prevented by treatment with a very small amount of crotoxin before or after freezing (22).

Because the emulsifying action of the egg depends upon the lecitho-protein complex, frozen egg products in which the complex has been protected by the addition of stabilizers are especially well adapted for use in baked goods (59). Jordan *et al*. compared the effects of adding salt, sugar and white corn sirup to whole eggs and egg yolks which were then frozen and stored in a home-type freezer (36). They prepared plain cakes with fresh whole eggs and untreated and treated frozen whole eggs and baked custards with fresh whole eggs and yolks and untreated and treated frozen whole eggs and yolks. None of the pretreatments of the whole eggs significantly influenced the volume of the cakes or the firmness of the custards. The scores for flavor of both cakes and custards prepared with the salt treated whole eggs and yolks were lower than those prepared with the sugar and corn sirup treated eggs. The investigators concluded that untreated and treated frozen whole eggs and treated yolks retained a high degree of the functional properties necessary for satisfactory performance in plain cakes and baked custards.

Dried eggs

Production of dried egg products in the United States increased greatly during World War II because of the large quantities of dried whole eggs which were bought for consumption by the armed forces (58, 78). Dried whole eggs, albumen and yolks offered several advantages: they were concentrated foods of high nutritive value, required relatively small shipping space, were fairly stable under armed forces field conditions and could be used in preparing many products (58). The availability of low-cost dried eggs which were imported from China impeded American commercial operations until the passage of protective tariff laws in 1922 (25, 59). At present, most dried whole eggs are produced by spray-drying, but the development of freeze-drying and foam-spray-drying have encouraged research on the effect of these processes on eggs (24, 33, 34, 50).

Problems involving stability, functional properties, microbiology and palatability of eggs have confronted the drying industry throughout the period of its development and growth (4). Rolfes _et al_. reported that intensive research on processing methods for dried egg products has resulted in longer shelf-life and better retention of functional properties (58). According to Ziemba, studies have shown that adverse quality changes resulted primarily from high moisture level, oxidation and browning, or Maillard reaction (78).

Ziemba also reported that development of off-flavors and, to some extent, changes in color and solubility were traced to changes in the phospholipid-egg fraction during drying (78). Elimination of these changes was brought about by acidification and by the removal of glucose, either by fermentation or enzymatic action, from the eggs prior to drying. A study of de-sugaring whole eggs by the methods of yeast fermentation and enzyme treatment was reported by Kline *et al.* who found no appreciable differences according to consumer preference tests performed with scrambled eggs and stability tests as appraised by chemical, functional and flavor tests of sponge cakes and scrambled eggs (39). Ziemba recommended drying the eggs to a moisture content of approximately 2 per cent and packing them in inert gas in hermetically-sealed cans (78). Conrad *et al.* reported that packing dried eggs in an inert gas, such as carbon dioxide, was essential to retain the desired aroma and flavor (10).

The addition of sucrose, lactose, invert sugar, light dextrin and dark dextrin to whole eggs before drying has been investigated. Dawson *et al.* reported improved flavor ratings and delayed deterioration of flavor and functional properties in lactose and sucrose treated dried eggs which were stored at 100°F. as compared to untreated dried eggs and dried eggs treated with invert sugar and both types of dextrins (16). Adding sucrose prior to drying helped retain the whipping ability of dried eggs, according to Ziemba (78). Bate-Smith and Hawthorne reported that adding sucrose before drying eggs had a stabilizing effect by retarding the Maillard reaction, or browning, in the dried eggs (2). Kline *et al.* compared adding low-dextrose-equivalent corn sirup solids with the addition of sucrose to eggs prior to drying and reported comparable maintenance of flavor and chemical stability with both types of carbohydrates (40).

Spray-drying. Spray-drying is the most commonly used method of producing dried whole eggs (4). Liquid whole egg is sprayed into a stream of hot air and the resulting powder is collected and cooled to a temperature below 85°F. immediately after drying (4, 73). According to Van Arsdel, the three problems inherent in the method are spray formation, contact of the spray with hot air, and separation of the powder from the hot humid air of the interior of the drier (73). Prior to the atomization step, liquid egg is either preheated to above 138°F. or chilled to below 45°F. to avoid the intermediate temperatures which are conducive to bacterial growth (4). According to Bergquist, atomized particles were smaller and more uniform in size if the liquid eggs were preheated rather than chilled (4). The chilled liquid eggs required more heat to dry the particles to the desired moisture content and hence the eggs reached higher temperatures in the drying chamber than did eggs which had been preheated. Some browning and changes in dispersibility took place if the temperature of the drying chamber was too high. Bergquist also reported that dried whole egg and yolk products were less susceptible than dried albumen to heat damage.

In efforts to improve the quality of dried whole eggs, Conrad et al. conducted various experiments (10).

They studied the effects of the action of the spray nozzle on the eggs by spraying without drying the eggs. After using the sprayed eggs in sponge cakes, baked custards and cream puffs, the investigators concluded that spraying did not affect the performance of the eggs. Conrad et al. also studied the effects of adding from 0 to 20 per cent sugar to whole eggs and spray-drying them at 140 and 180°F. Sponge cakes, baked custards and cream puffs were prepared with the samples of dried eggs and the investigators concluded that the functional properties of liquid whole eggs were best preserved by adding 10 per cent sugar to the liquid eggs before drying and that these eggs could be dried under a variety of conditions.

Studies of substituting spray-dried whole eggs for fresh eggs in several baked products were reported. Jordan and Sisson reported that plain muffins could be made satisfactorily with spray-dried eggs (38). They also found that sifting the egg powder with the other ingredients and adding the water necessary for reconstitution to the other liquid ingredients produced muffins comparable to those made with reconstituted dried eggs. Jordan and Pettijohn studied the leavening power of spray-dried whole eggs in sponge cakes, and prepared acceptable sponge cakes with and without the addition of baking powder (37). They also found that if the temperature of the egg-sugar-water mixture was approximately 60°C. at the beginning of the beating period, a lighter and more stable foam was formed and a much shorter beating time was required than if the ingredients were at room temperature. The effect of storage temperature on the flavor and cooking qualities of spray-dried whole eggs was investigated by Dawson _et al._, using scrambled eggs, baked custards, mayonnaise, popovers and cakes as media (15). They concluded that spray-dried whole eggs with a 3 to 5 per cent moisture content should be stored at 60°F. or lower to maintain quality for longer than six months.

Freeze-drying. Freeze-drying, also called sublimation drying or lyophilization, is the drying of a substance from the frozen state which results in light, porous and easily reconstituted products (73). Nair stated that the process depends basically upon the creation and maintenance of a difference in water vapor pressure between the very dry immediate surroundings of a product and the ice inside the frozen product, so that the water vapor is continuously transported away from the product without melting the ice in it (50). The material to be freeze-dried is placed on trays, blast-frozen at approximately -40°F. and the trays then put on hollow platens through which a heated liquid circulates to evaporate the frozen water.

According to Harper and Tappel, freeze-drying should be less detrimental than spray-drying to the functional properties of eggs (34). The physical and functional properties of freeze-dried whole eggs, yolks and albumen were studied by Rolfes _et al_. in angel cakes, mayonnaise and sponge cakes (58). They compared freeze-dried, spray-dried and frozen egg products and found that spray-drying was the most detrimental to egg proteins and impaired the emulsifying properties of yolks and the functional properties of whole eggs to a greater extent than freeze-drying.

Goldblith _et al_. reported that problems associated with freeze-drying included non-enzymatic browning, oxidation of lipids and storage problems (29). They suggested reducing the moisture content of freeze-dried foods to help resolve the problems of darkening, deteriorating color and undesirable flavors, which are often associated with non-enzymatic browning, and also recommended the exclusion of light and oxygen in packaging freeze-dried foods to help prevent oxidative deterioration.

Foam-spray-drying. Foam-spray-drying is a modification of the spray-drying technique and is still in the developmental stage (24). Compressed air or gas is injected into the pumped-fluid line through a mixing device located between the pressure pump and the spray nozzle which produces a foam of expanded spray droplets, thus increasing the surfaces and lowering the density of the droplets (33). Foam-spray-drying produces dried eggs with greater dispersibility and solubility than spray-dried eggs, however they are more hygroscopic and much lighter in weight than spray-dried eggs (23, 24, 33).

Emulsion of Cream Puff Batter

According to Wheeler, "Cream puffs are the most unpredictable of baked goods to make. They have long been accepted as the 'hallmark' of the master baker" (75). Cream puff batter is an emulsion made by combining water, fat, flour and eggs, and Lowe referred to it as "a good example of a batter in which the fat is emulsified" (47).

Lowe defined an emulsion as a colloidal dispersion of one liquid in another when both liquids are mutually immiscible (47). According to Griswold, the colloidal particles are called the dispersed phase and the material in which they are held is the continuous phase (31). In food emulsions one liquid is known as water although it may contain proteins, salts and other substances, and the other as oil which may contain other fat compounds or fat-soluble substances in addition to simple triglycerides (47). There are two types of food emulsions, oil-in-water and water-in-oil, which can be either temporary or permanent (31, 47). To obtain a stable or permanent emulsion a third substance, known as an emulsifier or emulsifying agent, is necessary. Emulsifiers may be in the form of proteins, gums, gels, fatty acids and phospholipids which have electric charges opposite to that of the material to which they are added, thus reducing the interfacial tension between the two liquids (47). According to Lowe, the emulsifier is positively adsorbed more by the dispersing medium than by the dispersed phase and the adsorption of the emulsifier at the interface lowers the surface tension of the dispersing medium, or continuous phase, more than that of the dispersed droplets (47).

Wheeler emphasized the importance of forming a stable emulsion of fat-in-water in making cream puffs. Heat is used to melt the shortening and to boil the water preparatory to stirring in the flour to form a partial emulsion, with water as the continuous phase and melted fat droplets as the dispersed phase. After slight cooling, the water-fat-flour paste is further emulsified by continued mixing during the gradual addition of the eggs (75).

Proportion and function of ingredients in cream puffs

The proportion of the ingredients is critical in preparing cream puffs and each ingredient has definite functions. Nason stated that slight variations in the proportion of ingredients may make the difference between a heavy, soggy, tasteless mass and a light, puffy cream puff (51). Consequently in making cream puffs, an equal volume of flour and water with 1 gm. of fat and 1.7 gm. of eggs for each gram of flour is recommended (47).

Water. Water is used in large proportion in cream puff batter. One cup of water is required for each cup of flour, or 240 gm. of water for each 112 gm. of flour, to furnish the steam required for the desired expansion of the batter and the formation of the hollow interior of the cream puffs (47, 54). Steam, the leavening agent of cream puffs, forms rapidly at the base of the batter early in baking and as the steam expands, it pushes much of the paste upward, developing a large hole inside (41, 47).

Water is an essential part of the emulsion in cream puffs. Kotschevar and Lowe reported that a broken emulsion could be caused by decreasing the amount of water in cream puff batter if the amounts of the other ingredients remained unchanged (41, 47). However, Lowe stated that if the amount of water is increased and the amount of eggs is proportionately reduced, no fat oozes out of the cream puffs while they are baking, thus showing no breakage of emulsion (47). With the large proportion of liquid used, the hydration of the flour in the cooking of the water-fat-flour paste is so great the gluten particles do not adhere tenaciously to each other, hence the batter may be beaten for long periods without appreciably toughening the baked cream puff (47, 51, 75).

Fat. According to Lowe, 1 gm. of fat for each gram of flour should be used in cream puff preparation (47). Fat is the dispersed phase of the emulsion in the cream puff batter. Fat, reported Nason, helps to make a smooth mixture of flour and water and also produces a desirable effect on gluten by permitting the glutenous fibers to slide past each other, thus giving extensibility to the batter and tenderness to the finished product (51). Decreasing the quantity of fat decreases the tenderness of the cream puffs, but if an excessive amount of fat is used, the emulsion is broken, the cream puffs flatten out and the shells do not expand properly (75).

Vail studied the effect of hydrogenated shortening, regular margarine and corn oil margarine on the volume and the appearance of cream puffs (72). She reported that the cream puffs prepared with corn oil margarine were acceptable, but did not receive as high scores as those made with the other two fats. The cream puffs prepared with the corn oil margarine had more webs and less hollow centers than those containing hydrogenated shortening and regular margarine.

Flour. In cream puff preparation, flour is the structure builder, it helps hold the shape of the shell and the gelatinized starch partly emulsifies the fat (49, 75). Lowe mentioned the protein of flour as one of the common food emulsifiers, however she added that emulsions stabilized with flour need a high percentage of water (47). As was noted earlier, the ratio of equal volumes of water to flour in cream puff recipes is very important. According to Nason, cream puff batter containing too much flour does not allow generation of sufficient steam pressure to leaven the heavy batter (51). With too little flour, the batter is soft, steam escapes, and when the crust has hardened sufficiently to allow the steam to create an internal pressure, most of the water has evaporated or has been adsorbed by the starch and coagulating eggs; in either case the shell will not puff. Nason recommended using all purpose flour rather than cake flour in cream puffs.

Eggs. To emulsify the large quantity of fat in cream puff batter, the ratio of eggs to flour is 1.7:1 in weight (47). Eggs also aid in obtaining desirable volume and rigid cell walls in cream puffs (35). Albumen helps give extensibility and provides liquid for the continuous phase of the emulsion and egg yolk acts as an emulsifying agent and adds fat to the cream puff batter (75).

If the proportion of eggs varies, adjustments must be made with the other liquid to give the cream puff batter the proper consistency (75). Lowe emphasized that if the amount of eggs is decreased or increased, the water must be increased or decreased accordingly to produce the same amount of liquid as in the original formula (47). Reducing the amount of eggs may cause the emulsion to break with the result that the fat runs out of the cream puffs during baking and volume is reduced. However, Nason pointed out that increasing the eggs can increase the extensibility to a point beyond which the batter becomes too soft and no puff results (51).

Salt and chemical leavening agents. Salt and chemical leavening agents may be included in cream puff batter. The amount of salt varies among recipes, ranging from 1/8 to 1 tsp. per cup of flour (27, 41, 54, 68). The salt is usually incorporated with the flour in the cream puff batter.

Baking ammonia or baking powder can be used to aid in leavening the cream puff batter. The amount of ammonia recommended is 0.25 per cent of the flour, according to Kotschevar, who stated that the small amount of leavening agent gives rapid and increased expansion to the cream puffs and allows for a slight reduction in the quantity of eggs (41). The ammonia escapes as a gas through the thin walls and is not present in the cooled cream puffs. Wheeler stated that 3.5 gm. of baking powder for each cup of flour can be added to the cream puff batter after the addition of eggs is completed (75). However, according to Wheeler, an excessive use of either leavening agent will result in a lack of volume and an excessive use of ammonia leavener may cause noticeably greenish discoloration in the interior of the cream puffs.

Preparation of cream puffs

In making cream puffs the flour is stirred into a mixture of boiling water and melted fat and cooked until the material forms a ball and leaves the sides of the pan, the paste is then cooled slightly before the eggs are added gradually and the batter beaten after each addition to develop a stable emulsion (47). The finished batter should be glossy and smooth and hold its shape when put on the baking sheet. The cream puffs must be baked under conditions which will rapidly produce sufficient steam to expand the batter and which will then allow the puffs to dry without browning excessively.

Preparation of cream puff batter. Conflicting statements as to the most important step in preparing cream puff batter were found in the literature. Wheeler considered cooking the paste as the most important part of preparation (75). On the other hand, Kotschevar and Lowe considered beating the batter while adding the eggs as the most important, or even critical, part of preparation (41, 47).

The first step in preparing cream puff batter is cooking the paste. The fat and water should be heated until rapid stirring will not stop the boiling, then the flour should be added and the mixture stirred rapidly to obtain a smooth paste (41, 75). The paste is sufficiently cooked when it leaves the sides of the pan and forms a ball around the spoon and at this stage the fat is partially emulsified (47). If the paste is overcooked, stated Kotschevar and Lowe, it looks oily and small droplets of fat collect, indicating a broken emulsion (41, 47). After cooking, the paste is cooled to about 150°F. to prevent coagulation of the egg proteins, but if the paste is cooled to lower temperatures, increased time and energy are required to incorporate the eggs (47). The emulsion forms more readily with the warm paste which is less stiff and has a lower surface tension than the cool paste.

The next step in preparing cream puff batter is incorporating the eggs to form the emulsion. Wheeler stated that best results were obtained when the eggs were at a temperature of 70 to 75°F. when added to the paste (75). To insure thorough blending of the first egg added and to promote a stable emulsion, the eggs are added gradually and the batter well mixed between each addition (41, 47, 75). According to Grewe, who studied the stability of emulsions produced by agitating butter, sugar and eggs, the emulsions were more stable if the eggs were added slowly than if they were all added at once (30). Miller and Barnhart recommended the gradual addition of eggs with much beating to promote a good emulsion rather than adding the eggs quickly with little beating (49). Lowe also stated that beating is very important to the formation of the emulsion because it increases the surface area of the dispersed phase at which the emulsifier is adsorbed (47). She pointed out that when eggs are first added, the batter usually becomes thin, but during mixing it becomes increasingly viscous, just as mayonnaise becomes stiff as large proportions of oil are emulsified. The beating of the batter during mixing is not done to incorporate air, but to completely emulsify the fat, stated Nason (51). According to Hughes, beating must be done rapidly as the heat of the batter must not be dissipated before all the eggs are added (35). Even though the batter is stiff, it may be beaten without danger of toughening the cream puffs because the high percentage of fat in relation to flour lubricates the gluten particles and prevents them from forming a tenacious mass.

At the conclusion of the mixing process the batter should have a medium to stiff consistency, should be very smooth, glossy and shiny and it should hold its shape when put on the baking sheet (41, 47, 51). The batter can be baked immediately after mixing or it can be refrigerated before baking if it is put into a bowl and well covered to prevent evaporation (47, 55).

Baking cream puffs. Instructions for baking cream puffs vary considerably (3, 5, 27, 41, 47, 52, 63, 64, 68, 75). Some recommend placing the cream puff batter on oiled or greased baking sheets and others specify baking on ungreased baking sheets, brown paper and paper liners. Recommended baking temperatures vary from 350 to 450°F. Although a few recipes specify the same temperature for the entire baking period, most recommend lowering the temperature after approximately 10 to 20 min. of baking. Nason emphasized that the baking of cream puffs is not difficult if the batter is well made as cream puffs will bake satisfactorily over a wide range of oven temperatures (51).

Peet and Lowe found that cream puffs baked satisfactorily in gas, electric or kerosene ranges when the batter was placed in unheated ovens, if temperatures of the ovens were brought to 425°F. in 50 min. (55). The ovens were turned off when they reached 425°F. and the cream puffs remained in the ovens for the remainder of the 50-min. period. The investigators also reported that oven temperatures should not fall below 275 to 325°F. during the 50-min. period.

Kotschevar and Lowe gave similar instructions for baking cream puffs in food services and homes, respectively (41, 47). They recommended baking cream puffs at initial high temperatures of approximately 425 to 465°F. with subsequent lower temperatures of approximately 325 to 375°F. so the walls of the cream puffs become rigid and do not collapse upon removal from the oven. The authors agreed that a high initial temperature is necessary to rapidly form the steam required for expanding cream puff batter and that baking must then proceed to sufficiently set the structure before the steam condenses. After the puffs begin to brown, the oven temperature is lowered to reduce the danger of burning and to help dry the cream puffs. Kotschevar pointed out that browning is not always an indication of doneness and a rapid cold shock upon removal from the oven may collapse the cream puffs. To avoid this, the baking sheet may be pulled to the front of the oven and allowed to stand a few moments with the door open so that heat is reduced gradually. Kotschevar also suggested that about 5 min. before the end of baking, cream puffs may be lightly pricked at the top to allow steam to escape.

Methods of Assessing Quality

Quality of foods, according to Kramer and Twigg, may be defined as the "composite of those characteristics that differentiate individual units of a product and have significance in determining the degree of acceptability of that unit by the buyer" (45). A cream puff of maximum quality should have a puffed appearance, be irregular in shape and have a uniformly golden brown color; its interior should be hollow and slightly moist, but not gummy; it should be crisp and tender and the flavor should be mild without a predominant egg flavor (49, 76).

Various methods of subjectively and objectively assessing quality may be applicable to cream puffs, however certain precautions should be taken in using subjective evaluations and objective measurements. Amerine *et al*. stressed that 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 (1).

Subjective evaluation

Subjective evaluation of food is accomplished whenever anyone consumes food (45). Sensory methods, in which palatability is evaluated by a panel of judges, are essential to most food experiments because they answer the all-important questions of how a food tastes, smells, looks and feels (31). Since the human instrument is used in subjective evaluations, noted Kramer and Twigg, it is subjected to many influences including environmental conditions, state of health, lack of an absolute point of reference, tendency for comparative instead of absolute evaluation and, above all, conscious or subconscious bias (45). They believed that the average result obtained from a validated sensory panel working under controlled conditions was less likely to be biased than the evaluation of an individual judge. Lowe also stated that since scores were based on human opinion, the validity of these scores could vary over wide intervals of time or from day to day (47). Even though many food characteristics can be measured objectively, some, such as flavor, can be best evaluated subjectively (45).

Types of subjective tests. There are many types of subjective evaluations. Amerine *et al*. described those they considered most important, which are difference tests, rank order tests, descriptive tests, acceptance and preference tests and scoring tests (1).

Difference tests are referred to as single-stimulus, paired-stimuli, duo-trio, triangle and multi-sample tests, depending on the number of samples being tested at one time (1). These tests reveal differences among treatments, but do not establish the nature and magnitude of the differences

(1, 47). According to Lowe, difference tests are often used to detect acuity of taste or smell in prospective panel members, in determining if differences exist among foods and in testing panel members throughout a study (47).

Rank order tests are used to determine how several samples differ on the basis of a single characteristic (1). However, Lowe pointed out that preferential ranking is of value in determining acceptability, but gives no evaluation of the particular gradation of quality as a permanent record (47).

Descriptive tests, such as flavor profile, are best conducted by highly trained experts completely familiar with the product or the process (1). A flavor profile provides a detailed, descriptive evaluation of the quantitative and qualitative attributes of a flavor complex without directly measuring acceptance of the flavor (1).

The acceptance and preference tests are best suited for consumer testing of food products (47). Amerine et al. pointed out that a distinction should be made between acceptance, which is willingness to use or eat a product, and preference, which relates to a greater degree of acceptance of one product over another when a choice is presented (1).

Scoring tests are best used in comparisons of a control sample with several experimental samples (1). Scoring may be expressed in terms of deviation from the reference sample or may be used on an absolute basis if the scale is clearly defined and understood by all judges. According to Griswold and Lowe, scoring tests are probably the most frequently used methods of evaluating the quality of food (31, 47). Scoring is called hedonic when the judges express their degree of liking by checking a point on a scale ranging from extreme disapproval to extreme approval (1).

Taste panel selection and training. The candidates considered for a panel, stated Dawson et al. and Lowe, should exhibit intelligence, comprehension, concentration, motivation toward sensory testing, and be available for the entire period of the experiment (13, 47). 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 (13, 31). Dawson et al. mentioned that variability exists among individuals in taste thresholds, degrees of difference they can distinguish and ability to give reproducible judgments (13). Health, age, sex, smoking and emotional factors are considered possible causes for variability in taste acuity among individuals (13, 47).

Amerine et al. emphasized that careful selection and training of judges is essential in order to achieve maximum discriminability (1). They noted that "there is considerable controversy in the literature on the value of a sensory panel that has been selected and trained," and stated that 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*. emphasized the importance of panel members working under controlled conditions, such as odor-free, air-conditioned, well-lighted rooms free from distractions (12). A small panel of high sensitivity and ability to differentiate perceptions may be preferable to a large panel of less sensitivity (47). Griswold noted that a successful sensory evaluation is also dependent on the method of scoring and the experience of the judges (31).

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 (12, 31). According to Griswold, more samples can be evaluated in one session if the flavor is bland than if it is strong (31). The samples should be prepared and served as uniformly as possible with their actual identity concealed by coding (12). The instructions given to the panel member, especially regarding scoring, should be clear and precise (45).

Objective measurements

Objective measurements of food quality are preferable to sensory evaluations only if the objective tests can provide a precise measure of the subjective quality (1). Objective tests offer a permanent record of results and invite confidence because they are reproducible and less subject to error than sensory methods (31). The ideal objective methods, according to Amerine et al. should be rapid, accurate and precise (1). Dawson and Harris as well as Kramer and Twigg summarized a wide variety of instrumental methods for measuring physical and chemical properties related to sensory responses (14, 45). They stated that since the final standard of quality is the human evaluation, objective procedures must be judged by their correlation with sensory results.

Care must be taken in choosing objective tests as some are too time-consuming to be practical and others are too expensive (31). One disadvantage of instrumental procedures is that the instrument may "repeat" readings when changes in the material may invalidate the correlation with subjective judgments, according to Amerine et al. (1). They agreed with Ehrenberg and Shewan that constant relationships between a sensory variable and external variables should be interpreted with caution (1, 19).

Texture measurement. One of the important qualities of food, stated Bourne, is texture (7). Texture of food is a composite property, undoubtedly related to the viscosity, elasticity and other physical properties of foods, but the relationship is complex according to Amerine et al., who reviewed the classification of the textural characteristics of food given by various authors (1). Kramer and Twigg classified texture into finger feel and mouth feel; Szczesniak classified texture into mechanical and geometrical qualities and into properties related to moisture and fat content (45, 66). Szczesniak listed tenderness as a mechanical characteristic of texture and as the popular term for chewiness or cohesiveness of food (66).

Tenderness of several foods can be measured with the Allo-Kramer shear press (43, 45). Work on the development of what eventually became the shear press was initiated in 1949 by Kramer, who desired an instrument which could measure the tenderness of food products ranging from tough meats or chewy biscuits to ripe strawberries or cream puffs. Kramer worked to develop an instrument which could provide opportunity to measure various kinds of force application, perhaps by the use of a series of interchangeable test cells, and which could be calibrated in absolute terms with maximum precision. The Kramer shear press, which has practically unlimited versatility, was released in 1958 as a result of research work done at the University of Maryland. Bourne classified the shear press as a force-measuring instrument designed to measure the hardness or tenderness of food products (7). He also pointed out that the measured variable is force, usually maximum force, while distance and time are held constant, or at least reproducible.

The shear press consists mainly of an hydraulic system, a proving ring dynamometer, an electronic recorder and a test cell (43, 45). The hydraulic drive system moves a piston at a predetermined rate of travel which is adjustable from 15 to 100 sec. for a full stroke. The measurement of force is provided by the compression of a proving ring dynamometer. Various proving rings are capable of providing ranges from 100 lbs., for relatively soft materials, to 5000 lbs., for tough or hard products. The moving part of the test cell is attached directly to the proving ring to eliminate any possible frictional error since the force developed by the resistance of the food material to shearing or compression is transferred directly to the measuring system. An electronic recorder attached to the shear press records a time-force curve from the beginning to the end of the stroke. The various parts of the resulting curve can be interpreted, according to Kramer, in terms of compressibility, the force required to break and the shearing properties (42, 43). The area-under-the-curve, stated Kramer, is directly proportional to the sample size. Various test cell assemblies may be used on the Kramer shear press, including the standard test cell, the compression cell, the tensile strength apparatus, the fixed blade and the succulometer cell.

The Kramer shear press has been used by many investigators to measure various textural characteristics of food. Funk _et al_. used the shear press to measure the tenderness, compressibility and tensile strength of angel cakes and compare the measurements with sensory evaluations (28). Gruber and Zabik also used the shear press to measure the tenderness, compressibility and tensile strength of butter cakes and compared the shear press measurements with the sensory evaluations (32). Correlations between sensory evaluations and maximum-force shear press measurements indicated that using the appropriate attachments and techniques with the Kramer shear press gave measurements which were accurate and precise enough to be used in place of the sensory evaluations in measuring the tenderness of angel cakes and butter cakes and the compressibility and tensile strength of angel cakes. Endres used the shear press to measure the gel strength of baked whole egg and milk slurries and Wolfe measured the gel strength of custards prepared with and without sugar (20, 77). They concluded that shear press measurements gave reliable measurements of gel strength. Kramer utilized the shear press to measure the texture of many food products, including the rheological properties of gels (44). The time-force curves he obtained gave an extensive description of the product tested.

Volume. Measurement of the volume is accomplished by a determination of the space occupied by the object being measured (45). The volume of baked products can be estimated by seed displacement in which the volume of seeds required to fill a container holding the baked product is subtracted from the volume of seeds required to fill the same container without the product (31). Bourne classified the volume-measuring instruments as distance-measuring instruments (7).

Cathcart and Cole reported an experiment to devise a piece of equipment that would measure, with a fair degree of accuracy, the volume of bread loaves (8). Their preliminary work was carried out using an hour-glass type of device, but they noted two possibilities of error with the instrument. One source of error was introduced if the loaf was not perfectly flat on the bottom of the instrument and a second possible source of error was the large quantity of displacement material which was needed and which resulted in variations in the degree of packing. They tested the accuracy of the instrument using mustard, poppy and rape seeds, glass and aluminum beads and rice. They then devised a smaller instrument with which they obtained very good results using glass beads, rape seeds and aluminum beads. The volume of the sample-holding box, suggested Griswold, can be adjusted with plywood blocks if desired (31). She also mentioned measuring volume of cakes by baking them in pans with sides which were enough higher than the baked cakes to allow for covering the top of the cakes with seeds.

Viscosity. Viscosity is a property of great importance in batters (45). Viscosity is a mechanical characteristic and is defined by Szczesniak as the rate of flow per unit force (66). According to Griswold, the resistance to flow, or viscosity, is caused by the attraction among the molecules of the product and this attraction, or internal friction, is greater among large molecules or well hydrated molecules than among small molecules (31).

The Brookfield Synchro-Lectric viscometer is an instrument which can be used to measure viscosity (31). This instrument is used to measure the viscosity of non-Newtonian materials, which are those materials whose resistance to flow changes with a change in rate of shear (45). The principle of operation of the Brookfield viscometer is the measurement of torque by a calibrated spring on a spindle rotating at a constant speed in the test material. The viscometer is geared for various rates of shear, enabling a wide range of viscosity measurement (45).

Szczesniak _et_ _al_. reported very good correlation between subjective evaluations and objective measurements of viscosity using a Brookfield viscometer (67). Using water, cream, sirups, condensed milk and mayonnaise mixed with heavy cream as testing media, the viscosity was perceived organoleptically as the force required to draw a liquid from a spoon over the tongue.

If the Brookfield viscometer is placed on an Helipath stand for measuring the viscosity of non-flowing materials, such as batters, more meaningful results can be obtained than if it is used alone (53). A special bar-type spindle is attached to the Brookfield viscometer when it is used on the Helipath stand. The motorized stand lowers the rotating spindle into the test material and then lifts it from the material. Since the trace of the spindle is a helical path, the channeling effect is eliminated.

EXPERIMENTAL PROCEDURE

A procedure was developed and standardized for preparing cream puffs from each of four types of processed whole eggs and for assessing the quality of the cream puffs. A formula for making cream puffs was selected, whole eggs from a common source were obtained and processed, a preparation procedure and schedule were developed and techniques for evaluating and measuring quality were selected. When feasible, institutional equipment was utilized.

Formula and Preparation Schedule

Table 1 shows the formula for cream puffs which was based on Lowe's recipe (47). The amounts of ingredients in the original recipe were used except for the eggs and the water. The amount of eggs was increased to compensate for the 10 per cent of carbohydrates present in the processed eggs and to obtain the desired 34 per cent of solids recommended in the USDA standard for eggs (71). The amount of water in the formula was decreased to compensate for the liquid in the additional eggs. The quantities of dried whole eggs and distilled water to equal the amount of frozen eggs were determined according to the moisture content of the dried eggs.

Table 1. Formula used for making cream puffs with four types of processed eggs

INGREDIENTS	Frozen	Spray-dried	Freeze-dried	Foam-spray-dried
	gm.	gm.	gm.	gm.
Water	222	222	222	222
Fat	112	112	112	112
Flour	112	112	112	112
Eggs[a]	231	77	75	77
Water for reconstitution[a]	---	154	156	154

TYPES OF PROCESSED EGGS (spanning header over Frozen through Foam-spray-dried)

[a] The variation in amounts of water and dried eggs was due to differences in moisture content of the dried eggs.

A randomized schedule of the four types of processed eggs and the baking order was prepared to allow for six preparations of cream puffs from each type of eggs as shown in Table 2. Cream puffs were prepared with two types of processed eggs on two days each week, thus allowing for data collection for one replication of each variable per week.

Table 2. Schedule for preparation and evaluation of cream puffs prepared from four types of processed eggs[a]

	FIRST DAY		SECOND DAY	
BAKING ORDER	1	2	1	2
First week	F	SD	FSD	FD
Second week	FD	FSD	SD	F
Third week	FSD	F	FD	SD
Fourth week	SD	FSD	F	FD
Fifth week	FD	SD	FSD	F
Sixth week	F	FD	SD	FSD

[a] F - Frozen; SD - Spray-dried; FD - Freeze-dried; FSD - Foam-spray-dried.

Procurement and Storage of Materials

Prior to the initial data collection, sufficient ingredients for preparing cream puffs were acquired for the entire study and stored in the laboratory. The materials necessary for the subjective evaluation were also purchased.

Eggs

Shell eggs from a common source were purchased from a commercial processor and equal portions were processed by each of four methods: freezing, spray-drying, freeze-drying and foam-spray-drying. The shell eggs varied in age from one to two weeks and in grades from A to C. After the shell eggs were machine-broken under USDA supervision, the whole eggs were strained through stainless steel screens (0.014-in. perforations) and churned to produce homogeneity. A refractometer was used to check the whole eggs during stirring and liquid yolk was added when necessary to adjust the solids to 25.5 per cent. On a basis of 31.5 ± 0.5 per cent carbohydrates and 1.5 ± 0.25 per cent salt in the whole egg solids, corn sirup and salt were added to the blended whole egg. The frozen and spray-dried eggs were commercially processed[1] and the freeze-dried and foam-spray-dried eggs were processed at Michigan State University.[2]

Freezing. After pasteurizing the whole eggs at 60 to 61°C. for 3.5 to 4 min., the eggs were frozen in 30-lb. containers and held at -30°C. until further processing or shipment. One-fourth of the frozen eggs was allocated for use as the control and equal amounts of the remaining eggs were spray-dried, freeze-dried and foam-spray-dried. The metal containers of frozen eggs were packed in dry ice and shipped to Michigan State University for use as the control, for freeze-drying and for foam-spray-drying.

Spray-drying. The frozen eggs were thawed, blended and then spray-dried[3] in a pilot plant spray-dryer under

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

[2] Dr. L. E. Dawson, Food Science Dept., Michigan State University.

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

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

Freeze-drying. The frozen eggs for freeze-drying were thawed in running tap water for 24 hrs. The thawed eggs were placed in trays in 3/4-in. layers in a Stokes Freeze Drier, Lab. Model 2003 F2, to be frozen at -22°C. and vacuum-dried at approximately 200 micron pressure for 24 hrs. with the plate temperature of 45°C. The freeze-dried eggs were pulverized through a Fitzmill, Model D, Comminutery Machine using a 0.050-in. sieve.[4] The freeze-dried eggs were packed in a polyethylene-lined heavy paper bag and refrigerated until packaging.

Foam-spray-drying. The eggs were foam-spray-dried by a modification of the process developed by Blakeley and Stine.[5] The eggs were thawed in running tap water for 24 hrs. and then heated to 54°C. in a water bath. Immediately prior to drying, nitrogen gas was injected into the eggs by means of a special unit between the high pressure and the nozzle under pressure of 950 psi. The eggs were then foam-spray-

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

[5] *Ibid*.

dried using a co-current horizontal inverted tear-drop dryer equipped with two No. 62 nozzles and No. 20 spinners. The eggs were sprayed under an atomization pressure of 850 psi. Inlet temperature in the dryer was 116°C. and exhaust temperature was approximately 79°C. The foam-spray-dried eggs were packed in a polyethylene-lined heavy paper bag and refrigerated until packaging.

Packaging the eggs. The bags of dried eggs were packed in dry ice and air-freighted to a commercial company[6] for packaging. The dried eggs were packaged in laminated-foil pouches consisting of three layers: polyethylene terephthalete (0.005-in. thickness), aluminum foil (0.001-in. thickness) and polyethylene (0.002-in. thickness). The packages of dried eggs were evacuated to at least 27 in. of vacuum and held under the vacuum for at least 1 min., then flushed with nitrogen. This procedure was followed three times allowing a small amount of nitrogen inner pressure to remain on the third flush, and the packages were immediately sealed. The spray-dried and freeze-dried eggs were packaged in 1-lb. units and the foam-spray-dried eggs were packaged in 6-oz. units, because of the low density of the product.

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[6] Jianas Brothers Candy Co., Kansas City 5, Missouri.

Storing and repackaging the eggs. The packaged dried eggs and the frozen control eggs were stored at approximately -10°C. in laboratory freezers. The eggs were repackaged for the entire investigation prior to the initial data collection. Three pounds of each type of processed eggs were blended in a 10-qt. mixing bowl with a wire whip. Portions of the dried eggs adequate for one replication were heat-sealed in plastic pouches and stored at approximately -10°C. A 10-gm. sample of each type of dried eggs was sealed for moisture determination. From each 10-gm. sample, three 2.0 gm. samples were weighed into pre-weighed aluminum drying dishes and dried for 6 hrs. under 28 to 30 in. of vacuum at 70 to 80°C. The percentage of moisture in the dried eggs was determined by dividing the weight of the eggs before drying into the amount of weight lost during drying.

A 30-lb. can of frozen eggs was refrigerated at 2 to 4°C. for 48 hrs. Portions of eggs adequate for one replication were weighed into 1-qt. plastic packages which were placed in 1-qt. plastic coated paper containers. The plastic packages were closed with paper-covered wires, the lids were placed on the paper containers and the packaged eggs were then refrozen at approximately -10°C. Samples of frozen eggs were also dried to determine the percentage of moisture, which was 68.5 per cent instead of 66 per cent as specified by the USDA (71).

Other materials

Six cans of a lecithin aerosol spray[7] were obtained and stored at room temperature. A 10-lb. bag of all-purpose flour[8] was purchased and portions adequate for one replication were heat-sealed in plastic pouches and stored at room temperature. Three 3-lb. cans of all-vegetable shortening[9] from a common lot were purchased and refrigerated. The distilled water, at room temperature, was obtained as needed from a Barnstead still, Model 92235. Lemon juice[10] used in the subjective evaluation was purchased from a common lot and refrigerated.

Preparation of Cream Puffs

The ingredients for two preparations of cream puffs were weighed, mixed and baked each day according to standardized procedures. All the ingredients were weighed to the nearest gram.

Preparation of ingredients

Frozen eggs were removed from the freezer and

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[7] Pam, a pure vegetable food release, a trademark of Gibraltar Industries, Chicago, Ill.

[8] Gold Medal, enriched, bleached all purpose flour, a trademark of General Mills, Inc., Minneapolis, Minnesota.

[9] Crisco, vegetable shortening, a trademark of Procter and Gamble, Cincinnati, Ohio.

[10] ReaLemon, reconstituted lemon juice, a trademark of ReaLemon Co., Chicago, Ill.

refrigerated at 2 to 4°C. for approximately 21 hrs. prior to use. Before cream puff preparation began they were weighed into two pre-weighed stainless steel bowls, covered and refrigerated for 30 min. A portion of eggs was refrigerated in a beaker for pH determination.

The dried eggs were reconstituted 30 min. before the preparation of cream puff batter was started. The package of dried eggs was removed from the freezer and refrigerated approximately 30 min. prior to the reconstitution. Distilled water at 23 to 25°C. for the reconstitution was divided into two pre-weighed stainless steel bowls. The dried eggs were weighed into a pre-weighed 5-qt. capacity mixer bowl. The mixer bowl was placed on the Kitchen Aid mixer, Model K5 - A, the distilled water was added to the dried eggs in two parts and mixed at speed 1 (108 rpm.) with the whip attachment for 30 sec. after each addition. The reconstituted eggs were then strained, weighed and divided into two stainless steel bowls which were covered and refrigerated until needed. A portion of reconstituted eggs was refrigerated in a beaker for pH determination.

The remaining ingredients and necessary equipment were pre-weighed for both preparations before the preparation of the first batch of cream puffs. The flour was weighed into two pre-weighed bowls, covered and kept at room temperature until needed. The distilled water and fat were weighed into two pre-weighed mixer bowls, covered with aluminum lids and kept at room temperature until needed.

To aid in determining the percentage of moisture lost during mixing, the paddle attachment and the rubber scraper were also weighed prior to mixing.

Mixing procedure

According to the procedure developed during preliminary investigation, a thermocouple was placed in the mixer bowl containing the distilled water and the fat and the temperature of the mixture was recorded on a Minneapolis Honeywell-Brown Electronik potentiometer, Model 153 X 65 - P12H - II - III - 81. The covered mixer bowl was placed on the speed heat unit set on "high" of a Frigidaire range, Model RDG 39-57. The paddle attachment was placed on the cover of the mixer bowl during the heating period to lessen the change in temperature when the paddle entered the water-fat mixture prior to blending in the flour.

When the water-fat mixture reached 99 ± 1°C., the thermocouple was removed and the mixer bowl was placed on the mixer, which was connected to an electric timer which automatically turned the power off at the completion of selected mixing periods. The flour was added, the paddle attached and the mixture allowed to beat at speed 2 (132 rpm.) for 15 sec. The speed of the mixer was changed to 4 (182 rpm.) and the mixture allowed to beat for 30 sec., after which the mixer bowl and the paddle were scraped. After 45 sec. of additional mixing on speed 4, the temperature of the mixture was recorded. During the mixing of the water, fat and flour, the two bowls of eggs were removed from the refrigerator and the temperature of the eggs was recorded. One-half of the eggs was added to the water-fat-flour mixture and mixed for 2.5 min. at speed 1. The bowl and paddle were scraped and the remaining eggs were added and mixed at speed 1 for another 2.5 min. The mixture was then beaten for 5 min. at speed 4, after which the temperature of the mixture was recorded and the bowl containing the batter was weighed along with the paddle and the scraper.

It was necessary to make cream puffs small enough to fit into the 2.5 in. sq. shear compression cell. After using ice cream dippers of varying sizes to dip the batter, it was determined that a No. 40 dipper produced a desirable size of cream puff. Therefore, the No. 40 dipper was used to portion cream puffs for both objective and subjective tests.

Four dippers of batter were each leveled with a knife and placed in a 150-ml. graduated beaker for viscosity measurements, covered with saran and kept at room temperature. Two aluminum baking sheets, one measuring 13 X 16.75 in. and the other measuring 16.5 X 24.5 in. were sprayed with a lecithin aerosol spray and covered with templates indicating the positions of the cream puffs as shown in Figures 1 and 2. Three dippers of batter were placed on the pre-weighed small baking sheet and the baking sheet was weighed after the addition of each dipper

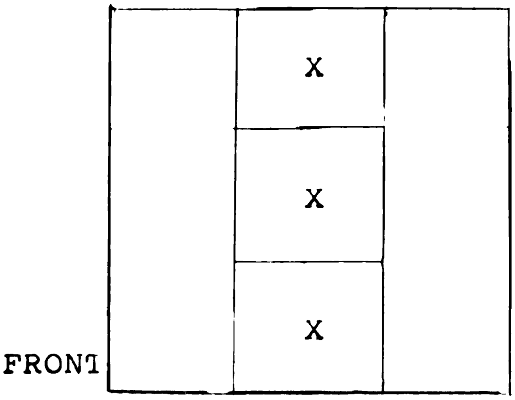


Figure 1. Positions of cream puffs baked on the small baking sheet for moisture determinations (13 X 16.75 in.).

Extra	Extra	Extra	Extra
Extra	Extra	Extra	Extra
Volume and Linear	Volume and Linear	Volume and Linear	Extra
Taste Panel	Taste Panel	Shear Press	Taste Panel
Taste Panel	Taste Panel	Shear Press	Taste Panel
Taste Panel	Taste Panel	Shear Press	Taste Panel

FRONT

Figure 2. Positions and purposes of cream puffs baked on the large baking sheet (16.5 X 24.5 in.).

of batter to obtain the original weight of each cream puff. A dipper of the batter was placed in each of 24 positions on the large baking sheet as shown in Figure 2.

Baking procedure

The oven temperature and the grids and damper settings had to be adjusted to prevent excessive browning of the top and bottom of the cream puffs, because of the reduced size of the cream puffs and the presence of 10 per cent carbohydrates in the processed eggs. After several trials, it was decided to preheat the upper deck of a two-deck Hotpoint roasting and baking oven, Model HJ225, to 227 ± 2°C. (440°F.) with both grids set at medium and the damper closed. A Minneapolis-Honeywell Versatronik controller, Model R7161B, which replaced the regular thermostat, was adjusted to regulate the upper oven temperature at 227 ± 2°C. and the bottom oven at 149 ± 2°C. (300°F.). Because another study in the laboratory involved the use of the bottom deck oven on some of the days that cream puffs were baked and the possibility of the influence of the bottom oven temperature on the temperature of the top oven, the bottom oven was always heated. Elevating the baking sheets about 2 in. from the bottom of the oven with two metal racks was necessary to prevent over-browning of the bottoms of the cream puffs.

The baking sheets containing the cream puff batter were placed in the oven immediately following a print-out of the oven temperature on the potentiometer. As soon as the oven door was closed, the top grid was turned to low, the bottom grid was turned off and the damper was left closed. The cream puffs were allowed to bake for 20 min., after which the oven controller was turned off and the damper was opened completely. The cream puffs were left in the oven for an additional 25 min., then the baking sheets were removed from the oven and placed on cooling racks.

Assessing the Quality of Cream Puffs

Methods for assessing the quality of the cream puffs subjectively and objectively were determined in preliminary investigations. Cream puffs were evaluated by a taste panel and some were submitted to selected objective measurements.

Subjective evaluation

Whole cooled cream puffs were served to each of seven panel members on coded white plates. During preliminary investigations cream puffs were cut both horizontally and vertically for subjective evaluations and it was decided to serve whole cream puffs and to instruct the panelists to cut them vertically with a serrated knife.

The cream puffs were assigned to the judges according to the pre-determined positions indicated in Figure 2. The serving of the cream puffs for the six replications of each variable was rotated so that six of the judges evaluated cream puffs which were baked in each of six positions on the left side of the baking sheet and the seventh judge evaluated two cream puffs which were baked in each of three positions on the right side of the baking sheet.

Each member of the taste panel was assigned a place in the taste panel room for evaluating cream puffs throughout the study. Glasses of tap water and of conditioning water at room temperature and serrated knives and forks were provided for use during the evaluations. The judges were instructed to condition their mouths by drinking some of the water containing lemon juice (2 tsp. per qt. of water) before judging each sample.

The judges evaluated each factor on a five-point rating scale ranging from "very good" to "very poor." Judges were asked to check or write descriptive terms for each factor which was scored fair or below. The ideal for each factor was described to use as a reference for scoring. The first sample of cream puff and the evaluation sheet were removed before serving the second sample. The instructions to the judges and an evaluation sheet are included in the Appendix.

The judges evaluated the individual cream puffs for shape and appearance, after which they were instructed to cut the cream puffs in half vertically with the serrated knife. The judges then evaluated the cavity size, shell thickness, interior appearance and interior moistness of the cut cream puffs. They were instructed to place one half of the cream puff with the cut side down, cut a sample from it with a fork, eat the removed portion and base the score for tenderness on the cutting and eating of the portion. The flavor was evaluated by eating a portion of cream puff containing both the shell and the webs.

Objective measurements

The viscosity measurements of the cream puff batter and the pH of the eggs and distilled water used in the batter were recorded. The volume, tenderness, moisture content and linear dimensions of the baked cream puffs were measured.

Viscosity. Twenty-five minutes after completing the preparation of the batter, the viscosity of the batter was measured. A Brookfield Synchro-Lectric viscometer, Model RVT, mounted on an Helipath stand, Model C, was used to measure the viscosity. A weight of 58.4 gm. was attached to the shaft of the viscometer to prevent swaying of the No. F spindle as it rotated at 5 rpm.

To measure the viscosity, the graduated 150-ml. beaker containing approximately 80 ml. of batter was placed so that the spindle was exactly in the center and about 1/8 in. above the batter. The level of the stand and the viscometer were checked and adjusted. The temperature of the batter was recorded and the Helipath stand and the viscometer were then turned on and a reading was recorded at each of the six revolutions as the spindle went into the batter to a depth of 1/2 in. from the bottom and also at each of the six revolutions of the spindle as it withdrew from the batter. The readings obtained at revolutions 5, 6, 7 and 8 were used in the analysis of data. The average of the four readings was multiplied by a factor of 0.01 and by 2,000,000 to convert it to centipoises.

pH. The pH values of the distilled water, of the frozen eggs and of the reconstituted eggs were determined on a Beckman Zeromatic pH meter. The temperature of the distilled water and the egg samples ranged from 23 to 25°C. when the pH values were read.

Volume. A 1-lb. size National Loaf volumeter was selected to determine the cubic centimeters of volume of the whole cream puffs and of the cavity of the cream puffs. Since the sample box of the volumeter was larger than necessary to accommodate the three cream puffs, a false bottom was installed by placing two pieces of 3/4-in. thick wood in the bottom of the box. Laminated foil covered the false bottom and was sealed to the sides of the box to prevent the seeds from falling through. The false bottom reduced the height of the interior of the sample box to 3 1/4 in.

The three cream puffs used for volume measurements were chosen according to the pre-determined baking positions indicated in Figure 2. The initial amount of rape seeds in the instrument was first determined and recorded. A small amount of the seeds, about 3/4 in., was allowed to fall in the sample box and leveled before the three cream puffs were placed bottom side down to prevent their movement while the seeds were falling and to insure that the cream puffs were completely surrounded by seeds. Because of errors in obtaining accurate readings when measuring individual cream puffs, three cream puffs were placed in the sample box simultaneously. A 3-in. high wire rack having 1/2-in. openings was placed over the cream puffs to prevent pieces of cut cream puffs from falling into the column of the instrument when it was inverted. After the upper part of the volumeter was inverted over the sample box the shutter was opened and the remaining seeds were allowed to fall into the sample box. The reading thus obtained was subtracted from the initial reading to calculate the composite volume of three cream puffs. The composite volume was divided by three to determine the approximate volume of each cream puff.

The procedure was repeated to determine the volume of the same three cream puffs after they had been cut in half vertically and the six halves placed in the sample box with their cut sides up. The approximate volume of the cavity of each cream puff was calculated by subtracting the composite volume of the cut cream puffs from the composite volume of the whole cream puffs and dividing by three.

Tenderness. The tenderness of three cream puffs from baking positions indicated in Figure 2 was measured on the Allo-Kramer shear press, Model SP12. Each cream puff was weighed to the nearest 0.01 gm. and then placed in a standard shear compression cell, Model C338. The 3000-lb. proving ring, the 10-lb. range, 25-lb. of pressure and an approximate 30-sec. downstroke speed were used. The amount of force used to shear each cream puff was continuously recorded on a Varian Associates electronic indicator, Model E - 2EZ, which was attached directly to the proving ring dynamometer. The validity of the Kramer shear press for measuring the tenderness of cream puffs was determined during an earlier investigation (9).

The average maximum force and the average area-under-the-curve were calculated from the recorder charts for the three cream puffs for each replication. The maximum pounds of force required to shear each cream puff was calculated by multiplying the maximum reading on the graph by a conversion factor of 300 and dividing that figure by the weight of the cream puff. The area-under-the-curve of each time-force curve was calculated according to a method described by Funk et al. (28). The area on the graph which was covered by each time-force curve was not handled and was carefully cut with sharp scissors along the line formed by the electronic indicator and weighed to the nearest 0.0001 gm. The weight of the paper was multiplied by a factor of 174.2

to obtain the square centimeters of area-under-the-curve.

Moisture lost during mixing. Upon completion of the cream puff batter preparation, the mixer bowl containing the finished batter, the paddle and the rubber scraper used during the preparation were weighed and the weight subtracted from the original weights of the mixer bowl, the paddle and the rubber scraper to determine the weight of the finished batter. The percentage of moisture lost during mixing was then calculated by subtracting the weight of the finished batter from the weight of the ingredients prior to mixing and dividing the difference by the weight of the ingredients.

Moisture lost during baking. The percentage of moisture which was lost during baking was calculated from the weights of the three unbaked and baked cream puffs which were baked on the small baking sheet. After the addition of each dipper, the baking sheet and the batter were weighed and the total weight recorded. The weight of batter in each cream puff was the difference between the appropriate consecutive weights. Immediately after removing the trays of three cream puffs from the oven, the cream puffs were individually weighed. The percentage of moisture lost during baking was calculated by subtracting the weight of each baked cream puff from the weight prior to baking and dividing the difference by the weight of the unbaked batter. The three percentages for each replication were averaged.

Moisture of the baked cream puffs. The three cream puffs which were used to calculate the moisture lost during baking were also used to determine the moisture content of the baked cream puffs. Each cream puff was cut in half vertically and placed in a pre-weighed aluminum drying dish and weighed to the nearest 0.01 gm. The drying dishes of cream puffs were dried for 4 hrs. in a Labline Inc. vacuum oven preheated to 60 to 70°C. with a pressure of 28 to 30 in. of mercury. Following the drying period, the dishes containing the cream puffs were put into a dessicator to cool for 10 min. before being reweighed. The percentage of moisture of each baked cream puff was calculated by subtracting the weight of the vacuum-dried cream puff from the weight of the baked cream puff and dividing by the weight of the baked cream puff. An average of the three percentages was calculated for each replication.

Linear dimensions. The linear dimensions of the whole cream puffs and of the cavities were measured with a vernier caliper. The three cream puffs which were used for the volume determination were also used for linear measurements. The maximum height of each cream puff was recorded and two measurements of the width of each cream puff were taken at right angles. The two measurements of width were averaged. After the volume of the whole cream puffs was measured, the cream puffs were cut in half vertically, the thickness of the shell at the center of the top and at the center of the bottom were measured prior to determining the volume of the cut cream puffs. The maximum width and length of the cavity were also measured. If there was more than one cavity opening, the largest ones were measured and averaged and a note made of the number of large cells present.

Analysis of Data

The data which were collected for cream puffs were analyzed by using statistical programs available for the CDC 3600 Computer at Michigan State University.

Numbers of 5, 4, 3, 2 and 1 were assigned to the subjective evaluations of very good, good, fair, poor and very poor, respectively, for the purpose of analyzing the data. The seven panelists' scores for each factor were averaged for each replication and the average scores were used in the statistical analyses of the subjective evaluations. The average values for each objective measurement for each replication were used as the basis for analyzing and examining the data from the objective measurements.

The AOV routine was used to calculate the analyses of variance of the averaged subjective scores and of the averaged objective measurements of viscosity, volume, linear dimensions, percentages of moisture, maximum force and area-under-the-curve of the cream puffs. The data were analyzed for statistical differences among the four types of processed whole eggs. The DMRT routine, or Duncan multiple range test, was used to locate the significant differences indicated by the analyses of variance (18). Correlation coefficients for all combinations of the data were calculated using the BASTAT routine. Standard deviations from the mean were calculated for each variable.

RESULTS AND DISCUSSION

The purpose of this investigation was to compare the emulsifying properties and the palatability of frozen, spray-dried, freeze-dried and foam-spray-dried eggs in cream puffs. Cream puffs were prepared by standardized procedures, were subjectively and objectively evaluated and the data from six replications for each variable were statistically analyzed to identify differences due to the four types of processed eggs.

Subjective Evaluation of Cream Puffs

A taste panel composed of seven judges subjectively evaluated the cream puffs for each of eight factors: shape, exterior appearance, cavity size, shell thickness, interior appearance, interior moistness, tenderness and flavor. The panelists used a five-point rating scale of very good, good, fair, poor and very poor, which were assigned values of 5, 4, 3, 2 and 1, respectively, for analyzing the data. The judges were asked to check or write descriptive terms on the evaluation sheet for each factor which was evaluated as fair or below.

Average scores for cream puffs prepared with the four types of processed eggs were between fair and good for all attributes except for the poor to fair scores for cavity size (Figure 3). The results of the statistical analyses of cream puffs and the average scores and standard deviations of the subjective evaluations are presented in Tables 3 and 4. Averages of the seven panelists' scores for individual factors for each replication of cream puffs are in the Appendix, Table 15. Significant differences among the four types of processed eggs were shown in the analyses of subjective evaluations of cavity size and tenderness and highly significant variations among replications were found in analyzing scores for interior moistness.

Shape

Average scores for the shape of cream puffs prepared from each of the four types of processed eggs ranged from 3.36 to 3.63 and did not vary significantly (Tables 3 and 4). The two comments made most frequently by the judges regarding the shape of the cream puffs were "flat" and "too irregular." According to the judges, the cream puffs prepared with the foam-spray-dried eggs were generally flatter than those made with the other three types of processed eggs. The shape of the cream puffs prepared with frozen, spray-dried and freeze-dried eggs were judged too irregular more often than the shape of the cream puffs prepared with foam-spray-dried eggs.

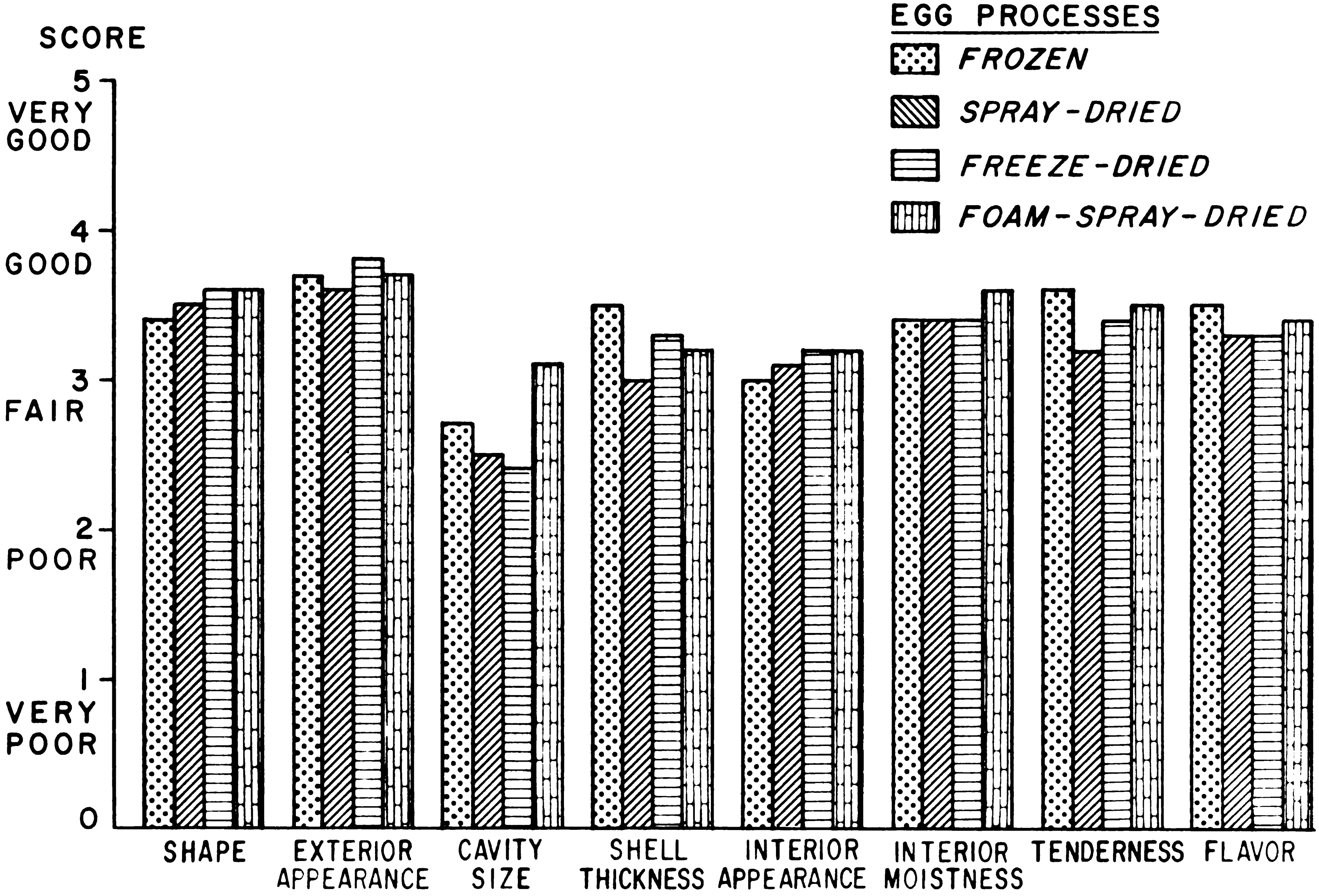


Figure 3. Comparison of the averages of scores for subjective evaluation of cream puffs prepared from four types of processed eggs

Table 3. Mean squares from analyses of variance of scores for subjective evaluations of cream puffs prepared from four types of processed eggs

		EVALUATION FACTORS							
SOURCE OF VARIANCE	DEGREES OF FREEDOM	Shape	Exterior appearance	Cavity size	Shell thickness	Interior appearance	Interior moistness	Tenderness	Flavor
Total	23								
Process	3	0.0865	0.0631	0.5415*	0.2068	0.0572	0.0502	0.1522*	0.0545
Replication	5	0.2121	0.0079	0.1720	0.1122	0.0197	0.1197**	0.0991	0.1218
Error	15	0.1544	0.0653	0.1185	0.0924	0.0631	0.0198	0.0384	0.0622

*Significant at the 5 per cent level of probability.

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

Table 4. Averages[a] and standard deviations of scores[b] for subjective evaluations of cream puffs prepared from four types of processed eggs

EVALUATION FACTORS	TYPES OF PROCESSED EGGS				STATISTICAL DIFFERENCES[c]
	Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	5% level
Shape	3.36 ±0.36	3.54 ±0.57	3.63 ±0.36	3.60 ±0.29	NONE
Exterior appearance	3.72 ±0.24	3.55 ±0.27	3.79 ±0.21	3.72 ±0.18	NONE
Cavity size	2.69 ±0.25	2.45 ±0.41	2.39 ±0.25	3.05 ±0.49	$\underline{\text{FD SD } \underline{\text{F}}}\ \underline{\text{FSD}}$
Shell thickness	3.46 ±0.16	3.03 ±0.32	3.32 ±0.31	3.17 ±0.41	NONE
Interior appearance	3.03 ±0.19	3.06 ±0.23	3.23 ±0.16	3.19 ±0.31	NONE
Interior moistness	3.39 ±0.21	3.39 ±0.23	3.40 ±0.25	3.57 ±0.13	NONE
Tenderness	3.55 ±0.11	3.19 ±0.18	3.44 ±0.32	3.48 ±0.27	SD $\underline{\text{FD FSD F}}$
Flavor	3.48 ±0.14	3.25 ±0.23	3.33 ±0.42	3.36 ±0.23	NONE

[a] Averages of six replications for each type of processed whole eggs.

[b] Scores based on scale of 5 = very good, 4 = good, 3 = fair, 2 = poor, 1 = very poor.

[c] All values spanned by the same line are not significantly different (18).

Exterior appearance

Average scores for the exterior appearance of the cream puffs prepared from each of the four types of processed eggs ranged from 3.55 to 3.79 and did not vary significantly (Tables 3 and 4). The cream puffs prepared with the foam-spray-dried and spray-dried eggs were frequently "too dark." The crusts were occasionally "spotty" for cream puffs prepared with each type of processed eggs.

Cavity size

Average scores for cavity size of cream puffs varied from 2.39 to 3.05, or from poor to fair, and differed significantly among the four types of processed eggs (Tables 3 and 4). Comparison of the average scores for cavity size indicated that, at the 5 per cent level of probability, cream puffs prepared with foam-spray-dried eggs had significantly larger cavities than the cream puffs prepared with spray-dried and freeze-dried eggs (Table 4). The average scores for cavity size of cream puffs were generally lower than scores for the seven other subjectively evaluated factors. The panelists frequently indicated that "too many cells" or "several cells" were present in cream puffs prepared from each type of processed eggs.

Shell thickness

Average scores for shell thickness of cream puffs were fair, varying from 3.03 to 3.46, and did not differ significantly among the four types of processed eggs (Tables 3 and 4). According to the judges, the shells of cream puffs prepared with each type of eggs were frequently "too thick," and those containing foam-spray-dried eggs most often had too thick shells and bottoms. Comments of "irregular" shell thickness were occasionally made for the cream puffs prepared with each type of processed eggs.

Interior appearance

Average scores for interior appearance of cream puffs ranged from 3.03 to 3.23, or fair, and were not significantly different among the four types of processed eggs (Tables 3 and 4). Cream puffs prepared from each of the four types of processed eggs frequently had oil droplets and streaks on the webs, according to the panelists.

Interior moistness

Average scores for interior moistness of cream puffs were close, varying from 3.39 to 3.57 (Table 4). No significant differences were found in the analysis of variance among the four types of processed eggs. The judges frequently noted the "too moist" interiors of cream puffs prepared with each type of processed eggs, but the comment was least frequent for the cream puffs made with foam-spray-dried eggs.

Highly significant differences existed in scores for interior moistness among replications (Table 3). The differences might have resulted from variations in moisture lost during mixing of the batter since, in some cases, the lower scores for interior moistness were obtained on days when the percentage of moisture lost during mixing was also low.

Tenderness

Average scores for tenderness of cream puffs varied from 3.19 to 3.55 and showed significant differences among the four types of processed eggs (Table 3). Comparison of the average scores for tenderness of cream puffs indicated that, at the 5 per cent level of probability, cream puffs prepared with spray-dried eggs were significantly tougher than those prepared with each of the other three types of processed eggs (Table 4). Cream puffs prepared with spray-dried eggs were frequently designated as being "too soft" or "not crisp."

A highly significant correlation existed between scores for tenderness and those for flavor (Appendix, Table 16). The scores for these two factors increased simultaneously.

Flavor

Average scores for flavor of cream puffs were fair and varied from 3.25 to 3.48 (Table 4). The analysis of variance of the scores for flavor showed no significant differences among the four types of processed eggs (Table 3).

According to the judges, the flavor of cream puffs was occasionally "oily," "flat" and/or "caramelized." Cream puffs prepared with freeze-dried eggs tasted oily more often than those made with the other types of processed eggs. Cream puffs prepared with spray-dried or foam-spray-dried eggs were most often indicated as tasting flat. Cream puffs made with frozen eggs tasted caramelized more often than those made with the other three types of processed eggs. The fair scores given by the judges for the flavor of cream puffs may have been partially due to the fact that cream puffs were served without a filling, thus the judges were probably more critical of the taste of cream puffs than they would have been if the cream puffs had been typically served with a filling. As was mentioned in the preceding section, flavor and tenderness scores correlated significantly (Appendix, Table 16).

Objective Measurements of Cream Puffs

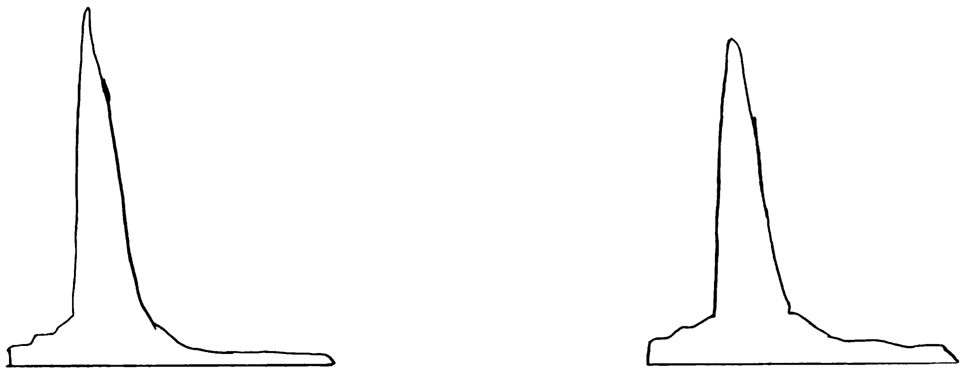
Tenderness, linear dimensions, volume and moisture content of the baked cream puffs and the viscosity of the batter were measured, the percentages of moisture lost during mixing and baking were calculated, and the pH values of the distilled water and the four types of processed eggs were recorded. The data for all objective measurements except the pH values were statistically analyzed for differences attributable to the processing of the eggs.

Shear press measurements of tenderness

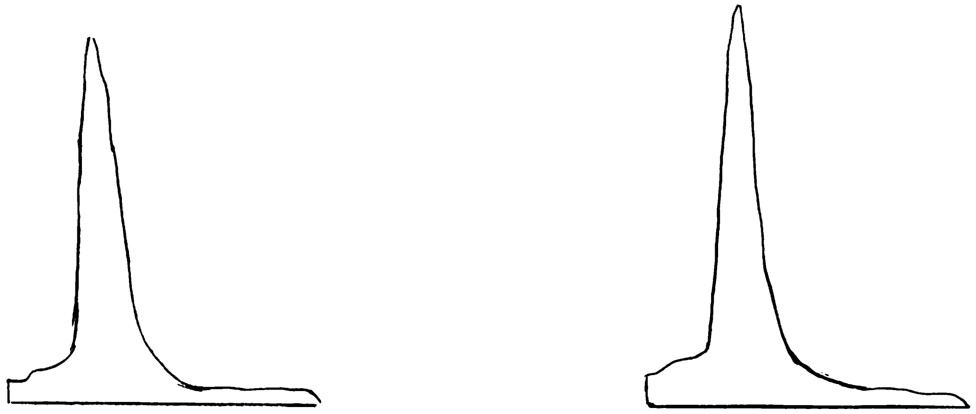
The tenderness of the cream puffs was measured using the shear compression cell on the Allo-Kramer shear press. Typical time-force curves for each variable of cream puffs are shown in Figure 4. The maximum pounds of force required to shear the cream puffs and the area-under-the-curve were calculated for three cream puffs from each replication. The average values for each shear press measurement for each replication are in the Appendix, Table 17.

Significant variations among the four types of processed eggs existed in both shear press measurements for the tenderness of cream puffs (Tables 5 and 6). Comparison of the average pounds of maximum force required to shear the cream puffs indicated that cream puffs prepared with foam-spray-dried eggs were significantly tougher than those containing spray-dried or freeze-dried eggs, at the 5 per cent level of probability. The analysis of variance of the measurements of area-under-the-curve showed that the cream puffs prepared with foam-spray-dried eggs were significantly tougher, at the 1 per cent level of probability, than those prepared with the other three types of processed eggs.

A highly significant correlation existed between the two shear press measurements of maximum force and area-under-the-curve, which was to be expected since these two



Frozen Spray-dried



Freeze-dried Foam-spray-dried

Figure 4. Typical Allo-Kramer shear press time-force curves for cream puffs prepared from four types of processed eggs

Table 5. Mean squares from analyses of variance of shear press measurements for cream puffs prepared from four types of processed eggs

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SHEAR PRESS MEASUREMENTS	
		Maximum force	Area-under-the-curve
Total	23		
Process	3	1.7721*	0.3326**
Replication	5	0.6584	0.0107
Error	15	0.5315	0.0315

*Significant at the 5 per cent level of probability.

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

Table 6. Averages and standard deviations of shear press measurements of cream puffs prepared from four types of processed eggs

SHEAR PRESS MEASUREMENTS	TYPES OF PROCESSED EGGS				STATISTICAL DIFFERENCES[a]	
	Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	1% level	5% level
Maximum force (lb.)	11.13 ± 0.77	10.77 ± 0.65	10.89 ± 0.46	11.97 ± 0.85		SD FD F FSD
Area-under-the-curve (sq. cm.)	3.359 ± 0.13	3.368 ± 0.18	3.382 ± 0.19	3.840 ± 0.13	F SD FD FSD	

[a] All values spanned by the same line are not significantly different (18).

measurements are closely related to each other (Appendix, Table 16). The area-under-the-curve increased as the maximum pounds of force increased. However, no significant correlations were found between either shear press measurement and tenderness scores of cream puffs.

Linear dimensions

A vernier caliper was used to measure linear dimensions of the baked cream puffs. The average values of the linear measurements of three cream puffs from each replication are located in the Appendix, Table 17.

The analyses of variance of the linear dimensions are found in Table 7. No significant differences existed among the four types of processed eggs, however significant differences among replications were found for the measurements of maximum height and for measurements of the thickness of bottom of cream puffs. According to the judges, cream puffs prepared with foam-spray-dried eggs were generally flatter than those prepared with the other three types of processed eggs, which corresponds with the average measurements of maximum height and width of cream puffs (Table 8).

Significant negative correlations were found between the measurements of thickness of the top of the cream puff shells and the measurements of maximum height and between the measurements of thickness of the bottom and the measurements of maximum width of the cream puffs. Cream puffs

Table 7. Mean squares from analyses of variance of linear dimensions of cream puffs prepared from four types of processed eggs

		LINEAR DIMENSIONS					
				Thickness of shell			
SOURCE OF VARIANCE	DEGREES OF FREEDOM	Maximum height	Maximum width	top	bottom	Cavity height	Cavity width
Total	23						
Process	3	0.0052	0.0286	0.0004	0.0002	0.0539	0.2248
Replication	5	0.0284*	0.0080	0.0041	0.0059*	0.0595	0.2028
Error	15	0.0087	0.0175	0.0017	0.0014	0.0539	0.3133

*Significant at the 5 per cent level of probability.

Table 8. Averages and standard deviations of linear dimensions of cream puffs prepared from four types of processed eggs

	TYPES OF PROCESSED EGGS				
LINEAR MEASUREMENTS	Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	STATISTICAL DIFFERENCES
Maximum height (cm.)	4.03 ±0.15	3.99 ±0.10	3.98 ±0.11	3.96 ±0.10	NONE
Maximum width (cm.)	5.58 ±0.10	5.51 ±0.12	5.53 ±0.12	5.67 ±0.11	NONE
Thickness of top (cm.)	0.31 ±0.04	0.31 ±0.05	0.31 ±0.04	0.33 ±0.06	NONE
Thickness of bottom (cm.)	0.37 ±0.04	0.36 ±0.05	0.36 ±0.03	0.36 ±0.07	NONE
Cavity height (cm.)	2.08 ±0.14	2.01 ±0.30	1.89 ±0.20	2.12 ±0.27	NONE
Cavity width (cm.)	3.56 ±0.69	3.59 ±0.46	3.61 ±0.40	3.97 ±0.59	NONE

which had thin top shells were higher than those with thick top shells and those with thick bottoms were wider than those with thin bottoms (Appendix, Table 16). A significant correlation was found between the measurements of the width and the height of cream puff cavities, indicating that cream puffs expanded both upward and outward during baking.

Moisture calculations

The percentages of moisture lost during mixing and baking and in the baked cream puffs were calculated for three cream puffs from each replication. The average percentages of moisture for each replication are in the Appendix, Table 18.

Significant differences due to the four types of processed eggs were found in the percentages of moisture in the baked cream puffs, but not in the percentages of moisture lost during mixing and baking (Tables 9 and 10). Baked cream puffs prepared with freeze-dried eggs contained significantly more moisture than those prepared with frozen or foam-spray-dried eggs, at the 5 per cent level of probability. Significant variations among replications existed in the percentages of moisture lost during baking.

A highly significant negative correlation was found between the moisture content of the baked cream puffs and the percentages of moisture lost during baking (Appendix, Table 16). As would be expected, cream puffs which lost the most moisture during baking were the driest at the end of the baking period.

Table 9. Mean squares from analyses of variance of percentages of moisture in the preparation of cream puffs from four types of processed eggs

SOURCE OF VARIANCE	DEGREES OF FREEDOM	PERCENTAGES OF MOISTURE		
		Lost in mixing	Lost in baking	In baked cream puffs
Total	23			
Process	3	0.6374	2.6742	2.4988*
Replication	5	0.5803	8.2623*	0.8523
Error	15	0.3916	2.3844	0.5548

*Significant at the 5 per cent level of probability.

Table 10. Averages and standard deviations of percentages of moisture in the preparation of cream puffs from four types of processed eggs

PERCENTAGES OF MOISTURE	TYPES OF PROCESSED EGGS				STATISTICAL DIFFERENCES[a]
	Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	5% level
Lost in mixing	6.18 ±0.35	6.73 ±0.53	6.93 ±0.70	6.75 ±0.93	NONE
Lost in baking	49.37 ±1.36	48.51 ±1.74	47.77 ±1.09	48.79 ±3.05	NONE
In baked cream puffs	13.09 ±0.91	13.71 ±0.52	14.59 ±0.98	13.41 ±0.67	F FSD SD FD

[a] All values spanned by the same line are not significantly different (18).

Viscosity of the batter

The viscosity of a sample of cream puff batter from each replication was measured with the Brookfield Synchro-Lectric viscometer mounted on the Helipath stand. The average viscosity values for each replication are in the Appendix, Table 18.

Highly significant differences were found among the measurements of viscosity of cream puff batter prepared with each of the four types of processed eggs (Tables 11 and 12). At the 1 per cent level of probability, the batter prepared with foam-spray-dried eggs was significantly thinner and the batter containing freeze-dried eggs was significantly thicker than batters prepared with the other three types of processed eggs.

Volume measurements

The volume of whole cream puffs and of cream puff cavities were measured in a volumeter. Three cream puffs from each replication were placed simultaneously in the volumeter and the composite volume recorded. The approximate volume of individual cream puffs was determined by dividing the composite volume by three. The average volumes of cream puffs for each replication are in the Appendix, Table 19.

The analyses of variance of the measurements of volume of whole cream puffs and of cream puff cavities and the average measurements of volume of cream puffs prepared

Table 11. Mean squares from analysis of variance of viscosity measurements of the cream puff batter prepared from four types of processed eggs

SOURCE OF VARIANCE	DEGREES OF FREEDOM	VISCOSITY MEASUREMENTS
Total	23	
Process	3	1122569444.25**
Replication	5	331041666.66
Error	15	128402780.13

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

Table 12. Averages and standard deviations of viscosity measurements of cream puff batter prepared from four types of processed eggs

VISCOSITY MEASUREMENTS	TYPES OF PROCESSED EGGS				STATISTICAL DIFFERENCES[a]
	Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	1% level
Viscosity	242,500	244,167	257,917	224,583	FSD $\underline{\text{F SD}}$ FD
(cps.)	±12,549	±9,958	±15,525	±14,783	

[a] All values spanned by the same line are not significantly different (18).

from each type of processed eggs are located in Tables 13 and 14, respectively. No significant differences existed for any of the measurements of volume. The lack of a significant correlation between the measurements of volume of whole cream puffs and of volume of cream puff cavities showed that the volume of whole cream puffs was not a dependable indication of the volume of the cavities. Considerable variation was often noted in the internal structure of the three cream puffs from a replication, ranging from a large cavity to two or more small cells.

pH values

The pH values of the distilled water and of the four types of processed eggs used in the preparation of cream puffs were determined with a Beckman pH meter. The average values of the pH of the distilled water and of the eggs for each replication are in the Appendix, Table 19.

The average pH values of the distilled water was 6.1 for each variable of cream puffs. The average pH values of the four types of processed eggs were 7.4, 7.7, 8.2 and 8.0 for frozen, spray-dried, freeze-dried and foam-spray-dried eggs, respectively. The pH values of the batter were not determined, therefore the influence of the differences in pH values of the four types of processed eggs on the pH of the batter is not known.

Table 13. Mean squares from analyses of variance of volume measurements of cream puffs prepared from four types of processed eggs

		VOLUME MEASUREMENTS	
SOURCE OF VARIANCE	DEGREES OF FREEDOM	Whole cream puffs	Cream puff cavities
Total	23		
Process	3	20.0417	50.1543
Replication	5	9.8380	11.5741
Error	15	19.0972	22.3765

Table 14. Averages and standard deviations of volume measurements of cream puffs prepared from four types of processed eggs

	TYPES OF PROCESSED EGGS				
VOLUME MEASUREMENTS	Frozen (F)	Spray-dried (SD)	Freeze-dried (FD)	Foam-spray-dried (FSD)	STATISTICAL DIFFERENCES
Whole puffs (cc.)	58.33 ±5.27	61.11 ±4.31	58.33 ±0.00	62.50 ±4.57	NONE
Cavity (cc.)	18.06 ±6.27	25.00 ±0.00	22.22 ±4.30	20.84 ±4.56	NONE

Significant Correlation Coefficients

Correlation coefficients were calculated for all combinations of subjective evaluations and objective measurements. Significant correlation coefficients between selected factors are shown in the Appendix, Table 16.

Correlations related to cavity size

A significant correlation was found between scores for cavity size and the measurements of volume of whole cream puffs and a highly significant correlation existed between scores for cavity size and measurements of maximum width of the cream puffs, which in turn were negatively correlated with the viscosity of the batter. As scores for cavity size increased, the measurements of the volume and of the width of the whole cream puffs increased and the viscosity of the batter decreased. The batter prepared with foam-spray-dried eggs was thinner and produced wider cream puffs with larger volumes than those prepared with the other three types of processed eggs. As discussed earlier, the measurements of cavity width and cavity height correlated significantly.

Significant correlation coefficients were found between the measured volumes of cream puff cavities and the subjective scores for interior appearance. The judges gave higher scores for the factor of interior appearance when the cavities of the cream puffs were large than when they were small.

Correlations related to tenderness

Significant correlation coefficients related to tenderness of cream puffs were found between the shear press measurements of maximum force and area-under-the-curve and between scores for tenderness and flavor, as discussed earlier. Additional correlations related to tenderness were found.

Significant correlation coefficients existed between taste panelists' scores for tenderness and the percentages of moisture lost during baking and between the scores and the volume of cream puff cavities. Cream puffs which lost the most moisture during baking were judged as the most tender. The significant negative correlation found between the scores for tenderness and the volume of cream puff cavities indicated that the cream puffs with small cavities were more tender than those with large cavities.

A highly significant negative correlation was found between the measurements of maximum force required to shear the cream puffs and the percentages of moisture in baked cream puffs, indicating that the moistest cream puffs required less force to shear them and therefore were the most tender. This is contrary to the correlation discussed earlier which showed that cream puffs which were the driest after baking were judged as the most tender. However, the objective and subjective evaluations of tenderness were not done on the same basis since the judges had to evaluate the tenderness of cream puffs both from the point of view of cutting a portion of cream puffs and eating it and the shear press measured only the action of shearing the cream puffs.

The measurements of area-under-the-curve were statistically related to the measurements of viscosity of the batter and of cavity width. A highly significant negative correlation between the measurements of area-under-the-curve and of viscosity of the batter showed that the batter containing foam-spray-dried eggs was thinnest and produced the toughest cream puffs, although, as noted earlier, these cream puffs had the largest volumes and cavities. The measurements of viscosity of the batter did not, however, correlate significantly with the measurements of maximum force, even though the shear press measurements were highly correlated. A significant correlation also existed between the measurements of area-under-the-curve and of cavity width. The two measurements increased together, indicating that the most tender cream puffs had narrow cavities.

Correlations related to shell thickness

A significant correlation related to shell thickness of cream puffs was found between scores for shell thickness and measurements of maximum width. The panelists' evaluation of shell thickness did not correlate with the measurements of shell thickness or other linear dimensions of cream puffs.

As discussed earlier, significant negative correlations were found between the measurements of thickness of the top of the cream puff shells and the measurements of maximum height and between the measurements of thickness of the bottom of the shells and the maximum width of cream puffs. A highly significant negative correlation existed between the measurements of thickness of the bottom of the shells and the percentages of moisture lost during baking. Cream puffs with thick bottoms were those which had lost the least amount of moisture during baking.

Correlations related to moistness

Significant negative correlations were found between scores for flavor and percentages of moisture in baked cream puffs and between the scores and percentages of moisture lost during mixing. Cream puffs prepared with frozen eggs obtained the highest scores for flavor, lost the lowest percentages of moisture during mixing and the highest percentages of moisture during baking, thus they were the driest and, according to the panelists' evaluation of tenderness, the most tender. However, the correlation between measurements of maximum force and percentages of moisture in baked cream puffs indicated that cream puffs having the most moisture were the most tender.

As discussed earlier, highly significant negative correlations were found between the percentages of moisture in baked cream puffs and the percentages of moisture lost during baking, as well as between percentages of moisture lost during baking and measurements of thickness of the bottom of the cream puff shells.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to compare the emulsifying properties and the palatability of frozen, spray-dried, freeze-dried and foam-spray-dried whole eggs in the preparation of cream puffs. Cream puffs were subjectively evaluated for shape, exterior appearance, cavity size, shell thickness, interior appearance, interior moistness, tenderness and flavor. Objective measurements of tenderness, linear dimensions, volume, moisture lost during mixing and baking, moisture in baked cream puffs, viscosity of the cream puff batter and pH of the distilled water and of the four types of processed eggs were determined. Cream puffs prepared with the four types of processed eggs were generally fair to good and significant differences were found among the four types of eggs in six of the analyses of subjective evaluations and objective measurements.

The scores for shell thickness, tenderness and flavor of cream puffs prepared with frozen eggs were higher than those prepared from the three other types of processed eggs. Cream puffs containing frozen eggs lost the lowest percentages of moisture during mixing and the highest percentages of moisture during baking. Although these cream puffs were the driest, the panel rated them relatively low for interior moistness. The cream puffs prepared with frozen eggs were the highest, had the smallest cavities, the lowest scores for interior appearance, the thickest bottoms and were judged to have the least desirable shapes.

The scores from the subjective evaluations were generally lower for cream puffs containing spray-dried eggs than for the cream puffs prepared from the other three types of processed eggs. According to the subjective evaluation, cream puffs prepared with spray-dried eggs were significantly tougher than those containing the other three types of eggs and were frequently described as being too soft, however, the shear press measurements indicated that they were significantly more tender than cream puffs prepared with foam-spray-dried eggs. The cream puffs prepared with spray-dried eggs were the narrowest, received the lowest scores for shell thickness and had cavities which were of the greatest volume, but which received next to the lowest scores for cavity size.

Average scores for shape and exterior and interior appearance of cream puffs prepared with freeze-dried eggs were the highest, although not significantly different from, those of the other three variables. The batter containing freeze-dried eggs was significantly thicker than those prepared with the other three types of processed eggs and produced cream puffs which lost the highest percentages of moisture during mixing and the lowest percentages of moisture during baking and which were significantly more moist than cream puffs prepared with frozen and foam-spray-dried eggs. Cream puffs prepared with freeze-dried eggs had the smallest volumes, the shortest cavities and the lowest scores for cavity size. The pH values for freeze-dried eggs were the highest, or 8.2.

Average scores for the subjective evaluation of cream puffs prepared with foam-spray-dried eggs ranged from fair to good for all attributes and were generally higher than those for the other three variables. The scores for cavity size were significantly higher than those for the cream puffs prepared with spray-dried and freeze-dried eggs. The scores for interior moistness were higher, but not significantly different from, those of the other three variables. The batter containing foam-spray-dried eggs was significantly thinner than batters prepared with the other types of eggs and produced cream puffs which were significantly toughest, according to shear press measurements. Cream puffs made with foam-spray-dried eggs were the shortest and widest and were frequently mentioned as being flat by the judges, however the average measurement of volume of the whole puff and linear measurements of the cavities were greater than measurements of cream puffs containing the other types of processed eggs.

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APPENDIX

Name______________________________

INSTRUCTIONS FOR EVALUATING CREAM PUFFS

Please follow these instructions when evaluating the two cream puffs, 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 conditioning water (marked L). If water is desired during the evaluation of a sample, use the water in the unmarked glass.

6. As you evaluate each factor, compare it with the "ideal" description and then check the space which best fits your overall judgment for that factor (very good, good, fair, poor, very poor).

   If you mark fair, poor, or very poor, also mark the descriptive term which best describes the reason you chose the score for the particular factor being evaluated. If an appropriate term is not listed, check other and write a brief description in the "comment" column.

7. Evaluate the factors for the cream puff as follows:
   a. First the shape and appearance.
   b. With the knife cut the cream puff vertically and evaluate the cavity size, shell thickness, interior appearance, and moistness.
   c. Remove a bite-size portion by cutting through the puff with the side of the fork; base your evaluation of tenderness on the combination of cutting and eating the puff; determine the score for flavor from eating a portion, which should include both shell and webs (if present in puff).

8. Check to make sure you have marked EIGHT spaces; also make sure you have indicated the descriptive terms as directed in no. 6 above.
9. When you have evaluated the first sample, it will be removed and the second sample will be presented for your evaluation according to the preceding procedures.
10. You may leave the room after evaluating the second sample.

THANK YOU

Judge:______________________

Sample No.______________ CREAM PUFF SCORE CARD Date:______________________

FACTORS \ SCALE	Very Good	Good	Fair	Poor	Very Poor	DESCRIPTIVE TERMS	COMMENTS	IDEAL
SHAPE						__peaked __flat __cracked __bottomless __too irregular __other		sphere-shaped puff with irregular surfaces
EXTERIOR APPEARANCE						__too pale __too dark __shiny __spots __oily __other		uniform golden dull brown
CAVITY SIZE						__med. cavity __two cells __several cells __too many cells __other		one large cavity with a few small cells around outside wall
SHELL THICKNESS						__thin walls __thick walls __thick bottom __too irregular __thin bottom __other		approximately 1/8 inch thick
INTERIOR APPEARANCE						__too light __too dark __oil droplets __spots __streaked __other		yellow webs, golden brown inside shell wall, with no oil droplets
INTERIOR MOISTNESS						__too moist __too dry __slightly dry __other		slightly moist to touch
TENDERNESS						__tough __too fragile __too soft __too hard __too brittle __other		crisp and tender
FLAVOR						__eggy __oily __flat __sweet __caramelized __other (identify)		mild egg flavor

Table 15. Average scores[a] for subjective evaluations of cream puffs prepared from four types of processed eggs[b]

PROCESS OF EGGS	REPLICATION NUMBER	EVALUATION FACTORS							
		Shape	Exterior appearance	Cavity size	Shell thickness	Interior appearance	Interior moistness	Tenderness	Flavor
Frozen	1	3.71	3.43	2.71	3.43	3.14	3.57	3.57	3.57
	2	3.57	3.86	2.43	3.29	2.71	3.57	3.57	3.29
	3	3.43	3.43	2.57	3.29	2.86	3.00	3.43	3.71
	4	3.14	3.86	2.57	3.71	3.14	3.43	3.43	3.43
	5	3.57	3.71	2.71	3.57	3.14	3.43	3.71	3.43
	6	2.71	4.00	3.14	3.43	3.14	3.29	3.57	3.43
Spray-dried	1	3.29	4.00	2.43	3.43	2.71	3.43	2.86	3.00
	2	3.43	3.71	2.71	2.57	3.14	3.71	3.29	3.57
	3[c]	3.83	3.33	2.83	2.83	3.17	3.00	3.33	3.17
	4	3.29	3.43	2.43	3.00	3.14	3.43	3.14	3.00
	5[c]	4.50	3.50	1.67	3.33	3.33	3.33	3.33	3.33
	6	2.86	3.29	2.57	3.00	2.86	3.43	3.14	3.43
Freeze-dried	1	3.43	3.71	2.29	3.29	3.43	3.29	2.86	3.00
	2	3.57	3.71	2.43	3.14	3.29	3.71	3.57	3.71
	3[c]	3.67	3.83	2.00	2.83	3.00	3.00	3.50	3.00
	4	3.43	3.71	2.71	3.71	3.14	3.57	3.29	2.86
	5[c]	4.33	4.17	2.33	3.50	3.33	3.50	3.67	3.83
	6	3.29	3.57	2.57	3.43	3.14	3.29	3.71	3.57
Foam-spray-dried	1	3.57	3.57	2.57	2.57	2.71	3.43	3.43	3.14
	2	3.57	3.71	3.43	3.29	3.29	3.71	3.14	3.29
	3	3.43	4.00	3.14	3.43	3.43	3.57	3.29	3.57
	4	3.57	3.57	2.43	2.86	3.14	3.57	3.43	3.14
	5	3.29	3.57	3.00	3.71	3.00	3.43	3.71	3.29
	6	4.14	3.86	3.71	3.14	3.57	3.71	3.86	3.71

[a] Scores based on scale of 5 = very good, 4 = good, 3 = fair, 2 = poor, 1 = very poor.

[b] Averages of seven taste panel members' scores unless otherwise indicated.

[c] Averages of six taste panel members' scores.

Table 16. Significant correlation coefficients for selected combinations of subjective evaluations and objective measurements of cream puffs prepared from four types of processed eggs

CORRELATIONS	CORRELATION COEFFICIENTS
Tenderness and flavor scores	0.58**
Maximum force and area-under-the-curve	0.69**
Thickness of top and maximum height	-0.41*
Thickness of bottom and maximum width	-0.42*
Cavity width and cavity height	0.51*
Moisture in baked cream puffs and moisture lost during baking	-0.52**
Cavity size scores and volume of whole cream puffs	0.41*
Cavity size scores and maximum width	0.59**
Cavity size scores and viscosity	-0.41*
Volume of cavities and interior appearance scores	0.41*
Volume of cavities and tenderness scores	-0.48*
Maximum width and viscosity	-0.40*
Tenderness scores and moisture lost during baking	0.46*
Maximum force and moisture in baked cream puffs	-0.60**
Area-under-the-curve and viscosity	-0.55**
Area-under-the-curve and cavity width	0.41*
Shell thickness scores and maximum width	0.43*
Thickness of bottom and moisture lost during baking	-0.57**
Moisture in baked cream puffs and flavor scores	-0.41*
Moisture lost during mixing and flavor scores	-0.50*

*Significant at the 5 per cent level of probability.

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

Table 17. Average values[a] for shear press measurements and linear dimensions of cream puffs prepared from four types of processed eggs

PROCESS OF EGGS	REPLICATION NUMBER	MEASUREMENTS							
		Shear press		Linear dimensions					
		Maximum force	Area-under-the-curve	Maximum height	Maximum width	Thickness of shell		Cavity height	Cavity width
						top	bottom		
		lb.	sq. cm.	cm.	cm.	cm.	cm.	cm.	cm.
Frozen	1	11.51	3.333	4.31	5.67	0.26	0.38	2.27	3.92
	2	10.90	3.519	3.93	5.55	0.28	0.36	1.90	3.45
	3	12.49	3.478	4.05	5.49	0.37	0.38	2.04	3.16
	4	10.92	3.336	3.98	5.47	0.31	0.42	2.22	4.62
	5	10.42	3.351	3.89	5.59	0.33	0.34	1.97	3.51
	6	10.53	3.136	3.99	5.71	0.31	0.32	2.05	2.58
Spray-dried	1	10.88	3.536	4.08	5.65	0.23	0.37	1.84	3.96
	2	9.90	3.124	3.81	5.61	0.35	0.39	1.74	2.84
	3	10.03	3.205	3.99	5.33	0.29	0.43	1.83	3.50
	4	11.31	3.397	3.99	5.54	0.34	0.33	2.50	4.16
	5	11.06	3.350	4.01	5.40	0.32	0.35	2.26	3.50
	6	11.41	3.594	4.08	5.51	0.34	0.27	1.89	3.56
Freeze-dried	1	10.33	3.385	4.14	5.63	0.31	0.38	2.21	3.96
	2	10.91	3.530	4.02	5.57	0.30	0.35	1.80	3.15
	3	12.18	3.617	3.87	5.35	0.25	0.39	1.99	3.39
	4	10.30	3.275	3.86	5.66	0.32	0.35	1.76	3.46
	5	11.20	3.409	4.04	5.57	0.35	0.40	1.64	4.22
	6	10.44	3.078	3.92	5.42	0.36	0.31	1.94	3.48
Foam-spray-dried	1	10.80	3.861	4.06	5.42	0.26	0.44	2.03	3.54
	2	11.45	3.838	3.82	5.62	0.41	0.41	2.18	4.72
	3	12.97	3.879	3.95	5.75	0.25	0.33	2.41	4.67
	4	11.67	3.983	4.09	5.63	0.32	0.37	2.23	3.83
	5	12.06	3.594	3.89	5.84	0.37	0.34	1.63	3.32
	6	12.89	3.885	3.93	5.74	0.35	0.24	2.24	3.75

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[a] Values based on three measurements for each replication.

Table 18. Average values[a] for calculations of moisture in the preparation of cream puffs and of viscosity of the batter for cream puffs prepared from four types of processed eggs

PROCESS OF EGGS	REPLICATION NUMBER	PERCENTAGES OF MOISTURE			VISCOSITY[b]
		Lost in mixing	Lost in baking	In baked puffs	Of batter
		%	%	%	cps.
Frozen	1	5.91	50.00	12.33	242,500
	2	6.20	47.27	14.07	225,000
	3	5.76	48.14	11.78	242,500
	4	6.79	50.88	13.70	262,500
	5	6.20	50.00	12.92	247,500
	6	6.20	49.95	13.76	235,000
Spray-dried	1	6.57	47.37	13.47	232,500
	2	6.06	47.37	14.22	235,000
	3	6.79	46.39	13.87	252,500
	4	6.65	49.02	14.08	247,500
	5	7.68	50.00	13.84	257,500
	6	6.65	50.88	12.79	240,000
Freeze-dried	1	6.65	47.37	15.03	252,500
	2	6.57	47.27	13.98	230,000
	3	8.12	49.12	13.22	260,000
	4	7.39	46.39	16.10	275,000
	5	6.20	47.37	14.91	265,000
	6	6.65	49.07	14.32	265,000
Foam-spray-dried	1	6.35	48.20	14.19	205,000
	2	6.50	46.39	13.26	240,000
	3	6.50	46.39	13.56	215,000
	4	8.57	47.37	13.69	242,500
	5	5.91	50.00	13.58	217,500
	6	6.65	54.38	12.19	227,500

[a] Values based on three measurements for each replication unless otherwise indicated.

[b] Values based on one measurement for each replication.

Table 19. Average values[a] for measurements of volume of baked cream puffs and of pH of distilled water and eggs used to prepare cream puffs from four types of processed eggs

PROCESS OF EGGS	REPLICATION NUMBER	MEASUREMENTS			
		Volume		pH[b]	
		Whole cream puffs	Cavity	Distilled water	Eggs
		cc.	cc.		
Frozen	1	50.00	16.67	6.5	7.8
	2	58.33	16.67	5.5	7.2
	3	58.33	16.67	6.0	7.3
	4	58.33	25.00	6.1	7.5
	5	58.33	8.33	6.0	7.3
	6	66.67	25.00	6.3	7.4
Spray-dried	1	66.67	25.00	6.5	7.7
	2	58.33	25.00	5.5	7.7
	3	66.67	25.00	5.7	7.6
	4	58.33	25.00	6.5	7.7
	5	58.33	25.00	6.3	7.7
	6	58.33	25.00	5.8	7.7
Freeze-dried	1	58.33	25.00	6.0	8.3
	2	58.33	25.00	6.1	8.1
	3	58.33	16.67	5.7	8.2
	4	58.33	25.00	6.1	8.2
	5	58.33	25.00	6.3	8.2
	6	58.33	16.67	6.3	8.2
Foam-spray-dried	1	58.33	16.67	6.0	8.1
	2	66.67	25.00	6.1	8.0
	3	58.33	25.00	6.0	8.0
	4	66.67	16.67	6.5	8.0
	5	58.33	16.67	6.0	8.1
	6	66.67	25.00	5.8	8.0

[a] Values based on three measurements for each replication unless otherwise indicated.

[b] Values based on one measurement for each replication.