A COMPARISON OF LARGE QUANTITY PLAIN CAKES MADE WITH LIQUID HOMOGENIZED MILK, INSTANT NONFAT DRY MILK, AND INSTANT NONFAT DRY MILK WITH ADDITIONAL FAT

by

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INTRODUCTION

The goal of most food services is the efficient production and service of high quality food at a reasonable cost to a satisfied clientele. The type and quality of baked products served may contribute to the achievement of these aims. Cake is popular as a menu item because it not only adds variety and interest to a meal, but also realizes a relatively large margin of profit.

Food service directors are interested in finding ways of improving or maintaining quality while decreasing cost. Milk, one of the most common ingredients found in cake formulas, is available in both liquid and dehydrated forms. The use of nonfat dry milk has become increasingly popular in food services for several reasons. When compared with fluid whole milk, the cost is considerably less. Dry milk powder can be handled with greater ease than fluid bulk milk and requires less storage space. When stored in the original container with the seal intact, it needs no refrigeration. After the seal has been broken, refrigeration is still not essential if the milk is used in a reasonable length of time. In the case of special diets, a further advantage is the ability to augment milk nutrients when the proportion of powder to water is increased.

There have been, however, certain restrictions encountered in the use of nonfat dry milk. The solubility of the powder has been limited and the flavor and odor sometimes objectionable. Since most recipes call for or imply the use of fluid whole milk, some users have found it difficult to make the substitution. Poor quality in the product made has been blamed on the use of dry milk in general rather than the failure of the user to follow the manufacturer's instructions. In some recipes, too, quality might be improved by compensating for the low fat content of the nonfat dry milk.

In 1954, an instant nonfat dry milk appeared on the market with improved flavor and dispersibility. Currently, several brands are available, each of which varies in some respect except for the common property of convenient reconstitution. The question arises as to the relationship between the improved properties and the performance of the instant product when incorporated in large quantity food formulas such as cakes.

Much of the work on nonfat dry milk that has been recorded in the literature has been done on its use in bread. Other work has been done using dry milk products such as dry whole milk or whey. Coulter et al. (1951) stated that

> Much of the advance in techniques of handling dry milk products has resulted from empirical trial and error studies designed to answer immediate problems. Basic research on the chemistry of these products, and the deteriorative changes they undergo has been rather limited. There is a lack of fundamental knowledge.

The purpose of this work was to compare the effects on volume, palatability, and cost of institutional plain cake made with liquid homogenized milk, instant nonfat dry milk, and instant nonfat dry milk with additional fat.

REVIEW OF LITERATURE

History of Nonfat Dry Milk

__Forerunners of Powdered Milk__. Several research workers including Coulter (1956), Webb (1956), and Johnson (1956) have related the development and progress of the dry milk industry. The earliest mention of dry milk dates back to Marco Polo in the thirteenth century followed by a reference to Appert in Europe, who made dry milk tablets in 1810.

Between 1835 and 1886, five British and five United States patents were issued for methods or processes for drying milk. Of these, nine called for additives, seven required sugar, and one used sulfuric acid or some similar material. Also, in one method an absorbent material was specified, whereas another one suggested the use of a preservative. The tenth process which was covered by a United States patent in 1872 was the forerunner of the spray drying process.

Development of Conventional Methods. From 1900 to about 1906, five methods were developed of which two have been successfully used to the present time. The unsuccessful processes were the dough method, the flake process, and the use of the vacuum drum dryer. The reasons for the nonacceptance of the dough and flake processes were not found in the literature, but the vacuum drum dryer was unsatisfactory because of excessive initial and operating costs. Of the two methods which survived, the spray process has been more widely used than the roller process.

The Rosemary Creamery Company in Adams, New York, the first commercially operated dry milk plant in the United States, was started in 1903 using an atmospheric roller-dryer. The first successful spray-dryer was used for fluid milk in 1906 and later for precondensed milk. A spray-dryer patented in 1914 by C. E. Gray and Aage Jensen was followed by a series of patents, eventually resulting in the appearance of what was to become the well-known Gray Jensen dryer. It was used for the fluid milk and later for the precondensed milk which was the starting material. The patent holders made the spray process available to the industry in 1916.

The early literature on this subject is largely contained in patents. In 1922, the first research papers on dry milk were published in the _Journal of Dairy Science_. The early need for an organization to set standards and do research on dry milk products for the industry was reviewed by Johnson (1956) In 1925 the American Dry Milk Institute was formed to set up committees for these purposes. The research committee first endeavored to find uses for the nonfat milks. Later they investigated the relative merits of different packaging materials, manufacturing procedures to improve the product, and consumer acceptance problems. Coulter et al. (1951) noted that until 1930, product standards were those of the individual processor. In that year the Standards Committee of the Dry Milk Institute suggested grades for dry skim milk.

For about 30 years following the early 1920's, attempts were made unsuccessfully to obtain a more soluble product by modifying the spray process. Another approach which eventually proved successful in solving the problem of insolubility was to try to modify the finished product. In general, the present process consists of controlled moistening and redrying of spray-dried nonfat milk. The resulting product is called instant nonfat dry milk to differentiate it from the older type which is referred to as conventional nonfat dry milk.

Instant Nonfat Dry Milk. Today, instant nonfat dry milk is produced by two basic processes as described by Webb (1956). One method employs the principle of agglomeration and can be used to produce two types of nonfat dry milk particles that are instantly soluble. The one type made by the Peebles process is nonhygroscopic and the lactose is in crystalline form. In the second type, the particles readily absorb and retain water, and the lactose remains in the noncrystalline form.

The second basic method of production of instant nonfat dry milk is the formation of large spherical particles during the original drying process.

Grades of Nonfat Dry Milk. In 1929, the American Dry Milk Institute established standards for grading nonfat dry milk. O'Malley (1951) stated that dry milks are graded according to butterfat, moisture, titratable acidity, solubility (using an inverse index), bacterial estimate, sediment, and flavor. According to Pyler (1952) and the American Dry Milk Institute (1953) the two grades designated for human consumption are Extra Grade and Standard Grade. In addition to specific requirements for these grades, the general requirements for all grades include: complying with state and federal regulations; fulfilling certain conditions for sanitary production; being free from additives; having uniformity of composition and color; being free from objectionable flavors and odors; and being suitably packaged. Specific requirements for spray dried nonfat dry milk are given in Table 1.

Table 1. Specific requirements for extra and standard grades of spray-dried nonfat dry milk.

	Extra Grade	Standard Grade
	Not greater than	Not greater than
Butterfat	1.25 %	1.50 %
Moisture	4.00 %	5.00 %
Titratable acidity#	0.15 %	0.17 %
Bacterial count#	100,000 per gm	300,000 per gm
Solubility index#	1.25 ml	1.25 ml
Scorched particles#	Disc B (15.0 mg)	Disc C (22.5 mg)

Reliquefied basis.

Extra Grade nonfat dry milk is entirely free from hard lumps and from any storage or scorched flavor or odor before or after reliquefication, whereas Standard Grade is reasonably free from hard lumps but may have a slight storage or scorched flavor or odor before or after reliquefication.

Name Fixing Legislation. Prior to 1944, the product made by removing water and fat from whole milk was called "dried skimmilk." This name was used for all grades of the product for both human and animal consumption. In 1944, Public Law Number 244 defined and established the identity of the product to comply with Federal Food Drug and Cosmetic Act requirements. In an effort to remove the stigma attached to the original name, this legislation established "nonfat dry milk solids" or "defatted milk solids" as the name of the product intended for human consumption, and retained "dried skimmilk" as the name for the animal feed grade of dried milk.

Nonfat dry milk solids was defined as "pure milk which has had the fat and water content removed and which retains the nonfat nutrients in the same relative proportions as in the fresh milk from which it was made."

In 1956, Public Law Number 646 was enacted which eliminated "solids" from the name and also dropped the alternate designation "defatted milk solids." In the first case, the word "solids" was considered superfluous. The alternate name was dropped because it was rarely used and was unfamiliar to the consuming public.

Composition of Nonfat Dry Milk

The proteins of skim milk have been enumerated by Jeness et al. (1956) as casein, lactalbumin, lactoglobulin, and proteose-peptone. Proteose-peptone is made up of heat stable milk serum proteins. Casein, comprising 80 percent of the total protein, has been found in complex particles containing calcium and phosphate.

Peterson and Strong (1953) identified lactose as the chief carbohydrate constituent of milk. According to Roberts et al. (1954), in addition to lactose, glucose, and galactose, at least 10 other carbohydrates are claimed to be present in milk galactose. Work done by Choi et al. (1951b) indicated that in fresh nonfat dry milk of low moisture content the lactose is noncrystalline. On the other hand, some workers have found crystalline lactose in both spray and roller process milks.

Characteristics of Nonfat Dry Milk

Shape of Particles. In 1938 Folger and Kleenschmidt observed that spray process particles were spherical. According to Coulter et al. (1951), particles of roller process powders were irregular in shape. As described by Peebles (1956), the remoistened spray process milk assumes a spongy porous structure. When viewed under a microscope, large aggregations of particles were apparent.

Size of Particles. The diameters of all conventional dry milk particles were said by Coulter et al. (1951) to fall in the range from 5 to 1000 microns with the majority under 240 microns. Diameters varied depending on the type of spraying equipment and the gas content of the milk at the time of drying. Webb (1956) stated that conventional spray-dryers gave particles that were in the 15 to 60 micron range. The theory was advanced by Bokian et al. (1957) that the remoistening and redrying occurring during the processing of instant nonfat dry milk caused the particles to become larger. According to Webb (1956) special nozzles for spray-drying have been used in the first step of the instant process to form particles 30 to 100 microns in size. By the phenomenon of agglomerization, aggregates of particles are formed of the magnitude of 30 to 100 microns also.

Dispersibility and Solubility. The terms solubility and dispersibility are often used interchangeably in the literature in connection with problems of reconstitution. Lowe (1955) stated that for drinking, the milk powder should be dispersible in water with no sediment or flocks; and added that spray-process powders are more soluble than roller process powders. When referring to the solubility of conventional nonfat dry milks, Coulter et al. (1951) called attention to the inappropriateness of the term, as only the lactose and some of the salts go into true solution. Litman (1956) defined wettability as the ability of the dry milk powder to dissolve without stirring.

Larger particle size was said by Bokian et al. (1957) to be responsible for the increased dispersibility of instant nonfat dry milk. Spray-process nonfat dry milk particles were found to be 200 mesh size, whereas the aggregate particles of the instant product were 80 to 20 mesh. Size was a contributing factor in keeping the particles farther apart when they were in contact with the water in reliquefying the milk. Distances between the particles enabled them to receive sufficient solute to go into solution. Improved dispersibility of instant milk was stated by Webb (1956) to be due to the large particle diameter that lessened the tendency of the powder to "ball-up" in water.

Haney et al. (1948) showed that casein, because of its greater concentration, is of more importance in the problem of insolubility than are the milk serum proteins. According to Coulter et al. (1951) changes in casein render dry milk products insoluble. In agreement with Lea et al. (1943), Peebles (1956) stated that casein of milk becomes denatured and made insoluble when excessive temperatures and times are used in the manufacturing processes. In 1957 Bokian et al. presented evidence that protein and insoluble calcium proteinate are translocated to the interior of the particle in the making of instant nonfat dry milk.

The work of Litman (1956) showed that during storage at room temperature or above, a complex is formed between fat and protein in whole or partly-skimmed milk. This material was thought to be associated with impairment of solubility in reconstituted milk.

The complexity of the sugar-protein solubility relationship was discussed by Coulter et al. (1951). Aldoses such as glucose react with milk proteins to form insoluble compounds. Lea (1948) showed that the disaccharide sucrose rendered proteins more soluble. He also found that the disaccharide aldose, lactose, was capable of producing both effects, so that he reported contradictory results in each of two experiments.

According to Peterson and Strong (1953), when lactose is crystallized at a temperature above 95° C. (203° F.) it is changed to anhydrous beta-lactose which is sweeter, more soluble, and apparently stable for a considerable time under ordinary conditions of moisture and temperature. Work done by Chois et al. (1951a) demonstrated that crystalline alpha-lactose hydrate will not dissolve in a saturated solution of lactose as will amorphous and crystalline beta-lactose. Work by Bokian et al. (1957) gave evidence that in conventional nonfat dry milk, lactose is uniformly distributed throughout each particle, whereas in instant dry milk, the lactose is oriented toward the surface of the particle.

In 1951 Coulter et al. stated that some of the salts of conventional dry milk go into true solution. According to Bokian et al. (1957), the ionizable portions of conventional dry milk powders were equally distributed throughout the particles, whereas chloride, potassium, and sodium components were oriented toward the surface of the instant dry milk particles. They further showed that demineralized spray process conventional powders wet very poorly as compared with normal conventional powders. They concluded that ions have an important role in the dispersibility of dry milk. However, they stated that calcium was in the form of insoluble calcium caseinate in the interior of the particle.

Work by Paul and Plummer (1949) showed that a loss of solubility of dry milk powder accompanied a moisture content of seven percent during home storage of the product. Supplee and Bellis (1925) and Lea et al. (1943) agreed that insolubilization can be retarded when the moisture content is below three percent.

Color. A moisture content of seven percent encouraged browning of the milk powder during home storage conditions, according to Paul and Plummer (1949).

Caking and Pouring Characteristics. Excessive heat and unregulated moistening of the spray process powder in the first stage of the final treatment in the manufacture of instant nonfat dry milk caused lumpiness and unevenness in the powder, according to Peebles (1956). This condition results in the production of a powder with poor pouring characteristics. With proper heat and moisture control, the lactose is partially crystallized and at the same time the hydration reaction is kept within favorable limits for the production of particles that flow freely. Coulter et al. (1951) pointed out that caking or hardening of dry milk occurred when lactose in the form of a very hygroscopic glass was diluted to the point where the molecules attained sufficient motility to be oriented in crystals.

Flavor. The American Dry Milk Institute's flavor requirement for all dry milks is that "the flavor and odor in dry form or on reliquefication shall be sweet and clean and entirely free from rancid, tallowy, fishy, cheesy, soapy or other objectionable flavors or odors."

The flavor of instant nonfat dry milk is preserved during drying by removing the water without causing heat damage, according to Peebles (1956). Paul and Plummer (1949) found that a moisture content of seven percent was accompanied by undesirable flavor and odor. Coulter et al. (1951) stated that there are flavor differences due to normal variation in commercial samples of dry milk. Cooked flavor, sometimes detected in dry milk, has been attributed by Jennes (1956) to denaturation of whey proteins. According to Peterson and Strong (1953), lactose is an almost tasteless sugar in its natural form. However, the beta--lactose form is relatively sweet as compared with lactose.

Uses of Nonfat Dry Milk

Coulter (1956) stated that of all dry milk products, dry skim milk has been produced in the largest bulk. Up to 1940, at least one-third of that manufactured went into animal feeds, and the rest was utilized for human nutrition. In contrast with this approximate ratio of 1 to 3, Webb (1956) quoted U.S.D.A. production totals for 1954 of 1,402,000,000 pounds for human consumption and 19,000,000 pounds for livestock rations.

During World War II an increasing proportion of nonfat dry milk was diverted to meet the demands of the Armed Forces and civilians, and less became available to the farmer. Today skim milk is channeled to feeds only when there is a surplus after drying the milk for human consumption. The many ways of using nonfat dry milk, notwithstanding, Coulter (1956) noted that utilization through the usual commercial channels has not kept up with production.

Historically, the supply and demand situation has been a problem. With the exception of the early case of the acceptance of dry milk as an infant food, as noted by Coulter (1956) and the extraordinary demand created during both World Wars, it has been necessary for the industry to try to create a demand for its product. He noted, also, that in 1923, Glabau wrote that uses for dry milk needed to be found, and that bakers resisted the efforts of processors to persuade them to use dry milk. Later, as the quality of dry milk improved, bakers became increasingly interested; and gradually this product was established as a standard ingredient in many bakery formulas.

According to Johnson (1956), the pre-World War II uses of nonfat dry milk were developed in the food industry field in such products as bread, sausage, candy, cake, and doughnut mix. As food products have been added to the list, it has become necessary to tailor the nonfat dry milk to meet specific needs. There are some commercially made foods that are of higher quality when the dry milk to be incorporated is given specific heat treatment in processing. For example, milk to be used in bread is given a high heat treatment and that to be used in cottage cheese is given a low heat treatment. There does not appear to be an optimum heat treatment for dry milk intended for use in ice cream, pancake flour, or sausage products.

Coulter et al. (1951) expressed the opinion that dry milks intended for use in manufactured food did not need to meet as high standards of palatability and redispersibility as those for use in rehydrated forms. In general, roller-dried milks, even though not as soluble as spray-dried products, may be used with good results in commercially prepared foods.

Paul and Aldrich (1953) gave the advantages of substituting nonfat dry milk for fluid milk. The ease of storage, lack of weight, ease of incorporation in bakery products, the possibility of increasing the nutritive value of foods, and decreased cost were presented as considerations in favor of using dry milk. Since customer reaction in general was favorable, they concluded that the advantages outweighed the disadvantages and indicated that the use of nonfat dry milk would increase.

Factors Affecting Cake Acceptability

Definition of Cake Acceptability. According to Justin et al. (1956), all good butter cakes have certain characteristics in common:

> First, in external appearance the cake should be symmetrical in shape and only slightly rounded. If a layer cake it should be almost flat on top. The crust should be soft and even golden brown. It should have no appearance of 'sugariness;' that is, it should be neither crisp nor shiney. The cake should have raised so that it is a good size in proportion to the ingredients used and feels light.

> When cut, a good cake holds its shape and does not crumble excessively. The crumb is light and moist. The cake is tender, and the grain is fine and uniform. The color is in keeping with the ingredients.

A good butter cake is defined by West and Wood (1955) as follows:

> A good butter cake is uniform in thickness and attractive in appearance. The crust is delicate brown, tender, daintily crisp with no cracks. The cake should be light, tender, and agreeably moist but not sticky. It should have an even fine-grained texture, and a delicate well-blended flavor. An excellent butter cake has the characteristic commonly spoken of as 'velvetiness,' meaning that to the tongue or fingers it feels like soft velvet. A cake with this characteristic is always light and has a fine, even grain although these qualities do not insure the velvety feeling.

Role of Ingredients. The chief problem involved in cake preparation is the production and retention of gas in the batter, according to Cathcart (1951). Certain components of the batter aid in producing the gas, whereas the batter itself should be a stable emulsion which will retain the gas as it is being formed.

Pyler (1952) listed cake ingredients as follows: flour, eggs, milk, sugar, shortening, salt, chemical leavener, and flavoring. These ingredients may appear in formulas ranging from rich pound cake to lean, low-sugar, low-fat cakes. The proportions and kinds of ingredients were given by West and Wood (1955), as the factors governing the character of a batter as related to its gas retention property.

Cake Flour. In discussing cake flour, Garnatz (1938-39) emphasized that certain properties are imparted to it from the nature of the wheat from which it is made. When mixed in a batter, sufficient tender, pliable gluten in adequate amount is developed to ensure a fine cellular structure in the baked cake.

According to West and Wood (1955), the gluten of cake flour offers little resistance to the expansion power of the baking powder. A tender cake results when the gluten can be stretched by the expanding gases before the cell walls coagulate. These authors stated further that the gluten is strong enough to just carry the other ingredients in cake batters. That the absorption value or liquid carrying capacity of cake flour is relatively low was ascribed by Pyler (1952) to its low, soft gluten content. Cathcart (1951) suggested that the optimum protein content of flour for high-sugar ratio cakes was 7.5 to 8.5 percent.

According to Pyler (1952b) the pH of unbleached soft wheat flour is usually from 5.8 to 6.1. When the flour has been treated with chlorine or with chlorine and nitrosyl chloride, certain improving effects have been noted. When treated to give a pH of 5.0 to 5.3, the flour has optimum performance potential. The so-called improving action is responsible for the following: mellowing the gluten and thereby reducing the toughening action of the flour, lowering the pH, removing the coloring matter and making the starch more soluble as well as increasing its absorption and retention capacities. It is of interest that the bleaching of cooky flours is detrimental to their performance as has been shown by Shellenberger (1940-41).

It has been noted by Pyler (1952b) that the best results have been obtained when the flour particles were fine and uniform. He suggested that this might be due to better dispersion of the smaller particles during the mixing process.

Baking Powder. Baking powder aerates the batter during baking, making it light and porous, according to Pyler (1952b), and is responsible for good volume and color, tenderness and softness of crumb, uniformity of cell structure, and good general palatability of the baked cake. In cakes containing shortening, West and Wood (1955) mentioned that practically all of the leavening is done by the use of baking powder.

Double action baking powder is described by Pyler (1952b) as one that permits only enough gas to evolve at room temperature to form a smooth flowing batter. The remainder of the gas is formed at elevated temperatures during the baking process. In relating the use of double action baking powder specifically to large scale baking, West and Wood (1955) enumerated its advantages. The delayed action makes it most satisfactory for products that are of necessity to be held for a period of time before baking. One-third less is needed for this type of leavener than for other baking powders. Also, the cake can and should be baked at a lower temperature to allow maximum production and expansion of gas before the cake structure coagulates.

The importance of the correct pH in chemically leavened baked products was discussed by Stamberg and Bailey (1939). In general, white or yellow cakes with a pH of 7.22 to 7.35 were said to be of the best quality. Above the range of pH 7.0 to 7.9, the flavor and eating quality were inferior. Texture became finer with an increase in pH, but there was an optimum point beyond which the cake was crumbly.

Shortening. Most authorities agree that fat intended for use in cakes should have the property of plasticity. Lowe (1955) described a plastic fat as one that is of such consistency that it will form thin sheets and layers throughout the batter. A fat having this property also will retain air bubbles when "creamed." Commercially hydrogenated shortenings were recommended by West and Wood (1955) for cake making because of their inherent plasticity.

The irregular shape of fat particles in a batter emulsion is explained by Pyler (1952b) as being due to their plastic nature. In an ordinary emulsion, the fat particles appear spherical. It has been proposed by Pyler (1952a) that plastic fats are capable of being extended into streaks or films, thus giving maximum shortening power for their volume.

Bailey (1951) observed that vegetable shortenings have high creaming and mixing properties as well as high stability and uniformity when compared with lard. In explaining the ability of fat to entrap air bubbles during the mixing of a batter, Pyler (1952b) stated that no other ingredient is able to do this. Air bubbles are not found in other ingredients when batters have been examined under a microscope. Lowe (1955) reported that air is incorporated into the mixture as fat and sugar are creamed together. Pyler (1952b) agreed with this, and added that in high sugar ratio cakes, enclosed air contributes to the leavening of the cake.

Previous storage temperatures were found by Dunn and White (1937) to influence the baking characteristics of shortenings. Extremes of either high or low temperature caused deterioration in baking performance of the fats tested.

According to Lowe (1955), fat is mainly responsible for the soft velvety crumb of cake. This effect is brought about, as related by Pyler (1952b), by the coating of the gluten and starch particles. Numerous points of weakness are set up as a result of the separation of the gluten strands and starch particles. They are deprived of their cohesiveness, an inherent quality which if not interferred with, contributes to toughness. The degree of tenderness obtained is influenced by quantity of fat and extent of dispersion in mixing. There is mutual agreement that when fat is increased beyond the optimum amount, volume of the baked cake is adversely affected.

In combination with the other ingredients, shortening forms the emulsion that is the batter itself. Pyler (1952b) gave the emulsification value of a shortening as its ability to make a white cake when the proportion of flour to both sugar and water is low. Salt, sugar, and baking powder, after dissolving in the liquid, combine with the flour to form one phase of the emulsion. The fat becomes the other phase. Usually the fat is the internal phase. According to Lowe (1955), under certain conditions, the reverse may be found. Pyler (1952b) also stated that fats which naturally have a fine dispersion pattern, enhance the shortening effect more than do fats which disperse less completely. An important effect of emulsification is the holding of considerable liquid which favors maintaining the softness of the cake.

Eggs. The major functions of eggs, as listed by Pyler (1952) are their leavening, emulsifying, tenderizing, and flavoring power. Eggs also contribute to the improvement of color, moistness, and cell structure of the cake.

Liquid. Pyler (1952b) classified eggs as well as milk as liquid ingredients. Lowe (1955) listed the principal functions of liquid as a solvent for sugar, soluble salts, and proteins, and a hydrating agent for flour and egg proteins. Liquid is necessary for the gelatinization of the starch fraction of the flour. According to West and Wood (1955), the liquid most commonly used in batters is milk. They added that nonfat dry milk in either the dry or reconstituted form, may be used. When the nonfat dry milk is used as a dry ingredient, the liquid used would be water.

Nonfat Dry Milk. Several investigators have agreed that nonfat dry milk of either the conventional or the instant type may be scaled with the dry ingredients when used in baked products. Paul and Aldrich (1953) added the milk powder to the dry ingredients in making biscuits and griddle cakes. The American Dry Milk Institute (1953) recommended the same general procedure. For uses in which the milk is not reconstituted before being added to the dry ingredients, Coulter et al. (1951) suggested that solubility may be of only minor importance.

Paul and Aldrich (1953) reported that when substituting nonfat dry milk for fluid milk, recipes need be changed very little unless large amounts of nonfat dry milk are used in cakes, cookies, or bread. Then it may be necessary to reduce the flour, reduce both the flour and sugar, or increase the liquid or fat.

The American Dry Milk Institute (1953) called attention to the improvement in cake quality when the milk solids level is increased above that which can be obtained through the use of fluid milk alone. It has been shown that changes made in sugar and shortening are less hazardous to the batters when liberal amounts of nonfat dry milk are used. They suggest that due to the colloidal properties of milk proteins, this product has a stabilizing effect upon emulsions, for example, cake batters. This is a contributing factor to uniform cake production under variable shop conditions. O'Malley (1951) stated that the quality of products made from prepared mixes is improved by the use of dry milk.

A study of Morse et al. (1950) demonstrated that nonfat dry milk increased the browning of waffles, and that large amounts gave an undesirable flavor to the food products tested. They concluded that in the recipes tested, moderate amounts could be used with satisfactory results.

Balancing the Formula. In a cake formula, Coughlin credited the ingredients with performing counterbalancing functions. The major ones are toughening and tenderizing, moistening, and drying. In addition, he mentioned flavoring as a minor function. Flour, milk solids, and egg whites contribute to toughness. Sugar, shortening, and the fat of egg yolks supply tenderness; whereas fluid milk and eggs afford moistness; and flour, sugar, and dry milk lend dryness. Sugar and other ingredients furnish flavoring.

According to Pyler (1952b) a cake formula may be called balanced when the essential ingredients are in such relative amounts that they will produce a highly palatable product. Cake characteristics that rate excellent in structure, volume, flavor, and keeping quality are achieved by proportioning ingredients so that one functional influence offsets another. For example, toughening materials such as flour can be counterbalanced by tenderizing substances like shortening.

The six indispensible element s of good cake making, as given by Treat and Richards (1951), are as follows: correctly balanced formula, correct temperature of ingredients, accurate weights, controlled mixing of ingredients, proper proportion of batter to pan, and correct baking time and temperature.

Measuring the Ingredients. It was emphasized by West and Wood (1955) that failure to standardize recipes and to weigh and measure ingredients accurately may result in the production of inferior products. Such products either cannot be served or if served, they will create patron ill-will. In either case, losses accrue to the operator. Treat and Richards (1951) considered the weighing of ingredients mandatory for the attainment of consistently successful results in large quantity cookery. Uniformity of quality and portion control can be achieved only when ingredients are accurately weighed rather than measured. The precise scaling or measuring of ingredients is given by Pyler (1952b) as the first basic step in production.

Mixing the Ingredients. The chief objective in mixing the ingredients, according to Pyler (1952b), is to obtain their uniform dispersion throughout the batter and at the same time to incorporate a maximum amount of air and to minimize gluten development in the flour.

Panning the Batter. It has been recommended by Pyler (1952b) that cake batter be panned and baked as soon as possible after mixing to prevent the loss of carbon dioxide gas. When the batter is allowed to stand, small bubbles of the gas have a tendency to coalesce and in doing so, form a larger bubble of greater buoyancy, some of which escape while those remaining have the effect of predetermining a coarse cell structure in the baked cake.

Attention was called by West and Wood (1955) to the lack of information at the institutional level concerning the effect of pan size, shape, and material on the quality of baked products. Food services have often selected pans for reasons other than performance in baking such as filling specific space requirements. The material may have been dictated either by the supplier or by budgetary limitations. A large share of the pans used by institutional bakers are identical or similar to those used by homemakers. In 1949, Peet and Thye reported work done on the use of household-sized cake pans. They found that the surface of the cake was browner at the corners when a sharp-cornered pan was used. Too large a pan caused the cake to brown excessively, while a shallow pan favored the production of a coarsely-textured cake. Charley (1952) found that the top of the cake was flatter and the browning was less as shallower cake pans were used, but in general, that the size and shape of the pan had no effect on cake texture.

According to Lowe (1955), the batter should be one to one and one-half inches in depth to yield a cake with fine and velvety texture and that better volume can be expected if the sides of the baking pan are not greased.

<u>Baking the Batter</u>. West and Wood (1955) cited Fritsche (1949) who found that when aluminum pans were used, 350° F. was the best oven temperature, producing cakes with the largest volume, the best top color, and the finest and most even crumb. Pyler (1952b) advised using low baking temperatures of between 325° to 350° F. for high sugar ratio cakes. For yellow layer cake, 350 to 360° F. was recommended. It was considered essential by Pyler (1952b) that the cake be baked thoroughly in the least time possible in order to have maximum moisture retention.

<u>Color of the Baked Cake</u>. It has been stated by Lowe (1955) that the brown crust color of cake may be attributed to the products of the browning reaction. This phenomenon, common in food preparation, has been the subject of extensive investigation. In 1952, Haney studied the mechanism of the Maillard or browning reaction in bread and sugar cookies. He suggested that the primary browning reaction involves the alpha-amino group and the numbers one and two carbon atoms of the reducing sugars. This first step may be followed by condensation to form high polymers.

According to Lowe (1955), the primary reaction, which is reversible, is between the free amino group of an amino acid or protein and the aldehyde group of a reducing sugar. With time or with heating, a second reaction takes place in which the brown color is developed. In this step of the process, more reducing sugar is bound than can be accounted for by the free amino groups. The product is insoluble over a high pH range. During the second stage of the reaction, the mixture becomes more acid.

Many investigators agree that the browning reaction is accelerated by elevated temperatures and by an increased pH. Mohammad et al. (1949) reported that browning was accelerated by an increase in alkalinity. Barnes and Kaufman (1947) studied the rate of browning at different pH levels. They noted that browning was twice as rapid at pH 6 as compared with pH 4. The work of Nordin and Johnson (1957) supports the theory that the initial step of the browning reaction is reversible and that a neutral or alkaline pH is a favorable medium for this reaction.

Miller et al. (1957) stated that most of the browning occurs near the end of the baking period. In agreement with earlier studies by other workers, they believed that excessive browning of the cake crumb may occur when high concentrations of reducing sugars are present. This reaction is accelerated by an increase in pH, typical of the Maillard reaction. They found that most of the browning could be prevented by lowering the pH of the batter.

Two types of sugar cookies were baked by Griffith and Johnson (1957); one containing 60 percent sucrose and the other honey. Eggs or milk which contain reducing sugars were not included in the formulas. The only reducing sugar available was a small amount from the flour. They found that the cookies containing sucrose did not brown noticeably. The honey or reducing sugar containing cookies browned to a marked degree.

The color of the top of a baked cake may be due to the caramelization of the sucrose in the cake, according to Lowe (1955). Also, lactose is caramelized at a relatively low temperature. In discussing the effect of alkalies on sugar, Lowe (1955) stated that salts with alkaline reaction such as $NaHCO_3$ react with disaccharides. By the process of hydrolysis, disaccharides are hydrolyzed to glucose which turns yellow and then brown in the presence of alkali.

Cost. From the standpoint of the food service manager, the proportion of income spent for food appears to be an important consideration in selecting recipes and ingredients for the preparation of foods to be used in the menu. West and Wood (1955) summarized the interrelatedness of food cost and the successful operation of food services. Some of the expense items in the food service budget are fixed, whereas others, such as food cost, fluctuate. There may be an inverse relationship between food cost and profit whereby profit decreases as food cost increases. Effective control of the expenditures for food may be accomplished by efficient methods of purchase, storage, and preparation.

Two principles of good purchasing are to find out what foods are on the market and to ascertain which foods will best fit the needs of the food service. The amount of money available for food purchases, the storage facilities, and the location of the source of supply may in some cases dictate the amount and kind of food to be purchased.

When purchasing food, a proper balance should be kept between cost, quality, and use. The meaning of quality was stated as the best quality obtainable and acceptable for a particular use. Good food and expensive food are not necessarily synonymous.

Perishable raw food products such as fluid milk are a potential source of financial loss to the food service operator because they are vulnerable to careless handling and storage procedures in the interval between procurement and preparation. Low cost foods such as pastries and desserts on which a good profit can be made, may be put on menus to offset high cost foods such as meat on which only a small profit is realized.

MATERIALS AND METHODS OF PROCEDURE

Formula Used

The large quantity food formula used was adapted from the recipe published by Fowler and West (1950). This recipe employs the dough-batter method of mixing which uses a combination of mechanical and manual manipulation. It is easy to follow through, is relatively rapid, and uses few utensils. The original formula and method was:

Ingredients	Amounts	Method
Flour Fat Baking powder	1 lb. 9 oz. 10 oz. 2½ tablespoons	Mix 2 minutes in mixer bowl (low speed). Scrape down bowl and mix 3 minutes more.
	Add	
Sugar Salt Milk	1 lb. 14 oz. 1½ teaspoons 1½ cups	Mix 2 minutes (low speed) and scrape down bowl; mix 3 minutes more.
		Add ½ following mixture; mix 30 seconds. Scrape down bowl; mix 1 minute. Add remainder of mixture. Mix 1 minute. Scrape down. Mix 2½ minutes.
Eggs, whole Milk Vanilla	5 1-2/3 cups 1 tablespoon	Mixed.
Bake 30-35 min. 350° F.		Pour into oiled pan 12 x 20 inches or six 9 inch layer pans.

One hundred fifty-five cakes were made to develop techniques and to standardize procedures for preparing and testing the batters and the baked product. In addition to the revised recipe calling for fluid whole milk, two formulas were developed using instant nonfat dry milk to replace the fluid milk. One specified instant nonfat dry milk and water, and the other designated additional shortening equivalent to the fat content of whole milk.

Armour's conversion table was used to aid in determining the amount of milk powder, water, and shortening to be used. The formula and method for plain cake with fluid whole milk (I) used throughout the investigation was:

Ingredients	Weights (g)	Method
Flour	693	Mix 2 minutes in mixer bowl (low speed). Scrape down (5 strokes--bowl, 6 strokes--beater). Mix 3 minutes.
Baking powder	43	
Fat	284	
		Add
Sugar	851	Mix 2 minutes (low speed). Scrape down (6 strokes--bowl, 9 strokes--beater). Mix 3 minutes.
Salt	7	
Milk	305	
		Mix separately
Eggs	284	Add ½ of mixture to mixer bowl. Mix 30 seconds. Scrape down (8 strokes--bowl, 8 strokes--beater). Mix 1 minute. Add remainder of mixture to mixing bowl. Mix 1 minute. Scrape down (8 strokes--bowl). Mix 2½ minutes.
Milk	404	
Vanilla		
Bake 43 minutes at 350° F.		Pour 1950 grams into greased pan, 12 x 18 x 2 inches. Cool on wire rack.

The formulas used throughout the investigation for the plain cake with instant nonfat dry milk and water (II) and instant nonfat dry milk, water, and additional fat (III) were:

Ingredients	Weights (g) (II)	Weights (g) (III)	Method
Flour	693	693	Mix 2 minutes in mixer bowl (low speed).
Baking powder	43	43	Scrape down (5 strokes--bowl, 6 strokes--beater).
Dry milk	62	62	Mix 3 minutes.
Fat	284	310	
			Add
Sugar	851	851	Mix 2 minutes (low speed).
Salt	7	7	Scrape down (6 strokes--bowl, 9 strokes--beater).
Water	354	354	Mix 3 minutes.
			Mix separately
Eggs	284	284	Add ½ of mixture to mixer bowl. Mix 30 seconds.
Water	267	267	Scrape down (8 strokes--bowl, 8 strokes--beater).
Vanilla	14	14	Mix 1 minute. Add remainder of mixture to mixer bowl. Mix 1 minute. Scrape down (8 strokes--bowl). Mix 2½ minutes.
Bake 43 minutes at 350° F.			Pour 1950 grams into greased pan, 12 x 18 x 2 inches. Cool on wire rack.

Schedule of Experimental Work

Each formula variation was repeated 24 times in a balanced incomplete block design, Table 2. A baking period consisted of mixing and baking three cakes. The cake formula utilizing fluid homogenized milk is designated as treatment I; that using instant nonfat dry milk and water as treatment II; and that having instant nonfat, dry milk, water, and additional fat as treatment III.

Table 2. Schedule of baking periods and balanced incomplete block design.

Baking period	Treatments		
1	I	II	II
2	II	I	I
3	III	III	III
4	II	I	II
5	II	III	III
6	I	I	III
7	I	II	II
8	III	I	III
9	I	III	II
10	III	I	II
11	I	II	III
12	III	I	II
13	III	I	I
14	III	II	I
15	II	II	III
16	II	III	III
17	I	I	III
18	II	I	II
19	I	I	II
20	III	III	III
21	II	II	I
22	II	III	III
23	I	I	I
24	II	II	III

Procurement of Ingredients

An attempt was made to have the ingredients as nearly identical as possible. A one week's supply of homogenized milk from the same dairy, and Grade A large fresh eggs from the same flock were purchased once a week from a local grocery. This purchasing was done late in the afternoon of the day before the ingredients were to be weighed. The other ingredients were obtained in sufficient quantity for all baking periods.

Fine granulated sugar, cake flour, and instant nonfat dry milk were procured in 100-pound bags. Other ingredients included 10-pound cans of double-acting baking powder, 1-quart bottles of pure vanilla extract, 1-pound boxes of table salt, and 110-pound cans of hydrogenated vegetable shortening. The same shortening was used for both the cake and for greasing the baking pans. When instant nonfat dry milk was used, tap water was the liquid.

Storage of the Ingredients before Weighing

The unopened bags and containers of all ingredients were stored at a temperature of approximately 35 to 40° F. in a walk-in refrigerator. Two covered stainless steel bins were used to store the opened bags of flour and sugar in the laboratory at room temperature. A third bin was used to keep the instant nonfat dry milk in the walk-in refrigerator.

A supply of shortening was allowed to remain over night at room temperature before it was weighed. Between weighing periods, the salt, baking powder, and vanilla were kept tightly covered at room temperature in the laboratory.

Paper cartons of milk and eggs were held at a temperature of approximately 40° F. in the experimental kitchen refrigerator. Before each weighing period, the fluid milk remained overnight in the refrigerator. The eggs were refrigerated until the mixing period.

Procedure for Weighing the Ingredients

With the exception of the eggs, all of the ingredients for the cakes to be baked the following week were weighed on the day following procurement. A Toledo gram balance was used. Individual ingredients were scaled into separate containers which were then tightly covered and stored. Flour, sugar, instant nonfat dry milk, and shortening were put into two-quart, one-quart, and one-pint square plastic freezer boxes, respectively. The fluid milk and the water were each divided into two parts. That portion of liquid to be mixed with the vanilla was put into a two-quart container and the remainder was put into a one-pint container.

Glass jars were used for weighing the salt, vanilla, and baking powder. A glass funnel was used to put the salt into bottles, and an eyedropper aided in measuring the correct amount of vanilla. Baking powder was placed in the jars with a small spoon.

From the bulk shortening, block-shaped pieces were first weighed onto 12 x 13 inch pieces of heavy waxed paper and then wrapped before putting in the containers for storing. At this time, fat for greasing the baking pans was weighed into 5-ounce Pyrex cups.

The procedure for weighing the eggs was carried out at the beginning of each mixing period. A change was made from the original recipe in that the eggs for three cakes were thoroughly mixed and then blended with the liquid ingredients before adding to the dry ingredients.

Storage of the Weighed Ingredients

For the experimental work, flour, sugar, salt, fat, and baking powder were stored in an incubator at a temperature of 22° C. (71.6 F.). Instant nonfat dry milk and the liquids were stored in the laboratory refrigerator at a temperature of approximately 40° F. (5° C.), and were conditioned in the incubator prior to use.

Procedure for Mixing the Batter

A 12-quart Hobart mixer was used to prepare the batter. All of the mixing was done at low speed. The bowl and the beater were cleaned periodically of the material that adhered during the mixing. In the instructions of the original formula, this was referred to as scraping down. In the present work, the scrape-down process was standardized. For a scrape-down period, the motor was stopped and the mixer bowl lowered. One stroke was counted for either one complete circular motion close to the sides of the bowl or one straight movement across the bottom of the bowl. The number of strokes to be used was noted in the outline for the procedure of mixing given with the adjusted formulas.

Next, the flour, shortening, and baking powder were removed from the incubator. When dried milk was to be used, it was taken from the incubator at the same time. These ingredients were put in the center of the mixer bowl in the following order: flour, baking powder, dry milk, and shortening. Rubber scrapers were used to remove all the material possible from each container.

The ingredients were mixed for two minutes. Using five strokes, a spatula with a flexible 10-inch steel blade was used to scrape down the sides of the mixer bowl. One stroke with the steel spatula was used to scrape down each side of the flat beater. Four strokes with the rubber scraper were used to remove the mixture from the narrow sides of the beater and from between the ribs of the beater. Each scraper was used to clean off the other one between strokes, on this and succeeding scrape-downs.

During the three minutes of further mixing, the containers of sugar, salt, and the first portion of the milk or water were removed from the incubator and uncovered. These ingredients were then added and the mixing was continued for two minutes. The bowl was scraped down using six strokes with the steel spatula. Two and seven strokes, respectively, were used on the broad sides and other parts of the beater as before. The mixture was then blended for three minutes more.

During this period, the container of egg-liquid mixture was taken from the incubator and one-half of it by weight was scaled into the one-quart empty sugar container. This mixture was added to the batter and the beater was turned on for 30 seconds. Employing similar scraping techniques to those described before, the bowl and beater were scraped down with eight strokes for each part of the operation.

Following a one-minute mixing period, the remaining egg-liquid mixture was added and the batter was again mixed for one minute. For the next step of the procedure, the bowl only was scraped down with eight strokes of the steel spatula. The batter was then mixed for two and one-half minutes to complete the mixing process. After the mixing period, the bowl was removed from the mixer.

While the batter was mixing for the final three minutes, the oven temperature was checked and, if necessary, adjusted and the baking pan was weighed.

Procedure for Panning the Batter

More batter was produced than was required because the amounts of egg and baking powder were increased and a smaller baking pan was used than was called for in the original recipe. It was ascertained in the preliminary work that 1950 grams of batter would give baked cake of sufficient size for the measurement of volume by seed displacement and standing height, as well as provide samples adequate for the tenderness, compressibility, and organoleptic tests.

Approximately 2500 grams of batter was scaled into the weighed baking pan and evenly distributed with the aid of a rubber scraper. Enough batter was then removed from the pan to leave the 1950 grams to be baked. This procedure facilitated distribution and weighing of the batter. Portions of the batter remaining in the mixing bowl were used for determining the consistency, specific gravity, and pH.

Procedure for Baking the Batter

After placing the pan in the oven, the timer was started and the cake was baked for 43 minutes at a temperature of 350° F. A small type directly-fired baker's oven was used. This style oven was similar to the one described by Pyler (1952), and consisted of a large baking compartment heated by free convection from a single gas unit in the bottom of the oven.

The baking compartment was equipped with a motor-powered mechanism from which four shelves were suspended in ferris wheel fashion. The shelves of open or grid construction were attached to vertically revolving wheels by means of stabilizer arms that prevented swaying of the suspended shelves when the apparatus was in motion. Direction of the rotation could be changed by use of a reversing switch lever near the outside of the oven door.

Procedure for Testing the Batter.

All of the tests were done in the Institutional Management Experimental Laboratory with the exception of those for standing height, tenderness, and compressibility of the baked product, which were carried out in the Experimental Foods Laboratory of the Department of Foods and Nutrition in the School of Home Economics.

Temperature. Immediately after mixing, a centigrade chemical thermometer was placed in the bowl of batter, where it remained until after the completion of the first viscosity test. The temperature was then read and recorded.

Viscosity. Viscosity was determined by adapting a simple method sometimes used for testing the viscosity of paints and oils. The device used consisted of a bullet-shaped stainless steel 57-cc cup attached to a looped metal handle approximately 11 1/2 inches long. A small ring at the top of the handle aligned the cup in a vertical position when withdrawn from the liquid to be tested. The cup had an orifice 0.168 inch in diameter in the bottom. A stop watch was used to time the number of seconds required for the 57 ml of fluid to flow through the orifice.

Other workers in testing the viscosity of batters have used a method which times the flow of batter between two measured marks on the stem of a glass funnel with an 8-mm bore. With thick batters it took a considerable length of time for the batter to move from one mark to the other.

For the present work, the cup was altered by increasing the orifice to 8 mm by precision drilling. This enlarged the opening so that even with thick batters, a more rapid viscosity determination could be made than by the funnel method. Immediately after the bowl was removed from the machine, the viscosimeter was held in a vertical position and lowered until the cup was submerged in the batter. The stop watch was started as the top edge of the cup broke the surface of the batter, and stopped when the steady flow of batter suddenly ceased. In this interval, the bottom of the cup was approximately 6 cm from the batter in the mixing bowl.

The time in seconds of the uninterrupted flow was recorded as the viscosity. The figures for three flow-times were averaged and recorded as the viscosity of each batter. Calculations were made to one decimal point. Higher values indicated less viscous batters.

After scaling the batter to be baked, the remainder was divided into portions for a further test for viscosity, and for determining specific gravity and pH values.

The second test for viscosity was done by the line-spread method using a paper diagram of equally-spaced numbered concentric lines placed between two sheets of glass and a metal ring having the same circumference as the smallest circle. The distance between any three adjacent lines was equal to one centimeter. The metal ring was five centimeters in diameter and two centimeters high.

The ring was filled with batter, leveled with a rigid steel spatula, and lifted from the glass, allowing the batter to flow for 30 seconds. Timing was done with a Kodak timer. The spread was read in four positions, the values noted, and the average of these figures was recorded as the viscosity of the batter. Higher values suggested less viscous batters.

Specific Gravity. To calculate specific gravity, batter was placed in a 51-ml flat-bottomed, straight-sided metal cup. Large air bubbles were removed by cutting through the batter 12 times with a spatula. The surface was leveled with the edge of the same spatula. The cup was weighed on an Ohaus trip balance and the weight of the batter was divided by the weight of an equal volume of water at room temperature. Three decimal places were figured and recorded as the specific gravity of the batter. Batters of low specific gravity may be less dense than those of high specific gravity.

pH Determination. Fisher scientific short-range alkacid test papers were dipped consecutively into the cup of batter following the specific gravity test. Excess batter was removed from the paper by drawing it over the edge of the cup. Before each strip dried, its color was compared with all colors on the case from which it was taken. Each color on the case was numbered with the appropriate pH value. The number of the nearest matching color was recorded as the pH of the batter.

Procedure for Testing the Baked Cake

Volume by Seed Displacement. When the cake cooled to room temperature, the volume was measured by seed displacement. An aluminum baking sheet, 20 x 26 inches, was covered with a piece of white muslin, and the pan of cake placed in the center of the cloth. Rape seed that had been kept in the refrigerator was poured around the edge of the cake to fill the space where it had pulled away from the sides in baking. Without removing the cake pan from the baking sheet, it was shaken moderately a few times to facilitate getting the seeds into this space. More seed was poured on the surface of the cake and a straight edge 24 inches long was used as the leveling device. The filled pan was set aside and the excess seeds were gathered in the cloth and poured into a container.

The cloth was again spread on the baking sheet and the filled pan placed in the center. The overhanging side portion of the cloth was drawn over the top of the pan which was then inverted while the cloth was held securely. At this point in procedure, the cloth simulated a tent which kept the seeds from bouncing and rolling. After the loose seeds had fallen from the cake surface, and while still inverted, the pan was shaken gently to further dislodge the seeds. Next, the pan was turned right side up and the seeds that still adhered to the cake surface were brushed onto the cloth, using a pastry brush.

The cake was removed to the rack. The seeds were poured from the cloth into a glass funnel resting in a 500-ml graduate. The seeds were measured and the volume in milliliters was subtracted from the known capacity of the pan. The resulting value was recorded as the volume of the baked cake.

Cutting the Test Piece. After the volume was measured by seed displacement, an 8-inch square piece was cut from the center of the cake. A cutting frame of cardboard covered with aluminum foil was used to guide the knife. The parts of the cake at the sides and at each end were lifted from the pan with spatulas and discarded. That area of the square to be used for the test slices was numbered with toothpicks to identify each cake in the series. A long flexible steel spatula was used to free the cake from the pan. Using a broad cake turner, the square was lifted from the pan and transferred to the palm of one hand. With the unmarked side nearest the open end, the cake was slipped into a pliofilm bag. Both ends of the bag were folded under before placing on an overturned tray and storing in the incubator overnight.

Cutting the Test Slices. On the morning following the baking period, the 8-inch square was removed from the incubator and cut into sections in a mitre-box similar to the one described by Tinklin (1944). A one-inch section of wood was cut from each side at the closed end of the box to facilitate the removal of each slice as it was cut. The cake was placed in the box with the side marked by the toothpicks touching the closed end. A one-inch slice was cut with a light sawing motion of a thin knife that had a blade 12½ inches long and 5/8 inch wide. After the cut was made, the knife served as a spatula in transferring the slice to a wax paper covered tray. The slice was placed on the tray so that the top crust was to the left. A second and a third slice were cut and transferred to the tray in the same manner.

The 8 x 5-inch section was used later in judging the cake for symmetry and top crust characteristics. As shown by Plate I, portions of the 8 x 1-inch slices were cut for samples for the palatability committee of eight members. Each judge evaluated one sample from each cake. A one and one-half inch piece cut from the ends of each of the slices furnished six of the eight samples. A seventh and eighth sample of the same size were taken from the left side of the first and second slices after they were used in testing for tenderness.

Standing Height. The center of each 8-inch slice was marked by inserting a toothpick at the point four inches from the ends. A second and third toothpick were placed at points midway between the center and the ends of each slice. Measurements of the height

EXPLANATION OF PLATE I

Eight-inch Square Cut from the Center of the Cake

Fig. 1. Positions 1, 2, and 3 represent location of samples for the tenderness and compressibility readings.

Fig. 2. Positions 1, 2, 3, 4, 5, 6, 7, and 8 represent location of samples for palatability panel.

Position 9 represents location of 8 x 5-inch piece for external appearance evaluation by the palatability panel.

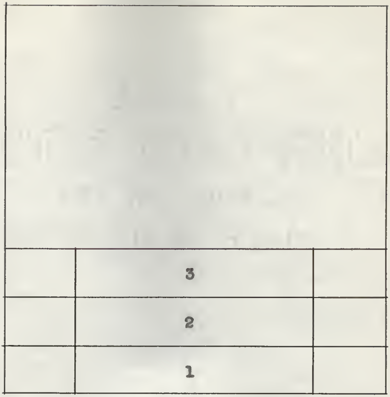

Fig. 1

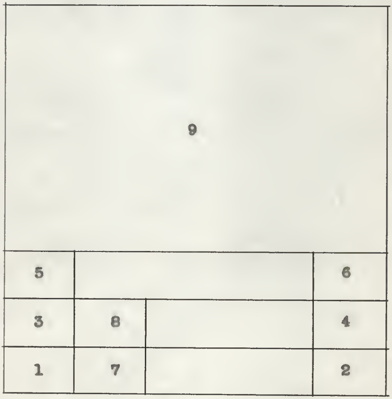

Fig. 2

of the slice at each end and at the three points marked by the toothpicks were taken and recorded. The average of these measurements was taken as the standing height of the slice, and the average for three slices was recorded as the standing height of the 8-inch square. A large value for standing height was an indication of great volume.

The section of cake left in the mitre-box was transferred to the tray and the 8-inch square was reconstructed. From this point, the cake was kept covered with a 9 x 9 x 2½-inch aluminum cake pan with the exception of the intervals when the slices were being removed or replaced during the testing for tenderness and compressibility.

Tenderness. In testing for tenderness, a shortometer was used to measure the force necessary to break a slice of cake five inches long and one inch thick. The apparatus consisted of a modified spring balance and a remodeled laboratory balance. The platform of the spring balance was fitted with two parallel bars three inches apart on which the slice of cake was supported. Two hands on the dial were fashioned so that one of them moved the other as weight was applied to the platform. From one of the pans of the laboratory balance, a third bar was suspended which was the breaker bar. The spring balance was placed directly under the breaker bar. The laboratory balance pan could be used in either a high or a low position. For this test it was placed in the high position.

The slice of cake was centered on the parallel bars with the top crust to the back. An adjustment was made to the breaker bar so that it was parallel to the platform bars as well as centered on the cake. The hands of the dial were set in a way that enabled one hand to act as a prod for the indicator hand. At the start of the test, the breaker bar, the center point of the cake slice, and the zero mark on the dial were in alignment.

Distilled water was siphoned at a constant rate into a 250-ml beaker placed on the balance pan above the cake. The flow of water was continued until the slice broke. As the increasing weight of the water lowered the balance pan, the attached breaker bar exerted force on the cake. This force was transmitted to the dial as was shown by the movement of the hands on the dial. When the slice broke, the pusher hand returned to zero, and the indicator hand stopped and remained stationary at the point where the breaking force was registered in grams. This procedure was repeated on the second and third slices and the average of the three slices was recorded as the value of tenderness for the cake. After testing, each broken slice was returned to its original position in the reconstructed cake sample.

Compressibility. Following the test for tenderness, the right-hand piece of each broken slice was tested for compressibility by using the laboratory balance with certain modifications. Mounted over one of the balance pans was a wooden drum that had a 200-gm chain fastened near one end. The chain could be wound and unwound by turning a handle at the end of the drum. When wound, the chain was lifted from the pan at a constant rate, thus assuring a corresponding steady transmission of weight to the plunger as it penetrated the cut surface of the cake.

Before the test was started, the following adjustments to the apparatus were made: the spring balance was removed; a metal plunger replaced the breaker-bar; an elevated platform mounted at the side, was turned into position and centered under the plunger; and the balance pan was lowered. Throughout the test, a 200-gm weight remained on the balance pan opposite the plunger.

The piece of cake to be tested was centered on the movable platform. After a 200-gm counterbalance was put in place, a 10-gm weight was added which had the effect of making a contact between the plunger and the cake. If necessary, the pointer at the base of the apparatus was adjusted to zero by sliding a paper millimeter scale.

The chain was wound on the drum with 10 turns of the handle at the rate of one revolution every three seconds. As the weight of the chain was lifted from the pan, the plunger penetrated the slice. The weight of the plunger was allowed to act for 90 seconds more and the depth of penetration of the crumb by the plunger weight was indicated by the position of the pointer on the millimeter scale. This value was recorded as the compressibility of the cake. The larger the number, the softer the cake.

Organoleptic Test. A palatability committee composed of three faculty members, four graduate students, and an office worker used a descriptive term and number type of rating scale in evaluating the external appearance, internal characteristics, and the flavor of the cakes. Possible scores ranged from perfect, six points, to bad, one point.

After cutting, the eight samples from each cake were numbered and placed on a wax paper covered tray in positions corresponding to the judge's place in the series. Samples for each committee member were from the same location in each cake. The tray was then covered with aluminum foil and stored in the incubator for approximately two hours. Meanwhile, numbers corresponding to the number of cakes to be sampled were marked clockwise on each of eight white china plates.

At the end of the two-hour period the tray was uncovered, the samples were transferred from the tray to the plates and covered with aluminum foil. The sections of cake remaining after the palatability samples were cut were placed on a tray, covered with aluminum foil, and stored with the taste samples. An appraisal was made by the judges of the shape and surface characteristics of the large sections. Sampling was done during the afternoon at the convenience of the committee members.

Statistical Analyses

Analyses of variances were run to study the effect of using fluid homogenized milk, instant nonfat dry milk and water, and instant nonfat dry milk with additional fat on the batter temperature, viscosity as measured by an adaptation of the Zahn viscosimeter and the line-spread test, and on the specific gravity.

Analyses of variance were done also to study the effect of using the three treatments on the volume of the whole cake, on the volume of an eight-inch sample by standing height, and on the shape, lightness, surface, texture, grain, color, flavor, tenderness, and compressibility of the baked cake.

When significant differences occurred among the three treatments, i.e., three formulas, ordered arrays of means were analyzed by least significant differences.

In addition, correlation coefficients were determined from data on batter for viscosity and batter temperature, and viscosity and specific gravity; and on the baked cake for viscosity and volume, viscosity and compressibility, viscosity and shape, viscosity and grain, specific gravity and volume, specific gravity and tenderness, specific gravity and compressibility, specific gravity and texture, and specific gravity and grain. It should be pointed out that when the statistical work was done, the data for all treatments were pooled in calculating correlation coefficients for the various factors rather than using the data for each treatment.

RESULTS AND DISCUSSION

Observations on the Batter

Large quantity cakes using fluid homogenized milk (treatment I), instant nonfat dry milk and water (treatment II), and instant nonfat dry milk and water with additional fat (treatment III) were made by the dough-batter method of mixing. Certain characteristics of the batter were observed at several stages during mixing and at the time of panning.

Mixing the Dry Ingredients and Fat. When the dry ingredients and fat were mixed, no differences in either the appearance of the mixture or the ease of manipulation during the scrape-down process were observed among the batters given the three treatments. At the end of the five-minute mixing period, the dry ingredients and fat gave the appearance of a dry, coarse meal, a creamy off-white in color.

Adding the First Portion of the Liquid Ingredients. In treatments II and III, using dry milk and water, the batter appeared glossy and white as compared with the mixture of dry ingredients and fat. Most of the batter stayed in the bottom of the mixing bowl, whereas a relatively small amount adhered to the beater. Moderate effort was required for the scrape-down process. Batter containing fluid homogenized milk was dull, but otherwise similar in appearance to the dry milk batters. In treatment I, there was a tendency for the batter to ride on the sides of the bowl and the beater. Considerable effort was needed to carry out the scrape-down procedure.

Adding One-half of the Egg-liquid Mixture. At this stage of the mixing, all batters were light yellow in color, smooth, and similar to whipped cream in consistency. With the exception of a tendency for the batter to adhere to the sides and bottom of the bowl when fluid homogenized milk was used, there were no apparent differences among the batters given the three treatments.

Adding the Remainder of the Egg-liquid Mixture. The consistency of all batters became thinner when the last portion of liquid was added. At this time, the batter made with dry milk and extra fat seemed to be somewhat thicker than that made with dry milk only. There appeared to be no great difference in the ease of manipulation during the scrape-downs.

Panning the Batter. In the majority of cases when panned, the batter with extra fat looked thicker than the batters made with dry milk and water or fluid homogenized milk. The former stood in waves, whereas the other batters seemed to flow more evenly. All the batters had a slightly curdled appearance that was especially evident on the sides of the mixing bowl after the 1950 grams of batter for baking had been removed.

When some of the pans of batter were placed on the suspended shelves of the oven, the batter flowed to the side of the pan nearest the oven door. In all probability, the shelves tilted forward causing the level of the cake to slant. No attempt was made to record which cake batters were affected. It was thought that perhaps this "one-sidedness" at the beginning of baking might be a characteristic of the thinner batters, and that it might be reflected in the shape of the baked cake. However, these assumptions were not supported by the data obtained.

Objective Tests on the Batter

The temperature of the mixing room and the temperature of the batter were recorded every time a cake was mixed. In addition, the viscosity of the batter was measured using an adaptation of a Zahn viscosimeter and by the line-spread test. Also, the specific gravity and pH of the batters were determined. Average of mean values for these tests are presented in Table 3. The detailed data are in Tables 8 through 10 (Appendix).

Room Temperature. Throughout the experiment, the temperature of the mixing room ranged from 24° to 30° C., and averaged 27.3°,

Table 3. Effect of the type of milk upon the characteristics of the batter.

Treatment	Batter					
	Viscosity					
	Room temp. ° C.	Batter temp. ° C.	Viscosimeter sec	Line spread cm	Specific gravity	pH
I Homogenized milk	27.3	22.8	12.3	1.83	0.903	8.0
		ns	*	ns	*	
II Dry milk and water	27.3	22.6	10.7	1.76	.867	8.0
		ns	*	*	ns	
III Dry milk, water plus fat	27.8	23.2	5.7	1.42	.857	8.0
	--	--	lsd 1.5+	lsd 10.12	lsd .016	

ns - nonsignificant.
* - significant at the 5% level.
lsd - least significant difference.

27.3°, and 27.8° C. for batters made with homogenized milk, nonfat dry milk and water, and nonfat dry milk and water plus fat, respectively (Table 3). Therefore, the temperature of the room probably had little effect on the characteristics of the batter and the baked cake.

Batter Temperature. It was pointed out by Lowe (1955) that the temperature of the ingredients when mixed, influences the structure of the batter and the baked cake. Temperature influences the behavior of the fat, sugar, and protein in a batter. In the work reported here, the temperature of all batters ranged from 20° to 26° C. (68.0° to 78.8° F.). However, the mean temperatures for batters given treatments I, II, and III were 22.8°, 22.6°, and 22.2° C., respectively (Table 3). In examining possible relationships of batter temperature to the viscosity, specific gravity, and pH of the batter, as well as to the volume, tenderness, and compressibility of the baked cake, it was believed that any results noted were probably due to the treatment used rather than the batter temperature.

Batter Viscosity. The higher the values (both viscosimeter and line-spread) for the viscosity of the batter, the thinner the batter. When measured in the viscosimeter, the average of mean values for the viscosity of the batters given treatments I, II, and III were 12.3, 10.7, and 5.7, respectively (Table 3). The batters containing homogenized milk were significantly thinner than those made with instant nonfat dry milk. The batters containing instant nonfat dry milk and water were significantly thinner than those made with instant nonfat dry milk and water plus fat. The values obtained with the line-spread test ranked the viscosity of the batters given the three treatments in the same order as those obtained with the viscosimeter. However, the differences between the line-spread values for batters given treatments I and II were nonsignificant (Table 3).

When correlation coefficients were determined for the viscosity of the batter as measured by two methods (the viscosimeter and the line-spread test) and the batter temperature (Table 4), a positive but nonsignificant correlation was found in each case. The data from all three treatments were pooled for these calculations.

Batter Specific Gravity. The mean specific gravity of the batter using homogenized milk was 0.903 and that for batter made with instant nonfat dry milk and water was 0.867 (Table 3). There was a significant difference between these two batters. The difference in specific gravity between batters made with instant nonfat dry milk and instant nonfat dry milk plus fat was nonsignificant.

Specific gravity and viscosity values showed a significant ($P < .001$), but low positive correlation. The thinnest batters had the highest specific gravities (Table 3). The mean specific gravity of the cakes made with homogenized milk was higher than that of either of the cakes made with instant nonfat dry milk.

Batter pH. According to Stamberg and Bailey (1939), the kind and quantity of baking powder influence the pH of batters more than any other common ingredient. They stated that dry milk, when used in a cake formula in the proportion of 8 to 30 parts to 100

Table 4. Correlation coefficients.

Variables correlated	r and significance
Viscosity (visc.) and batter temperature	0.012 ns
Viscosity (line spread) and batter temperature	.120 ns
Viscosity (visc.) and specific gravity	.469 ***
Viscosity (line spread) and specific gravity	.508 ***
Viscosity (visc.) and volume (seed disp.)	- .332 **
Viscosity (line sp.) and volume (seed disp.)	- .307 **
Viscosity (visc.) and tenderness	- .047 ns
Viscosity (line sp.) and tenderness	.051 ns
Viscosity (visc.) and compressibility	.126 ns
Viscosity (line sp.) and compressibility	.144 ns
Viscosity (visc.) and shape	.197 ns
Viscosity (line sp.) and shape	.368 **
Viscosity (visc.) and grain	.227 *
Viscosity (line sp.) and grain	.197 ns
Specific gravity and volume (seed disp.)	- .548 ***
Specific gravity and tenderness	- .098 ns
Specific gravity and compressibility	.346 **
Specific gravity and texture	.264 *
Specific gravity and grain	.220 ns
Tenderness and compressibility	- .375 **

ns - nonsignificant.
* - significant at the 5% level.
** - significant at the 1% level.
*** - significant at the 0.1% level.

parts of flour (8 to 30 percent) has no significant effect on the pH of the batter. In the present work, the kind and amount of baking powder was the same in all batters, and the proportion of dry milk used was equal to 9 percent of the flour. Fisher scientific short-range alkacid test papers were used to test for pH. All of the batters appeared to have pH values of approximately 8 (Table 3).

Observations on and Judges' Scores for the Baked Cakes

A committee of eight judges rated sections of the 8-inch cake sample for certain external and internal qualities as well as for flavor. A rating scale, ranging from perfect with a value of six points to bad with a value of one point, was used. An 8 x 5-inch section was evaluated for external qualities of surface and symmetry of shape. The theoretically perfect cake used as a basis for comparison was described as having a rounded top, free from cracks or peaks, and a smooth, uniform, golden brown surface. The 1½-inch samples to be judged were evaluated for lightness in weight in proportion to size; for texture qualities of tenderness, moistness, and velvetiness of crumb; for fineness and evenness of cells; for uniform characteristic color; and for a pleasing flavor. A summary of the averages of the mean scores for these factors will be found in Table 5.

Appearance of the Crust. There was a difference in the pattern of browning of the crust on the cakes made with homogenized milk and of that on those made with dry milk as shown in Plate II. Each cake made with homogenized milk had a golden brown border

Table 5, Judges' scores for cakes made with homogenized milk, nonfat dry milk, and nonfat dry milk plus fat.

Treatment	Surface	Shape	Lightness	Texture	Grain	Color	Flavor
I Homogenized milk	5.1	4.8	4.7	4.9	5.0	5.6	5.2
	*	*	ns	ns	*	ns	ns
II Dry milk and water	4.2	4.2	4.9	4.8	4.7	5.6	5.3
	ns	ns	ns	ns	ns	ns	ns
III Dry milk, water plus fat	4.2	4.4	4.8	4.8	4.8	5.6	5.3
	lsd .30	lsd .35	--	--	lsd .21	--	--

Rating scale: 6 Perfect
5 Excellent
4 Good
3 Fair
2 Poor
1 Bad

ns - nonsignificant.
* - significant at the 5% level.
lsd - least significant difference.

EXPLANATION OF PLATE II

Browning Effect on Top Crust of Cake

Fig. 1. Shows dark line bordering brown area on surface of cake made with homogenized fluid milk.

Fig. 2. Shows dark area on surface of cakes made with nonfat dry milk.

PLATE II

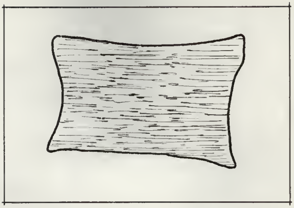

Fig. 1

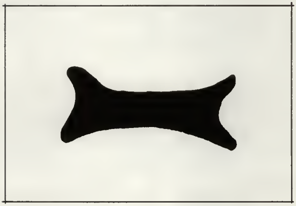

Fig. 2

that was wider at the ends of the pan. A medium brown line was the common boundary for the inner edge of the border and the outer edge of the approximately rectangular area in the center. This area was darker in color than the border, but lighter than the adjacent line.

The crust on cakes made with instant nonfat dry milk and water or instant nonfat dry milk and water plus fat had a dull, light brown border and a darker brown free-form area in the center that tapered toward the middle of the cake. The dry milk cakes tended to have browner crusts than the homogenized milk cakes. No attempt was made to measure the brown areas or their intensity of brownness. The cakes made with homogenized milk tended to have a uniformly smoother crust, particularly in the center area, than those made with dry milk.

The appearance of the crust or surface was evaluated by a committee of judges. Average of mean scores for this factor are given in Table 5. The surface of the cakes made by treatments I, II, and III received average scores of 5.1, 4.2, and 4.2, respectively. There were significant differences between the average of mean surface scores for cakes made with homogenized milk and those made with dry milk, but there were no differences in the average of mean scores for the cakes made with instant nonfat dry milk and water and instant nonfat dry milk and water plus fat. In institutional food services, cakes usually are served with toppings such as icing or sauce. Consequently, the surface characteristics generally are of minor importance.

Shape of the Cake. There was some variation in the symmetry of the cakes. When a whole cake was higher on one side than on the other, this probably was brought about by the slanting position of the oven shelf. This irregularity may have been minimized or obscured in the general outline of the 8 x 5-inch sample section judged by the palatability committee. Some of the judges commented that certain of the cakes appeared to have fallen in the center. This was supported by measurements of the test slices. However, the differences in measurement between the center and side slices were small.

Average of mean scores for the shape of the cakes may be found in Table 5 and the detailed data in Tables 11 through 13 (Appendix). There was a statistically significant, but not a practical difference between the average mean scores for cakes made with homogenized milk and those made with dry milk. The difference was in favor of the homogenized milk cakes, and it was only 0.4 to 0.6 of a point.

Correlation coefficients were calculated from the data for shape of the cake and viscosity of the batter as measured by the viscosimeter and the line-spread test (Table 4). The data from treatments I, II, and III were pooled in these calculations. There was a significant ($P < .01$) but low positive correlation between shape and viscosity as measured by line spread. The correlation coefficient for these factors was nonsignificant when viscosity was measured with the viscosimeter.

Lightness. Lightness referred to the weight of the cake sample in proportion to its size as rated by the judges. The analysis of variance showed no significant differences in the average of mean scores for treatments I, II, and III which were 4.7, 4.9, and 4.8, respectively (Table 5).

Texture, Grain, Color, and Flavor. The committee of judges could not detect differences in the texture which included tenderness, moistness, and velvetiness, in the color of the crumb, or in the flavor of the cakes. Analyses of variance indicated that any differences in these factors were not significant. The mean flavor scores for all the cakes ranged from 5.2 to 5.3 (Table 5). According to the rating scale, all were excellent.

On several occasions, the judges commented that the grain of the cakes containing dry milk was compact. Statistical analysis showed that the grain of the homogenized milk cakes varied significantly from the grain of the cakes made with dry milk and that there were no statistical differences between the cakes made with instant nonfat dry milk.

A significant ($P < .05$) positive correlation coefficient was obtained for the data on texture and specific gravity. Data for grain of the cakes and viscosity of the batter as determined by the viscosimeter also gave a positive significant ($P < .05$) correlation coefficient, whereas when grain and viscosity as measured by line spread were analyzed, a low positive, but nonsignificant correlation coefficient was evident. The data for grain and specific gravity gave a low positive correlation coefficient which was not statistically significant.

Objective Tests on the Baked Cakes

The volume of each cake was measured by rape seed displacement, whereas the volume of an eight-inch sample taken from the center of each cake was measured by standing height. Tenderness, using a shortometer, and compressibility, using a modified laboratory balance, were measured objectively. Averages of mean values for these tests are presented in Table 6 and the detailed data are given in Tables 8 through 10 (Appendix).

Baked Cake Volume. The average volume of nonfat dry milk cakes was 5924 milliliters, whereas the average volumes of homogenized milk and nonfat dry milk plus fat cakes were 5490 and 5803 milliliters, respectively (Table 6). There were significant differences in the volumes of cakes made by all three treatments as shown by the ordered arrays of means. Volume by seed displacement was largest in the cakes made with dry milk and water and smallest in the cakes made with homogenized milk.

Cakes containing the most fat, that is, those made with homogenized milk and those with instant nonfat dry milk with fat added, had the least volume. As pointed out by Lowe (1955), this may be explained in part, by the depressing effect on cake volume when fat is increased beyond a certain proportion.

Measuring the volume of the cake by seed displacement was more accurate in the present work than by standing height which was actually only a measurement of the eight-inch sample rather than of the entire cake. In the preliminary work, the conventional method of determining standing height by measuring slices of the

Table 6. Effect of the type of milk upon the characteristics of the baked cake.

Treatment	Cake: Volume: Seed displacement ml	Cake: Volume: Standing height cm	Cake: Tenderness gm	Cake: Compressibility mm
I Homogenized milk	5490	4.0	85.6	3.5)
	*		ns	) *
II Dry milk and water	5924	4.1	89.3	3.2)
	*		ns	)
III Dry milk, water plus fat	5803	4.3	89.1	2.9)
	lsd 71.3	--	--	lsd 0.51

ns - nonsignificant.
* - significant at the 5% level.
lsd - least significant difference.

whole cake was not used because of the difficulty of handling the entire 12 x 20 x 2-inch cake. Instead, it had been planned to take two eight-inch squares from opposite ends of each cake as samples representative of the entire cake. The final decision, however, was to use one eight-inch square from the center of each cake to furnish the slices for measurement of standing heights, compressibility, tenderness, and the palatability factors.

There was a significant ($P < .01$) positive correlation between volume as measured by rape seed displacement and viscosity (Table 4). The thinnest batters gave the smallest volume of baked cake. This is in agreement with the results of Berrigan (1937); but does not agree completely with the findings of Tinklin and Vail (1947) whose work demonstrated that in some cases, thin batters produced cakes of large volume, and in other instances, cakes of small volume. On the other hand, in the present study, cakes with the thickest batters did not produce the greatest volume of baked cake.

The batters made with homogenized milk and instant nonfat dry milk and water showed no significant variation in viscosity when line spread was used as the measurement. They were significantly thinner than the batters made with dry milk and water with added fat. When the viscosimeter was used as the method of measurement of viscosity, there were significant differences among the three batters with the fluid milk cake producing the thinnest batter, and the instant nonfat dry milk plus fat giving the thickest batter (Table 4).

Correlation coefficients calculated from the data for specific gravity and volume by seed displacement indicated a significant ($P < .001$) but negative correlation between these two factors (Table 4). This is in agreement with the results of work reported by Tinklin and Vail (1947) and Bailey and LeClerc (1935) who stated that a low specific gravity accompanied a large volume.

Tenderness. The average tenderness reading for all treatments, as measured by a shortometer, ranged from 85.6 to 89.1 (Table 6). The variation among these values was found to be statistically nonsignificant. The values obtained ranked the tenderness of the cakes given the three treatments in the following descending order: homogenized milk, instant nonfat dry milk, and instant nonfat dry milk plus fat (Table 6). According to Lowe (1955), a less tender cake would be expected when made with nonfat dry milk and water, since "fat renders a product tender and short." However, it should be pointed out that in the present study, all of the cakes were tender.

When correlation coefficients were determined for tenderness of the cake and the viscosity of the batter, as measured by two methods (the viscosimeter and the line-spread test, Table 4), a nonsignificant correlation was found in each case. There was also a nonsignificant correlation for tenderness and specific gravity. When the cakes were tender, they were also more compressible, as indicated by the significant ($P < .01$) negative correlation obtained from the data for tenderness and compressibility. These results were compatible with those of Tinklin and Vail (1947) who found a negative significant correlation between these two factors.

Compressibility. The softer cakes tended to receive higher mean scores when evaluated for texture (Tables 5 and 6). Softness of crumb was a texture factor on the rating sheet used by the judges. When measured by a modified laboratory balance, the homogenized milk cakes had the highest compressibility, whereas the cakes made with instant nonfat dry milk plus fat were the least compressible. There was no significant difference between the average of mean compressibility of the cakes made with homogenized milk and the cakes made with dry milk and water; or between the cakes made with dry milk and water and dry milk plus fat. However, the homogenized milk cakes were significantly more compressible than the cakes made with instant nonfat dry milk plus fat (Table 6). Since Lowe (1955) stated that fat is one of the major factors in producing a soft, velvety crumb, it was interesting to note that although the homogenized milk cakes were not significantly softer than those made with dry milk and water, they were significantly softer than those cakes made with dry milk plus fat.

Correlation coefficients run for compressibility of the cake and viscosity of the batter, as measured by two methods (the viscosimeter and the line-spread test, Table 4), indicated a nonsignificant positive correlation in each case. Compressibility and specific gravity values showed a significant ($P < .01$) positive correlation, indicating that a batter of high specific gravity would tend to produce softer cakes. A significant ($P < .01$) but negative correlation was obtained from data for tenderness and compressibility, implying that the more tender the cake, the more likely it was to be soft (Table 4).

Cost of the Baked Cakes

The proportions of the ingredients and their costs for each treatment are summarized in Table 7. Using current market prices, the cost of each cake prepared by the three treatments was calculated for one recipe of 40 servings. The cost of the flour, sugar, eggs, baking powder, and vanilla was the same for each cake, since the proportions of these ingredients did not differ. The raw food cost varied according to the kind of milk used, and in the case of additional fat, the amount of fat used. In treatment I, when homogenized milk was used, the raw food cost of the whole cake was approximately 25 percent higher than when instant nonfat dry milk was used as in treatments II and III. The dry milk cake to which fat was added had only a 0.015 percent higher raw food cost than the cake containing dry milk and water only.

SUMMARY

This study was undertaken to compare the volume, palatability, and cost of institutional plain cakes made with homogenized milk, instant nonfat dry milk, and instant nonfat dry milk with additional fat. The formula used was adapted from a recipe employing the dough-batter method of mixing, published in FOOD FOR FIFTY by Fowler and West (1950).

The formula utilizing homogenized milk was designated as treatment I, that using instant nonfat dry milk as treatment II, and that using instant nonfat dry milk plus fat as treatment III. Armour's conversion table was used to aid in determining the amount

Table 7. Comparison of portion cost of three cakes using fluid whole milk, instant nonfat dry milk and water, and instant nonfat dry milk and water with additional fat.

Ingredients	Treatment					
	I Fluid milk		II Instant nonfat dry milk		III Instant additional fat	
	Amount	Cost	Amount	Cost	Amount	Cost
Cake flour	24 oz	$0.137	24 oz	$0.137	24 oz	$0.137
Sugar	30 oz	.183	30 oz.	.183	30 oz	.183
Shortening	10 oz	.150	10 oz	.150	11 oz	.165
Fluid whole milk	25 oz	.290				
Instant nonfat dry milk			2 oz	.037	2 oz	.037
Water						
Eggs	10 oz	.180	10 oz	.180	10 oz	.180
Baking powder	1½ oz	.016	1½ oz	.016	1½ oz	.016
Vanilla	1 T	.041	1 T	.041	1 T	.041
Total cost of cake		.997		.744		.759
Cost/serving		.0250		.0186		.019

of milk powder, water, and fat to be used when compensating for the reduced butterfat in instant nonfat dry milk. Each formula variation, i.e., treatment, was repeated 24 times in an incomplete block design comprising a total of 72 cakes.

An attempt was made to have the ingredients as nearly identical as possible in respect to source, storage conditions of time and temperature, and weights. Procedures were standardized for preparing and testing the batters and the cakes during a period in which 155 practice cakes were made. For each cake, 1950 grams of batter were weighed in an aluminum baking pan measuring 12 x 18 x 2-inches and baked in a reel gas oven at a temperature of 350° F. for 43 minutes. Three cakes were made during a baking period.

From observation alone, it appeared that when compared with treatment I, the batters containing instant nonfat dry milk were manipulated with greater ease and less expenditure of effort in the scrape-down process. At the time of panning, the batter with extra fat looked thicker than the batters made with dry milk and water or homogenized milk. All batters had a slightly curdled appearance.

Every time a cake was mixed, the temperature of the mixing room and the temperature of the batter were recorded. In addition, the viscosity of the batter was measured by two methods (an adaptation of a Zahn viscosimeter and the line-spread test), as well as the determination of the specific gravity and pH being made.

After the cake was baked, a committee of eight judges rated sections of an eight-inch sample for certain external and internal characteristics and flavor. The volume of each cake was measured by rape seed displacement; whereas the volume of an eight-inch sample, taken from the center of each cake, was measured by standing height. Tenderness and compressibility were measured objectively; the former by means of a shortometer and the latter by means of a modified laboratory balance.

Analyses of variance were run to study the effect of using fluid homogenized milk, instant nonfat dry milk and water, and instant nonfat dry milk and water with additional fat on the batter temperature, viscosity, and specific gravity; as well as on the baked cake volume, shape, lightness, surface, texture, grain, color, flavor, tenderness, and compressibility. Correlation coefficients were determined from data on batter for viscosity and batter temperature, viscosity and specific gravity; and on the baked cake for viscosity and volume, viscosity and compressibility, viscosity and shape, viscosity and grain, specific gravity and volume, specific gravity and tenderness, specific gravity and compressibility, specific gravity and texture, and specific gravity and grain. The data for all treatments were pooled in calculating correlation coefficients for the various factors rather than using the data for each treatment.

The temperature of the room in which the batters were mixed probably had little effect upon the characteristics of the batters and the baked cakes, since the average temperatures for treatments I, II, and III were 27.3°, 27.3°, and 27.8° C., respectively. When examining possible relationships between batter temperature and viscosity, specific gravity and pH of the batter, as well as similar relationships between batter temperature and volume, tenderness, and compressibility of the baked cake, it was believed that any results noted were more likely due to the treatment used rather than to the batter temperature.

The batters containing homogenized milk were significantly less viscous than those made with instant nonfat dry milk, whereas batters containing instant nonfat dry milk and water were significantly thinner than those made with instant nonfat dry milk and water plus fat. Homogenized milk batters were less viscous and had greater specific gravity values than did all batters having instant nonfat dry milk.

According to the test used, there was no apparent variation in pH of the batters made with the different treatments. All batters had a pH of approximately 8.

There was a difference in the pattern of browning of the crust or surface on the cakes made with homogenized milk from that of those made with instant nonfat dry milk. The dry milk cakes tended to have browner and less smooth surfaces, especially in the center area, than the homogenized milk cakes.

Some variation in the symmetry of the cakes may have been caused by the tendency of the oven shelves to slant at times. Measurement of test slices from the eight-inch sample taken from the center of the cake indicated an occasional slight tendency to fall in that portion of the cake. There was no practical difference in the shape of the cakes which were all rated very good by the judges. Little or no correlation existed between the shape of the baked cake and viscosity of the batter, depending upon the method of measurement used for the last named factor.

All cakes were equally light in proportion to size as evaluated by the committee of judges, who also could not detect differences in the texture which included tenderness, moistness, and velvetiness, in the color of the crumb, or in the flavor of the cakes. Texture factors were rated higher than very good and flavor was judged to be excellent. The grain of all cakes was considered better than very good. Texture and grain rated highest when the specific gravity of the batter was greater. A better grain was also associated with the less viscous batters, particularly when viscosity was measured by the viscosimeter.

Volume was as great or greater than would be expected in relation to the weight of the batter in all cakes. Volume by seed displacement was largest in the cakes made with instant nonfat dry milk and water, and smallest in the cakes made with homogenized milk. Cakes made with instant nonfat dry milk plus fat had intermediate volumes. Measuring the volume of the cake by seed displacement was more accurate in this study than by standing height which was only a measurement of the eight-inch sample rather than of the entire cake.

The least viscous batters which were those made with homogenized milk, produced the smallest cakes. However, the most viscous batters, which contained instant nonfat dry milk and added fat, did not produce the largest cakes. Higher specific gravity in the batter was associated with smaller volume in the baked cake, as exemplified by the homogenized milk batters which had higher specific gravity values and the smallest volumes. The reverse also was true, as demonstrated in the batters and cakes made with instant nonfat dry milk and water only.

All cakes were practically identical in tenderness as evidenced by shortometer values. There was little if any relationship between tenderness of the baked cake and viscosity of the batter. When cakes were tender, they tended to be compressible and soft.

According to the objective tests, the homogenized milk cakes were the most compressible, whereas the instant nonfat dry milk plus fat cakes were the least compressible. There was no correlation between compressibility and viscosity for any of the cakes. Batters of high specific gravity, as in the case of batters made with homogenized milk produced more compressible cakes. The reverse was true in instant nonfat dry milk batters. Also, the more compressible cakes were most likely to be tender.

There was a marked difference in raw food cost between the cakes made with homogenized milk and those made with instant nonfat dry milk. In the amount used, the homogenized milk was the most costly ingredient in the cake made by treatment I and accounted for approximately 29 percent of the total raw food cost of the cake. On the other hand, when instant nonfat dry milk was substituted for fluid homogenized milk, it represented about five percent of the total cost of the cake. Cakes containing instant nonfat dry milk had a raw food cost approximately 25 percent lower than those made with the fluid homogenized milk.

When additional fat was incorporated in the formula in treatment III, the raw food cost was increased 0.015 percent over the food cost of treatment II. A more acceptable cake was produced when instant nonfat dry milk was used without adding fat to compensate for the removal of most of the butterfat during the manufacture of the nonfat dry milk.

From the standpoint of cost, there was a considerable advantage in using instant nonfat dry milk, per se, in the preparation of institutional plain cake.

CONCLUSIONS

Under the conditions of this study, the following conclusions may be drawn:

1. All treatments produced cakes in which the volume was as great or greater than would be expected in relation to the weight of the batter.

2. Judges could not detect differences in cakes made by the three treatments in respect to lightness in proportion to size; texture, which included tenderness, moistness, and velvetiness; in the color of the crumb; or in the flavor.

3. Homogenized milk batters were less viscous and had higher specific gravities than instant nonfat dry milk batters.

4. Homogenized milk cakes were more compressible, and were superior in shape, surface characteristics, and grain to instant nonfat dry milk cakes.

5. Instant nonfat dry milk cakes had greater volume than homogenized milk cakes.

6. Instant nonfat dry milk and water cakes had greater volume than instant nonfat dry milk, water, and fat cakes.

7. Homogenized milk cakes cost approximately 25 percent more than instant nonfat dry milk cakes.

8. It would not seem necessary to compensate for the lower fat content of instant nonfat dry milk when used in an institutional plain cake formula.

RECOMMENDATIONS FOR FURTHER WORK

At the termination of this study, certain fallacies in reasoning and procedure became apparent. The amount of fat to be added to compensate for the lower fat content of the instant nonfat dry milk should be calculated on the basis of the brand of milk used. Optimum baking times should be determined for all treatments rather than for one as was done in this study. If standing height is to be used as a measurement of volume for the whole cake, corrections in procedure should be made. Correlation coefficients should be run on data for the individual treatments rather than on the pooled data of all treatments.

In further work, it might be of interest to include whole dry milk as a treatment, and to study the effect of use of different brands of instant nonfat dry milk, varying the amounts of instant nonfat dry milk in the formula, different methods of incorporation of the instant nonfat dry milk in the formula, different methods of mixing, or the use of different types of institutional ovens.

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APPENDIX

FORM I.

SCORE CARD FOR PLAIN CAKE

Date________________

Experiment No. ______

Key:		
	Perfect	6
	Excellent	5
	Good	4
	Fair	3
	Poor	2
	Bad	1

	Factor	Qualities	Sample No. 1	2	3	Comments
I.	External Appearance	Shape--Symmetrical, slightly rounded top, free from cracks or peaks				
		Lightness--light in weight in proportion to size				
		Surface--smooth, uniform, golden brown				
II.	Internal Characteristics	Texture--Tender, slightly moist crumb, velvety feel to tongue and finger				
		Grain--Fine, round, evenly distributed cells with thin cell walls, free from tunnels				
		Color--Uniform, characteristic of the kind of cake				
III.	Flavor	Pleasing blend of ingredients, free from unpleasant odors or taste				

Which cake do you prefer?
1st choice__________
2nd choice__________
3rd choice__________

____

Signature of the Judge

Instructions to Taste Panel Members

1. Judge large sections of cake on the tray first.
   a. Consider the shape.
   b. Consider the surface--top crust.
2. Evaluate lightness of the small sample on your plate. Consider size in relation to its weight.
3. Do not consider volume of either the large pieces on the tray or the small samples on your plate. (Volume will be determined by objective tests.)
4. Consider differences in color and make a note in the "comments" column. All cakes are made with whole eggs and the color of the eggs may vary.

General Suggestions:

1. Try to refrain from eating or drinking coffee, etc., for at least one hour before tasting.
2. Feel free to make comments that will identify differences in the samples.
3. It is considered helpful to take a small amount of water between samples when tasting for flavor.
4. Small bites rolled on the tongue help in determining flavor and texture.
5. Whatever way by which you arrive at a decision should be <u>consistent for each sampling period</u>.
6. Make a notation if you have a cold.

Table 8. Measurements of batter temperature, viscosity, specific gravity, pH; volume, tenderness, and compressibility of cakes made with homogenized milk.

Treatment I Homogenized milk Cake No.	Room temp. ° C.	Batter temp. ° C.	Viscosity		Specific gravity	pH	Volume		Tenderness gm	Compressibility mm
			Viscosimeter sec	Line spread cm			Seed displacement ml	Standing height cm		
1	27	21	7.5	1.5	0.897	8	5594			
2	25	22.5	14.2	1.7	.832	8	5536			
3	26.5	22	9.8	1.9	.897	8	5516			
4	27.5	25	8.7	1.7	.869	8	5620	4.2	80	4.5
5	26	22	7.8	2.0	.936	8	5564	4.1	84	4.4
6	26	23	7.3	1.8	.910	8	5515	4.3	87	5.0
7	27	22	15.0	1.8	.895	8	5614	4.0	90	3.3
8	28	23.5	15.0	1.8	.921	8	5501	3.8	68	2.2
9	27	22	13.8	1.8	.913	8	5594	3.2	71	3.6
10	26.5	20.5	15.3	2.0	.951	8	5290	3.6	73	3.7
11	27	22	10.5	1.8	.910	8	5580	3.8	67	5.1
12	28	22	12.0	1.8	.956	8	5205	3.8	84	3.5
13	28	23	10.7	1.8	.910	8	5590	4.2	76	4.7
14	27.5	23.5	13.5	2.1	.931	8	5625	4.1	93	4.5

Table 8 (concl.).

Treatment I Homogenized milk Cake No.	Room temp. ° C.	Batter temp. ° C.	Viscosity		Specific gravity	pH	Volume		Tenderness gm	Compressibility mm
			Viscosimeter sec	Line spread cm			Seed displacement ml	Standing height cm		
15	29	24	16.3	1.8	0.897	8	5516	4.0	66	4.7
16	27	23.5	12.5	1.9	.869	8	5510	4.0	90	4.1
17	27.5	24	14.2	1.8	.936	8	5611	4.9	95	3.8
18	27.5	22	11.6	1.8	.882	8	5345	3.6	102	2.0
19	26	22	13.7	1.7	.885	8	5510	4.0	78	2.6
20	26.5	22	12.8	--	--	8	5591	3.8	88	2.0
21	28.5	23.5	12.5	1.9	.882	8	5281	3.9	111	1.6
22	28	24	11.0	2.0	.900	8	5360	3.9	88	2.9
23	29	23.5	12.7	1.7	.867	8	5401	3.9	100	4.1
24	30	23.5	17.3	2.0	.918	8	5291	3.8	107	2.0
Av.	27.3	22.8	12.3	1.8	.903	8	5490	4.0	86	3.5

Table 9. Measurements of batter temperature, viscosity, specific gravity, pH; volume, tenderness, and compressibility of cakes made with dry milk and water.

Treatment II Dry milk and water Cake No.	Room temp. ° C.	Batter temp. ° C.	Viscosity		Specific gravity	pH	Volume		Tenderness gm	Compressibility mm
			Viscosimeter sec	Line spread cm			Seed displacement ml	Standing height cm		
1	27	21	7.5	1.5	0.897	8	5610		92	
2	24	21.5	5.7	1.5	.832	8	5997		76	
3	26	22	4.2	1.5	.821	8	5974			
4	28	23	8.5	1.6	.859	8	6099		80	3.9
5	27	23.5	10.3	1.9	.833	8	5890	4.3	91	3.4
6	27.5	23	10.0	1.9	.869	8	5955	4.4	85	4.1
7	27.5	22	10.5	1.5	.867	8	5985	4.3	98	3.1
8	27.5	22.5	9.3	1.3	.823	8	6105	4.3	90	2.8
9	27.5	23	12.8	1.8	.867	8	5980	4.2	73	3.4
10	26.5	21.5	10.2	1.9	.900	8	5775	4.2	83	3.0
11	27.5	22	10.7	1.9	.872	8	5801	4.1	86	2.6
12	27.5	23.5	8.2	2.0	.887	8	5725	4.4	99	2.5
13	28	23.5	10.8	1.7	.854	8	6091	4.3	84	3.7
14	27	22	12.6	1.9	.859	8	5919	4.2	69	3.3

Table 9 (concl.).

Treatment II: Dry milk and water Cake No.	Room temp. ° C.	Batter temp. ° C.	Viscosity		Specific gravity	pH	Volume		Tenderness gm	Compressibility mm
			Viscosimeter sec	Line spread cm			Seed displacement ml	Standing height cm		
15	28	23	12.2	1.9	0.905	8	5790	4.3	101	4.5
16	27.5	22	9.5	1.5	.859	8	5969	4.3	90	3.1
17	28	22	10.3	1.7	.872	8	5996	4.4	104	4.2
18	27.5	22.5	11.2	1.7	.864	8	5840	4.3	67	2.6
19	27	22.5	17.3	1.8	.869	8	5891	4.2	95	2.8
20	28	23	14.5	1.9	.890	8	5912	4.4	97	2.8
21	28.5	23.5	10.7	2.0	.856	8	6111	4.6	101	2.2
22	28.5	24	12.3	1.8	.933	8	5952	4.5	95	3.9
23	26.5	23	12.8	2.0	.849	8	5899	4.3	103	3.0
24	28	23	13.8	2.0	.874	8	5907	4.6	96	2.8
Av.	27.4	22.6	10.6	1.8	.867	8	5924	4.3	89	3.2

Table 10. Measurements of batter temperature, viscosity, specific gravity, pH; volume, tenderness, and compressibility of cakes made with dry milk and water with fat added.

Treatment III: Dry milk, water, and added fat			Viscosity				Volume			
Cake No.	Room temp. ° C.	Batter temp. ° C.	Viscosimeter sec	Line spread cm	Specific gravity	pH	Seed displacement ml	Standing height cm	Tenderness gm	Compressibility mm
1	27	23	4.0	1.0	0.895	8	5674	4.2	79	3.7
2	27	23	6.3	1.5	.859	8	5630	4.4	83	2.4
3	25	23	2.8	1.5	.838	8	5920	4.2	80	2.4
4	29	24	8.7	1.6	.844	8	5821	4.6	99	2.6
5	29	24.5	5.3	1.6	.836	8	5836	4.1	90	2.9
6	26.5	23	6.3	1.5	.854	8	5975	4.3	83	2.8
7	27.5	23	6.3	1.6	.885	8	5915	4.3	72	3.6
8	28	23	5.7	1.0	.883	8	5876	4.2	89	3.4
9	27	23	5.0	1.3	.823	8	5825	4.2	88	2.5
10	25.5	20	4.7	1.1	.821	8	5709	4.1	77	2.0
11	28	22.5	8.8	1.7	.895	8	5731	4.3	83	3.4
12	28	22.5	4.3	1.6	.864	8	5614	4.3	111	1.9
13	27	22	6.7	1.5	.900	8	5944	4.3	82	3.5
14	28	23.5	9.1	1.6	.841	8	5855	4.4	91	3.1

Table 10 (concl.).

Treatment III: Dry milk, water, and added fat Cake No.	Room temp. ° C.	Batter temp. ° C.	Viscosity Viscosimeter sec	Viscosity Line spread cm	Specific gravity	pH	Volume Seed displacement ml	Volume Standing height cm	Tenderness gm	Compressibility mm
15	27.5	23	9.2	1.3	0.869	8	5950	4.3	93	3.5
16	28	22.5	4.5	1.2	.846	8	5615	4.2	88	2.8
17	28.5	22.5	5.2	1.3	.838	8	5850	4.3	81	3.3
18	27.5	26	2.5	1.2	.849	8	5961	4.2	80	4.8
19	28	22	2.2	1.3	.844	8	5714	4.4	104	2.1
20	28	23	3.5	1.3	.867	8	5835	4.3	105	2.3
21	28	22.5	2.5	1.3	.877	8	5796	4.4	112	2.2
22	30	25.5	10	1.9	.846	8	5605	4.2	91	2.3
23	30	25	9.5	1.7	.872	8	5740	4.3	94	3.5
24	28.5	23.5	3.3	1.5	.867	8	5870	4.3	84	2.9
Av.	27.8	23.2	5.7	1.4	.857	8	5805	4.3	89	2.9

Table 11. Average scores for cakes containing whole fluid milk.

Treatment I Homogenized milk Cake No.	Shape	Lightness	Surface	Texture	Grain	Color	Flavor
1	4.9	4.3	4.7	4.3	4.3	5.0	5.1
2	3.0	4.4	3.7	4.3	4.7	5.1	5.3
3	4.9	4.6	5.0	4.9	4.9	5.0	5.3
4	5.1	4.8	5.5	5.1	5.1	5.6	5.5
5	4.8	4.8	5.3	5.0	4.6	5.6	4.9
6	4.8	4.5	4.9	4.9	4.8	5.6	4.9
7	5.1	4.4	4.9	4.9	5.3	5.4	5.6
8	4.0	4.5	4.9	4.9	4.6	5.5	5.3
9	4.1	4.6	5.1	3.9	5.3	5.3	5.3
10	4.9	4.4	4.4	4.9	5.0	5.6	5.3
11	5.4	4.6	5.1	5.0	4.9	5.9	5.4
12	5.0	4.9	5.1	5.3	5.3	5.9	5.1
13	5.0	5.0	5.3	5.3	5.0	5.9	5.4
14	4.7	4.7	4.9	5.0	5.3	5.9	5.3
15	4.6	5.1	5.0	5.0	5.4	5.9	5.0
16	4.9	5.0	5.1	4.6	4.9	5.6	5.6
17	5.3	4.6	5.3	5.0	5.4	5.6	5.5
18	5.2	4.3	5.3	4.7	4.5	5.6	5.2
19	5.2	4.5	5.5	4.8	5.0	5.6	5.2
20	5.5	4.7	5.5	4.7	5.2	5.7	4.8
21	4.3	4.6	4.9	4.7	5.3	5.4	4.9
22	4.0	5.0	5.0	5.0	5.3	5.9	5.1
23	5.6	5.0	5.9	5.1	5.3	5.9	5.3
24	5.6	4.9	5.4	5.0	5.3	5.9	5.3
Av.	4.8	4.7	5.1	4.9	5.0	5.6	5.2

Table 12. Average scores for cakes containing instant nonfat dry milk and water.

Treatment II Dry milk and water Cake No.	Shape	Lightness	Surface	Texture	Grain	Color	Flavor
1	3.1	3.9	3.9	4.1	4.1	5.0	5.1
2	3.7	4.6	3.7	4.3	4.3	5.3	5.1
3	3.9	4.4	3.4	4.6	4.1	5.1	5.3
4	5.0	5.1	5.0	5.1	5.4	5.6	5.4
5	4.1	4.6	4.3	5.0	5.1	5.6	5.4
6	4.1	5.0	3.9	4.6	5.1	5.6	5.4
7	4.3	4.8	4.3	4.5	4.9	5.5	5.4
8	3.9	5.0	3.6	5.1	4.6	5.4	5.4
9	4.1	4.8	3.9	5.0	5.1	5.4	5.3
10	2.9	4.3	3.1	5.0	4.3	5.9	5.1
11	3.0	4.9	3.4	5.1	4.1	5.9	5.3
12	4.7	5.1	4.3	5.0	5.1	5.8	5.3
13	4.0	5.4	3.9	4.6	4.4	5.9	5.0
14	4.6	5.3	5.0	5.0	5.1	5.8	5.8
15	4.3	4.6	4.3	5.0	4.3	5.6	5.6
16	5.1	4.9	4.9	4.4	4.4	5.6	5.3
17	4.0	5.2	4.5	5.0	5.2	5.7	5.3
18	4.5	4.3	5.3	4.7	4.5	5.6	5.2
19	4.8	5.0	5.0	4.8	4.7	5.7	5.3
20	4.7	4.9	4.3	4.9	5.1	5.4	5.1
21	4.3	5.0	4.3	4.4	4.6	5.4	4.9
22	3.4	5.1	3.7	4.9	4.9	5.6	5.3
23	4.9	4.6	5.0	5.0	4.9	5.4	5.4
24	4.3	5.1	4.1	4.6	4.1	5.4	5.3
Av.	4.2	4.9	4.2	4.8	4.7	5.6	5.3

Table 13. Average scores for cakes containing instant nonfat dry milk and additional fat.

Treatment III Dry milk, water, and added fat Cake No.	Shape	Lightness	Surface	Texture	Grain	Color	Flavor
1	3.9	4.6	4.0	4.7	5.0	5.6	5.7
2	4.4	4.4	4.3	4.9	5.0	5.6	5.6
3	4.0	4.0	4.0	4.6	4.7	5.6	5.6
4	4.1	4.9	4.1	5.3	5.1	5.5	5.3
5	3.9	4.1	3.5	4.8	5.8	5.6	5.3
6	4.0	4.9	3.8	4.9	4.6	5.5	5.0
7	4.3	4.6	4.4	4.8	5.1	5.5	5.2
8	4.3	4.8	4.3	5.1	4.9	5.5	5.0
9	4.6	4.9	4.3	3.9	5.1	5.4	5.4
10	2.9	4.3	3.3	4.7	4.1	5.6	5.0
11	2.9	4.6	3.1	4.7	4.0	5.9	5.6
12	4.4	5.3	4.9	4.9	5.0	5.9	5.1
13	4.7	5.3	4.6	5.3	5.0	5.9	5.3
14	4.3	5.1	4.0	4.4	4.7	5.9	5.3
15	3.5	4.4	3.5	4.9	4.1	5.6	5.5
16	4.9	4.5	4.9	5.0	5.3	5.6	5.5
17	5.1	5.3	4.8	4.6	4.4	5.6	5.3
18	5.0	5.5	5.0	4.9	5.0	5.6	5.5
19	3.6	5.0	3.4	4.6	5.1	5.6	4.7
20	4.7	5.0	4.1	4.4	4.6	5.6	5.1
21	4.7	4.4	4.1	4.7	4.7	5.6	5.3
22	4.4	4.3	4.6	4.7	5.1	5.6	5.1
23	4.7	4.9	4.6	5.1	5.4	5.6	5.3
24	5.1	5.0	4.6	5.3	5.0	5.5	5.4
Av.	4.4	4.8	4.2	4.8	4.8	5.6	5.3

Table 14. Conversion table for nonfat dry milk.

When added with:	Milk	Fat	Water
	grams		
Sugar and salt	35	15	354
Eggs and vanilla	27	11	267
Total	62	26	621

Table 15. Conversion table for whole milk by volume.

When added with:	Milk	Water
	grams	
Sugar and salt	35	354
Eggs and vanilla	27	267
Total	62	621

Table 16. Baking pan weights and volumes.

Pan No.	Weight in grams	Volume in ml
1	1075	7024
2	1036	6940
3	1066	7015
4	1060	6990
5	1068	7036
6	1062	7056

A COMPARISON OF LARGE QUANTITY PLAIN CAKES MADE WITH LIQUID HOMOGENIZED MILK, INSTANT NONFAT DRY MILK, AND INSTANT NONFAT DRY MILK WITH ADDITIONAL FAT

by

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The purpose of this study was to compare the volume, palatability, and cost of institutional plain cakes made with fluid homogenized milk, instant nonfat dry milk, and instant nonfat dry milk with additional fat.

Large quantity cakes using fluid homogenized milk (treatment I), instant nonfat dry milk and water (treatment II), and instant nonfat dry milk, water, and additional fat (treatment III) were made by the dough-batter method of mixing. Armour's conversion table was used to aid in determining the amount of instant nonfat dry milk, water, and fat to be used when compensating for the reduced butterfat in instant nonfat dry milk. Each treatment was repeated 24 times in an incomplete block design comprising a total of 72 cakes. Three cakes were made at each baking period.

Procedures were standardized for preparing and testing the batters and the cakes during a practice period in which 155 cakes were made. Batter in the amount of 1950 grams was scaled into a 12 x 18 x 2-inch aluminum baking pan and baked in a reel gas oven at 350° F. for 43 minutes.

The following data were obtained: (a) for the batter-room temperature, batter temperature, viscosity by two methods (an adaptation of the Zahn viscosimeter and the line-spread test), specific gravity and pH; and (b) for the baked cake--volume of the whole cake by rape seed displacement, volume of an eight-inch square sample by standing height, tenderness, compressibility, scores for certain external and internal characteristics and flavor of the baked cake as evaluated by a committee of eight judges, and cost.

Analyses of variance were run to study the effect of using fluid homogenized milk, instant nonfat dry milk and water, and instant nonfat dry milk and water with additional fat, on the batter temperature, viscosity, and specific gravity; as well as on the baked cake volume, shape, lightness, surface, texture, grain, color, flavor, tenderness, and compressibility. Correlation coefficients were determined from data on batter for viscosity and batter temperature, viscosity and specific gravity; and on the baked cake for viscosity and volume, viscosity and compressibility, viscosity and shape, viscosity and grain, specific gravity and volume, specific gravity and tenderness, specific gravity and compressibility, specific gravity and texture, and specific gravity and grain. The data for all treatments were pooled in calculating correlation coefficients for the various factors, rather than calculating the coefficients for data within each treatment.

In this investigation, the temperature of the mixing room and the batters probably had little effect upon the characteristics of the batters and the baked cakes.

The batters containing homogenized milk were less viscous than those made with instant nonfat dry milk, whereas batters containing instant nonfat dry milk and water were thinner than those made with dry milk and water plus fat. Homogenized milk batters had greater specific gravity values than batters containing instant nonfat dry milk.

There was a difference in the pattern of browning of the crust or surface on the cakes made with homogenized milk from that of those made with instant nonfat dry milk. The dry milk cakes tended to have browner and less smooth surfaces, especially in the center area, than the homogenized milk cakes. Surface characteristics are generally of minor importance when cakes are served in institutional food services, because of the use of toppings of various kinds.

There was no practical difference in the shape of the cakes which were all rated very good in this respect by the judges. Little or no correlation existed between the shape of the baked cake and viscosity of the batter, depending upon the method of measurement used for the last named factor.

All cakes were equally light in proportion to size as evaluated by the judges who also could not detect differences in the texture which included tenderness, moistness, and velvetiness; in the color of the crumb; or in the flavor of the cakes. Texture factors were rated higher than very good and flavor was judged to be excellent. The grain of all cakes was considered better than very good. Texture and grain rated highest when the specific gravity of the batter was greatest. A better grain also was associated with the less viscous batters.

Volume was as great as would be expected in relation to the weight of the batter in all cakes. Volume by seed displacement was largest in the cakes made with instant nonfat dry milk and water, and smallest in the cakes made with homogenized milk. Cakes made with instant nonfat dry milk plus fat had intermediate volumes.

The least viscous batters, those made with homogenized milk, produced the smallest cakes; but the most viscous batters, those that contained instant nonfat dry milk plus fat, did not produce the largest cakes. Higher specific gravity in the batter was associated with smaller volume in the baked cake.

All cakes were practically identical in tenderness. There was little, if any, relationship between tenderness of the baked cake and viscosity of the batter. When cakes were more tender, they tended to be more compressible and softer. The homogenized milk cakes were the most compressible, whereas the instant nonfat dry milk plus fat cakes were the least compressible. There was no correlation between compressibility and viscosity of the batter for any of the cakes. Batters of high specific gravity, as in the case of batters made with homogenized milk, produced more compressible cakes. The reverse was true in instant nonfat dry milk batters.

There was a marked difference in raw food cost between the cakes made with homogenized milk and those made with instant nonfat dry milk. Cakes containing the dry milk had a raw food cost approximately 25 percent lower than those made with the fluid homogenized milk. When additional fat was incorporated in the formula in treatment III, the raw food cost was increased 0.015 percent over the food cost of treatment II.

A more acceptable cake was produced when instant nonfat dry milk was used without adding fat to compensate for the removal of most of the butterfat during manufacture of the nonfat dry milk.