UTILIZATION OF DRIED CHEESE IN THE MANUFACTURE OF PROCESS CHEESE

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ABSTRACT

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OF PROCESS CHEESE

by N. Dale Finch

A study was conducted to determine the physical and chemical properties of process cheese made from dehydrated Cheddar cheese. Formulations for such a product made from foam-spray dried or freeze-dried Cheddar cheese were evaluated. Dried cheese and water (and emulsifier, salt, flavoring materials and natural Cheddar cheese, when used) were mixed together in a steam jacketed vessel. The ingredients were pasteurized under constant stirring at 150°F for a holding time of 30 to 60 seconds. The hot cheese was packaged in polystyrene containers and stored at 40°F or at 70° to 80°F.

Process cheese made from 75 per cent foam-spray dried mild Cheddar cheese and 25 per cent of the aged product similarly dried possessed rather good body and flavor characteristics. The melting quality and body firmness of process cheese can be improved slightly by cooling the freshly prepared product to 40°F rather than to 70° to 80°F. Process cheese made with 3 per cent emulsifier (sodium citrate, sodium aluminum phosphate, or disodium phosphate) was preferred over cheese made with higher percentages. Commercial flavor fortifiers or condiments were successful in improving the flavor of process cheese made from

foam-spray dried cheese. However, organic acids, leucine, methionine, ethyl butyrate, 2-heptanone, methyl sulfide, and hydrogen sulfide individually were of relatively little value in this respect. The flavor of process cheese made from foam-spray dried cheese containing blue-veined cheese was preferred over cheese processed without this product. The food product made by combining natural and foam-spray dried Cheddar cheese has properties superior to those of process cheese made solely from the dehydrated cheese.

Freeze-dried cheese can be used to produce a process cheese comparable to the product made from natural cheese. The flavor and physical properties of such a cheese are good. High quantities of natural cheese can be replaced with an equivalent amount of the freeze-dried cheese without adversely affecting the properties of the finished product. Low, and comparable, bacterial counts were obtained on process cheese manufactured from foam-spray dried, freeze-dried, and natural Cheddar cheese.

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INTRODUCTION

Cheese is a very important part of the American diet. In 1964, the United States per capita consumption of all varieties including cottage cheese was 13.9 pounds. Today, approximately 12.3 per cent of the total United States milk production is utilized in the manufacture of cheese.

Process cheese was introduced into this country in 1916. Since then the consumption of process cheese has increased steadily, and now about 35 per cent of the domestic natural cheese is used in the production of this product.

Easily prepared food products that can be stored at room temperature are becoming a basic part of our everyday lives. Various kinds of dehydrated food mixes can be found in all supermarkets. Many housewives consider them indispensable in the preparation of meals.

For centuries, dehydrated cheese has been produced throughout the world. However, the uses of dried cheese have been limited to such products as bases for chip dips, sauces, gravies, salad dressings, and soups, or directly, as a garnishing for foods.

The research studies reported herein were undertaken not only to determine if a desirable process cheese could be made from dried cheese, but also to study formulations for this product, and to evaluate the acceptability of various flavor additives for use in such a process cheese.

REVIEW OF LITERATURE

Process cheese has been produced in the United States for approximately 50 years (Bauertal, 1932a). The tremendous success that process cheese has had during these years is due to several factors: a) mild flavor, b) smooth texture, c) excellent slicing and melting properties, and d) uniformity (Sommer and Templeton, 1939). If the present population trends continue and if the amount of milk available for the production of natural cheese continues to decrease, the importance of process cheese in total milk utilization is likely to increase (Wearmouth, 1959).

For many years natural cheese, manufactured throughout the world, has been dried. In the last decade, considerable emphasis has been directed to the problems of theory, technology, and economics of dried cheese (Boháč, 1957). Dried cheese has many uses. With the advent of "convenience foods," the demand for this product has increased (Bradley and Stine, 1963). This food product has a high caloric value, is easily digested, is rich in protein and fat, and is fairly stable under normal conditions of storage (Makar'in, 1959).

Manufacture of Process Cheese

Process cheese is the modified cheese prepared by mixing and heating several different lots of cheese. Water, salt, emulsifying salts, color, and seasoning are the

optional ingredients that may be added (Van Slyke and Price, 1952). Swiss was the first hard cheese to be processed (Bauertal, 1932a). Later, Cheddar, Gouda, Tilsit, Gruyere, and, finally, soft cheese were used in making process cheese (Bauertal, 1932a). Van Slyke and Price (1952) reported Cheddar cheese as the variety most commonly processed in the United States; however, Swiss, Limburger, Brick, and similar varieties are also used. The German Kochkäse, the Belgian and French Canquillote, the French and Swiss fondue, and the Welsh rarebit were suggested by Sommer and Templeton (1939) to be forerunners of this product.

Bauertal (1932a), in an abstract on process cheese, noted that this product was first manufactured in Switzerland at the beginning of the twentieth century. From 1905 to 1911, a Swiss factory worked out a completely new method of preserving cheese, which resulted in the manufacture of pasteurized cheese. The cheese was originally called "box cheese." After World War I process cheese manufacture spread rapidly throughout Europe. The first United States patent on process cheese was issued in 1916.

The intent in processing cheese is to produce a finished product that has sufficient fluidity for convenient packaging and which possesses long keeping qualities (Wilster, 1955). The pasteurization process, in combination with low storage temperatures, slows down further ripening (Sommer and Templeton, 1939). Sommer and Templeton (1939) summarized the steps in the processing of cheese as follows: a) choosing the proper cheese; b) trimming and grinding; c) pasteurizing the cheese and ingredients; and d) packing the hot, finished product.

Selection and blending of natural cheese. The selection of cheese for processing is the first essential step in the manufacture of process cheese (Bauertal, 1932). Hard varieties of cheese are the most common varieties used for processing. Cheddar cheese is the variety most often used for processing in the English speaking countries, and Swiss cheese is chiefly used on the European continent.

Old cheese alone is not suitable for processing because the final product will have a loose and grainy texture and will be subject to fat separation during processing and packaging. The chief function of old cheese is to impart satisfactory flavor to the process cheese. Young cheese, if used as the total cheese supply, will yield a product of firm body, smooth texture, and mild flavor. Thus, young cheese is used for its desirable texture, body, and slicing properties. In order to produce a process cheese of desirable body and flavor characteristics, old cheese must be blended with young cheese (Jackson and Wearmouth, 1959).

Blending is the operation of selecting the cheese that will make up a batch or blend. Selection requires much technical skill and experience. The factors determining the selection for the blend are the age, acidity, flavor, texture, body, and composition of the lots of cheese available (Templeton and Sommer, 1930). Normally, very large stockpiles of natural cheese are kept in storage for selection by the blender (Barker, 1942a). Van Slyke and Price (1952) recommended using 20 to 30 vat lots, and these combinations frequently represent as many different factories as there are lots of cheese in the blend. Barker (1939) reported cheese from at least five factories is required to blend cheese successfully. Zakariasen (1952) indicated that successful blending requires at least three and often up to 12 different kinds of bulk cheese.

The importance of the quality of the cheese used has been discussed by Kierkegaard et al. (1952). Generally, approximately 75 per cent of the cheese used for processing will be under three months of age, whereas the remainder will be from 6 to 12 months old. Templeton and Sommer (1930) obtained good results in process cheese manufacture by using cheese averaging 4 to 7 months of age.

A batch formulated by Barker (1941a), consisting of 70 per cent short-held (1 to 3 months) or short-held plus storage (about 6 months) cheese, had a smooth texture. This batch should contain also 15 per cent "acid" cheese (curd drippings should test at least 0.9 per cent lactic acid before salting), short-held, and be at least 8 weeks old; the remaining 15 per cent should be "current" cheese (fresh made cheese). When acid current cheese was used, color defects were noted by Zakariasen (1952) and Barker (1941a). Zakariasen (1952) also reported that a typical American batch of process cheese should contain mostly short-held (1 to 6 months) cheese.

Barker (1947a) recommended that 30 to 40 per cent of the natural cheese used should be on the "acid" side and the rest on the "sweet" side (curd drippings should test 0.6 per cent lactic acid before salting). He reported that cheese stored at 60°F for 1 month will produce a product with excellent flavor and thereby eliminate the need for cheese older than 1 month for process cheese making.

The process cheese industry has now developed methods to produce cheese especially for processing. Kraft and Ward (1956) produced cheese that is ready for processing two days after manufacture. The cheese curd is soaked in a lactic acid solution and heated to 102° to 110°F for six to 40 minutes. The curd is then drained, washed with cool water, salted, hooped, and finally pressed. The finished product is stored for two days at 42°F, and after this period the cheese is ready for processing. Another procedure for manufacturing cheese for process cheese has been developed by Klimovskii (1954).

Defective cheese may be used in limited amounts for process cheese manufacture. Barker (1947a) advised using not greater than 1 to 2 per cent gassy or off-flavored cheese. O'Shea (1954) noted that inferior cheese could be blended with good cheese if not more than 5 per cent of the former cheese were used. However, he stated that putrid cheese should never be used because even 1 per cent is detectable in the finished cheese.

Another problem of blending is selecting cheese of the right composition, so that the process cheese made from this cheese will be within the limits of the standards set by the Federal Food and Drug Administration. Process cheese may contain not greater than 1 per cent moisture above that of the natural cheese from which the process cheese was made. The butterfat content of process Cheddar cheese must be not less than 50 per cent of dry matter. As noted by Wilster (1955), salt, emulsifying agents, and the flavor materials do not increase the fat content but do add to the dry weight. Therefore, the cheese selected must have a high enough fat content to yield a product with the legal butterfat content. Sommer and Templeton (1939) and Barkan (1939) reported procedures for standardizing the blends of cheese for processing.

Emulsifying salts. The choice of emulsifying agents has been discussed by many workers (Templeton and Sommer, 1930, 1932a, 1936; Sommer and Templeton, 1939; Palmer and Sly, 1943; Faivre, 1946; Khmelev, 1952; Boháč, 1956; Jackson and Wearmouth, 1959; Wearmouth, 1959; Schulz and Hetzel, 1960). Emulsifying agents are used in the manufacturing of process cheese, at levels of 2 to 4 per cent, to prevent butterfat separation during the heating operations

(Palmer and Sly, 1943). Some blends of cheese can be processed without using emulsifying agents, but they generally do not have as desirable melting and slicing properties as cheese produced using these salts. Process cheese produced without emulsifying salts have been studied by Wilster (1955) and found to be grainy in texture and weak in body. Barker (1941a) indicated that too much emulsifier would produce a coarse, stiff finished product.

Templeton and Sommer (1930) stated that sodium citrate yielded a cheese with a firmer body than phosphates, the latter causing a less firm body with increasing percentages of the salt used. These workers, comparing two forms of sodium citrate ($2Na_3C_6H_5O_7 \cdot 11H_2O$ and $Na_3C_6H_5O_7 \cdot 2H_2O$), were unable to detect any appreciable difference in the action of the two salts. Later these (1932a) reported that the use of Rochelle salt produced the firmest body as compared with disodium phosphate and sodium citrate.

The use of emulsifiers makes the selection of cheese for the blend less critical. Sommer and Templeton (1939) stated that the flavor, texture, remelting properties, and costs are the important considerations that should be made when choosing an emulsifying salt. They also reported that emulsifying salts affect the protein directly and the fat only indirectly. The emulsifying salt chosen must be a good cheese protein solvent and must produce a viscous emulsion.

Habicht (1934) concluded that an emulsifying salt with an alkaline monovalent cation and a polyvalent anion would be the ideal salt. Previously, Habicht (1933) found the emulsifying properties of sodium acetate, disodium tartrate, and trisodium citrate to be 1:20:100 respectively. Lithium and potassium (monovalent, alkaline cations), when incorporated into a process cheese, cause a peculiar and characteristic off flavor. Templeton and Sommer (1936) reported that European investigators had found sodium citrate to be the most satisfactory emulsifier.

On the basis of flavor, Templeton and Sommer (1936) found sodium salts superior to ammonium salts when used in making process cheese. Habicht (1934) suggested that partial saponification between the cation of the salt and the free fatty acids took place. Also, the anion combined with the casein to envelop the fat, thereby preventing fat loss from the cheese.

Several salts have been suggested as possible emulsifying salts, but relatively few have been used in commercial practice. Templeton and Sommer (1936) found levels of potassium citrate greater than 3 per cent to be detrimental to the flavor of the cheese. Also process cheese made with sodium citrate showed a decrease in fat loss as the emulsifier content was increased; with pyrophosphate the fat loss increased slightly.

Templeton and Sommer (1936) noted that 3 per cent or more of phosphates caused an unpleasant aroma in the cheese. Metaphosphate and pyrophosphate emulsifiers yielded cheese of poor melting quality. They concluded "no emulsifier is superior to sodium citrate, and it is very doubtful if any of them is equal to sodium citrate when all the factors are considered."

Palmer and Sly (1943) concluded that sodium citrate or a sodium citrate-phosphate blend was the most satisfactory emulsifying salt in the manufacture of process cheese.

Boháč (1956) claimed that a better flavor and color can be produced in process cheese using citrates as the emulsifying agents. He further stated that phosphates permit more water to be incorporated in the cheese without adversely affecting the body of the cheese. He suggested the use of ammonium phosphate if prolonged liquefaction were desired for ease of pumping and handling in spray or roller drying.

In a comprehensive study on the emulsifying salts, Faivre (1946) reported polyphosphates produced the "aroma of natural cheese in all its fullness." He indicated that the amount of "salt of fusion" (emulsifier) needed will vary between 1.5 to 3.0 per cent.

Khmelev (1952) noted that disodium phosphate, although a good emulsifying salt, corroded aluminum foil. He advised against the use of sodium-potassium tartrate because crystals of tartrate were likely to form in the cheese upon storage. Sommer (1930) discussed this defect of process cheese in great detail. The use of sodium pyrophosphate at levels less than 2 per cent has been recommended by Khmelev (1952). This worker, as did Palmer and Sly (1944), found sodium citrate to be very satisfactory as an emulsifying salt.

Roland (1951) obtained a United States patent for the use of water-insoluble crystalline sodium or potassium metaphosphate with sufficient quantities of an alkali metal, (calcium or magnesium salt) to bring the metaphosphate into solution. Patented blends of various emulsifying salts are used in the industry today.

Flavoring agents. In addition to natural cheese and emulsifying salts, condiments are also sometimes used in the manufacture of process cheese. Walberg and Lucas (1943) investigated the potential of pimiento, green chili, pickle relish, stuffed olives, cottage cheese, caraway seeds, sage, pineapple, pickled onions, mustard pickle, pecan meats, and walnut meats in process cheese. They found pimiento, green chili, stuffed olives, and sage to be the most satisfactory condiments for this purpose. These workers stated that other flavoring agents might have proved satisfactory if proper levels had been established. Process cheese made with caraway, pecan, and walnut were not very asthetic because the cheese looked as if non-food material had been incorporated in the product. Pecan and walnut meats produced a cheese with undesirable flavor.

Sadokova (1948) reported that the addition of 10 per cent oat protein to process cheese improved the flavor and consistency of the product. Bauertal (1932b) suggested using spices and seasoning materials such as salt, caraway, nutmeg, porret, and clove in process cheese.

Processing. After the cheese, emulsifiers, and spices or seasoning have been selected, the next step is the actual processing of these materials. Before trimming and grinding, Barker (1939) advised that the cheese should be stored at 70°F for 72 hours to allow the cheese to temper throughout. Cheese tempered to 70°F can be trimmed and ground easily and efficiently. The first operation in processing is the trimming and grinding of the cheese. Wilster (1955) stated that the dry rind does not have to be removed completely because processing will eliminate this condition. Bauertal (1932b) recommended that mold and bacterial growth be removed before processing. The ground cheese is put into the cheese kettle and emulsifiers, salt, water, and color are added. The amount of emulsifier is generally determined by making small trial batches, as recommended by Bauertal (1932b) and Van Slyke and Price (1952).

Water is added to insure the proper body and texture, while salt is added to enhance the flavor (Barker, 1941a). Templeton and Sommer (1932a) studied the effects of salt additions up to 2 per cent on properties of process cheese. They found that increasing salt levels caused weaker body and higher fat loss. They also noted that salty flavor became objectionable at salt concentrations above 1 per cent. Cheese made with 3 per cent emulsifier and 2 per cent salt did not have the defects of cheese containing 2 per cent emulsifier and 2 per cent salt.

The heat may be applied by direct steam or by means of a steam jacketed kettle. According to Barker (1940c), direct steam methods cut processing time to one third when compared to other methods. However the quality of the cheese thus produced was not as good as that obtained by indirect heating. He also stated that most firms use direct steam because it is cheaper. Bauertal (1932b) indicated that lower temperatures are used when using steam jacketed kettles without vacuum than with direct steam and vacuum. Barker (1946) reported that continuous agitation and stirring during processing is essential.

Templeton and Sommer (1932a) summarized the factors affecting the body and texture of process cheese as follows: a) emulsifiers; b) processing temperature; c) moisture content; d) reaction (pH and titratable acidity); e) age of the cheese used; f) salt content; and g) casein-to-fat ratio. To attain optimal body in the finished cheese, pH must be maintained between 5.6 to 6.1, or a titratable acidity of 1.1 to 1.8 per cent, calculated as lactic acid. They noted that high moisture process cheese had a weak body, whereas low moisture process cheese was dry, brittle, and firm. The body firmness of the process cheese decreased with increasing age of the cheese from which this product was made. The body of the natural cheese also became weaker with increases in fat content. A low ratio of casein-to-fat produced a weak process cheese.

Bauertal (1932b, 1932d) stated that the temperature of processing ranged from 140° to 160°F. Sommer and Templeton (1939) recommended 150°F for no holding time for process cheese and 160° to 170°F for soft cheese and cheese spreads. They also reported that high moisture content and low acidity cheese require high processing temperatures. Excessive heating of process Cheddar cheese will cause off colors to occur. Barker (1947a) claimed the average finishing temperature should be approximately 160°F; and, if heating is controlled, the texture will not be destroyed. Templeton and Sommer (1930) advised removing the cheese from the kettle as soon as a temperature of 140° to 150°F was reached. Schulz and Hetzel (1960) indicated that the temperature of heating can not vary much but should be high enough to pasteurize the product. Jakubowski and Bijok (1959b) stated that 85°C for ten minutes was the optimum processing time and temperature relationship.

Faivre (1946) reported that rapid stirring during processing will produce a cheese with a weak body and that rapid melting will produce a product with a firm body. He stated that the slower the process cheese cooled, the firmer the product would be. Jakubowski and Bijok (1960) noted a

strong relationship between the texture and flavor of the process cheese and the pH of the product. They indicated the pH could not be satisfactorily adjusted using salts but acid or alkali worked quite well. Wearmouth (1959) reported that "Solva salts" (buffering salts) could be used to adjust the pH of process cheese.

"Oiling off" defect in process cheese has been observed by several workers (Bauertal, 1932b; Templeton and Sommer, 1936; Barker, 1941a; Palmer and Sly, 1943). Bauertal (1932b) listed the factors affecting fat separation as the age of the cheese, the acidity, the water content, and the velocity of agitation. Some lots of cheese can be heated without emulsifier and the fat will not separate. Other blends, under the same conditions, will oil off. Templeton and Sommer (1936) contend that if a lot of cheese containing emulsifier oils off, this phenomenon is direct proof of improper blending and poor choice of emulsifying salt.

Fat separation has been reported by Sommer and Templeton (1939) to occur between 95° to 120°F. In a comprehensive study of Palmer and Sly (1943), the fat content was not found to be an important factor in "oiling off." They indicated fat separations occurred most commonly at pH values of 5.8 to 6.0 or below 5.4. Very mature cheese is very susceptible to fat separation while young cheese forms a stable oil-in-water emulsion. Free fat may occur during cooking, but it will generally be reincorporated. Bauertal

(1932b) and Templeton and Sommer (1930) reported the fat will be reincorporated at about 130°F.

Barker (1947a) indicated that process cheese should form strands "15 inches long" when the product is finished cooking. He stated that these strands should not contain free fat or moisture, should not be rubbery, but may be elastic. Overrun in process cheese is approximately 5 per cent. The cheese mixture is packaged hot; thereby, the hot cheese sanitizes the container. Erekson (1940) concluded that certain cellulose films were the best packaging material at that time. Barker (1941b) suggested the air and equipment be sprayed or washed with a hypochlorite solution to eliminate mold and yeast spores. After packaging Van Slyke (1952) advised cooling at 65° to 70°F before placing under refrigeration.

Cheese spreads. A pasteurized process cheese spread is a cheese food containing more than 44 per cent moisture but not more than 60 per cent moisture and a butterfat content of not less than 20 per cent fat. A spread should be spreadable at 70°F. Barker (1940a) describes a method in which cream is used as the base for spreads. This same author (1942b) reported that current cheese is the type of cheese used mainly in spreads. Templeton and Sommer (1932b) recommended temperatures of 160° to 180°F for processing spreads. These authors attributed the spreading properties of these products to their fat and moisture content.

Templeton and Sommer (1934b) reported that basically there are two types of cheese spreads: a) the base is cheese with milk solids added; b) the base is cream or cream cheese with enough aged cheese added to produce a good flavor. These workers found that whey powder, when added to spreads, produced a weaker product than skim milk powder. Sommer and Templeton (1939) reported cheese spreads made by processing cheese with the addition of milk solids were preferred over spreads in which cream cheese was used as the base. A spread with 41 to 45 per cent moisture will have good spreading quality. Barker (1940b) advised using condensed whey, whey powder, condensed skim milk, or skim milk powder in spreads but warned against the use of greater than 10 per cent whey solids in the finished product. If this level is exceeded, the whey will impart a sweet flavor to the spread. Barker (1942a) recommended heating aged cheese to 160°F before adding such cheese to the other ingredients. This worker reported (1955) a desirable process cheese loaf could be made using 50 per cent non-fat dry milk, 25 per cent old English daisy cheese, and 25 per cent new daisy cheese.

Barker (1947b) claimed nearly all special varieties of spreads are pasteurized at higher temperatures than process cheese. The temperatures used are 165°F and higher, and the holding time is generally longer than those employed for process cheese. He also discussed the role of gums in spreads, dressing, and process cheese (1947c).

Softness of a spread varies directly with moisture content and with replacement of cheese solids-not-fat by nonfat dry milk or lactose (Olson and Price, 1959). Fat appeared to have no effect on firmness at the levels checked. Barth (1959) received a patent for a process involving the use of glutamic or aspartic acid or their alkaline salts plus an alkaline salt of phosphoric acid to adjust the acidity and pH of spreads and process cheese.

Methods of measuring physical and chemical properties. The melting quality of process cheese and spreads is very important. Zakariasen (1952) suggested that a half inch plug of an ideal process cheese should melt completely when steamed for 10 minutes. Olson and Price (1958) described a method in which spreads were put into glass tubing and the distance of cheese movement was measured. The correlation of their method was 0.8771 when comparing melting test values and spreadability values with the scores obtained by organoleptic means. The most comprehensive work on the melting properties of process cheese was carried out by Arnott, Morris, and Combs (1957). These workers found no significant relationship between moisture, fat, and pH to melting quality. They did report a slight dependency of melting quality on free tyrosine levels. Process cheese with free tyrosine levels greater than 0.16 mg per gram generally had good melting properties.

Several workers (Rogers and Sanders, 1942; Olson and Price, 1959; Schneider and Danek, 1962; Vakaleris, Olson, Price, 1962) have used penetrometers to evaluate the physical properties of process cheese and cheese spreads. The viscosity of process cheese was determined with a Brabender-Viscograph by Becker and Clemens (1955). Jakubowski and Bijok (1959a) used a Hoppler consistometer to determine the consistency of process cheese, and Boháč (1956) used the instrument for spreads.

Templeton and Sommer (1932a) used an instrument that crushed an inch cube of process cheese to one half inch as an indication of firmness of body. The weight (in grams) required to accomplish this task was recorded as the "crushing strength." The Ball Compressor was used by Wearmouth (1954) to measure body firmness at room temperature.

Wearmouth (1954) used a mixture of 12 parts of cheese to 30 parts of water (w/w) to determine the pH of process cheese. By this method most process cheese will have a pH of 5.9 to 6.6. Templeton and Sommer (1934a) weighed 50 grams of comminuted cheese into 500 ml of distilled water and titrated 25 ml of this suspension. They reported their results as percentage lactic acid. The suspension was also used for determining hydrogen ion concentration.

Keeping Quality of Process Cheese

Albus and Ayers (1928) studied gassy fermentation that had been reported to occur in reheated or process cheese products containing pimientos. Pimientos are fermentable carbohydrates that can be attacked by anaerobic spore-forming bacteria. This gassy fermentation can be prevented by washing the fermentable sugars from the pimientos. Sommer (1930) showed that a case of sandiness in process cheese was due to the formation of calcium tartrate crystals when tartrate was used as the emulsifier. A pasteurization temperature of 160°F for no holding time has been shown (1932c) to destroy 99.6 to 100 per cent of the bacteria present in process cheese.

Clostridium coagulans has been implicated as the organism causing putrefactive spoilage (1939). Heat treatments of 160° to 165°F for 5 minutes have been suggested for control of gas formation by Palmer and Sly (1941). Hlynka and Hood (1948) recommended the use of sulfites or sulfur dioxide to prevent a brown discoloration of malted process cheese, which is caused by an interaction of the amino acids and proteins with the aldose sugars in the malt. Erekson (1948) showed the pink color defect of process cheese to be due to the fading of the added cheese color. Brown discoloration of process cheese may be caused by lactose concentration, if 8 to 10 per cent milk or whey powder is used. Hood and Bowen (1950) identified Clostridium sporogenes as the organism causing gassy slits and a putrid odor in Canadian process cheese. The source of contamination was skim milk powder.

Hood and Smith(1951) confirmed these findings and added that raw milk Cheddar cheese may also be an important source of contamination. They identified Clostridium sporogenes and C. pasteurianum as the causative organisms and suggested controlling spoilage by use of 1 per cent salt and maintaining the pH below 5.

Ledabyl (1953) concluded that cooking process cheese for ten minutes at 80°C was sufficient to destroy acid-and alkali-producing bacteria and molds. However, to eliminate spore-forming bacteria temperatures exceeding 95°C for ten minutes were required. A 3 per cent hydrogen peroxide solution was found to be adequate for sanitizing hands and equipment. Berridge (1953) showed that cultures of nisin producing streptococci could prevent gassy fermentation in process cheese and other cheese. Wagenaar and Dack (1954) studied the effect of emulsifier on the growth and toxin production of Clostridium botulinum. They found that 2.5 per cent disodium phosphate reduced the amount of salt required to inhibit experimentally inoculated samples.

A skim milk cheese curd, inoculated with nisin producing cultures, has been found to inhibit the growth of gas producing clostridia when added to process cheese at the 1 to 2 per cent level (Anonymous, 1956). Nelson (1958) reported spoilage of canned cheese paste by the reaction of phosphate emulsifier with the calcium of the cheese to form brushite nodules and that the hydrogen swells observed were due to the reaction of the cheese acids with the corroded tin plate. Milacek (1959) developed a method of sterilizing flavoring materials for process cheese. Butyric acid fermentation can be prevented by treating flavoring materials such as caraway seeds with 3 per cent hydrogen peroxide for 15 to 30 minutes at room temperature. Niki et al. (1959) discussed the factors affecting the color of process cheese and methods of preventing color defects. Alpern, Kosikowski, and Hill (1960) reported a case of gas blowing of packaged process cheese that was associated with high bacterial counts rather than reaction with the foil packaging material.

Dehydration of Cheese

Research at the Bureau of Dairy Industry led to the development of a satisfactory method for dehydrating full-fat cheese (Anonymous, 1943). This method consisted of partially drying grated cheese at room temperature followed by further drying in a tunnel or by any other heated air method. The first stage of this drying operation "case-hardened" the particles of cheese and thereby entrapped the fat. A maximum final drying temperature of 145°F was used. The moisture content of cheese dried in this manner is approximately 3 per cent; the flavor, keeping quality, and physical properties are good (Sanders, 1943).

Traisman and Kurtzhalts (1954) developed a method for making grated cheese. Part of the cheese used in this method is air-dried to 10 to 12 per cent moisture, and the other portion is melted with 1 per cent disodium phosphate, heated to 200°F, and spray-dried. Equal amounts of the two cheese products are mixed, milled, tempered, sieved, and packaged.

A modification of Sander's method (1943) was reported (Anonymous, 1955). The cheese particles were first case-hardened and then were dried to less than 3 per cent moisture at 145°F in a room in which the relative humidity was maintained at less than 35 per cent. This product could be reconstituted by adding emulsifiers and heating to 160°F with rapid stirring.

Yakhontov (1956) described a method of drying in which cheese with 32 to 35 per cent moisture is ground and dried in a current of air at approximately 40°C. The product after sieving contains 10 per cent moisture and must be stored in a well-ventilated room at 10° to 15°C and 70 to 75 per cent relative humidity. Boháč (1957) dried grated natural cheese using fans and infra-red lamps. Cheese emulsified with tetrasodium pyrophosphate and the ammonium salt of polymeric phosphate was roller dried at 85°C for 7 minutes. Olsansky and Schmidl (1960) used warm air current or bright or dark infra-red lamps to dry samples of Parmesan cheese. They claimed that warm air current methods were too slow and that bright infra-red lamps adversely affected the cheese on storage. The best product was obtained using dark infra-red lamps with filters eliminating the visible light.

Czulak, Hammond, and Forss (1961) were unable to dry Cheddar cheese in a current of air at relatively low temperatures, at low relative humidity and under partial vacuum. These workers were able to dry grated cheese by air current at temperatures up to 160°C, if mixed with 30 per cent by weight dried skimmed milk, dried buttermilk, or dried whey. The final product containing 9 to 10 per cent moisture can be crushed into a powder. Czulak et al. reported a loss of most of the volatile cheese flavor and off-flavor when drying by this method. A mixture of fatty acids, methyl ketones or commercial cheese was used to restore some of the lost volatiles. Riesen (1960) received a French patent for developing a method of producing cheese in powder or chip form. He coagulated pasteurized milk with calcium chloride; and the curd was then salted, drained, brined in saturated salt solution, ripened at low temperatures, grated, and dehydrated.

Freeze-drying. Freeze-drying was known as "drying by sublimation" as far back as 1813. However, sublimation was not used successfully for preserving biological substances until 1909. This method of dehydration has now been applied to the preservation of many foods. The advantages of freeze-drying have been summarized as follows: a) freeze-dehydration does not destroy the original shape and volume of the product; b) this method reduces the weight and allows the product to be stored at ambient temperatures; and c) the flavor of products dehydrated by this method is often better than by conventional means (Meyer and Jokay, 1959).

Meyer and Jokay (1959) applied freeze-dehydration to cheese products. The cheese was frozen at quiescent air temperatures of -5° to -10°F, and the frozen cheese was dried in 10 to 20 hours depending on the size and shape of the sample. Rehydration of Cheddar and process Cheddar cheese required 12 hours. The body of the rehydrated cheese was soft, and the flavor was described as "fair." The shelf life ranged from one week to 24 weeks at storage temperatures of 0°F to 100°F respectively. Evstrateva, Kuryachev, and Sinitsyn (1959) preserved a low fat and a fat free lactic cheese by freeze-drying for 18 hours using an absolute pressure of 0.50 to 0.88 mm. The finished product contained 2.9 to 4.0 per cent moisture and could be reconstituted using water at 20° to 30°C. A German dairy has used freeze-drying to preserve quarg. The product is stored in plastic bags and can be easily rehydrated using cold water (Anonymous, 1964).

Spray-drying. Boháč (1957) reported spray-drying a blend of natural cheese that had been emulsified with potassium polyphosphate and alkaline polyphosphate at 80°C for ten minutes. He noted that natural cheese with flavor defects were improved by spray-drying. He attributed this improvement in flavor to the loss of soluble nitrogenous substances. Makar'in (1959) suggested using spray-dried cheese to manufacture process cheese. The product should be standardized to 35 per cent total solids before drying. After drying, the cheese is blended with water at 65° to 70°C with constant stirring and the product is then cooled. Krasheninin, Shubin, and Markhinin (1960) spray-dried natural cheese that had been emulsified at 70° to 80°C for 20 minutes. The inlet air temperature for drying was 150° to 160°C while the exit air temperature was 75° to 85°C. They recommended reconstituting this powder into a process cheese.

Giraud (1960) received a French patent for a method of spray-drying hard or mold-ripened cheese. Ten to 20 per cent moisture was added to the cheese and the mixture heated to 80°C. The mixture was spray-dried at an inlet air temperature of 140°C, and the finished powder contained 3 to 5 per cent moisture. Rogers (1962) described a method of drying cheese at temperatures of 165°F or less. A cheese and water mixture of 35 to 42 per cent total solids was heated to 160°F and then cooled to 140°F, homogenized at 2500 to 5000 psig and spray-dried. Bullock (1963) reported spray-drying in a laboratory Swenson Research Spray Dryer equipped with a pneumatic atomizing nozzle. Small particles would plug the nozzle unless the cheese mixture was homogenized before spraying. If an emulsion of greater than 40 per cent total solids was used, the viscosity was too great to obtain proper atomization. Aged cheese of 1½ to 2 years old did not emulsify or dry well, and the dried product was coarse and tended to stick to the drying chamber. However, good results were obtained when cheese of 4 to 5 months old was used. Blue-veined cheese at levels of 5 and 10 per cent were used in an attempt to improve the dried cheese flavor. Five per cent blue-veined cheese increased the flavor, but the flavor was not typical of Cheddar cheese. Inlet air temperature for drying was 400°F, and the outlet air temperature was 180°F.

Bradley and Stine (1963) studied the spray-drying of natural cheese in considerable detail. They reported that a cheese emulsion containing 2 per cent sodium citrate, 0.5 per cent salt, and 40 per cent total cheese solids could be spray-dried readily. Cheddar cheese less than 3 months old caused the homogenizer valves to stick, while cheese older than 3 months formed a smooth emulsion that homogenized easily. Cheese that was judged bitter or acid before drying produced powder of the same defect. Cheese dried at an exit air temperature of 160°F in a Rogers cocurrent, horizontal, inverted tear-drop drier was judged fair; while cheese dried at 190°F was judged stale. Powder collected in-flight and not allowed to remain in contact with the walls of the drier was superior to powder collected in the normal manner. The powder of large particle size was preferred over powder of small particle size.

Reich and Johnston (1957) were awarded a patent for a method of spray-drying foamed coffee and tea. They indicated that air, carbon dioxide, and nitrogen when injected into product concentrates could control and improve the bulk density, color, free-flowing properties of powders. Hanrahan and Webb (1961) applied foam spray-drying to the dehydration of acid whey. Cottage cheese whey is difficult to dry and contains lactic acid which causes the product to agglomerate and adhere to the equipment. The whey is concentrated to 45 to 50 per cent solids, and air is injected into the concentrated product as the whey is spray-dried. The powder is allowed to pick up moisture, which causes lactose crystallization, and the crystallized product is then redried.

Bradley and Stine (1964b) adapted the foam spray-drying procedure to the dehydration of natural cheese. One half per cent salt and 2.0 per cent sodium citrate were added to a cheese slurry containing 40 per cent total solids, and this mixture was heated to 180°F for 10 minutes. The heated emulsion was homogenized at 2000 psig in a two-stage, Manton-Gaulin homogenizer. Nitrogen gas was injected at a rate of 1 ft^3/minute while the mixture was being dried at an exit air temperature of 160°F. Foam spray-dried cheese retains more flavor volatiles and is less susceptible to oxidation during storage.

<u>Storage of dried dairy products</u>. Lea, Moran, and Smith (1943) noted that tallowiness can be prevented by packing

powder in gas-tight containers in a nitrogen atmosphere containing not more than 0.5 to 2.0 per cent oxygen. Bradley and Stine (1963) indicated that more lipid oxidation occurred in cheese powder packed in air than in nitrogen-packed samples. These same authors (1964b) reported that antioxidants do not improve the initial flavor of cheese powder. Coulter and Jenness (1945) suggested regassing dry whole milk 20 hours after the first gassing in order to reduce the final oxygen content of the headspace gas to a safe level. Nitrogen and carbon-dioxide were found to be equal in their ability to maintain oxygen levels in dry whole milk. Greenbank et al. (1946) in a study of the keeping quality of dried milk samples demonstrated that gas packing with inert gas was superior to packing in air.

Flavor Evaluation of Cheese

Templeton and Sommer (1930) suggested adding 0.1 to 0.2 per cent citric acid to process cheese to improve the flavor. Caserio (1938) reported that pasteurized cheese has less flavor and a more uniform flavor than unpasteurized cheese. He attributed this loss of flavor to partial insolubilization of nitrogenous constituents, as well as loss of ammonia, esters, aldehydes, ketones, and acids to a lesser degree. Kass (1951) obtained a United States patent for a process in which leucine and amino acids or an acid hydrolysate of zein were added to dough to produce a cheese flavor.

Quantities of 0.05 to 0.5 per cent leucine or the acid hydrolysate of zein were found to be quite satisfactory in their ability to impart cheese flavor to baked goods.

In a study on the vitamin B_{12} content of cheese, Hartman and Dryden (1956) reported process Cheddar cheese to contain approximately one half that of natural Cheddar. Wertz (1956) investigated the essential amino acid content of cooked and ready-to-eat foods. Process Cheddar cheese contains less free isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine than natural Cheddar cheese. Process cheese contains emulsifiers and salt which decrease the amount of amino acids per gram of product. Kosikowski (1957) noted that the flavor of the resulting cheese was dependent on the milk source. He found that leucine, glutamic acid, and valine were present in cheese in the free state 48 hours after manufacture.

Jackson (1958) claimed that cheese flavor is present in the fat portion and that beta-methylmercaptopropionaldehyde is related to cheese aroma. Patton, Wong, and Forss (1958) isolated heptanone-2 from Cheddar cheese and found dimethyl sulfide to be important as an aroma component of Cheddar cheese. Bassett and Harper (1958) identified pyruvic acid, alpha-ketoglutaric acid, oxalacetic acid, alpha-acetolactic acid, alpha-ketoisocaproic acid, diacetyl and acetylmethylcarbinol as components of Cheddar cheese. Harper (1959) studied the chemistry of cheese flavors. He indicated that cheese taste was associated with lactic acid, amino acids, nonvolatile fatty acids, keto acids, nonvolatile amines, salts, and various fragments of the proteins and fats. The aroma of cheese comes from amines, fatty acids, aldehydes, ketones, alcohols, esters, and volatile sulfur compounds. Free amino acids, such as glutamic acid and leucine, may contribute to the flavor of cheese. Walker and Harvey (1959) suggested that 3-methylthiopropanal is the "key component of Cheddar cheese flavor."

In general, Kristoffersen and Gould (1959) found no relationship between the presence and relative concentrations of carbonyl compounds and Cheddar cheese flavor. Nakanishi and Tokita (1959) indicated that the intermediate metabolic products of the citric acid cycle were associated with cheese flavor. Cheese containing large quantities of citric acid is sour and will not ripen properly. Day, Bassette, and Keeney (1960) identified the 2, 4-dinitrophenylhydrozones of 2-nonanone, 2-heptanone, 2-pentanone, butanone, acetone, 3-methylbutanal, propanal, ethanal, methanal, and 3-methylthiopropanal from Cheddar cheese.

Mabbitt (1961) suggested that hydrogen sulfide formation may only be an indicator of flavor production and that methyl sulfides may be of much more importance. He also reported that the "cheesy" odor or methional was due to oxidized impurities. Methyl mercaptan was isolated and identified by Libbey and Day (1963) as a component of

Cheddar cheese. This compound is present in concentrations of 3-30 parts per billion and has an estimated odor threshold of 0.02 ppb. Patton (1963) claimed that acetic, butyric, caproic, and caprylic acids are the "backbone of Cheddar aroma." Acetic acid is present in the highest concentrations among the volatile acids and is thought to be particularly important in cheese aroma. Kroger and Patton (1964) used gas chromatography to identify ethyl ether, acetaldehyde, dimethyl sulfide, acetone, ethyl acetate, butanone, iso-propanol, ethanol, pentanone-2, diacetyl, n-valeraldehyde, chloroform, 2-butanol, n-propanol, hexanone-2, and heptanone-2 from cheese. They observed that each cheese had a certain number and amount of components. Kristoffersen, Gould, and Purvis (1964) reported that Cheddar cheese flavor was related to the concentration of active sulfhydryl groups rather than bacterial numbers. The concentration of active sulfhydryl groups was dependent upon the severity of the heat treatment of the milk used to make the cheese. Bradley and Stine (1964a) showed by gas chromatographic separation of volatiles collected from spray dried cheese and fresh cheese slurries a loss of some flavor components and the formation of some new compounds. Gas-injection spray-dried cheese powder retained more volatiles than did conventional cheese powders.

EXPERIMENTAL PROCEDURES

The purpose of these experiments was threefold:

1) to determine if a desirable process cheese could be made from dried cheese,

2) to study formulations for this product, and

3) to evaluate the acceptability of various flavor additives used for process cheese made from dried cheese.

Preparation of Dried Cheese

Several different lots of Cheddar cheese, having 38 to 40 flavor scores, were selected by experienced cheese judges. The cheese was ground and blended to obtain the desired mixture of mild and aged Cheddar cheese. In some instances, cheese ripened to a certain age was used directly without blending.

Mild Cheddar cheese (cheese ripened less than 3 months) and blended cheese (various mixtures of mild and aged cheese) were slurried with tap water to 35 per cent total solids. Aged Cheddar cheese (cheese ripened more than 6 months) was slurried with tap water to 40 per cent total solids.

These cheese slurries were heated to 180°F for 10 minutes with 3 per cent sodium citrate, disodium phosphate, or sodium aluminum phosphate and 1 per cent sodium chloride. The hot emulsions were homogenized immediately at 2000 psi using a two-stage, Manton-Gaulin homogenizer. These homogenized emulsions at approximately 140°F were delivered to the high pressure pump. To induce foaming prior to drying, water-pump nitrogen was injected into the cheese slurries at an average rate of 2.0 ft^3/gal in a mixing cylinder located between the high-pressure pump and the atomizing nozzle. The slurries were atomized with two Spraying Systems SX high-pressure nozzles with an orifice diameter of 0.038 in. into a Rogers cocurrent inverted tear-drop drier. The inlet and exit air temperatures averaged 270° and 165°F respectively.

Also, samples of mild, blended, and aged Cheddar cheese were dried in a Stokes freeze drier. These samples were frozen at -10°F for 24 hours and subsequently freeze-dried in a chamber evacuated to 100 microns of mercury, measured on a McLeod guage with 90°F water circulating through the heating platens.

Methods of Storage

The foam-spray dried powder was packed in No. 307 X 409 cans and cryovac plastic bags. The cans were sealed on an Automatic Master Sealer, punctured, and then evacuated under 200 microns pressure for 30 minutes. After complete air exhaustion, the cans were flooded with water-pump nitrogen and resealed immediately with solder. The can seams were dipped in a Wood's metal and lactic acid bath to guard against entrance of atmospheric oxygen. The cans and the cryovac bags of foam-spray dried cheese were stored at 35°F.

Analytical Methods

Moisture. The moisture content of all dried cheese samples was determined by a Cenco Infra-red Moisture Balance.

Titratable acidity. A 10-g sample of cheese powder was blended with 100 ml distilled water in an electric mixer. After 1 hour of quiescence, the suspension was restirred and sampled. An 18-g sample was titrated with 0.1 N sodium hydroxide using phenolphthalein as the indicator. The acidity was calculated and reported directly as percentage lactic acid.

Solubility index. The solubility index of foam-spray dried cheese was determined by measuring the insoluble material using the method recommended by the American Dry Milk Institute for dry whole milk (1955).

Bulk density. A weighed graduated cylinder was filled to the 100 ml mark with cheese powder. The cylinder was then tapped gently by hand 100 times to facilitate settling. The final volume of the powder in the cylinder was noted and recorded. The cylinder containing the packed powder was then reweighed. The bulk density was calculated as g/ml.

Preparation of Process Cheese Samples

Dried cheese and water (also emulsifier, salt, flavoring materials, and natural Cheddar cheese, when used) were mixed together in a double boiler. The ingredients were pasteurized at 150°F for a holding time of 30 to 60 sec. Stirring was constant. The hot cheese was packaged in polystyrene containers and stored at 40°F or at 70° to 80°F.

Evaluation of Process Cheese Prepared from Dried Cheese

Total solids. The total solids of the process cheese was determined by the vacuum-oven method, using a Mojonnier apparatus.

pH. After grinding a 10-g sample of cheese into a fine paste, the pH was determined with a Beckman Zeromatic pH meter, using glass and calomel electrodes.

Meltdown. The meltdown quality of the sample was evaluated using a modification of the method described by Arnott et al. (1957). Cheese plugs of 17 mm diameter were obtained and positioned on glass chromatography plates. The height of the plugs was measured accurately with a Cenco Spherometer before and after heat treatment. Each plug was covered to reduce possible surface drying before placing in the oven. After being positioned on the plates, the plugs were placed in a 100°C oven where they were held for 15 min. The melted plugs were removed from the oven and were measured as before. Meltdown quality was calculated in percentage decrease in cylinder heights before and after heat treatment.

<u>Penetrometer</u>. An indication of body firmness was obtained using a Precision Scientific penetrometer with 150g weight added to the loading bar. (The cone weighs 102.5 g and the test plunger weighs 47.5 g; and, therefore, the weight of the loaded cone was 300 g.) After positioning the sample on the base, the point of the cone was lowered until it just touched the sample surface. Then the test plunger was released using the clutch trigger which was held exactly 5 sec before releasing. The depth of penetration was obtained by depressing the depth guage. Penetration was recorded in tenths of millimeters.

<u>Shear force</u>. An indication of body firmness and slicing properties was obtained using a modified Warner-Bratzler shear on a 21mm diameter plug. The Warner-Bratzler scale was replaced with a 2000g Ohaus scale. After placing the sample in the holding bar, the blades were then released and the total weight required to cut through the cylinder was noted. The recorded weight in grams was the shear value for the sample.

<u>Organoleptic analysis</u>. The body and flavor of the process cheese was judged by a panel of 3 to 6 members. The hedonic preference test, with a range of 0 to 9, was in evaluating the samples. The average value for each sample was reported.

<u>Coliform test with solid media</u>. Sample dilutions prepared from distilled water and cheese were plated out using violet red bile agar and an incubation period of 24 hr at 32°C. The number of "apparent coliform" organisms per ml was reported as the coliform count for the sample (American Public Health Association, Inc., 1960).

<u>Standard plate count test</u>. Sample dilutions prepared from distilled water and cheese were plated out using standard plate count media and an incubation period of 48 hr at 32°C. The number of organisms per ml growing on this media under these conditions was reported as the standard plate count for the sample (American Public Health Association, Inc., 1960).

RESULTS

Obtaining Dry Cheese by the Foam-spray Drying Process

Several cheese slurries were foam-spray dried to obtain cheese powder. These basic slurries contained different amounts and varieties of cheese and several emulsifiers. Either 35 or 40 per cent total solids were obtained. The components of the cheese slurries prior to foam-spray drying are presented in Table 1.

Slurries of aged Cheddar cheese and tap water were compounded to 40 per cent total solids. Those containing mild Cheddar cheese and tap water were made up to 35 per cent total solids. In addition, mixtures containing various percentages of aged and mild Cheddar cheese were slurried. Also, Cheddar cheese slurries containing small amounts of blue-veined and Limburger cheese were prepared. All of these cheese slurries contained added emulsifiers such as sodium citrate, sodium aluminum phosphate, or disodium phosphate. Ultimately, process cheese was made from the powders obtained by foam-spray drying the several cheese slurries.

Table 1. Constituents of cheese slurry prior to foam-spray drying.

Slurry (No.)	Additive (%)		Variety of cheese used (%)			Total solids of slurry %
	Sodium citrate	Sodium chloride	American Cheddar		Other	
			Mild[c]	Aged[d]		
1	3	1	75	25	0	35
2	3	1	0	100	0	40
3	3	1	100	0	0	35
4	3	1	0	100	0	40
5	3	1	100	0	0	35
6	3	1	75	25	0	35
7	3[a]	1	75	25	0	35
8	3[b]	1	75	25	0	35
9	3	1	71	24	5[e]	35
10	3	1	71	24	5[f]	35

[a] Sodium aluminum phosphate was used as the emulsifier instead of sodium citrate.
[b] Disodium phosphate was used as the emulsifier instead of sodium citrate.
[c] The pH of this cheese was 5.10.
[d] The pH of this cheese was 5.25.
[e] Blue-veined cheese
[f] Limburger cheese

Some Chemical and Physical Properties of Foam-spray Dried Cheese

The data on the chemical and physical properties of the foam-spray dried cheese mixtures are presented in Table 2.

The moisture content of the powders ranged from 2.9 to 3.4 per cent. The dried cheese containing sodium aluminum phosphate or blue-veined cheese had the lowest percentages of moisture. Those made from aged or mild Cheddar cheese, or a blend of these cheese, containing disodium phosphate had the highest percentage of moisture.

The titratable acidity of all the powders, other than the sample containing sodium aluminum phosphate, was either 0.29 or 0.32 per cent lactic acid. The dried product made from aged Cheddar cheese, or the blend containing blue-veined cheese had the highest titratable acidity of 0.32 per cent. Six out of the 10 powders (or 60 per cent) had the same titratable acidity of 0.29 per cent.

The solubility indexes of powders made from aged Cheddar cheese were 3.0 or 3.5 which were over four times those of powders made from mild Cheddar cheese. The indexes of powders containing sodium aluminum phosphate or disodium phosphate were 3.0 and 1.8 respectively. However, a similar powder made with sodium citrate had an index value of 0.3. In general, dried cheese prepared from a blend of aged Cheddar cheese and mild Cheddar cheese had solubility index values slightly lower than powders containing only mild Cheddar cheese.

The difference in relative bulk densities between the powders was quite narrow, ranging from 0.09 to 0.17 g/ml. The powder containing disodium phosphate had the lowest bulk density, while one of the powders made from aged Cheddar cheese had the highest bulk density. All the other dried cheese had values of 0.13, 0.14, or 0.15.

Table 2. Some chemical and physical properties of the foam-spray dried cheese.

Dried cheese* (No.)	Bulk density (g/ml)	Solubility index (ml insol. material)	Titratable acidity (%)	Moisture (%)
1	0.14	0.2	0.29	3.2
2	0.15	3.0	0.32	3.4
3	0.14	0.5	0.29	3.4
4	0.17	3.5	0.32	3.3
5	0.14	0.7	0.29	3.4
6	0.14	0.3	0.29	3.0
7	0.13	3.0	0.23	2.9
8	0.09	1.8	0.29	3.4
9	0.15	0.1	0.32	2.9
10	0.14	0.2	0.29	3.0

* The dried cheese indicated by numbers in the above table correspond to similarly numbered slurries in Table 1.

Process Cheese Made from Foam-spray Dried Cheddar Cheese

The effect of various combinations of dry aged and mild Cheddar cheese on properties of process cheese. The data on the physical properties and hedonic values of process cheese made from foam-spray dried cheese are presented in Table 3. Mild and aged foam-spray dried cheese, in varying concentrations, were evaluated to determine the optimum formulations of process cheese made from these products. Process cheese made from 100 per cent dry mild Cheddar cheese had the firmest body and lowest flavor score of any of

Table 3. The effect of various combinations of dry aged and mild Cheddar cheese on the physical properties and hedonic values of process cheese made therefrom.

Process cheese (No.)	pH of process cheese	Total solids of process cheese (%)	Dry American Cheddar cheese used in the manufacture of process cheese (%)		Physical properties			Hedonic value	
			Mild	Aged	Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1	5.40	60.45	100	0	71.4	128	337	7	4
2	5.45	60.85	75	25	65.1	175	275	7	7
3	5.40	59.89	65	35	70.3	145	250	7	6
4	5.40	60.03	50	50	68.8	184	250	6	6
5	5.35	60.15	0	100	71.8	262	50	-2	5

those processed. That made from 100 per cent dry aged cheese had the softest body and next to the lowest flavor score of any. The process cheese made from 75 per cent mild and 25 per cent aged cheese powder was judged on the basis of flavor and desired firmness to be the best. The melting quality of all the finished products was satisfactory.

The effect of foam-spray drying on properties of process cheese. Two process cheese were manufactured; one, the control, was prepared from 75 per cent mild and 25 per cent natural aged Cheddar cheese and the other, similarly proportioned, from the same identical lots but foam-spray dried before processing. A comparison of several values on these cheese is shown in Table 4. The lot prepared from dry cheese had a weaker body, lower meltdown value, and slightly lower hedonic rating than the process cheese prepared from natural Cheddar cheese.

The effect of blending mild and aged Cheddar cheese before and after foam-spray drying on properties of process cheese. Process cheese were prepared from: a)foam-spray dried cheese in which mild and aged Cheddar cheese had been blended before drying, or b) an equivalent mixture of mild and aged Cheddar cheese powder blended after drying. In either case a blend equivalent to 75 per cent mild and 25 per cent aged Cheddar cheese was used (Table 5). The physical properties and hedonic values of the two lots were similar. However, the flavor of the process cheese obtained by blending foam-spray dried was preferred consistently over that made from cheese

Table 4. Comparison of the physical properties and hedonic values of process cheese manufactured from natural Cheddar cheese and foam-spray dried Cheddar cheese.

Process cheese (No.)	pH of process cheese	Total solids of process cheese (%)	Treatment of Cheddar cheese used	Physical properties			Hedonic value	
				Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1[a]	5.40	60.54	None	79.7	145	375	8.0	8.0
2[b]	5.45	60.85	Dried	65.1	176	275	6.5	6.5

[a] Process cheese no. 1 was a control prepared from 75 per cent natural mild Cheddar cheese and 25 per cent natural aged Cheddar cheese.

[b] Process cheese no. 2 was prepared from 75 per cent mild Cheddar cheese powder and 25 per cent aged Cheddar cheese powder

Table 5. The effect of blending mild and aged Cheddar cheese before foam-spray drying on the physical properties and hedonic values of process cheese made therefrom.

Process cheese (No.)	pH of process cheese	Total solids of process cheese (%)	Treatment of Cheddar cheese used	Physical properties			Hedonic value	
				Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1	5.45	60.04	"blended before"[a]	55.8	143	312	4.3	4.5
2	5.45	60.51	"blended after"[b]	48.7	188	275	5.4	5.0

[a] A blend of 75 per cent mild and 25 per cent aged natural Cheddar cheese was foam-spray dried.

[b] Mild and aged natural Cheddar cheese was foam-spray dried separately and 75 per cent mild and 25 per cent aged Cheddar cheese powder was blended.

powder in which the cheese were blended before drying.

The effect of cooling process cheese to 40°F on physical properties of this product. Lots of process cheese were pasteurized: one portion of this cheese was cooled to 40°F, while the other portion was cooled to 70° to 80°F. The physical properties of the process cheese cooled at the two temperatures are presented in Table 6. The meltdown value of cheese cooled to 40°F was approximately 10 per cent greater than cheese cooled to 70° to 80°F. Process cheese made from foam-spray dried aged Cheddar cheese only had the highest percentage meltdown of any of the lots evaluated.

The penetrometer value (PV) of process cheese cooled to 70° to 80°F were approximately double those of cheese cooled to 40°F and measured at that temperature. Except for the PV of the lot cooled to 70° to 80°F made from 75 per cent mild and 25 per cent aged Cheddar cheese powder, the other PV could be directly correlated to the percentage aged Cheddar in the product.

Shear values of cheese cooled to 40°F were three to four times higher than similar products cooled to 70° to 80°F. Measurements were obtained at 40°F and 70° to 80°F respectively. The shear force of process cheese cooled to 70° to 80°F decreased as the amount of aged Cheddar cheese powder used in the lot was increased.

The effect of tempering process cheese to 70° to 80°F on physical properties of the cheese. Process cheese was manufactured and cooled to 40°F or 70° to 80°F. The cheese

Table 6. Comparison of the physical properties of process cheese cooled to 40°F after manufacture to that cooled to 70° to 80°F.

Process cheese* (No.)	Total Solids of process cheese (%)	Dry Cheddar cheese used in the manufacture of process cheese (%)		Physical properties					
				Meltdown (%)		Penetrometer (mm/10)		Shear force (g)	
		Mild	Aged	40°F	70°-80°F	40°F	70°-80°F	40°F	70°-80°F
1	60.45	100	0	71.4	53.6	63	128	1000	337
2	60.85	75	25	65.1	55.6	64	175	1000	275
3	59.89	65	35	70.3	51.1	68	145	1000	250
4	60.03	50	50	68.8	51.6	79	184	1125	250
5	60.15	0	100	71.8	62.6	167	262	150	50

* Twenty-four hours after manufacture the samples were removed from storage and evaluated at the respective temperatures.

Table 7. Comparison of the physical properties of process cheese cooled to 40°F after manufacture and tempered to 70° to 80°F to that cooled to 70° to 80°F initially.

Process cheese* (No.)	Total solids of process cheese(%)	Dry Cheddar cheese used in the manufacture of process cheese (%)		Physical properties					
				Meltdown (%)		Penetrometer (mm/10)		Shear force (g)	
		Mild	Aged	Tempered	Initial	Tempered	Initial	Tempered	Initial
1	62.63	100	0	62.3	53.6	124	131	475	475
2	62.58	75	25	62.5	58.3	125	130	512	412
3	62.87	65	35	69.9	65.6	128	131	450	437
4	62.35	50	50	71.2	66.1	135	150	400	375
5	61.98	0	100	73.3	73.4	161	153	350	237

* Half the sample was cooled to 40°F and tempered to 70° to 80°F, while the other portion of the sample was initially cooled to 70° to 80°F.

cooled to 40°F was removed from storage and allowed to temper for 72 hours to 70° to 80°F before evaluation. In general, cheese tempered to 70° to 80°F had more desirable melting properties and slightly firmer bodies than similar lots which had been cooled initially to 70° to 80°F (Table 7). However, the difference in physical properties of process cheese cooled in either manner were slight.

The effect of different types and quantities of emulsifiers on quality and properties of process cheese. The physical properties and hedonic values of process cheese made with different types and quantities of emulsifiers are presented in Table 8. The effect of 3 per cent sodium citrate, sodium aluminum phosphate, or disodium phosphate on the physical properties and hedonic ratings of process cheese was compared. Process cheese made with 3 per cent disodium phosphate exhibited melting properties superior to cheese made with 3 per cent sodium citrate or sodium aluminum phosphate. However, the lot containing 3 per cent disodium phosphate had the weakest body of cheese in this group. The hedonic flavor ratings of these cheese were essentially identical.

Process cheese was made also with 4, 5, and 6 per cent emulsifier. All lots containing greater than 3 per cent emulsifier had higher PV and lower shear values than those made with 3 per cent emulsifier. The meltdown values of cheese containing 4, 5, or 6 per cent sodium citrate or disodium phosphate were lower than similar cheese containing 3 per cent emulsifier. However, process cheese containing

Table 8. Comparison of the physical properties and hedonic values of process cheese made with different types and quantities of emulsifiers.

Process cheese (No.)	Emulsifier used in the manufacture of process cheese	Emulsifier (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body[d]	Flavor
1	Sodium citrate[a]	3	69.7	165	312	5.8	4.3
2	"	4	63.9	198	200	3.0	1.0
3	"	5	65.1	200	225	3.0	1.0
4	"	6	67.3	193	200	3.0	1.0
5	Sodium aluminum phosphate[b]	3	60.9	150	325	6.3	4.3
6	"	4	62.4	204	225	3.0	1.0
7	"	5	67.6	193	212	3.0	1.0
8	"	6	9.2	175	275	4.0	1.0
9	Disodium phosphate[c]	3	73.7	198	275	4.0	4.5
10	"	4	68.0	217	150	3.0	1.0
11	"	5	67.4	190	187	3.0	1.0
12	"	6	39.5	178	162	4.0	1.0

[a] Made with 200 g of dried slurry no. 6 of Table 1 and 140 g of water.
[b] Made with 200 g of dried slurry no. 7 of Table 1 and 140 g of water.
[c] Made with 200 g of dried slurry no. 8 of Table 1 and 140 g of water.
[d] The hedonic body values of process cheese 2, 3, 4, 6, 7, 8, 10, 11, and 12 are not averages, but the values of one judge.

4 and 5 per cent sodium aluminum phosphate had slightly better meltdown properties than process cheese 5 containing 3 per cent emulsifier.

The flavor of all cheese containing greater than 3 per cent emulsifier was extremely objectionable and criticized as tasting salty and powdery.

The effect of commercial flavor fortifiers on flavor of process cheese. A series of process cheese was made containing various levels of fortifiers. The purpose of the addition of fortifiers was to add back some of the flavor volatiles that apparently are lost during spray-drying. Five commercial fortifiers were evaluated organoleptically to determine their acceptability and proper level of usage. The recommendations of the companies supplying the fortifiers were used as guide lines to determine the proper level of fortifier.

The results reported in Table 9 illustrate the effect of commercial fortifiers on the flavor of process cheese made from cheese powder. Process cheese 1, a control, was judged at the same time cheese 2 to 6 were evaluated. Fortifier A was used in lots 2, 3, 4, 5, and 6 at levels ranging from 100 to 5000 ppm. This fortifier contributed a foreign, artificial taste to the process cheese at levels of 500 ppm and above, No improvement in flavor was noted at a concentration of 100 ppm.

Cheese 8, 9, and 10 were made with fortifier B at

Table 9. The effect of commercial fortifiers on the hedonic flavor value of process cheese made from foam-spray dried Cheddar cheese.

Process cheese* (No.)	Fortifier used in making process cheese (No.)	Fortifier (ppm)	Hedonic flavor value
1	Control	0	5.0
2	A	100	5.0
3	"	500	3.4
4	"	1000	3.3
5	"	2000	2.8
6	"	5000	2.2
7	Control	0	5.8
8	B	1000	5.4
9	"	2000	5.6
10	"	5000	4.4
11	Control	0	5.8
12	C	1250	6.4
13	"	2500	5.0
14	"	3750	4.4
15	Control	0	5.7
16	D	10	5.8
17	"	100	5.0
18	"	1000	2.7
19	Control	0	5.7
20	E	10	5.3
21	"	100	5.0
22	"	1000	2.7

* Made with 200 g of dried slurry no. 6 of Table 1 and 140 g water.

levels of 1000 to 5000 ppm. Presumably, the proper level of this fortifier would be at levels less than 5000 ppm since the cheese was downgraded at this concentration. Cheese made with this fortifier had a blue-cheese taste which was extremely ob

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objectionable at a level of 5000 ppm. Process cheese 7 was the control for this group and was preferred over the other products.

Fortifier C was used at levels of 1250 to 3750 ppm in lots 12, 13, and 14. The proper level of usage for this fortifier would be approximately 1250 ppm. Cheese made with levels as high as 3750 ppm tasted "ketony." The hedonic flavor value for the cheese containing 1250 ppm was 6.4 while that of the control was 5.8.

Lots 16, 17, and 18 were made with 10, 100, and 1000 ppm of fortifier D respectively. This fortifier was preferred at a level of 10 ppm over cheese made with 100 and 1000 ppm. Cheese containing 100 or 1000 ppm were judged respectively to have a slight or strong ketone flavor.

The flavor contributed to process cheese by fortifier E was atypically unpleasant. The control cheese was considered superior to cheese containing this fortifier. As concentration of the flavor fortifier was increased, the process cheese was criticized for a fruity off-flavor.

The effect of organic acids on flavor and physical properties of process cheese. Process cheese was made with 100, 1000, and 10,000 ppm of the organic acids listed in Table 10. These acids were added in hope of enhancing the cheese flavor. Process cheese 2, 3, and 4 were made with 100, 1000, and 10,000 ppm lactic acid respectively. Lactic acid at a level of 100 ppm was preferred over process cheese

Table 10. The effect of organic acids on the physical properties and hedonic values of process cheese made from foam-spray dried Cheddar cheese.

Process cheese[a] (No.)	Organic acid used in making process cheese	Organic acid (ppm)	Physical properties		Hedonic value	
			Meltdown (%)	Penetrometer[b] (mm/10)	Body	Flavor
1	None	0	69.7	76	5.2	6.0
2	Lactic	100	60.9	87	4.8	5.3
3	"	1000	67.0	96	5.0	5.0
4	"	10000	17.3	55	1.7	3.2
5	None	0	69.7	76	5.3	5.3
6	Acetic	100	41.3	81	5.5	5.2
7	"	1000	41.2	93	5.3	5.5
8	"	10000	18.7	57	1.5	1.5
9	None	0	69.7	76	5.3	5.7
10	Citric	100	67.5	87	6.5	5.8
11	"	1000	33.8	67	5.8	6.0
12	"	10000	7.6	55	2.0	2.0
13	None	0	69.7	76	5.3	5.7
14	Phosphoric	100	46.7	69	6.0	5.7
15	"	1000	64.2	75	6.0	5.2
16	"	10000	13.4	52	2.0	2.0

[a] Made with 200 g of dried slurry no. 6 of Table 1 and 140 g water.
[b] Penetrometer readings were made on cheese stored at 40°F.

containing 1000 and 10,000 ppm of this acid. Process cheese 2 and two controls were also evaluated to determine if cheese containing 100 ppm lactic acid was preferred to cheese without lactic acid. Four out of six judges were unable to detect the lactic acid at 100 ppm. The two judges capable of detecting the sample containing 100 ppm lactic acid expressed neither a like nor a dislike for the acid. However, process cheese containing 1000 ppm had a definite acid taste which was objectionable. The percentage meltdown of samples containing 100 and 1000 ppm lactic acid was more than three times the value of the sample made with 10,000 ppm. The body of this latter cheese was extremely firm; the texture was mealy.

The meltdown of process cheese containing acetic acid was one third to two thirds lower than the cheese control. The hedonic values of lots made with 0, 100, and 1000 ppm acetic acid were above 5.0. Cheese containing 100 ppm acetic acid could not be distinguished from that made without added acetic acid, but the cheese containing 1000 ppm had a pronounced acid flavor.

Citric acid was added to cheese 10, 11, and 12 at levels of 100, 1000, and 10,000 ppm respectively. Lots 10 and 11 were judged superior to the control cheese. The body of cheese 11 and 12 were adversely affected by the citric acid, and the melting qualities of these products were not satisfactory. Four of six judges were able to distinguish between cheese containing 100 ppm citric acid and cheese without citric acid, but these judges did not express a preference for either of the cheese.

Process cheese prepared with phosphoric acid at levels of 100 and 1000 ppm were given satisfactory flavor values (greater than 5). The percentage meltdown of the sample made with 10,000 ppm phosphoric acid was very low and the body was extremely firm. Phosphoric acid could be detected in the cheese at levels of 100 ppm. The cheese was not liked as well as the control by the majority of the judges in the trio test.

<u>The effect of added leucine, methionine, and the acid hydrolysate of corn on flavor of process cheese</u>. The effect of leucine, methionine, and the hydrolysate was studied. The results of the evaluation are given in Table 11. Kass (1951) had reported using leucine or the acid hydrolysate of corn to produce cheese flavor in baked goods. Jackson (1958) had indicated that methionine may be important in the aroma of Cheddar cheese. Accordingly, leucine was added to process cheese 2, 3, and 4 at levels of 500, 3000, and 10,000 ppm respectively. Cheese 2 containing 500 ppm leucine was preferred over that made with 3000 and 10,000 ppm of this amino acid. The cheese containing 10,000 ppm leucine was criticized as tasting salty and bitter. Leucine did not improve the flavor of process cheese at the quantities used.

The hedonic flavor values of process cheese made with added methionine were similar to the control. Very little difference in flavor values was noticed among cheese containing 0, 100, 1000, and 10,000 ppm methionine. A mixture of 1000 ppm methionine and 1000 ppm leucine did improve the flavor of the process cheese slightly.

The control process cheese was judged superior to cheese

Table 11. The effect of leucine, methionine, and the hydrolysate of corn on the hedonic flavor value of process cheese made from foam-spray dried Cheddar cheese.

Process cheese[a] (No.)	Additive used in making process cheese	Additive (ppm)	Hedonic flavor value
1	None	0	5.3
2	Leucine	500	5.3
3	"	3000	5.0
4	"	10000	3.8
5	None	0	4.8
6	Methionine	100	4.5
7	"	1000	4.3
8	"	10000	4.8
9	None	0	5.8
10	Corn hydrolysate	100	5.7
11	"	1000	5.5
12	"	10000	5.3
13	None	0	5.2
14	Leucine, Methionine	1000	5.8
15[b]	Leucine	1000	3.2
16[c]	Methionine	1000	3.2

[a] Made with 150 g dry mild Cheddar cheese, 50 g dry aged Cheddar cheese, and 140 g water.
[b] Allowed to incubate at 23°C for 4 hours with 1 per cent dry yeast before the mixture was pasteurized.
[c] Allowed to incubate at 23°C for 4 hours with 1 per cent dry yeast before the mixture was pasteurized.

the hydrolysate of corn at any of the concentrations studied. The hedonic flavor values of the lots indicated that 100 ppm hydrolysate is the maximum quantity that could be used without adversely affecting the flavor. The flavor of process cheese made with the hydrolysate was criticized as tasting "medicinal" and "artificial."

Inasmuch as Kass (1951) had stated that the dough had to incubate at least two hours with leucine or the acid hydrolysate of corn in order to produce "cheese-like flavor" in baked products, process cheese was made with 1000 ppm leucine or 1000 ppm methionine and 1 per cent dry yeast blended into the freshly processed cheese at 23°C. Each cheese was then allowed to incubate at 23°C for four hours. These lots were given identical flavor values and criticized as tasting "dough-like" and "yeasty."

<u>The effect of added ethyl butyrate, 2-heptanone, methyl sulfide, and hydrogen sulfide on the flavor of process cheese.</u> The data in Table 12 summarize the results obtained by the addition of these volatile compounds to cheese. Four volatile components of Cheddar cheese were added to process cheese made from foam-spray dried cheese in an effort to improve the flavor of the cheese. Cheese 2 contained 5 ppm ethyl butyrate and was given a hedonic flavor value lower than that of the control. Six and six-tenths ppm of 2-heptanone was added to lot 3. This cheese sample was given a lower hedonic flavor rating than the control. Also, those lots containing methyl and hydrogen sulfide were given lower flavor values than the control.

Table 12. The effect of ethyl butyrate, 2-heptanone, methyl sulfide, and hydrogen sulfide on the hedonic flavor value of process cheese made from foam-spray dried Cheddar cheese.

Process cheese* (No.)	Additive used in making process cheese	Additive (ppm)	Hedonic flavor value
1	None	0	6.0
2	Ethyl butyrate	5.0	5.0
3	2-heptanone	6.6	4.0
4	Methyl sulfide	5.0	4.3
5	Hydrogen sulfide	1.0	5.0

* Made with 150 g dry mild Cheddar cheese, 50 g dry aged Cheddar cheese, and 140 g water.

The effect of added blue-veined and Limburger cheese on the body and flavor of process cheese. Five per cent blue-veined or Limburger cheese was added to Cheddar cheese slurries before foam-spray drying in an effort to enhance the cheese flavor of the powder (Table 13). All the cheese, including the control, had similar physical properties and hedonic body values. The process cheese containing blue-veined cheese was superior in flavor to the control cheese or that containing Limburger cheese. The latter product was criticized as being bitter and not typical of Cheddar cheese.

Table 13. Comparison of the physical properties and hedonic values of process cheese made from dry Cheddar cheese containing small quantities of dry blue-veined and Limburger cheese.

Process cheese* (No.)	Total solids of process cheese(%)	Variety of cheese foam-spray dried (%)				Physical properties			Hedonic value	
		American Cheddar Mild	American Cheddar Aged	Blue-veined	Limburger	Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1	60.35	75	25	0	0	69.7	165	312	5.6	4.6
2	60.75	71	24	5	0	74.0	168	325	5.8	5.2
3	60.63	71	24	0	5	75.6	163	312	6.0	3.4

* Made with the foam-spray dried powders obtained from drying the various cheese mixtures in the above table.

The effect of added condiments on cheese flavor. Five condiments were evaluated to determine their acceptability as flavoring materials for process cheese made from foam-spray dried cheese (Table 14). Process cheese 1, 2, and 3 were made with 1.0, 4.0, and 8.0 per cent Jalapeno peppers respectively. This condiment was successful in improving the flavor of process cheese made from dry Cheddar cheese. The optimum flavor level of peppers is approximately 8 per cent depending of course on the preference of the individual judge or consumer.

The proper level of garlic-onion is less than 1.0 per cent for process cheese made from dry Cheddar cheese. This condiment did improve the flavor of process cheese.

The flavor of process cheese made with 0.5 per cent smoke concentrate was good, but cheese made with 1 and 2 per cent were criticized for excessive flavor. The proper level of this condiment is less than 1 per cent.

Pimiento as a condiment was less effective than other materials evaluated in this study in improving the flavor of process cheese. This may be a reflection of the mild flavor characteristics of pimientos. Lot 11, containing 4 per cent pimiento, was given a flavor score one point higher than the other cheese.

The last condiment used in these process cheese trials was bacon, added at levels of 2, 5, and 10 per cent. Bacon can be used effectively as a flavor-enhancing condiment for

Table 14. The effect of condiments on the hedonic flavor value of process cheese made from foam-spray dried Cheddar cheese.

Process cheese[a] (No.)	Condiment used in making process cheese	Condiment (%)	Hedonic flavor value
1	Jalapeno peppers	1.0	5.0
2	"	4.0	6.0
3	"	8.0	7.5
4	garlic-onion[b]	0.5	6.7
5	"	1.0	5.7
6	"	2.0	5.7
7	smoke concentrate	0.5	7.0
8	"	1.0	5.3
9	"	2.0	3.7
10	pimiento	2.0	4.7
11	"	4.0	5.7
12	"	8.0	4.7
13	bacon	2.0	5.3
14	"	5.0	5.3
15	"	10.0	4.3

[a] Made with 200 g of dried slurry no. 6 of Table 1 and 140 g water.

[b] Fifty per cent dry garlic and 50 per cent dry onion.

process cheese made from foam-spray dried Cheddar cheese. Lots containing 2 and 5 per cent bacon were preferred over the cheese made with 10 per cent bacon.

The effect of substituting foam-spray dried mild Cheddar cheese for natural mild Cheddar cheese on flavor and physical properties of process cheese. Process cheese were made with 75 per cent mild and 25 per cent aged natural Cheddar cheese. The effect of replacing portions of this mild cheese with an equivalent amount of mild cheese powder was studied (Table 15). The process cheese in which 25 per cent of the natural mild Cheddar cheese was replaced with foam-spray dried mild Cheddar cheese exhibited the best meltdown of cheese in this trial. However, the meltdown of the control cheese was very similar to this lot. The product containing 25 per cent natural aged Cheddar cheese and 75 per cent mild Cheddar cheese powder had the lowest percentage meltdown. All cheese had good melting quality. Correlation between the amount of replacement of natural mild cheese and the PV or shear values was poor. All the cheese received relatively good body scores except lot 6, which was made with 75 per cent dried mild Cheddar cheese. The hedonic flavor values of lots were virtually identical up to 25 per cent replacement of mild Cheddar cheese. However, lots made with 50, 75, or 100 per cent substitution of natural mild Cheddar cheese were given lower hedonic flavor values than those cheese containing less foam-spray dried cheese.

The effect of substituting foam-spray dried aged Cheddar cheese for natural aged Cheddar cheese on flavor and physical properties of process cheese. The physical properties and hedonic values of process cheese made with various amounts of dried aged Cheddar cheese are given in Table 16. Cheese

Table 15. The effect of substituting foam-spray dried mild Cheddar cheese for natural mild Cheddar cheese on the physical properties and hedonic value of process cheese made therefrom.

Process cheese* (No.)	Total solids of process cheese(%)	Natural mild Cheddar cheese replaced with foam-spray dried mild Cheddar cheese (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1	62.50	0	79.7	145	375	6.9	7.0
2	62.38	10	76.4	127	387	6.5	7.0
3	62.21	25	80.0	130	312	6.8	6.8
4	62.85	50	78.2	140	350	6.0	4.7
5	62.52	75	74.9	136	325	6.7	5.0
6	62.82	100	73.2	130	387	5.3	4.3

* Made with 25 per cent natural aged Cheddar cheese and 75 per cent natural mild Cheddar cheese or the equivalent using foam-spray dried mild Cheddar cheese.

Table 16. The effect of substituting foam-spray dried aged Cheddar cheese for natural aged Cheddar cheese on the physical properties and hedonic values of process cheese made therefrom.

Process cheese* (No.)	Total solids of process cheese(%)	Natural aged Cheddar cheese replaced with foam-spray dried aged Cheddar cheese (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetro-meter (mm/10)	Shear force (g)	Body	Flavor
1	62.50	0	79.7	145	375	6.2	6.8
2	62.45	25	73.0	117	425	6.0	6.2
3	62.03	50	71.5	123	375	6.2	5.3
4	62.62	100	74.9	132	375	6.3	5.5

* Made with 25 per cent natural aged Cheddar cheese or the equivalent using foam-spray dried aged Cheddar cheese and 75 per cent natural mild Cheddar cheese.

containing foam-spray dried aged Cheddar cheese had lower meltdown values than the control. However, all the lots exhibited comparable melting properties.

Body measurements of the process cheese were similar. The process cheese made with 25 per cent of the natural aged Cheddar cheese replaced with dried cheese had the firmest body; the control had the weakest body. However, the difference in PV among the cheese was relatively small.

The control received the highest hedonic flavor value, and the cheese made with 50 per cent of the aged cheese replaced with dried cheese was given the lowest flavor value. On the basis of these trials, 25 per cent of the aged cheese can be replaced with powder without greatly affecting the flavor of the final product. The staleness contributed to the cheese by the powder is the limiting factor.

The effect of substituting foam-spray dried blended Cheddar cheese for natural blended cheese on flavor and physical properties of process cheese. Seventy-five, 85, and 95 per cent of the total natural Cheddar cheese used in making process cheese was replaced with an equivalent amount of foam-spray dried blended cheese (Table 17). The term blended is intended to mean a mixture of 75 per cent mild and 25 per cent aged cheese. The melting and body properties of all lots were satisfactory. However, the meltdown of the control cheese was significantly superior to the others in the series. All cheese had relatively good hedonic flavor

Table 17. The effect of substituting foam-spray dried blended[a] Cheddar cheese for natural blended Cheddar cheese on the physical properties and hedonic values of process cheese made therefrom.

Process cheese[b] (No.)	Total solids of process cheese(%)	Natural blended Cheddar cheese replaced with foam-spray dried blended Cheddar cheese (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetro- meter (mm/10)	Shear force (g)	Body	Flavor
1	62.50	0	79.7	145	375	6.2	6.8
2	62.73	75	61.5	130	387	6.0	6.0
3	62.98	85	61.2	130	375	6.0	6.0
4	62.65	95	61.2	177	300	5.3	5.3

[a] The term blended means the mixture contained 75 per cent mild Cheddar cheese and 25 per cent aged Cheddar cheese.

[b] Made with a blend of 25 per cent natural aged Cheddar cheese and 75 per cent natural mild Cheddar cheese or the equivalent of each of these cheese using foam-spray dried blended Cheddar cheese.

values, but the flavor of the control again was definitely preferred over the other lots. Very little difference in flavor was noted between cheese made with 75 and 85 per cent cheese powder.

Process Cheese Made from Freeze-dried Cheddar Cheese

The effect of added freeze-dried natural cheese on properties and flavor of process cheese. The data of Table 18 can be used to compare the physical properties and hedonic values of process cheese made from natural and freeze-dried Cheddar cheese. The meltdown of process cheese made with freeze-dried cheese was slightly lower than the meltdown obtained on process cheese prepared from natural Cheddar cheese. Freeze-dried cheese also imparted a slightly weaker body to the finished product. The flavor of the control was superior to that of the process cheese prepared from freeze-dried cheese; however, the flavor values of these two cheese were similar.

The effect of replacing natural mild Cheddar cheese with freeze-dried mild Cheddar cheese on the body and flavor of process cheese. Process cheese were made by replacing portions of the mild natural Cheddar cheese with comparable freeze-dried cheese. The evaluations of the lots are presented in Table 19. The variation in percentage meltdown of cheese was less than 7 per cent, and all lots exhibited

Table 18. Comparison of the physical properties and hedonic values of process cheese manufactured from natural Cheddar cheese and freeze-dried Cheddar cheese.

Process cheese (No.)	Total solids of process cheese(%)	Treatment of Cheddar cheese used	Physical properties			Hedonic value	
			Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1[a]	62.58	None	79.7	154	312	7.0	7.6
2[b]	62.97	Freeze-dried	78.8	172	250	6.4	6.8

[a] Process cheese no. 1 was a control prepared from 75 per cent natural mild Cheddar cheese and 25 per cent natural aged Cheddar cheese.

[b] Process cheese no. 2 was prepared from 75 per cent freeze-dried mild Cheddar cheese and 25 per cent freeze-dried aged Cheddar cheese.

Table 19. The effect of substituting freeze-dried mild Cheddar cheese for natural mild Cheddar cheese on the physical properties and hedonic values of process cheese made therefrom.

Process cheese* (No.)	Total solids of process cheese(%)	Natural mild Cheddar cheese replaced with freeze-dried mild Cheddar cheese (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1	63.49	0	74.4	134	462	6.5	6.7
2	62.84	10	77.1	142	387	6.7	6.8
3	62.33	25	77.4	150	387	6.2	6.2
4	62.56	50	77.0	153	325	6.8	7.0
5	62.03	75	78.1	167	300	6.7	7.0
6	62.81	100	80.8	166	300	6.7	6.3

* Made with 25 per cent natural aged Cheddar cheese and 75 per cent natural mild Cheddar cheese or the equivalent using freeze-dried mild Cheddar cheese.

good melting properties. The control cheese had the lowest meltdown value; the highest meltdown was exhibited by lot 6, which contained 75 per cent freeze-dried mild Cheddar cheese and 25 per cent natural aged Cheddar cheese. The control possessed the firmest body of the group while cheese made with 75 and 100 per cent substitution of natural mild Cheddar cheese had the weakest body. All cheese had good hedonic flavor values; the difference in these values was less than 0.8 of a point.

A trio test was arranged in which two samples alike and one different from the other two were evaluated. The cheese compared were the control and a sample in which all of the mild natural cheese had been replaced by freeze-dried mild natural Cheddar cheese. Both cheese then contained only 25 per cent natural aged Cheddar cheese. Of five judges, two were unable to tell any difference between these samples, and three could tell a very slight difference. Two of the judges preferred the sample made with freeze-dried mild Cheddar cheese, while one judge preferred the control over this cheese. The three judges stated that the flavor difference was very slight.

<u>The effect of replacing natural aged Cheddar cheese with freeze-dried aged Cheddar cheese on the flavor and body of process cheese</u>. Four lots of process cheese were made with 75 per cent natural mild Cheddar cheese and 25 per cent natural aged Cheddar cheese or the equivalent using freeze-dried

Table 20. The effect of substituting freeze-dried aged Cheddar cheese for natural aged Cheddar cheese on the physical properties and hedonic values of process cheese made therefrom.

Process cheese* (No.)	Total solids of process cheese(%)	Natural aged Cheddar cheese replaced with freeze-dried aged Cheddar cheese (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetro-meter (mm/10)	Shear force (g)	Body	Flavor
1	62.66	0	78.4	148	350	8.0	6.6
2	62.02	25	78.3	160	325	7.0	6.6
3	62.43	50	78.9	149	350	7.0	6.2
4	62.39	100	78.3	158	312	7.0	7.0

* Made with 25 per cent natural aged Cheddar cheese or the equivalent using freeze-dried aged Cheddar cheese and 75 per cent natural mild Cheddar cheese.

aged Cheddar cheese (Table 20). The meltdown values of these cheese were practically identical and the objective body measurements were very similar. Lots made with any freeze-dried cheese were given lower hedonic body values than the control. Process cheese 4, made with 75 per cent natural mild Cheddar cheese and 25 per cent freeze-dried aged Cheddar cheese, received the highest flavor value. The lowest hedonic flavor value was given to lot 3 which was prepared with 50 per cent of the natural aged Cheddar cheese replaced with freeze-dried aged Cheddar cheese.

<u>The effect of replacing natural blended Cheddar cheese with freeze-dried blended Cheddar cheese on the flavor and body of process cheese</u>. The results of replacing high quantities of natural cheese with freeze-dried cheese are given in Table 21. Process cheese was made from 0, 75, 85, 95, and 100 per cent freeze-dried blended Cheddar cheese. The percentage meltdown of the cheese were comparable, but the lots made with some freeze-dried cheese had weaker bodies than the control. Lots prepared with some freeze-dried cheese were given lower hedonic values than the control, but again all products received good scores.

<u>The effect of increasing the total solids content of process cheese with added freeze-dried cheese on properties of the process cheese</u>. The results tabulated in Table 22 illustrate the effect of increasing the total solids content of

Table 21. The effect of substituting freeze-dried blended[a] Cheddar cheese for natural blended Cheddar cheese on the physical properties and hedonic values of process cheese made therefrom.

Process cheese[b] (No.)	Total solids of process cheese(%)	Natural blended Cheddar cheese replaced with freeze-dried blended Cheddar cheese (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetro-meter (mm/10)	Shear force (g)	Body	Flavor
1	62.58	0	79.7	154	312	7.0	7.6
2	62.73	75	81.7	175	250	6.0	6.6
3	62.34	85	77.9	174	250	6.2	6.0
4	62.83	95	79.7	178	237	6.4	6.8
5	62.97	100	78.8	172	250	6.4	6.8

[a] The term blended means the mixture contained 75 per cent mild Cheddar cheese and 25 per cent aged Cheddar cheese.

[b] Made with a blend of 25 per cent natural aged Cheddar cheese and 75 per cent natural mild Cheddar cheese or the equivalent of each of these cheese using freeze-dried blended Cheddar cheese.

Table 22. The effect of increasing the total solids content of process cheese with freeze-dried mild Cheddar cheese in the physical properties and hedonic values of this product.

Process cheese* (No.)	Total solids of process cheese(%)	Natural mild Cheddar cheese replaced with freeze-dried mild Cheddar cheese (%)	Physical properties			Hedonic value	
			Meltdown (%)	Penetrometer (mm/10)	Shear force (g)	Body	Flavor
1	62.75	10	59.9	148	450	5.3	6.7
2	64.80	25	73.5	158	450	4.7	7.0
3	66.25	50	71.7	129	650	4.0	5.7
4	68.51	75	63.0	116	762	3.0	4.7

* Made with natural aged Cheddar cheese, natural mild Cheddar cheese, and freeze-dried mild Cheddar cheese.

process cheese with freeze-dried cheese. The body of cheese made with increased total solids content was criticized, and the flavor of this cheese was inferior to cheese made without freeze-dried cheese. Twenty-five per cent of the natural mild Cheddar cheese of lot 2 was replaced with freeze-dried mild Cheddar cheese, and this product was given a good hedonic flavor value. However, lots 3 and 4, which had 50 and 75 per cent respectively of their natural mild cheese replaced were given relatively poor hedonic values. Judges expressed a dislike for those cheese because they were excessively dry.

Bacterial Content of Process Cheese and Cheese Powders

Process cheese were made using natural Cheddar cheese, freeze-dried Cheddar cheese, foam-spray dried Cheddar cheese, or natural blue-veined cheese as the source of cheese solids. The results of standard plate count and coliform determinations on these cheese appear in Table 23. All cheese were free of coliform organisms and the highest standard plate count was less than 3000 bacteria/ml.

The results of bacterial analysis on some foam-spray dried powders are given in Table 24. The coliform count for all lots was less than 1 per ml, while the standard plate counts of the cheese powders ranged from less than 3000 to 11,000 bacteria per ml.

Table 23. Bacterial content of process cheese.

Process cheese No.	Source of cheese solids	Standard plate count (bacteria/ml)	Coliform plate count (bacteria/ml)
1	Natural Cheddar cheese	430	<1
2	Freeze-dried Cheddar cheese	<3000	<1
3	Foam-spray dried Cheddar cheese	400	<1
4	Natural blue-veined cheese	<300	<1

Table 24. Bacterial content of some foam-spray dried Cheddar cheese.

Foam-spray dried cheese* No.	Standard plate count (bacteria/ml)	Coliform plate count (bacteria/ml)
1	<3000	<1
2	<3000	<1
3	11,000	<1
4	3000	<1
5	3300	<1

* Foam-spray dried cheese 1, 2, 3, 4, and 5 refer to the dried slurries 4, 5, 6, 9, and 10 respectively of Table 2.

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DISCUSSION

Process Cheddar cheese is generally composed of a blend of well aged and mild Cheddar cheese. The aged Cheddar cheese is added to the blend to produce a satisfactory flavor in the finished product, while the mild Cheddar cheese is used to enhance the desired pleasing texture, body, melting, and slicing properties. A process cheese manufactured from 100 per cent aged Cheddar cheese has a loose, grainy texture inclined toward fat separation. If mild Cheddar cheese is used as the sole source of cheese, the final product may lack desired flavor and have too firm a body. In view of these causes and effects, experiments were performed to determine the optimum combination of aged and/or mild Cheddar cheese powder for making satisfactory process cheese.

All of the cheese made with different combinations of aged and mild Cheddar cheese powder had satisfactory melting properties. Process cheese 1, made from 100 per cent mild Cheddar cheese powder, retained some of the typical firmness of the mild Cheddar cheese from which the powder was made. Fresh Cheddar cheese is rubbery and, except for the slight acid taste, is virtually void of flavor. Process cheese made solely from dried mild cheese also lacked the desirable flavor of good process cheese.

During ripening, Cheddar cheese undergoes chemical and physical changes that transform the tough, curdy product into a soft mellow cheese. Process cheese made from 100 per cent foam-spray dried aged Cheddar cheese had a very soft body and grainy texture. The best process cheese was made from a 75:25 blend of mild to aged Cheddar cheese powder. As the quantity of aged Cheddar cheese powder in the blend was increased above 35 per cent, the body and/or flavor of the finished cheese was adversely affected.

Process cheese made from foam-spray dried powder had a weaker body and less flavor than a cheese made from natural cheese (Table 4). The heating and homogenization processes to which the cheese was exposed prior to foam-spray drying apparently destroyed some of the curd structure.

Heating cheese caused a loss of some critical volatile flavor components and was instrumental in producing other flavors. Cheese that had been dried and then reconstituted to make process cheese received more processing than natural cheese that was just made into process cheese without being dried. Therefore, the physical and chemical characteristics of process cheese made from cheese powder may be less desirable than those of process cheese made from natural cheese.

Very little difference in physical properties or hedonic values could be detected in cheese blended before drying and cheese powder from these cheese blended after drying (Table 5). Thus, cheese could be blended economically at one factory before spray-drying, and thereby obviate the necessity of blending of various powders for processing. A possible reason for the difference in flavor scores of such cheese is that more free amino groups are present in aged Cheddar cheese than in mild Cheddar cheese. This latter cheese contains more carbohydrate carbonyls than aged Cheddar cheese. Therefore, when these cheese are blended before drying, optimum conditions of moisture and temperature may be reached during drying so that reactions between free amino and carbonyl groups can occur. Cheese blended after drying are not exposed together to the above drying conditions; and, therefore, the reactive constituents of the two cheese do not have an opportunity to combine under the ideal conditions encountered in drying.

Process cheese cooled to 40°F had meltdown properties superior to those of cheese cooled to 70° to 80°F. This may be a function of fat crystal number and size attained at different temperatures. Smaller fat crystals are formed when cheese is cooled to 40°F rather than 70° to 80°F. These small fat crystals melt more easily and uniformly than the larger crystals formed at 70° to 80°F. The cheese cooled at the lower temperature will possess a closer texture and firmer structure due to the accelerated cooling at this temperature. Van Slyke and Price (1952) have reported a freezing point of 19.6°F for one process Cheddar cheese. At the colder temperature the cheese will contract; and, therefore, the body will be relatively firm. Cheese cooled to 40°F and then tempered at room temperature exhibited body and meltdown characteristics somewhat superior to those of cheese cooled to 70° to 80°F and held at that temperature. The difference in fat crystal size, number, and structure again may account for this variation in properties.

The results presented in Table 8 show that disodium phosphate was unable to emulsify the cheese as well as sodium citrate and sodium aluminum phosphate at the 3 per cent level. The body of cheese made with 3 per cent disodium phosphate was not as firm, and the melting qualities were not as good as those properties of cheese made with the latter emulsifiers. The properties of cheese made with 3 per cent sodium citrate or 3 per cent sodium aluminum phosphate were similar, but the emulsifying action of citrate offered an advantage as far as meltdown was concerned. The data in this table illustrate the effect of increasing amounts of emulsifier. Cheese made with 4 to 6 per cent emulsifier was criticized as tasting salty and powdery. At the 4 per cent level, the concentration of emulsifier was still high enough to affect the flavor adversely. The physical properties of cheese made with 4 to 6 per cent emulsifier were not improved and in some cases showed inferior meltdown and grainy texture when compared to cheese containing 3 per cent emulsifier.

Spray-drying caused the loss of a portion of the flavor volatiles from the natural cheese. A number of companies have produced flavor fortifiers intended to be used for increasing the cheese flavor of food products. Concentrations of fortifiers above critical levels imparted very characteristic and peculiar flavors to the cheese. The flavor of process cheese was generally increased by the addition of fortifiers but was not always judged to be a typical Cheddar cheese flavor.

During the dehydration of cheese, volatile acids normally present in the cheese are lost in the exhaust air from the dryer. The amount lost varies of course with the vapor pressure of the acid and the conditions employed in drying. The organic acids selected and added to cheese during processing did enhance cheese flavor at concentrations up to 1000 ppm. The level of 1000 ppm was the approximate maximum level for these acids. However, the pH and physical properties of process cheese made with organic acids were altered. The proteins of cheese made with 10,000 ppm of various organic acids were solubilized and broken down. These chemical changes were responsible for poor melting properties and excessively firm body in the process cheese.

The flavor of process cheese made with added leucine, methionine, or the acid hydrolysate of zein was not appreciably improved. In every instance, concentrations of less than 1000 ppm of these additives singly were preferred over cheese containing higher concentrations of these materials. Cheese containing added dried yeast plus an amino acid tasted "yeasty"; therefore, the possibility of adding yeast in hopes of changing the amino acid to a desirable product are remote. A mixture of all the amino acids present in process cheese at their proper concentrations might improve the flavor of process cheese made from spray-dried cheese. The chance of improving the flavor of process cheese by adding a single amino acid or small group of amino acids is slight, since such amino acids are not volatile and at best could only modify the flavor components remaining in dried cheese.

Mabbitt (1961) reported hydrogen and methyl sulfide are important in cheese flavor. Walker et al. (1959) and Day et al. (1960) isolated 2-heptanone from Cheddar cheese. Harper (1959) attributed cheese aroma to the amines, fatty acids, aldehydes, ketones, alcohols, esters, and volatile sulfur compounds present in cheese. Concentrations of ethyl butyrate, 2-heptanone, methyl sulfide, or hydrogen sulfide other than those tried might improve the total flavor, but the flavor would probably be atypical. Foam-spray drying results in the loss of some volatile compounds and possible alteration in other chemical components present in cheese. Therefore, adding only one of the compounds that has been lost should have little effect on the overall flavor spectrum of components that have been chemically changed or lost.

Commercial cheese dryers believe that the flavor of dried cheese can be enhanced by the addition of small quantities of highly flavored cheese to the cheese mixture before drying. Bullock et al. (1963) recommended adding 5 per cent blue-veined cheese to the emulsion before drying to enhance the flavor of the powder. In fact this has been common practice in cheese drying plants. The body measurements and meltdown qualities of process cheese made with and without other cheese were very similar. The flavor of spray-dried cheese could be increased satisfactorily and easily by adding blue-veined cheese. The flavor of such a product is slightly atypical, but the overall flavor is slightly enhanced and is pleasing.

The flavor of process Cheddar cheese made from spray-dried cheese powder containing Limburger cheese was poor. The flavor of the Limburger cheese in process Cheddar cheese was disliked extremely because of the unnatural flavor of the final product.

In general, condiments improved the flavor of process cheese made from cheese powder. Process cheese made from spray-dried cheese lacks flavor, and condiments contribute to the flavor of the final product. The proper level acceptable for a given market area would have to be determined for each condiment, if the additive were to be used successfully.

The replacement of natural cheese with foam-spray dried cheese decreased the percentage meltdown of the process cheese. One hundred per cent of the natural mild cheese could be replaced with powder without greatly affecting the body or flavor of the finished product. The flavor of natural cheese is more desirable than that of cheese powder. However, process cheese made from a blend of natural and dried cheese is acceptable (Table 15).

Aged Cheddar cheese is used in the manufacture of process cheese for the flavor this product imparts to the finished food. Spray-drying causes a volatilization of some flavor components of cheese; and, therefore, process cheese made with foam-spray dried aged Cheddar cheese lacks flavor. One hundred per cent of the natural aged Cheddar cheese could be replaced with aged Cheddar cheese powder without being extremely detrimental to the flavor of process cheese. The meltdown, body, and flavor properties of these lots were less affected than those of the cheese made with dry mild Cheddar cheese because 100 per cent replacement of aged cheese represents only 25 per cent of the total cheese in the product. Cheese made with 85 per cent of the total natural cheese replaced with spray-dried cheese was judged fairly good. Fifteen per cent natural cheese, present in the preceding product, was enough to mask, in part, the stale flavor of spray-dried cheese. Although the percentage meltdown was decreased by the addition of large amounts of spray-dried cheese, the melting properties of all cheese were fairly good.

During freeze-drying some volatile flavor components are lost; and, therefore, the flavor of process cheese made from freeze-dried cheese is slightly less desirable than a product made from natural cheese. Freeze-drying destroys some of the cheese structure, and products dried in this way do not always rehydrate readily. In making process cheese, one problem is rehydrating the freeze dried product. Also, the ice crystals formed during freezing cheese disrupt the natural structure of the product. These factors could account for the slightly less firm body of process cheese made from freeze-dried cheese.

As the amount of freeze-dried cheese in the product was increased, the body firmness decreased due to properties contributed by the freeze-dried cheese. The flavor of all products was good because the cheese was not subjected to heat damage during freeze-drying; and, therefore, the loss of flavor volatiles was kept to a minimum. Also, the relatively mild conditions of freeze-drying do not affect the product as much as more severe conditions encountered in other methods of drying.

Process cheese containing 75 per cent natural mild Cheddar cheese and 25 per cent freeze-dried aged Cheddar cheese had good meltdown, body, and flavor properties. Process cheese made with high quantities of freeze-dried cheese had properties comparable to products made solely from natural cheese.

Sometimes natural cheese is low in fat. Therefore, appropriate blending must be used to correct this shortage before processing. Freeze-dried cheese could be an ideal product to add to low-fat cheese blends so that the fat content of the resulting process cheese would meet standards of identity. Dried cheese contains over 50 per cent fat and, consequently, would be a good concentrated source of butterfat. Increasing the solids content of a product naturally decreases the moisture content and causes a drier and firmer body in the process cheese. The body and flavor of process cheese was not adversely affected until the percentage total solids reached 66.25 per cent. At this point the lack of moisture caused the cheese to be excessively firm.

The bacterial content of process cheese appears to be unaffected by the source of cheese since all estimates of coliform and total microbial populations were uniformly low.

SUMMARY AND CONCLUSIONS

1. A relatively good process cheese was made by combining 75 per cent foam-spray dried mild Cheddar cheese with 25 per cent of the aged product similarly dried.
2. The body of process cheese became less firm as the percentage of foam-spray dried aged Cheddar cheese used was increased. Conversely, the body firmness increased with increasing percentages of foam-spray dried mild Cheddar cheese.
3. Blending cheese before or after foam-spray drying had little to no influence on the physical properties and hedonic values of the finished cheese.
4. The body and melting properties of process cheese (made from foam-spray dried cheese) was improved slightly by cooling the hot process cheese to 40°F rather than to 70° to 80°F.
5. Process cheese made from foam-spray dried Cheddar cheese had a weaker body, poorer melting properties, and a less desirable flavor than that made from natural Cheddar.
6. Seventy-five per cent of the natural mild Cheddar cheese used in making process cheese was replaced with 75 per cent foam spray-dried mild Cheddar cheese without greatly affecting the body and flavor of the finished product.

7. One hundred per cent of the natural aged cheese used in making process cheese was replaced satisfactorily with spray-dried aged cheese.
8. As much as 85 per cent of the required amount of natural Cheddar cheese was replaced with foam-spray dried cheese without impairing the physical properties and hedonic values of the process cheese.
9. Three per cent sodium citrate or sodium aluminum phosphate were used satisfactorily as emulsifiers in making process cheese from foam-spray dried cheese.
10. Process cheese made with 3 per cent emulsifier (sodium) citrate, sodium aluminum phosphate, or disodium phosphate) was preferred over cheese made with higher percentages.
11. Commercial flavor fortifiers improved the flavor of process cheese made from foam-spray dried cheese; however, the flavor was not always a typical Cheddar flavor.
12. Organic acids, leucine, methionine, ethyl butyrate, 2-heptanone, methyl sulfide, and hydrogen sulfide individually were of relatively little value in improving the flavor of process cheese made from cheese powder.
13. The addition of 5 per cent blue-veined cheese to a cheese slurry prior to foam-spray drying was effective in improving the flavor of the dried cheese.
14. Condiments improved the flavor of process cheese made from foam-spray dried cheese.

15. Process cheese made from freeze-dried cheese is comparable to that made from natural cheese. Any amount of natural cheese can be replaced with an equivalent amount of freeze-dried cheese without harming the properties of the process cheese made therefrom.
16. Freeze-dried cheese can be used effectively to increase the solids content of process cheese.
17. Low, and comparable, bacterial counts were obtained on process cheese manufactured from foam-spray dried, freeze dried, and natural Cheddar cheese.

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