A STUDY OF FACTORS AFFECTING DISPERSION OF NITROUS OXIDE, NITROGEN AND CARBON DIOXIDE IN NEUFCHATEL CHEESE

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This is to certify that the

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ABSTRACT

A STUDY OF FACTORS AFFECTING DISPERSION OF NITROUS OXIDE, NITROGEN AND CARBON DIOXIDE IN NEUFCHATEL CHEESE

By

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Neufchatel cheese was prepared by the conventional Neufchatel process from pasteurized homogenized milk containing 4.0 and 5.0 per cent milk fat. Direct acidification and lactic acid fermentation methods were used to coagulate the milk during the cheese preparation process. Variables in processing and additives were investigated as to their effect upon the softness of Neufchatel cheese. The processing and additive variables were also investigated as to their effect upon the overrun, shrinkage and rheology of whipped Neufchatel cheese. Milk coagulation methods noted above and different milk pasteurization methods were studied in this research to evaluate their effects on whipped cheese. The additives used included eight different emulsifiers added to milk during pasteurization and to the cheese prior to whipping, and four different stabilizers added to the cheese milk. Investigations also included the use of nitrous oxide, nitrogen, carbon dioxide and a nitrous oxide-carbon dioxide gas mixture (84-16 per cent by weight) for aeration of the cheese during the whipping process.

A penetrometer was used to measure the softness of Neufchatel cheese made in these studies. The Brabender visco/amylo/graph was

adapted to evaluate differences in rheological properties of the whipped cheese which accompanied variation in formulation and processing conditions.

Lactic acid fermentation was found to be advantageous over direct acidification in coagulating the cheese mix because of the more desirable flavor and aroma of the finished cheese. High pressure aeration of the prepared cheese with different gases resulted in high overruns in the whipped Neufchatel cheese. Nitrous oxide and a nitrous oxide-carbon dioxide gas mixture (84-16 per cent by weight) produced the highest overruns. An increase in the fat content of cheese milk, from 4.0 to 5.0 per cent, improved the softness and smoothness of Neufchatel cheese, as did the addition of emulsifiers to the milk.

There was an inverse relationship between the milk pasteurization temperature and softness of the prepared cheese, and overrun of the whipped cheese. Glucosyl glucan and locust bean gum stabilizers added to milk increased the overrun of whipped Neufchatel cheese; whereas, sodium alginate and sodium caseinate decreased overrun. The addition of either of two different emulsifiers to the cheese during a mixing process increased the overrun in the whipped cheese samples. These included a highly saturated monoglyceride and a high HLB emulsifier. Emulsifiers added to milk decreased the overrun of whipped Neufchatel cheese.

The cheese aerated with nitrous oxide showed less shrinkage than cheese which had been aerated with other gases. Added emulsifiers were found to decrease shrinkage of the whipped cheese. Locust bean gum and glucosyl glucan stabilizers decreased shrinkage; sodium caseinate increased shrinkage of the whipped cheese.

An increase in the fat content of cheese milk or the addition of sodium caseinate to the milk decreased the resistance of the whipped cheese to physical stress. Direct acidification in cheese preparation, addition of glucosyl glucan to the milk during the pasteurization process and emulsifiers added to the cheese increased the body stability of whipped Neufchatel cheese.

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INTRODUCTION

Neufchatel cheese is a product which offers good use of surplus milk and is a profitable item for the dairy industry. One particular advantage in the manufacture of this cheese is the relatively modest amount of equipment needed for small scale production.

Consumers in the United States in recent years have shown an interest in lowering their intake of food calories. Food spreads, snacks and dips which utilize cheese in their formulations have gained in popularity in this country and much emphasis has been placed upon the development of convenience type foods.

Neufchatel cheese contains less fat and consequently furnishes less calories than cream cheese which is often used in gourmet dishes. This cheese, however, is often coarse and crumbly when spread with a knife and sometimes difficult to work into a dip.

This project was undertaken to evaluate the development of a whipped Neufchatel cheese that could be easily served and which contained fewer calories than other equivalent products.

REVIEW OF LITERATURE

The conversion of milk into cheese is an important method of utilizing and preserving milk constituents, particularly during periods of surplus. Factors such as consumer convenience and ease of distribution play important roles in the merchandising of milk, milk products and foods in general today. One example of a soft, unripened variety of cheese is Neufchatel. This cheese may be used in a greater number of ways than many other cheese varieties because it is soft in texture and blends well with other food items (Matheson and Cammack, 1918a). Food spreads, dips and snacks which utilize cheese in their formulations have gained popularity in recent years and serve as an excellent outlet for excess fluid milk in the form of Neufchatel cheese. This cheese is a nutritious food because of its fat, mineral and protein content.

Neufchatel Cheese

Neufchatel cheese is defined by the Food and Drug Administration as containing not less than 20 per cent fat but less than 33 per cent, and not more than 65 per cent moisture. Stabilizers may be used individually or in combination if they do not exceed 0.5 per cent of the weight of the cheese. As reported by Van Slyke and Price (1952), the dairy products which may be used in the production of Neufchatel cheese include cream, milk, skimmilk, concentrated milk, concentrated skimmilk and nonfat dry milk solids. According to Lundstedt (1954), Neufchatel cheese was first manufactured commercially in this country during the

Civil War period by William A. Lawrence of Chester, Orange County, New York.

The traditional Neufchatel process (Van Slyke and Price, 1952) was developed in France. Neufchatel made by this process has the general properties of Neufchatel and cream cheese made by the cooked-curd process, but it is not as smooth in consistency and is more acid in flavor. The Food and Drug Administration definition of Neufchatel cheese includes the product that is made by either the cooked-curd process, or non-cooked curd by the traditional process. Dahlberg and Marquardt (1934) observed that Neufchatel cheese had the same general characteristics of cream cheese except that it was lower in fat, not as rich in flavor, and less smooth and buttery in body and texture.

Downs (1957) and Michels (1910) indicated that the fat content of milk used for Neufchatel cheese should range from 3.5 to 5.0 per cent. Miller, Stine and Harmon (1965) found that Neufchatel cheese made from milk containing 5.0 per cent fat was smoother in body and texture than cheese made from milk with a fat content of 3.5 per cent.

Marcus (1944) noted that pasteurization of milk or cream intended for use in making Neufchatel or cream cheese should eliminate nearly all bacteria, yeasts and molds in order to provide a good base for the manufacturing process. Various workers (Dahle, 1949; Matheson and Cammack, 1918b; Reichart, 1932; Roundy and Price, 1935) recommended a pasteurization temperature of 143 F for 30 minutes, while Marquardt (1927) and Marcus (1944) preferred 180 F for 30 minutes. Matheson and Cammack (1918a) as well as Marquardt (1930), observed that pasteurization of milk rendered the resulting cheese safe from disease-producing organisms, improved keeping qualities of the cheese and increased the yield from one-half to one per cent.

Any homogenization pressure between 2000 and 4000 psi is adequate when Neufchatel or cream cheese is to be made from the resulting milk (Dahlberg, 1927; Dahle, 1949; Marquardt, 1927; Marquardt, 1929; Reichart, 1936). Dahlberg (1927) stated that homogenization of the cream or milk at any temperature above 105 F produced a suitable body and texture in the resulting cheese. The primary purpose of homogenization is to reduce fat losses in whey (Reichart, 1936; Zakariasen and Combs, 1941). Marquardt (1927) pointed out that homogenization improved the texture of the finished cheese, but noted that difficulties were encountered in attempting to drain curds produced from milk or cream homogenized at pressures greater than 4000 psi.

A lactic acid starter is generally used to produce the acid required for coagulation and for development of the characteristic mild-acid flavor of Neufchatel cheese. Dahle (1949) recommended 1.0 per cent lactic culture in the manufacture of Neufchatel cheese by the long set method and Van Slyke and Price (1952) found that 5.0 per cent lactic culture was suitable for the short set method of manufacture. Roundy and Price (1935) claimed that there was no advantage in using more than 5.0 per cent starter as excessive amounts hindered drainage. Goss (1924) and Marcus (1944) preferred a ripening temperature of 75 F for the long set method and Van Slyke and Price (1952) suggested a temperature of 90 F for the short set. Neufchatel cheese is sufficiently ripened when the titratable acidity of the mix reaches 0.6 to 0.8 per cent (Roundy and Price, 1941b). Reichart (1936) reported that low acidities failed to give complete drainage and if the acidity were too high the cheese naturally tasted sour (Marquardt, 1927). According to Marcus (1944) acidity development to the extent of 0.6 to 0.8 per cent improved the keeping quality of Neufchatel and cream cheese.

Various researchers have studied the use of direct acidification in the manufacture of cottage, Cheddar and Mozzarella cheese. Mabbitt *et al.* (1955) and Breene *et al.* (1964a) used direct acidification procedures in making Cheddar cheese. Mabbitt and co-workers (1955) observed that a successful direct acidification procedure for manufacture of Cheddar cheese would "cut the Gordian knot of bacteriophage, antibiotics, winter slowness and other difficulties encountered when using lactic acid cultures." Both groups of researchers utilized commercial lactic acid in their direct acidification procedure; however, Mabbitt *et al.* (1955) added lactic acid to the whole milk at 86 F to bring the pH to 5.4. Breene and his group (1964a) added lactic acid to the milk at 40 F to lower the pH to 5.4 and 5.6 and slowly warmed the acidified mix to 86 F. Mabbitt *et al.* (1955) reported that the resulting Cheddar cheese possessed a crumbly texture and acid flavor. Typical Cheddar flavor did not develop in the cheese. Breene *et al.* (1964a) noticed a bitter off-flavor in the cheese after 3 to 4 weeks of aging.

McNurlin and Ernstrom (1962) reported the use of concentrated lactic or hydrochloric acid in the manufacture of cottage cheese. Acid was added to the skimmilk at 40 F followed by warming the acidified milk without agitation to 70 to 80 F. The pH of the resulting cheese curd was in the range of 4.5 to 5.0. Breene, Price, and Ernstrom (1964b) successfully made "pizza" (Mozzarella) cheese by direct acidification using acetic, hydrochloric or lactic acid.

Marquardt (1937) reported that most procedures at that time involved bagging of the Neufchatel curd prior to draining. One pound of salt should be added to 100 pounds of curd when drainage is completed. Storage at temperatures near 32 F improve the shelf life of Neufchatel cheese (Downs, 1957).

Previous findings (Baird, 1919; Lundstedt, 1953; Matheson and Cammack, 1918b) have shown that Neufchatel cheese serves well as a sandwich spread and in salads and dressings. This soft unripened cheese variety may be made into spreads containing various condiments. For example, pimentos improve the keeping quality of Neufchatel cheese, either acting as a preservative or tending to mask any undesirable flavors which may be present.

Attempts to assess the body and texture qualities of cream and Neufchatel cheese have been primarily subjective. Sensory evaluations by judges are most widely employed but thus far have not been satisfactorily compared to an arbitrary objective standard. The use of rheological instruments, such as the penetrometer, has proven successful in measuring the softness of pasteurized process cheese spreads, margarines, shortenings, butter and cream cheese (Baron, 1952; Haighton, 1959; Roundy and Price, 1941a; Olson *et al.*, 1958).

Rheology

The study and application of rheological measurements in food research was well reviewed by Scott Blair (1958). It was pointed out that in a certain sense, all rheological problems are the concern of the manufacturer or processor, since the consumer does little about rheology except to tend to reject the rheologically unsatisfactory.

Rheology is defined as "the science of the deformation and flow of matter" (Scott Blair, 1958). Rheology is therefore mainly concerned with forces, deformations and time. The passage of time does not always of itself result in changes in materials; chemical changes in foodstuffs, however, often occur with time and they may be studied by rheological methods. Temperature is also important and often appears in rheological equations.

Scott Blair (1958) suggested three reasons why the consumer might be conscious of the rheological properties of foods:

1. normal response to the mechanical behavior of foodstuff;
2. unfounded prejudices; and
3. unrationalized preferences.

Several instruments have been developed to transform the subjective methods of the practical man to the objective methods of the scientist. Scott Blair (1958) classified these instruments into three main groups:

1. imitative tests, which tend to imitate the conditions to which the material will be subjected in practice;
2. indirect empirical tests--for example the penetrometer value which measures: (a) the rigidity of gels, (b) the force required to penetrate the material, and (c) the consistency of the material as measured by resistance to further penetration;
3. fundamental tests, applied where foodstuffs have complex rheological properties.

Aeration

A search of the literature revealed that aeration studies involving dairy products to date have been concerned mainly with the whipping of cream. According to Getz *et al.* (1937) cream whipping as ordinarily practiced is the process of agitating cream in such a manner that the volume is increased through entrapping of air in the form of small bubbles. Mechanical whipping of cream requires sufficient agitation to bring about partial clumping of the fat globules in order to retain the incorporated air. The process of whipping cream by aeration departs markedly from mechanical methods. Fat globules are not clumped during aeration whipping as the gas cells are generated within the body of the cream and are not incorporated by agitation (Getz *et al.*, 1937). The gas cells are created by dissolving a soluble gas under pressure in the cream and then allowing the cream to flow out from under this pressure. As the cream flows through the valve of the pressure bottle, the gas cells are formed owing to a decrease in solubility of the gas with the decrease in pressure. Thus the whipping takes place by physical-chemical rather than by mechanical means (Getz *et al.*, 1937).

Graham (1950) noted that gaseous dispersion of products from small containers became familiar to many as the aerosol insecticide "bomb" of World War II. He stated that adaptation of inexpensive single trip low pressure containers for packing of pressurized whipping cream was a natural step and proposed that the term "pressure propelled products" is more meaningful than aerosol whipped cream.

The gas used for food aeration should be odorless, tasteless, non-toxic and be within the desirable solubility range. Some individual gases and gas combinations that have been used in aeration of cream and other foods in closed containers include oxygen (Graham, 1950), nitrous oxide alone or mixed with carbon dioxide (Herzka, 1956), a mixture of 85 to 99 per cent by weight of perfluorocyclobutane and 15 to 1 per cent by weight of difluoromethane (Eiseman, 1970), carbon dioxide (Anonymous, 1969a), and dimethyl oxide (Getz, Smith and Tracy, 1936). There is general agreement that nitrous oxide alone or in combination with carbon dioxide appears to be most desirable for aeration of cream because of the desired solubility characteristics, lack of flavor and low toxicity.

According to Henry's law the solubility of a gas in liquid varies directly with the partial pressure of the gas. Therefore, when cream is placed in a pressure bottle and gas is passed into it to some definite pressure, a certain amount of gas will dissolve in the serum of the cream (Getz *et al.*, 1937). If this pressure is doubled, approximately twice as much gas will dissolve in the cream. Therefore, varying amounts of gas can be made to dissolve in a given quantity of cream by varying the gas pressure. If the cream is saturated at some elevated pressure with some soluble gas and then allowed to flow out to atmospheric pressure, the gas that was forced to dissolve because of the elevated pressure comes out of solution in the form of small gas bubbles or cells uniformly distributed throughout the body of the cream. The increase in the volume (overrun) depends upon the amount of gas that is dispelled from solution, which in turn is dependent upon the absolute pressure in the chamber. Getz *et al.* (1937) noted that the rigidity or stiffness of the whip depends upon many factors, the most important of which are fat content, overrun attained, temperature and age of the cream. Cream saturated with gas at elevated pressures remains in the liquid state.

Gas injection accompanied by shaking increases the rate at which the gas goes into solution in the mix (Getz *et al.*, 1937). Longer shaking periods are required to saturate the liquid phase at any given pressure with an increased viscosity of the cream. Homogenization of the cream or addition of sodium alginate and gelatin increase viscosity and retard solution of the gas in the mix. However, Getz *et al.* (1937) stated that homogenized cream whips equally as well as non-homogenized cream by the aeration process. The above group reported 600 per cent overrun in whipped cream when using nitrous oxide at a pressure of 200 psi and the body of the whip was surprisingly good. The stability of the whip upon standing is not as good in appearance as is cream perfectly whipped by mechanical means; however, the stability of the whip is of less importance because the whip need not be produced by this process in excess of the amount needed for immediate consumption.

The unusually high overruns that can be attained by the aeration process are explained by the fact that the process affords a means of entrapping large quantities of gas without the usual beating out of the gas that has already been entrapped (Getz *et al.*, 1937). Furthermore, the gas cells are, on the average, larger than those in mechanically whipped cream, thus less cream is necessary to act as lamellae. Also, the larger milk fat globules are partially broken down into smaller globules during the whipping process, which allows the formation of thinner lamellae than when larger globules and clumps must be included in the walls of the gas cells.

Sommer (1946) mentioned the efficiency of the whipping device, size of the gas cells, and diameter of the fat globules as being related to the maximum overruns obtainable when whipping cream mixtures mechanically. Getz *et al.* (1937) stated that these three factors also seem to be closely related to maximum overruns obtainable when whipping cream mixtures by the aeration process. Whipping instantly by aeration is extremely efficient as a whipping device because the gas cells are instantaneously produced within the body of the cream as it flows from a high pressure vessel and because there is no mechanical device beating out the gas cells as in mechanical whipping. Studies involving the size of gas cells in cream whipped by aeration have shown that as the saturation pressure increases, the diameter of the gas cells increases (Getz *et al.*, 1937). The diameter of the gas cells resulting from aeration (50 psi of nitrous oxide) is some three times greater than the diameter of gas cells found present in mechanically whipped cream. Uniformly large gas cells resulting from whipping by aeration should increase the maximum overrun obtainable. The third important factor concerning the degree of maximum overrun is the thickness of the lamellae which is believed to be largely determined by the diameter of the fat globules. The researchers mentioned above found that whipping by aeration decreased the number of large fat globules thereby allowing formation of thinner lamellae which contributed to a higher overrun.

Gas dispersion of foods has become increasingly popular in recent years. Green (1969) and Rio (1969) report that aeration is popular in Europe in such food items as jams, condensed fruit juices, coffee extracts and chocolate drinks. This method has also been used successfully to package cake decorating icings (Sciarra, 1969), non-dairy whips (Anonymous, 1970), and fresh ice cream packaged in aerosol form (Anonymous, 1968). A British patent was issued to Diamond (1969) for a process whereby syrup compositions were adapted to be discharged into milk or water to make thick shakes or puddings. Katz (1969) received a United States patent for making an instant dry dessert mix for rehydration and aeration that relied upon gelatinized starch and a surfactant to provide the ultimate whipped product without specifically necessitating the employment of fats, oils and proteinaceous materials.

Stabilizers and Emulsifiers

Stabilizers have been used more extensively in ice cream manufacture than any other segment of the dairy industry. They function through their ability to form gel structures in water or their ability to bind water as water of hydration. Milk and milk products contain some natural stabilizing and emulsifying materials, namely milk protein, fat, lecithin, phosphates and citrates (Turnbow *et al.*, 1947). Among the stabilizer substances which are permitted and used in ice cream and certain cheese and cheese products are: agar, sodium alginate, propylene glycolalginate, gelatin, gum acacia, guar seed gum, gum karaya, locust bean gum, oat gum, carrageenin, lecithin, pectin and sodium carboxymethylcellulose (Arbuckle, 1966; Van Slyke and Price, 1952).

Van Slyke and Price (1952) stated that pasteurized process cheese spreads may contain stabilizers in amounts not in excess of 0.8 per cent of the weight of the finished food; whereas, the stabilizer content of cream and Neufchatel cheese shall not exceed 0.5 per cent of the weight of the finished cheese. The function of stabilizers in the cheese and cheese spread is to prevent syneresis. Miller, Stine and Harmon (1965) reported that 0.1 per cent locust bean gum prevented syneresis in both cream and Neufchatel cheese.

Sodium alginate, sodium caseinate, locust bean gum and other stabilizers have been used in cream whipped by aeration (Herzka, 1956). Getz *et al.* (1937) used gelatin and sodium alginate in cream whipped by aeration. They found these foam stabilizers in the amount of 0.2 per cent to have beneficial effects on the stability of the whip with regard to drainage and appearance upon standing; however, the gelatin mix showed a marked increase in viscosity and a decrease in overrun in comparison to other mixes aerated with nitrous oxide at identical pressures. Goel, Calbert and Marth (1969) investigated the effectiveness of gelatin, propylene glycolalginate, and a stabilizer mixture consisting of carboxymethylcellulose, carrageenin and locust bean gum in preventing wheying-off of low fat dairy spread. This group of workers stated that propylene glycolalginate and the stabilizer mixture used at a level of 1.0 per cent were more effective in reducing whey separation than was gelatin. The advantageous effects of these stabilizers over gelatin were especially noticeable during the first two weeks of storage.

The terms emulsifier and surface-active agents are often used interchangeably throughout literature. An emulsifier may be defined as a substance which will promote a particulate dispersion of one liquid in a liquid continuous phase. Emulsifiers are natural components of many foods. Phospholipid emulsifiers are present in egg lipids, milk lipids (Jenness and Patton, 1959), and vegetable oils. Surface-active agents are especially important in stabilizing foams and emulsions. The molecules of such agents arrange themselves on a surface with the polar group of the molecule in water and the nonpolar group in the other phase, which in foods is often air or oil (Griswold, 1962). A numerical system for expressing the predominant affinity of a surfactant for oil or water has been developed and is called the HLB or hydrophile-lipophile balance. This system of classifying surface-active agents is based on a scale of 0 to 20, and when the lipophilic and hydrophilic groups of the surfactant are chemically balanced, the HLB rating is 10 (Knightly, 1965).

Researchers and industry have found uses for emulsifiers in various foods and food products. Many shortenings contain one or more emulsifying agents added to provide specific functional properties advantageous in certain specialized uses (Bailey, 1964). Monoglycerides are frequently added to shortenings to improve their cake-making quality as they contribute to an increase in cake volume. Birnbaum (1963) stated that emulsifiers contribute to bread manufacture and quality as they promote a softer crumb, shorten proof time and strengthen the physical loaf structure.

Many of today's emulsifiers are actually blends of lipophilic and hydrophilic emulsifiers (Knightly, 1964). According to Arbuckle (1966) the value of emulsifying agents in the manufacture of ice cream lies mainly with the improved whipping quality of the mix and the production of a drier ice cream with a smoother body and texture. Hamilton (1970) found that high and low HLB emulsifiers improved the dispersibility of freeze-dried cultured cream. Emulsifying salts are used in the commercial manufacture of process cheese to prevent the separation of fat from the cheese during heating operations. The two most commonly used emulsifiers for this purpose are disodium phosphate and sodium citrate and mixtures of these salts (Van Slyke and Price, 1952). Miller, Stine and Harmon (1965) found that monoglycerides improved the smoothness and spreadability of Neufchatel and cream cheese.

Overrun

Overrun is a term common to both the ice cream and butter industry; however, the term does not have an identical meaning for these two products. Overrun in butter is all the constituents present in this product except milk fat, which includes moisture, salt and curd, but not air (Hunziker, 1940). The definition as applied to ice cream could also be useful in calculating overrun in aerated or gas dispersed foods. Overrun may be defined as the increase in volume of the whipped product over the volume of the mix, expressed as per cent of the volume of the mix. There are two basic fundamental methods of calculating percentage overrun; one is by volume, and the other by weight (Frandsen and Nelson, 1950). The following formula is often used to calculate per cent overrun in ice cream manufacture and is useful in determining the same in other whipped products:

$$\frac{\text{Wt. of mix - Wt. of same volume of whipped product}}{\text{Wt. of same volume of whipped product}} \text{ X } 100 = \text{\% overrun}$$

Per cent overrun naturally varies in different products; overrun in butter is about 20 per cent, in ice cream it is often in the range of 80 to 100 per cent and the overrun taken in the manufacture of sherbet is usually 40 to 60 per cent. Both Neufchatel cheese and ice cream mix contain some of the major milk constituents (based upon percentage composition) such as milk fat, protein and water. However, the percentage of each of the above mentioned milk constituents varies appreciably between these two milk products, and treatments of these constituents in manufacture of the two products certainly differ. Neufchatel cheese contains approximately 63 per cent water, 22 per cent milk fat and 13 per cent protein; whereas, ice cream contains some 60 per cent water, 13 per cent milk fat and 6 per cent protein.

Some factors that affect or control overrun in ice cream may also be of importance in Neufchatel cheese whipped by aeration. According to Frandsen *et al.* (1950) ice cream mixes which have a high total solids content justify the incorporation of more air to give a higher per cent overrun than mixes lower in total solids. Although no definite per cent can be stated, some authorities indicate as most desirable a per cent overrun between two and three times the per cent total solids content of the mix in order to have a desirable finished product. The amount of air which should be incorporated in the whipping of ice cream mix depends upon the composition of the mix and the manner in which it is processed, and is regulated so as to give that per cent overrun or yield which will give the proper body, texture and palatability necessary to good quality ice cream (Arbuckle, 1966).

Too much incorporation of air will produce a snowy, fluffy, unpalatable ice cream; whereas, too little air gives a soggy, heavy product.

Sommer (1946) noted that either a low total solids content or a low stabilizer content contributed to the snowy or flaky defect. He believed this defect to be primarily a result of incorporation of an excess amount of air as large air cells. The above author made the following observations concerning the effect of mix composition on overrun in ice cream:

1. only minor changes can be produced in whipping ability by varying the fat and serum solids content.
2. fat from butter, butter oil, and frozen cream do not produce as good a whipping mix as fat from fresh sweet cream.
3. serum solids are somewhat variable in composition; if their calcium content is high and their citrate and phosphate content is low they may cause lower whipping ability by virtue of their effect on fat clumping.
4. increasing the gelatin content decreases the rate of whipping.
5. gums generally reduce whipping ability with the exception of sodium alginate, which is likely to improve it, but excessive amounts will also limit whipping.
6. egg yolk solids greatly improve the whipping ability of mixes. Egg white has no beneficial effect on whipping. Two per cent fresh eggs in the mix equals or slightly exceeds 1.0 per cent fresh egg yolk or 0.5 per cent dried egg yolk in the effect on whipping.
7. sweet buttermilk solids are an advantageous source of serum solids because the lecithin-protein compounds in it give it properties similar to egg yolk.

Shrinkage

Occasionally the shrinkage of ice cream in its final container becomes a serious problem. The ice cream may shrink away from the wall, or may fall to a lower level in the container. As it is packaged from the freezer the product consists of partly frozen mix in a semifluid state with a substantial volume of air incorporated in the form of air cells. Sommer (1946) stated that both the volume of air and the size of the air cells are important from the standpoint of shrinkage. With an overrun range of 70 to 120 per cent, the volume of air ranges from 70 ml to 100 ml per 100 ml of mix. Such proportions of air to mix are important in view of the volume or pressure changes which gases undergo with changes in temperature. The size of the air cells is important because that determines the pressure within the cells due to the surface tension of the surrounding semiliquid. As noted by Sommer (1946) the pressure within the cells is inversely proportional to their radii or diameters.

Destabilization of the proteins in ice cream mix has been noted as a contributing factor to shrinkage (Kohler, 1940; Erb, 1940). This is in agreement with Tracy and Ruehe (1929) that the use of enzymatic ice cream improvers tends to cause shrinkage. Some factors that cause low stability of the proteins in the product and are conducive to shrinkage include high mix acidity, a high calcium and magnesium content, a low citrate and phosphate content, and excessive homogenization (Sommer, 1946).

Excessive overrun has also been claimed to be a contributor to shrinkage. According to Arbuckle (1966) emulsifiers in a mix seem to favor very small air cells and consequently, shrinkage. Frazeur and Dahle (1953) reported, however, that the addition of sodium caseinate to ice cream mix reduced shrinkage and the use of individual emulsifiers tended to increase shrinkage. They also studied the effect of heat treatment on proteins of the mix in relation to ice cream shrinkage and concluded that temperatures of from 135 F to 145 F for 30 minutes appeared to be optimum for keeping shrinkage to a minimum. Temperatures from 145 F to 160 F for the same pasteurization time seemed to result in maximum shrinkage, but shrinkage decreased as the pasteurization temperature was increased from 160 F to 190 F for one-half hour.

PROCEDURES

Preparation of Neufchatel Cheese

Fresh raw whole milk for this study was obtained from the Michigan State University Dairy Department. The milk was heated to 90 to 100 F and separated by means of a Westphalia Model LWA 205 separator. The cream obtained from separation contained approximately 40 to 45 per cent fat and was standardized with fresh skimmilk to a fat content of 5.0 per cent unless otherwise noted.

The standardized whole milk was poured into stainless steel cans which were placed in a steam heated water bath for pasteurization. The milk was constantly agitated throughout this process. Raw milk was heated to 130 to 135 F and additives such as casein, stabilizers and emulsifiers (added to milk rather than cheese), if used, were added at this point and held for 30 minutes to facilitate their hydration and dispersion. Each emulsifier whether added to milk during the pasteurization process or to the prepared cheese, was mixed with an equal weight of 1,2-propanediol (propylene glycol) to facilitate its incorporation into the mix. The 30 minute holding period at 130 to 135 F was eliminated in experiments where the above mentioned additives were not used. Pasteurization of the milk was completed by one of the three processes mentioned below.

(1) heat to 161 F and hold 20 seconds,

(2) heat to 145 F and hold 30 minutes, or

(3) heat to 175 F and hold 30 minutes.

The mix was homogenized twice in a 75 gallon Manton-Gaulin homogenizer at 2000 pounds pressure per square inch (single stage) and cooled to 40 F. The processed milk was stored at 33 F until it was used, usually a period of one to four days.

The following procedure was used in the preparation of Neufchatel cheese except in experiments where direct acidification was used.

1. The pasteurized homogenized milk (5.0 per cent fat) was warmed to 90 F.
2. Five per cent lactic starter was stirred into the milk.
3. Stainless steel beakers containing the thoroughly stirred milk and lactic culture were placed in a water-jacketed bath maintained at 90 F.
4. When the titratable acidity of the mix reached 0.60 to 0.85 per cent, 2.0 per cent salt (based on the initial weight of the milk) dissolved in water was added.
5. The mix was poured into muslin bags which were hung in a 40 F cooler and left 12 to 15 hours to drain.
6. The cheese bags were removed from the hangers and placed on a stainless steel rack in the cooler so that drainage could be completed. A weighted stainless steel tray was placed on each bag to facilitate whey drainage.
7. When the moisture content of the cheese reached 65.0 per cent or less (usually 60.0 to 63.0 per cent), drainage was stopped.
8. The cheese was removed from the muslin bags, placed in stainless steel beakers and stored in a 40 F refrigerator.

Direct Acidification Procedure

The direct acidification procedure of McNurlin and Ernstrom (1962) was followed. The amount of food grade lactic acid (50 per cent) to add to a given lot of milk was determined by acidifying a one pound aliquot of the milk at 70 F to a pH of 4.6 to 4.7. According to McNurlin and Ernstrom (1962), acid can be added to cold skim at 40 F without causing localized coagulation.

The predetermined volume of lactic acid was slowly added and stirred into the 5.0 per cent milk at 40 F. This was followed by quiescent heating of the mix in a steam heated water bath to 70 to 90 F which resulted in a firm gel. Steps 5 through 8 as stated in the starter or culture procedure above were then followed in this method of Neufchatel cheese manufacture.

Treatment of Neufchatel Cheese Prior to Whipping by Aeration

Early in this study the aeration of Neufchatel cheese was found to be a difficult process to accomplish satisfactorily unless some method was devised to soften the cheese, thereby facilitating gas dispersion. The following gas dispersion pretreatment was found to be beneficial for subsequent incorporation of gas into the cheese.

Eight hundred and fifty grams of each cheese sample at 40 F were weighed into a two-quart stainless steel mixing bowl and mixed at room temperature by means of a Hobart Model K5-A mixer (speed control set at 10) equipped with a wire whip. The softening process consisted of mixing the cheese two minutes, stopping and using a rubber spatula to scrape cheese from the walls of the bowl and the cheese softening process was completed by mixing two more minutes. Some experiments involved the addition of emulsifier or a combination of emulsifiers to the cheese rather than to milk as described in the milk pasteurization procedure. In such instances the emulsifier was added to the cheese immediately prior to the second two-minute mixing period.

An Erlenmeyer flask containing a 50-50 mixture by weight of the particular emulsifier and 1,2-propanediol was placed in a beaker of warm water and heated sufficiently to melt the mixture. A desired amount of the emulsifier-propylene glycol liquid was weighed into the partially softened cheese. The emulsifiers used in this research are shown in the following table.

Table 1. An alphabetical code for the commercial emulsifiers used in this study

Code letter*	Commercial emulsifier
A	Myverol 18-07
B	Myverol 18-30
C	Myverol 18-45
D	Atmos 150
E	Atmos 300
F	Polyoxyethylene sorbitan monostearate (Tween 60)
G	Polyoxyethylene sorbitan tristearate (Tween 65)
H	Sodium stearoyl 2-lactylate (Emplex)

*The code letters will be used throughout this thesis to denote the specific commercial emulsifier.

ANALYTICAL PROCEDURES

Gas Dispersion

A one-quart stainless steel pressurized bottle (Kidd) was used in gas dispersing the cheese. The bottle was equipped with a rubber bottle washer and a removable head. The head contained a check valve, piercing pin, o-ring washer, decorator valve tip and toggle valve stem. The bottle head was altered, however, by replacing the check valve, piercing pin and o-ring washer with a 3 inch pipe having an inside diameter of 1/4 inch, and valve so that various gases could be dispersed into the cheese. A 3/8 inch high pressure rubber hose was used to transfer the gas from its cylinder into the pressurized stainless steel container. The high pressure rubber hose was capable of withstanding 3000 psi and the one-quart bottle was capable of withstanding 1000 psi. Gas pressures used in the gas dispersion process never exceeded 300 psi.

Seven hundred and seventy-five grams of each softened cheese sample were weighed into the pressurized stainless steel container for gas dispersion, unless otherwise noted. The head was tightly screwed onto the quart bottle and it was placed and thoroughly secured on an Eberbach Model 75-731 variable speed shaker. Whipping the cheese by aeration was accomplished by opening the bottle valve and dispersing a given gas into the bottle at a given pressure for 10 minutes while the Eberbach shaker was simultaneously operating at a speed of 340 revolutions per minute. The gas valve on the bottle head was closed at the end of the 10 minute gas dispersion and shaking period.

Determination of Overrun

Aluminum total solids dishes having a capacity of 142 ml were used in overrun determinations. These dishes were 4.6 cm high and had an inside diameter of 6.3 cm. Prior to softening each sample of cheese for aeration, a numbered aluminum dish was filled with the particular cheese sample and weighed. After cheese from this given lot had been whipped by the gas dispersion and shaking process mentioned previously, a portion of the whipped Neufchatel cheese was dispersed from the quart container into the same numbered aluminum dish and again weighed. Duplicate overrun determinations were made on each sample of cheese. The following formula as recommended by Frandsen and Nelson (1950) was used to calculate per cent overrun.

$$\frac{\text{Wt. of mix} - \text{Wt. of same volume of whipped product}}{\text{Wt. of same volume of whipped product}} \times 100 = \%\ \text{Overrun}$$

Determination of Shrinkage

Aluminum dishes containing the whipped Neufchatel cheese were stored in a 40 F refrigerator for 4 days after which the amount of shrinkage of each sample was determined. The volume of petroleum ether required to fill each aluminum dish was recorded as the shrinkage for the particular sample of whipped cheese.

Determination of Penetrometer Value

Rheological measurements were made with a "Precision" Universal Penetrometer equipped with a universal penetrometer cone (102.5 gram) (Precision Scientific Company, 1954). Prior to making measurements, the cheese which had been packaged in rigid polystyrene containers was removed from a 40 F refrigerator and held at room temperature 4 to 6 hours in order for the cheese temperature to equilibrate to 70 F. A five second penetration time was used after aligning the tip of the cone with the surface of the cheese at the center of the container and the results were recorded as cone penetration in tenths of millimeter $(\frac{mm}{10})$.

Determination of Relative Viscosity by the Brabender Visco/amylo/graph (VAG)

The VAG instrument was adapted for the evaluation of the rheological properties of whipped Neufchatel cheese by virtue of its reproducibility and its sensitivity to small changes in the properties of the product. The VAG is a fully recording instrument for measuring and recording apparent viscosity at fixed or varying temperatures. The determination is made by means of a suspended sensing element immersed in the material under test and connected through a precise measuring spindle to a pen arm controlled by an interchangeable linear calibrated spring cartridge. The VAG is a rotational instrument which permits continuous determination of viscosity. The rotating cup contains a number of fixed vertical pins and is driven by a variable speed synchronous motor.

A circular metal disc with metal pins projecting vertically downward into the sample serves as a sensing element which is dynamically balanced by a calibrated torsion spring. Application of the restoring force is accompanied by an angular deflection of the sensing element shaft which is recorded continuously on a strip chart recorder. The sample cup is positioned in an electrically heated air bath and a cooling coil projects into the cup. Heating and cooling are controlled by a mechanically operated thermoregulator which maintains a constant temperature or which increases or decreases the temperature at a constant rate of 1.5 C per minute. The range of measurement of the instrument may be increased by the addition of weights to suppress the zero, or by substitution of a less or more sensitive cartridge. Shear rates can be changed by varying the speed of rotation of the bowl.

Use of this instrument afforded the opportunity of obtaining an initial penetrometer value of the Neufchatel cheese as well as a more objective appraisal of the resistance of the whipped product to varying degrees of agitation for increasing lengths of time. For the evaluation of the body or viscosity of the whipped Neufchatel cheese, test conditions were standardized. A cartridge of 700 centimeter gram of torque (cmg) with a preload of zero cmg was used unless otherwise indicated. Certain whipped samples in which the overrun was low, usually less than 100 per cent, required preloads; for example, a preload of 350 cmg was needed in some instances. The range on the strip chart (0-1000), therefore, represented 0-100 per cent of the measuring range of the cartridge or 0-700 cmg. If a preload of 350 cmg were used the zero would be changed and the range would be increased to 1050. A reading of 500 Brabender units on the strip chart would be equivalent to 525 cmg. The speed of rotation of the bowl was set at 25 revolutions per minute to control the shear rate.

The arbitrary Brabender units were not reported because of the different factors of time and shear rate involved. The different treatments evaluated were compared on the basis of the response or pattern of breakdown that resulted from the prescribed treatment. Because of the inverse relationship between density and overrun, the weight of the whipped cheese dispersed into the VAG bowl, varied from 200 to 300 grams. However, all samples involved in each particular trial weighed the same so that a more accurate comparison of their viscosity could be made.

To analyze the whipped samples, periods of agitation ranging from 1 to 30 minutes sufficed to obtain a curve which represented the initial and final body of the stirred product. The sample was maintained cold by the circulation of cold water to offset the slow increase in temperature that would occur due to frictional heat and prevailing atmospheric conditions.

Fat and Total Solids

The separated cream containing 40 to 45 per cent fat was standardized to 5.0 per cent whole milk on the basis of the official Babcock fat test (AOAC, 1970). The Babcock test was also used for fat determinations of the prepared Neufchatel cheese.

Total solids analyses of the cheese were determined by a method of the Association of Official Analytical Chemists for cheese (AOAC, 1970).

Titratable Acidity

Titratable acidity determinations in this study were made by titrating a nine-gram sample with accurately standardized 0.100 N sodium hydroxide to the phenolphthalein end-point. All titratable acidities were expressed as per cent lactic acid.

pH

The pH measurements were made with a Beckman Expandomatic pH meter using a calomel half cell and a glass electrode. The results were expressed to the nearest one-tenth of a pH unit.

RESULTS AND DISCUSSION

Neufchatel cheese has been classified as a soft variety of cheese; however, preliminary studies in the area of whipping this cheese by aeration indicated that the whipping process could be more easily accomplished if the cheese were softer in body and texture than the Neufchatel cheese usually found on the market. Therefore, various processing procedures and additives were investigated as to their effect upon softening the body and texture of Neufchatel cheese. Some of the processing variables that were investigated included different pasteurization methods, variation of the fat content of the cheese milk and direct acidification versus lactic acid fermentation for coagulation of the milk in the cheese preparation process. Additives to the cheese milk included monoglyceride emulsifiers, high and low HLB emulsifiers and different stabilizers such as locust bean gum, glucosyl glucan, sodium alginate and sodium caseinate. A "Precision" Universal Penetrometer equipped with a 102.5 gram universal penetrometer cone was used for rheological measurements of the prepared Neufchatel cheese.

The effect of the above mentioned variables upon the per cent overrun, the amount of shrinkage and relative viscosity of the whipped Neufchatel cheese were also investigated. The control and experimental samples of cheese in each trial were drained to within one per cent moisture content of each other, if possible, so that comparative results obtained could be made and interpreted.

Since processing variables were often interrelated, the systematic evaluation of one variable such as heat treatment or an added ingredient, required that all processing be carefully standardized and controlled. Trials were therefore repeated and parameters were individually varied to eliminate or compensate for possible interactions. This permitted conclusions to be drawn with regard to each parameter tested without the aid of statistical analysis.

Rheology of Prepared Neufchatel Cheese

The effect of the fat content of cheese milk upon the softness of Neufchatel cheese

In order to determine the effect of the fat content of cheese milk upon the softness of Neufchatel cheese, two batches of cheese were prepared, one of which was made from milk containing 4.0 per cent fat and the other from milk containing 5.0 per cent fat.

Table 2. Rheology of Neufchatel cheese as influenced by its composition

Cheese lot	Fat in milk	Acidity of coagulum at beginning of drainage	Rheology* of Neufchatel cheese of different composition			
			composition and pH of the cheese			Penetrometer reading
			Fat	Water	pH	$\frac{mm}{10}$
(No.)	(%)	(%)	(%)	(%)		
I	4.0	0.76	20.1	59.71	4.54	202
II	5.0	0.74	23.6	58.84	4.56	221

*As measured by the universal penetrometer, "Precision" model.

The data in Table 2 show that the variation in moisture content of the two samples of cheese was less than 1.0 per cent. The fat content of the cheese made from 5.0 per cent milk was 3.5 per cent higher than the sample made from 4.0 per cent milk. The cheese made from the lower fat milk was only 0.1 per cent fat above the legal minimum for Neufchatel cheese. The penetrometer readings listed in Table 1 indicated that the higher the fat content of Neufchatel, the softer the body and texture of the resulting cheese. Therefore, milk containing 5.0 rather than 4.0 per cent milk fat had two advantages in Neufchatel cheese preparation for this study. One advantage was the assurance of a legal product from the composition standpoint and the other was a softer cheese for subsequent aeration. Therefore, all lots of milk used in this research were standardized to 5.0 per cent fat.

The effect of milk pasteurization treatments on the softness of prepared Neufchatel cheese

The effect of different methods of milk pasteurization on the softness of Neufchatel cheese was investigated. One high temperature short time method and two batch pasteurization methods were used in this area of the softness study. Triplicate penetrometer readings on each lot of finished cheese indicated that the softness of the cheese varied among the three different methods of cheese milk pasteurization.

The data in Table 3 pertaining to the penetrometer readings of the prepared cheese showed that the batch pasteurization method, in which the milk was heated to 145 F and held for 30 minutes, resulted in a softer cheese than either of the other two methods of pasteurization. The penetrometer reading of the cheese varied inversely with the temperature of pasteurization. These data show that the time/temperature relationship of milk pasteurization affects the softness of the resulting Neufchatel cheese.

Table 3. The rheology of Neufchatel cheese as influenced by the milk pasteurization method

Cheese lot (No.)	Time and Temperature of pasteurization	Rheology of Neufchatel cheese prepared from milk pasteurized by different methods		
		Moisture (%)	pH	Penetrometer reading $\frac{mm}{(10)}$
I	145 F - 30 min.	61.55	4.49	214
II	175 F - 30 min.	62.80	4.52	196
III	161 F - 20 sec.	62.80	4.52	209

The moisture content of the cheese made from milk which was pasteurized by heating to 145 F and holding for 30 minutes was 1.25 per cent less than the moisture content of the other two samples of cheese, and yet the lower moisture cheese was softer (Table 3). According to the penetrometer reading there was not a great difference in the softness of cheese prepared from milk pasteurized using the batch method of 145 F for 30 minutes and the high temperature short time method of 161 F for 20 seconds. Therefore, the milk lots in all subsequent trials of this research investigation were pasteurized by one of the two methods mentioned above. The batch pasteurization method was used when stabilizers were added to the milk in order to get better hydration of these substances.

Direct acidification versus lactic acid fermentation for coagulation of milk during Neufchatel cheese preparation

Direct acidification has been used in the preparation of Mozzarella cheese, cottage cheese and Cheddar cheese in recent years. Food grade lactic acid (50 per cent) was used in the direct acidification of milk for Neufchatel cheese preparation in this study, and the softness of the resulting cheese was compared to Neufchatel cheese made by adding a lactic acid culture to the milk and allowing the mix to ferment.

Table 4. The rheology of Neufchatel cheese as influenced by the method of milk coagulation

Cheese lot (No.)	Milk coagulation method	Rheology of Neufchatel cheese prepared from milk coagulated by different methods: Moisture (%)	pH	Penetrometer reading ($\frac{mm}{10}$)
I	Direct acidification*	62.84	4.58	219
II	Lactic acid fermentation	62.04	4.55	214

*Used 50 per cent food grade lactic acid to acidify the milk.

According to the penetrometer readings given in Table 4, the cheese prepared by using direct acidification to form the coagulum was slightly softer than the Neufchatel cheese in which lactic acid fermentation was used to clot the milk. However, the moisture content of the direct acidified cheese was 0.80 per cent higher than the moisture content of the other cheese sample. Therefore, the opinion was formed from results such as these that there was not a significant difference in the softness of the two samples of cheese.

The Neufchatel cheese prepared by the direct acidification method lacked the desirable flavor and aroma qualities that were present in the cheese prepared by the lactic acid fermentation method. Another defect of the direct acidified cheese was that it was "sticky" to the touch. One should note, however, that direct acidification had certain advantages over the culturing method of cheese preparation, one of which was the better assurance of a coagulated milk. Secondly, bacteriophage, antibiotics in milk and slow or dead cultures are known to occasionally result in failures of lactic acid fermentation cultures to produce adequate amounts of lactic acid in fermented dairy products. Since culture failures did not occur throughout this research and because of the improved flavor, aroma and texture of the cultured cheese, the lactic acid fermentation method of Neufchatel cheese preparation was used unless otherwise noted.

Effect of stabilizers added to milk upon the softness of Neufchatel cheese

The milk for the control and experimental samples of cheese was standardized to 5.0 per cent fat and the batch pasteurization process was initiated by warming the milk to 130 to 135 F with constant stirring, at which time the stabilizer, if used, was added. The mix was then stirred for 30 minutes at this temperature to facilitate hydration of the stabilizer. Agitation was continued as the mix was heated to 145 F and held 30 minutes to complete the pasteurization process. Stabilizers used in this study were added individually to the milk. Combinations of two or more stabilizers were never used.

The primary purpose of adding stabilizers in soft cheese preparation has been to prevent syneresis of the finished product in the consumer package. The whipped control Neufchatel cheese samples in this study did not show signs of syneresis which indicated that the stabilizers were not of any particular benefit from the standpoint of whey leakage. However, as indicated by penetrometer readings taken on the prepared

Neufchatel, the stabilizers in some instances appeared to result in a softer cheese.

Table 5. The moisture content and pH of Neufchatel cheese made from milk to which stabilizers were added

Cheese lot (No.)	Stabilizer added (%)*	Acidity of coagulum at beginning of drainage (%)	pH and moisture content of cheese	
			pH	Moisture (%)
I	Locust bean gum-			
	0.0	0.73	4.59	63.42
	0.1	0.79	4.71	62.08
	0.2	0.79	4.68	63.51
	0.3	0.74	4.68	60.08
II	Glucosyl glucan-			
	0.0	0.76	4.55	62.04
	0.1	0.80	4.56	62.83
	0.2	0.76	4.56	61.59
	0.3	0.75	4.56	62.44
III	Sodium alginate-			
	0.0	0.85	4.51	62.70
	0.1	0.85	4.49	62.52
	0.2	0.79	4.49	60.39
	0.3	0.82	4.55	62.71
IV	Sodium caseinate-			
	0.0	0.76	4.55	62.04
	1.0	0.79	4.50	62.55
	2.0	0.88	4.48	62.45

*Percentage stabilizer was based on pounds of milk in the particular batch.

The data listed in Table 5 showed that the moisture content of the experimental samples was relatively close to the control in each lot, except lot 1 (locust bean gum) in which the moisture content varied from 63.42 per cent in the control sample to 60.08 per cent in the cheese made from milk containing 0.3 per cent locust bean gum. Stabilizers added to the milk delayed drainage of whey from the bagged cheese as much as 24 to 48 hours. The samples containing locust bean gum were the most difficult to drain. Locust bean gum added to milk at the 0.3 per cent level resulted in a cheese that possessed a grainy texture and showed a tendency to be fluid or semifluid. Because of these defects it is recommended that locust bean be used at a level of not more than 0.1 per cent based upon the weight of the milk. The grainy texture and fluidity did not occur in cheese samples made from milk containing glucosyl glucan, sodium alginate or sodium caseinate.

The bar graphs shown in Figure 1 reveal the effect of the four stabilizers upon the softness of Neufchatel cheese as determined by penetrometer reading. A control cheese sample was used in each of the four trials which involved the addition of stabilizers to the whole milk so that more accurate evaluations could be made of the effect of each stabilizer upon cheese softness. Sodium caseinate was added at much higher levels than the other three stabilizers as noted in Table 5 and Figure 2.

Sodium caseinate added at rates of 1.0 per cent and 2.0 per cent resulted in cheese samples having penetrometer readings of 215 and 211 respectively, as compared to a reading of 214 for the control sample. These results suggested that sodium caseinate added at the levels mentioned above had essentially no effect upon the softness of Neufchatel cheese.

Locust bean gum added at the 0.3 per cent level produced an extremely soft cheese as compared to the corresponding control cheese sample in that particular trial. This same stabilizer added in the amount of 0.1 per cent softened the cheese somewhat as indicated by

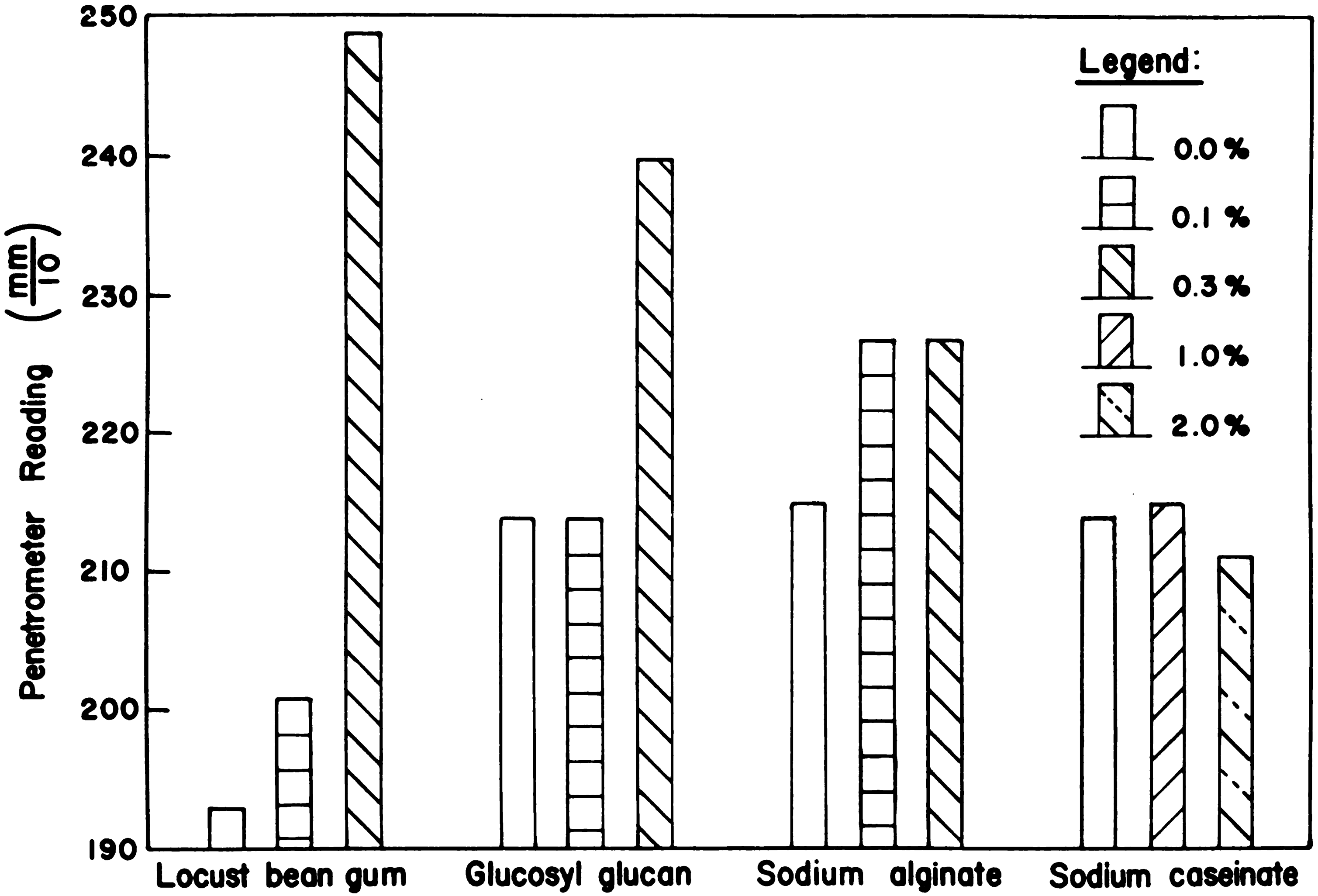

Figure 1. The effect of added stabilizers upon the softness of Neufchatel cheese.

the penetrometer reading of 201 as compared to the 193 reading of the control cheese sample. One should note that the control cheese (Table 5) contained 3.34 per cent more moisture than the cheese prepared from milk containing 0.3 per cent locust bean gum, but had a firmer body and texture (Figure 1).

Glucosyl glucan added at the rate of 0.1 per cent did not alter the cheese softness; however, this stabilizer had an appreciable softening effect when added at the 0.3 per cent level. Sodium alginate resulted in a softer cheese than the corresponding control. Apparently 0.1 per cent was the concentration resulting in maximum effect on softness since cheese containing 0.3 per cent was no softer.

Results from this study indicated that glucosyl glucan added to the milk at a concentration of 0.3 per cent was the most desirable stabilizer used from the standpoint of yielding a soft cheese with none of the defects previously mentioned.

The influence of monoglyceride emulsifiers added to milk during pasteurization upon the softness of Neufchatel cheese

Three monoglyceride emulsifiers (A, B and C; Table 1, p. 22), each having a minimum monoester content of 90 per cent (Table 6) were evaluated to determine their effect upon the body and texture of Neufchatel cheese. Two additional commercial emulsifiers (D and E, Table 1, p. 22) were used; however, their minimum monoester content was much lower than 90 per cent (Table 6) so their effect on the softness of Neufchatel cheese will be discussed from the standpoint of hydrophile-lipophile balance (HLB).

A one gram sample of commercial monoglyceride preparation A was fractionated using a 100-200 mesh silicic acid column prepared according to the procedure of Smullin and Olsanski (1959). The triglyceride

Table 6. Source and some chemical properties of specific emulsifiers used in the study

Emulsifier		Source	Minimum monoester content (%)	Iodine number*
Myverol-				
	A	Prepared from edible, fully hydrogenated, cottonseed oil	90	3
	B	Prepared from edible animal fat	90	40
	C	(Not given)	90	56
Atmos-				
	D	(Not given)	64	1
	E	(Not given)	56	76

*Iodine number is defined as the number of grams of iodine absorbed by 100 grams of lipid.

fraction was removed from the column with benzene and was found to be 1.90 per cent of the weight of material placed on the column. A mixture of benzene plus 10 per cent ethyl ether was used to remove the diglyceride portion which amounted to 5.95 per cent of the initial weight. The monoglyceride was removed with ethyl ether and was 93.67 per cent of the original weight. Thus the total recovery was 101.5 per cent.

Monoglycerides A, B and C had iodine values of 3, 40 and 56 respectively, as shown in Table 6, and were solid at room temperature. In preparing the monoglyceride for the first few batches of cheese the desired amount of the solid emulsifier was weighed and stirred into the milk during pasteurization. However, this method of adding the monoglyceride to the milk was not satisfactory because as much as 50 per cent of the monoglyceride was found in the homogenizer block following disassembly. The following procedure permitted all of the monoglyceride to be quantitatively incorporated into the milk. A 50-50 mixture (w/w) of each monoglyceride and 1,2-propanediol was prepared. Prior to use, an Erlenmeyer flask containing the mixture was placed in a beaker of warm water and heated sufficiently to melt the mixture. A desired amount of the monoglyceride-propylene glycol mixture was promptly weighed and stirred into the milk which was at 130-135 F. Pasteurization of the mix was completed and the mix was then homogenized.

In order to determine the possible effect of 1,2-propanediol on the body and texture of Neufchatel cheese, two batches of cheese were made, one of which served as a control and the other contained 0.2 per cent propanediol. The data in Table 7 indicated that 1,2-propanediol did not soften the Neufchatel cheese; in fact, the cheese containing propylene glycol possessed a slightly coarser body and texture than the corresponding control.

Table 7. Rheology of Neufchatel cheese as influenced by 0.2 per cent 1,2-propanediol added to the milk from which the cheese was prepared

Cheese lot	Propanediol in milk	Acidity of coagulum at beginning of drainage	Moisture content, pH and rheology of Neufchatel cheese prepared from milk containing propanediol		
			Moisture	pH	Penetrometer reading
(No.)	(%)	(%)	(%)		$\left(\frac{mm}{10}\right)$
I	0.0	0.79	62.53	4.60	220
II	0.2	0.77	62.67	4.61	209

Ten batches of cheese were prepared in an effort to determine the effect of A, B and C monoglycerides (Table 1, p. 22) upon the softness of Neufchatel cheese. As shown in Table 8, each of the three emulsifiers was added at three different levels which included 0.1, 0.2 and 0.3 per cent. Acidity of the coagulum and pH of the cheese for the 10 samples were similar; however, the percentage moisture in the 10 batches of cheese prepared simultaneously was extremely difficult to control. Since the pH of the cheese was relatively constant, the coagulum acidity at beginning of drainage did not appear to be responsible for any differences noted in softness of the Neufchatel cheese. According to the coagulum acidity of samples listed in Table 8, the monoglyceride emulsifiers did not appear to have a detrimental effect upon growth of the lactic fermenting bacteria. The fermented control and experimental batches of milk containing monoglycerides were poured into muslin bags and drained simultaneously.

One disadvantage of adding monoglycerides to the milk, rather than to the prepared cheese, was that a longer period of time was required to drain the experimental samples of cheese as compared to the control lot. Also, the higher the monoglyceride content of the milk the more difficult was the task of draining the cheese. Each of the three emulsifiers; A, B and C, added at the 0.3 per cent level caused a pasty texture in the cheese. However, this defect was less prominent in the Neufchatel cheese made from milk containing 0.3 per cent C monoglyceride.

The data in Figure 2 indicated that each of the three monoglycerides (A, B and C) added to milk at levels ranging from 0.1 to 0.3 per cent resulted in a softer cheese than the corresponding control. All samples of cheese containing the monoglyceride emulsifiers were smoother in appearance than the corresponding control. According to the moisture

Table 8. The moisture content and pH of Neufchatel cheese made from milk to which monoglyceride emulsifiers were added

Cheese lot (No.)	Monoglyceride added (%)*	Acidity of coagulum at beginning of drainage (%)	pH and moisture content of cheese	
			pH	Moisture (%)
I	0.0	0.77	4.48	62.95
II	A-			
	0.1	0.78	4.56	62.83
	0.2	0.80	4.58	60.30
	0.3	0.79	4.60	54.38
III	B-			
	0.1	0.76	4.58	58.22
	0.2	0.80	4.58	61.30
	0.3	0.80	4.60	60.81
IV	C-			
	0.1	0.77	4.52	58.92
	0.2	0.80	4.59	61.84
	0.3	0.81	4.63	64.76

*Percentage added monoglyceride based upon the pounds of milk in each lot.

contents of cheese samples listed in Table 8, it was noteworthy that all samples of cheese, except the one prepared from milk containing 0.3 per cent C monoglyceride, contained less moisture than the control cheese (62.95 per cent water). The two cheese samples made from milk containing 0.1 per cent B and 0.1 per cent C monoglycerides contained 4.73 and 4.03 per cent less moisture respectively than the control cheese. The extremely low moisture contents of those two samples of cheese accounted for their slightly lower penetrometer readings than that of the control cheese.

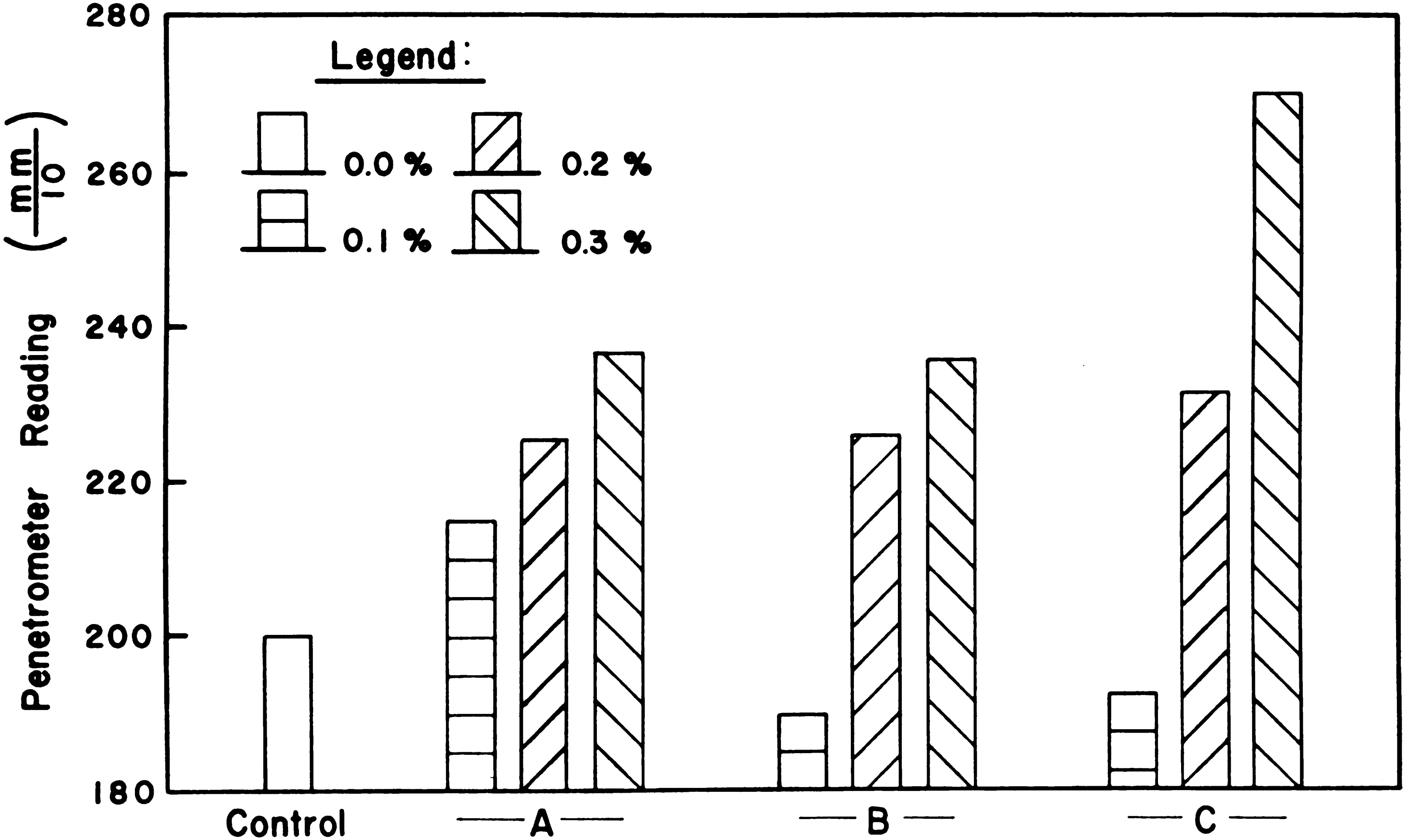

Figure 2. The effect of monoglyceride emulsifiers added to milk upon the softness of Neufchatel cheese.

The remaining seven samples of cheese containing monoglycerides were softer than the control cheese (Figure 2); however, six of those contained less moisture than the control (Table 8). According to Figure 2, both A and B emulsifiers (Table 1, p. 22) added to milk at levels of 0.2 and 0.3 per cent resulted in cheese of comparative softness. As the concentration of each monoglyceride was increased, the resulting cheese had a higher penetrometer reading which indicated that the cheese was softer (Figure 2). The monoglyceride emulsifiers were beneficial from the standpoint of producing Neufchatel cheese with a softer and smoother body and texture.

<u>The influence of high and low HLB emulsifiers added to milk during pasteurization upon the softness of Neufchatel cheese</u>

Two emulsifiers having a high hydrophile-lipophile balance rating (F and G; Table 1, p. 22) and one emulsifier having a low HLB rating (E) were added to milk in an attempt to determine their effect upon the softness of Neufchatel cheese. The HLB ratings of emulsifiers D, E, F and G are given in Table 9. As noted in Table 6, the E emulsifier had a minimum monoester content of 56 and an iodine value of 76; therefore, this emulsifier had a higher degree of unsaturation than the A, B and C monoglycerides previously discussed. The F and G emulsifiers were manufactured commercially by reacting ethylene oxide with lipophilic sorbitan esters, thus making them more hydrophilic, and therefore more efficient in the stabilization of oil in water emulsions. They were blended with lipophilic surfactants of either the glycerol or sorbitan ester type to produce a wide variety of effects over an extensive HLB range. Emulsifiers F and G were liquid and solid compounds respectively.

Table 9. Hydrophile-lipophile balance of four emulsifiers used in this study

Emulsifier	HLB rating*
D	3.2
E	2.8
F	14.9
G	10.9

*An HLB rating of 10.0 means that the hydrophile and lipophile groups of the surfactant are balanced.

Emulsifiers E, F and G were prepared for addition to the milk in the same manner as were the monoglyceride emulsifiers. Therefore, a 50-50 mixture by weight of each of the three emulsifiers mentioned above and 1,2-propanediol was prepared, melted as previously described, added to the milk at 130-135 F, agitated for 30 minutes and the pasteurization process was completed by heating the mix to 145 F and holding 30 minutes. Ten batches of cheese were prepared in this trial in order to compare the effect of high and low HLB emulsifiers upon the softness of Neufchatel cheese. This trial consisted of one control and nine experimental batches of cheese containing emulsifiers. The pH and moisture content of each of the cheese samples are shown in Table 10.

A period of one to two days was generally required to drain the control cheese. The cheeses made from milk containing the E, F and G emulsifiers (Table 1, p. 22) required 24 to 48 hours longer for drainage than the control cheese. The two samples of cheese made from milk containing 0.2 and 0.3 per cent emulsifier F failed to drain properly. After a seven day drainage period these two cheese samples contained 81.87 and 83.82 per cent moisture respectively. Therefore, data concerning the cheese pH and penetrometer readings were not collected from

Table 10. The moisture content and pH of Neufchatel cheese made from milk to which high and low HLB emulsifiers were added

Cheese lot (No.)	Emulsifier added (%)*	Acidity of coagulum at beginning of drainage (%)	pH and moisture content of cheese: pH	pH and moisture content of cheese: Moisture (%)
I	0.0	0.77	4.58	58.71
II	F-			
	0.1	0.81	4.52	59.53
	0.2	0.82	--	--**
	0.3	0.81	--	--**
III	G-			
	0.1	0.79	4.53	58.35
	0.2	0.78	4.58	63.62
	0.3	0.78	4.62	62.32
IV	E-			
	0.1	0.79	4.58	59.13
	0.2	0.81	4.59	58.17
	0.3	0.79	4.58	57.61

*Percentage added emulsifier based upon pounds of milk in each lot.

**The cheese samples would not drain to the 65.0 per cent moisture level.

these two lots of cheese. Results in Table 10 showed that the coagulum acidity and cheese pH were relatively the same among the 10 cheese samples. The F emulsifier appeared to bind the moisture tenaciously in the coagulum when added to milk at levels of 0.2 per cent or greater.

Data in Figure 3 indicated that both the high and low HLB emulsifiers used in this study resulted in cheese that was softer than the control cheese and they were especially effective when added in the amount of 0.2 and 0.3 per cent. Noteworthy were the results which showed that the two high HLB emulsifiers (F and G) had a greater softening effect upon the prepared cheese than the low HLB emulsifier (E).

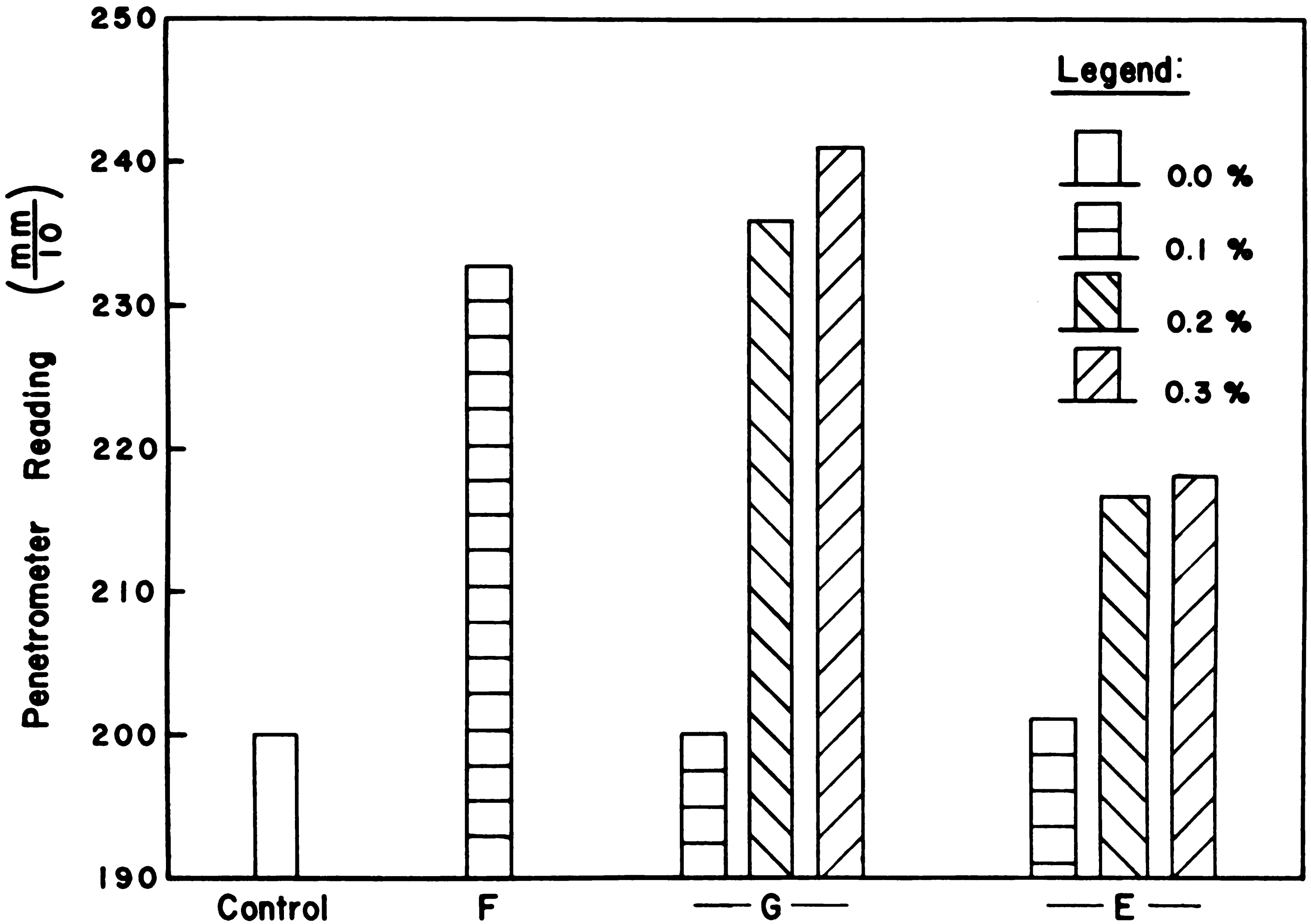

Figure 3. The effect of high and low HLB emulsifiers added to milk upon the softness of Neufchatel cheese.

The F emulsifier was especially effective as a softening additive as indicated by the cheese penetrometer reading of 233 when 0.1 per cent of this emulsifier was added to the milk. The control cheese in this particular trial had a penetrometer reading of 200 as shown in Figure 3. The high HLB emulsifier (F) should be added to the cheese milk at some level less than 0.2 per cent because of the drainage problem encountered. Addition of the E and G emulsifiers to cheese milk in the amount of 0.1 per cent did not soften the Neufchatel cheese appreciably (Figure 3).

As can be seen from the data in Figure 3, there was a direct relationship between the amount of high or low HLB emulsifier added to the milk and the softness of the finished cheese. The results of this study indicated that increasing emulsifier concentration from 0.1 to 0.2 had a much greater softening effect upon Neufchatel cheese than increasing the emulsifier from 0.2 to 0.3 per cent. These data also show that the higher the HLB rating of an emulsifier the greater its softening effect upon the body and texture of Neufchatel cheese.

The results shown in Figures 2 and 3, based upon the addition of six different emulsifiers to milk used for cheese preparation, indicated that emulsifiers were effective softening agents for Neufchatel cheese. The high HLB emulsifiers appeared to have a greater softening effect upon the cheese than either the monoglyceride or low HLB emulsifiers. A comparison of the B emulsifier graphs (Figure 2) and the E emulsifier graphs (Figure 3), showed that these two emulsifiers resulted in cheese samples having similar penetrometer readings. One should note that the addition of emulsifiers to milk for Neufchatel cheese preparation resulted in slow and sometimes incomplete cheese drainage.

Overrun of Aerated Neufchatel Cheese

The initial objective of this research was to develop a method whereby Neufchatel cheese could be satisfactorily whipped by aeration. This objective was accomplished by employing the equipment, pre-aeration treatment, and aeration of the cheese as described in the Procedures. Investigations of the overrun obtained by dispersing gas in Neufchatel cheese included different areas of interest, such as variations in:

1. fat content of milk for Neufchatel cheese preparation,
2. heat treatment of the milk,
3. methods of preparing the cheese,
4. the type of gas used for aeration,
5. stabilizers and emulsifiers added to the milk,
6. individual emulsifiers added to the prepared cheese,
7. emulsifier combinations (high and low HLB) added to the cheese, and
8. stabilizer (added to milk) - emulsifier (added to cheese) combinations.

The results concerned with the above mentioned areas of interest and discussion of such will not necessarily be covered in the preceding order.

Influence of different gases upon the percentage overrun of Neufchatel cheese whipped by aeration

Four different gases were used for aerating Neufchatel cheese in this study. The gases and the pressures (psi) used for aerating the cheese are listed in Table 11. The pressure used for injection of each gas into the Neufchatel cheese was the maximum psi that could be delivered with the various carbon dioxide, nitrogen and nitrous oxide gauges available to us. The nitrous oxide gauge was used for injection of the nitrous oxide-carbon dioxide gas mixture (84-16 per cent by weight) into the cheese. The purpose of using maximum gas pressures was to determine the maximum percentage overrun that could be attained in the whipped cheese.

Table 11. Gases used for aerating Neufchatel cheese

Gas	Pressure used for aerating Neufchatel cheese (psi)
Carbon dioxide	87
Nitrous oxide	150
Nitrous oxide-carbon dioxide mixture (84-16 per cent by weight)	150
Nitrogen	300

Figure 4 is a typical graph drawn from the results of this study showing the maximum overrun percentages attained by using the individual gases at the pressures given in Table 11. The Neufchatel cheese used in this particular trial was prepared from milk containing 5.0 per cent fat and pasteurized by the high temperature short time method (20 second hold at 161 F). This batch of cheese had a pH of 4.56 and contained 61.99 per cent moisture.

Data in Figure 4 indicated that nitrogen was ineffective in producing a high overrun in whipped Neufchatel cheese as compared to the overrun attained by using the other three gases. Nitrous oxide and the carbon dioxide-nitrous oxide gas mixture resulted in the highest overrun. The gas mixture, nitrous oxide and nitrogen did not impart off-flavors to the cheese; however, carbon dioxide gas alone resulted in a slightly

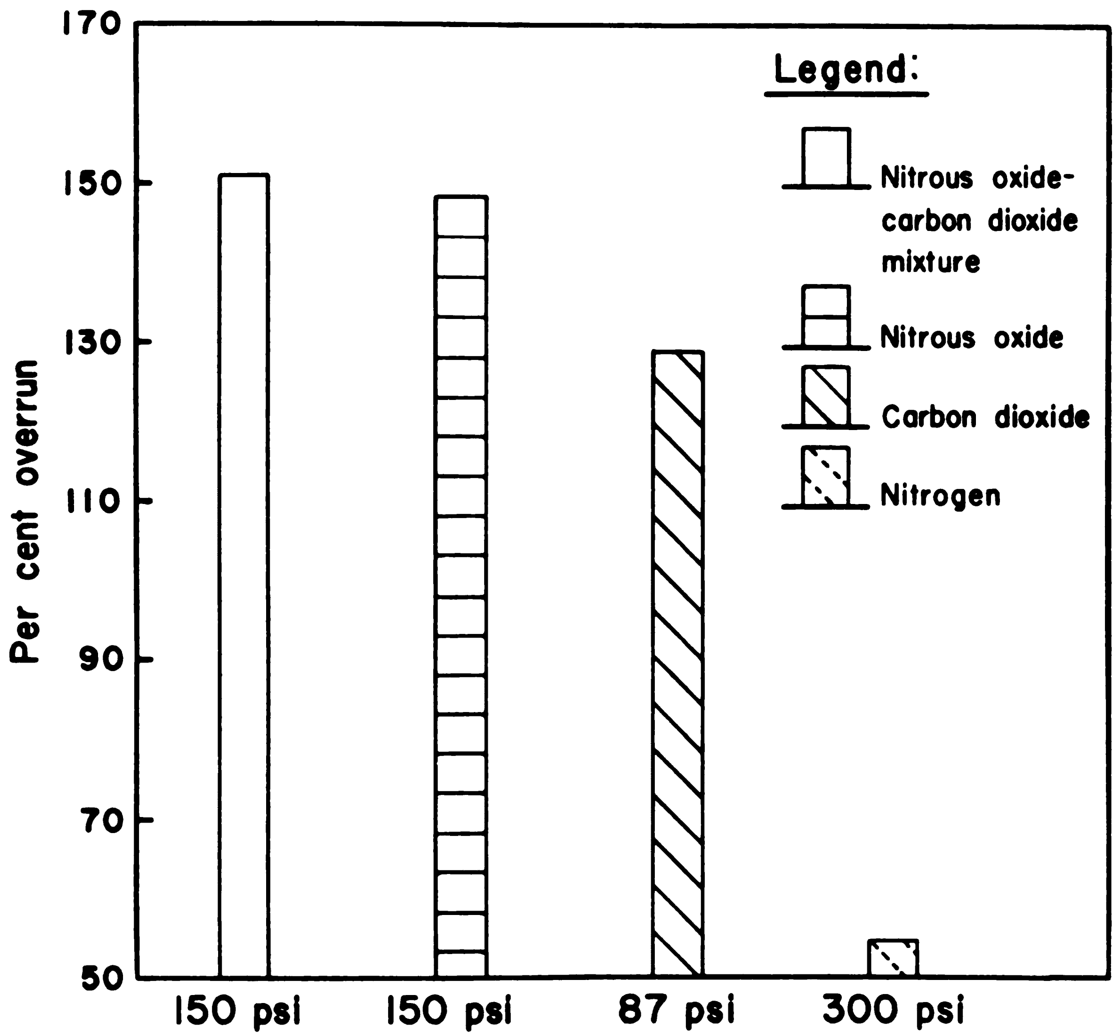

Figure 4. The effect of the gas used for aeration upon percentage overrun of whipped Neufchatel cheese.

sour off-flavor in the whipped cheese. Possibly the carbon dioxide gas combined with moisture in the cheese to form carbonic acid which consequently contributed to the off-flavor. Gas injection and shaking periods as long as 30 minutes, rather than 10 minutes, were used in an attempt to increase the overrun in whipped Neufchatel cheese when using nitrogen gas; however, those efforts failed to increase the overrun percentage appreciably.

The influence of the fat content of milk and the resulting cheese upon the percentage overrun of Neufchatel cheese whipped by aeration

As was shown in Table 2, (p. 29) increasing the fat content of milk for Neufchatel cheese preparation from 4.0 to 5.0 per cent resulted in an increase of 3.5 per cent fat in the finished cheese where the two samples of cheese were drained to within 1.0 per cent moisture content of one another. Two individual gases, carbon dioxide and nitrogen injected at pressures of 87 and 300 psi respectively, were used in an attempt to determine if the per cent fat in Neufchatel cheese had any effect upon the percentage overrun in this cheese whipped by aeration. The results of these findings are shown in Figure 5.

Aerating the cheese with nitrogen gas resulted in lower overruns than aeration with carbon dioxide, nitrous oxide or the nitrous oxide-carbon dioxide gas mixture. According to the data in Figure 5, an increase in the per cent fat of Neufchatel cheese resulted in a higher percentage overrun of the whipped cheese in experiments where either carbon dioxide or nitrogen was used to aerate the product. Increasing the fat content of the milk from 4.0 to 5.0 per cent increased overrun 1.9 times in cheese aerated with nitrogen, and the increase in overrun was 1.4 times in cheese aerated with carbon dioxide. According to the penetrometer readings listed in Table 2, one might assume that the

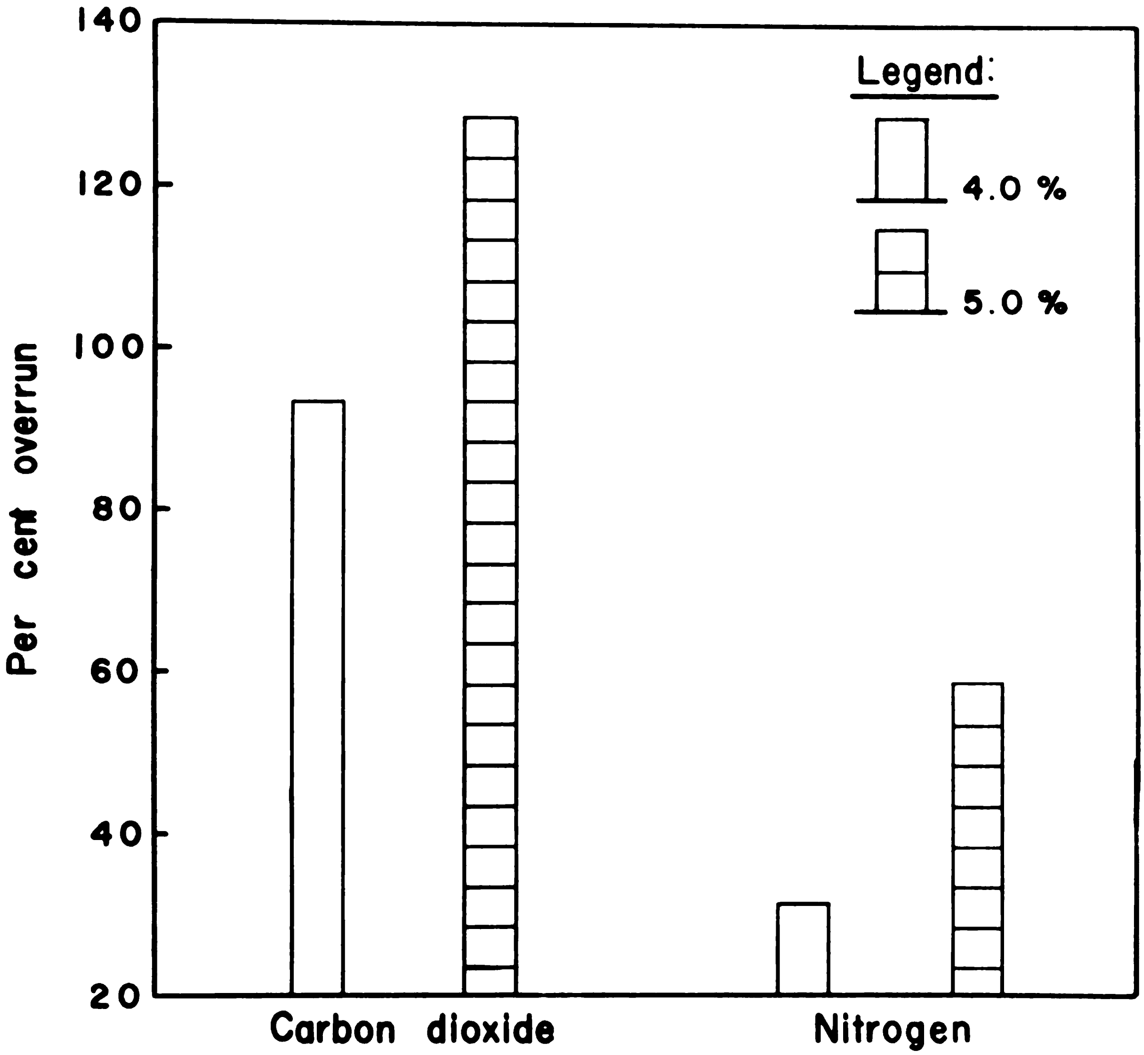

Figure 5. The effect of the fat content of cheese milk upon the per cent overrun attained in whipped Neufchatel cheese.

cheese softness was the sole contributor to the increased overrun when using the higher fat milk; however, other results obtained in the study discount this assumption. For example, direct acidification resulted in softer cheese than when lactic acid fermentation was used for coagulating the milk in the manufacture of Neufchatel cheese; however, the cheese prepared by direct acidification yielded a slightly lower percentage overrun in the whipped cheese as will be discussed later.

The influence of milk pasteurization methods upon overrun of Neufchatel cheese whipped by aeration

Table 3 (p. 31) contained information concerning the two batch milk pasteurization methods and the high temperature short time method of pasteurization used in this study. Acidity of the coagulum at beginning of drainage, cheese pH and the moisture content of the cheese samples were also given in Table 3. The percentage overrun attained from whipping each of the three samples of cheese by aeration with nitrous oxide gas (150 psi) is shown in Figure 6.

According to Figure 6, the Neufchatel cheese made from milk batch pasteurized by heating to 145 F and holding 30 minutes resulted in the highest overrun (159 per cent) of the three different pasteurization methods employed in this study. The higher temperature batch pasteurization method (175 F 30 minutes) of milk resulted in cheese that yielded the lowest percentage overrun. It was interesting to note that by decreasing the pasteurization temperature by 30 F, and using the same holding time of 30 minutes, the percentage overrun attained in the whipped Neufchatel cheese was increased over 5 times (Figure 6). The cheese made from milk pasteurized by heating to 175 F was coarser in texture and appeared to have a tough body as compared to the cheese samples made from milk pasteurized by the other two methods.

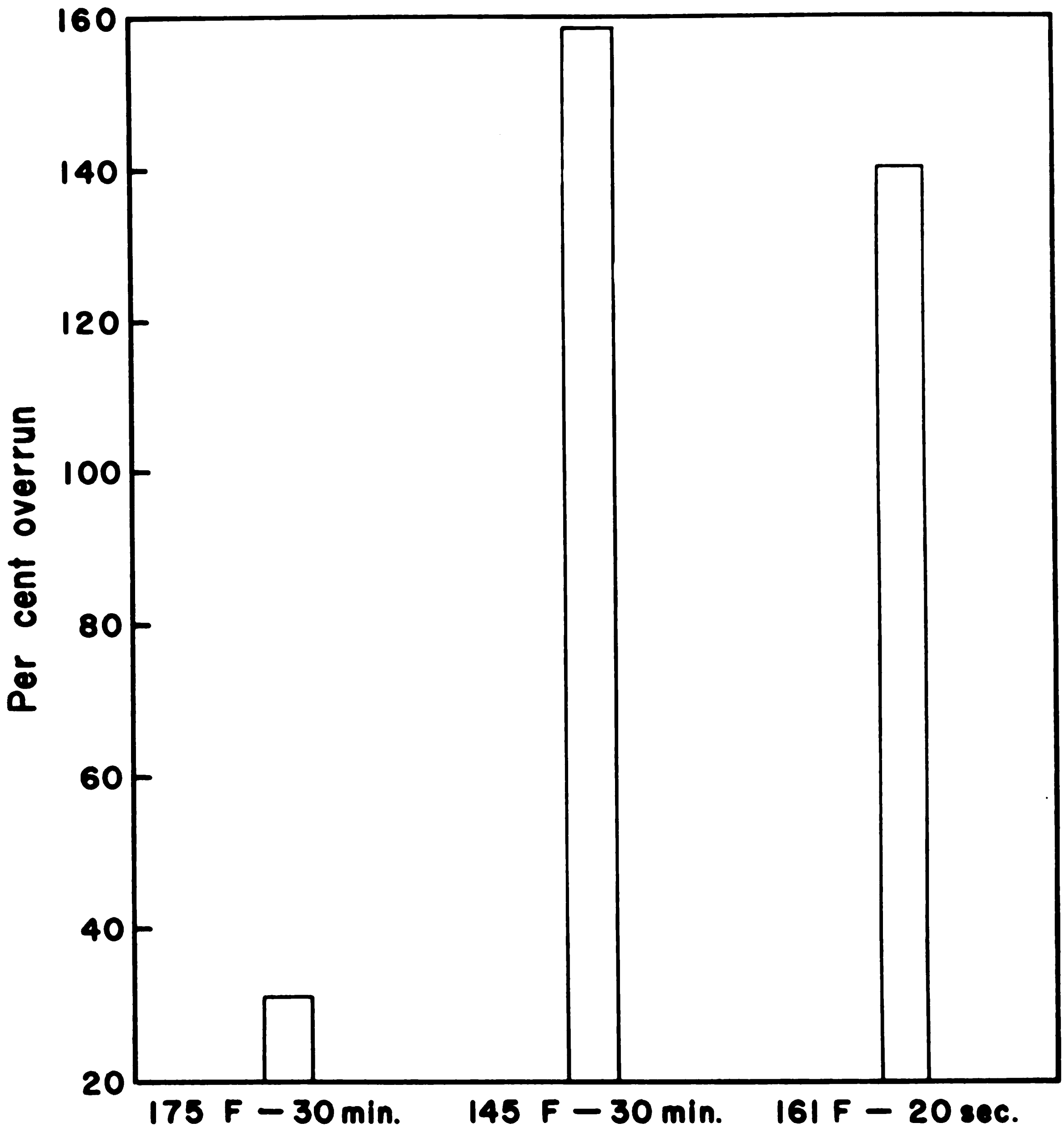

Figure 6. The effect of milk pasteurization methods upon percentage overrun of whipped Neufchatel cheese.

These results indicated that the effects of pasteurization are the result of time/temperature relationships; possibly at some critically high temperature denaturation of whey proteins and/or interaction of caseins and denatured whey proteins caused a weakening of the film adsorbed at the gas interface. Destabilization of the milk proteins at the higher pasteurization temperature was probably responsible for the tougher cheese that yielded a lower overrun in the whipped product.

The overrun attained in whipped Neufchatel cheese prepared from milk pasteurized by the high temperature short time (HTST) method (161 F 20 second hold) further indicated the significant time/temperature effects of pasteurization. The cheese made from milk pasteurized by this method yielded a whipped product with an overrun of 140 per cent (Figure 6). As shown in Figure 6, this overrun was over 4.5 times higher than the 31 per cent overrun attained in whipped cheese made from milk that had been heated to 175 F. The HTST pasteurization method has an advantage over the batch milk pasteurization methods in commercial practice because of the increased volume of milk that can be processed per day in preparation for cheese manufacture. The results in Figure 6 indicated that pasteurization of milk by heating to either 161 F and holding 20 seconds or to 145 F and holding 30 minutes were satisfactory for attaining high overruns in Neufchatel cheese whipped by aeration.

The influence of direct acidification versus lactic acid fermentation of milk upon the percentage overrun of whipped Neufchatel cheese

Table 4 (p. 32) contains information pertaining to acidity of the coagulum at beginning of drainage, the pH and moisture content of two lots of Neufchatel cheese. One sample was prepared by lactic acid fermentation and the other by direct acidification of the milk at 40 F.

Lactic acid (50 per cent) was used in the direct acidification method of coagulating the whole milk. As shown in Table 4, the cheese prepared by direct acidification contained 0.80 per cent more moisture and was slightly softer (penetrometer reading) than the cheese prepared by lactic acid fermentation. Each of these two samples of cheese was aerated with nitrous oxide gas (150 psi) for 10 minutes and the per cent overrun was calculated. The cheese prepared by direct acidification resulted in a whipped cheese having an overrun of 134 per cent; cheese prepared by the lactic fermentation method yielded an overrun of 135 per cent. The penetrometer readings (219 and 214 respectively) also showed almost identical values for the cheese prepared by these methods. Apparently, neither method of reducing pH in the Neufchatel cheese had any significant affect in promoting dispersion of gas in the cheese.

The influence of stabilizers added to milk upon overrun of the resulting Neufchatel cheese whipped by aeration

All milk samples that involved the addition of stabilizers were pasteurized by the batch method (145 F 30 minutes). Data concerning stabilizers added to milk and the prepared cheese are recorded in Table 5 (p. 34). Cheese samples containing locust bean gum, glucosyl glucan, sodium alginate and sodium caseinate were aerated with nitrous oxide (150 psi). Figures 7 and 8 showed the effect of different stabilizers added at various levels to milk upon the percentage overrun obtained in the resulting whipped Neufchatel cheese. Locust bean gum and glucosyl glucan overrun data are reported in Figure 7 and the same data concerned with the addition of sodium alginate and sodium caseinate are shown in Figure 8.

Locust bean gum and glycosyl glucan added individually to the milk at levels of 0.1, 0.2 and 0.3 per cent produced cheese that resulted

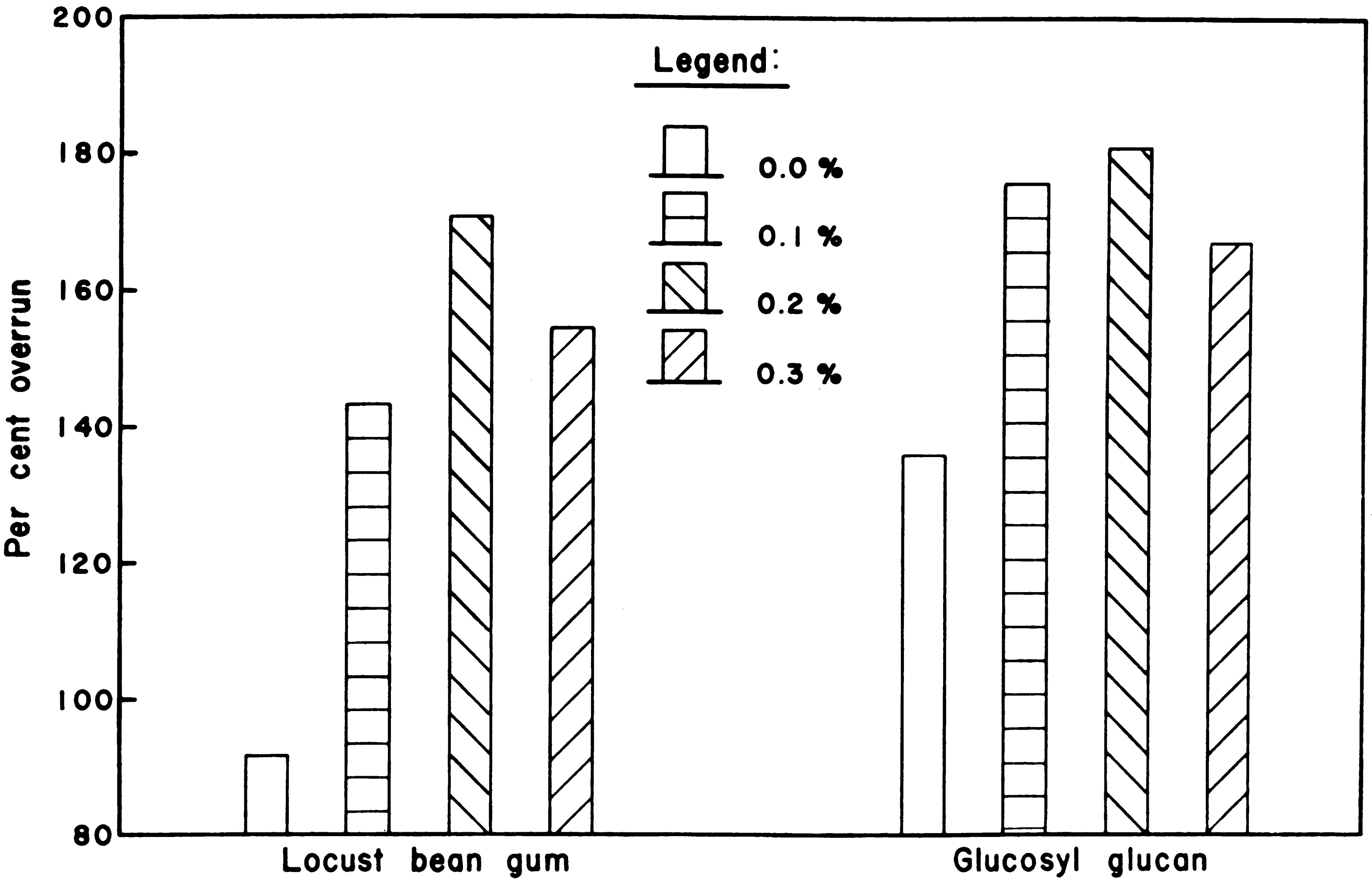

Figure 7. The effect of locust bean gum and glucosyl glucan added to milk upon the percentage overrun attained in whipped Neufchatel cheese.

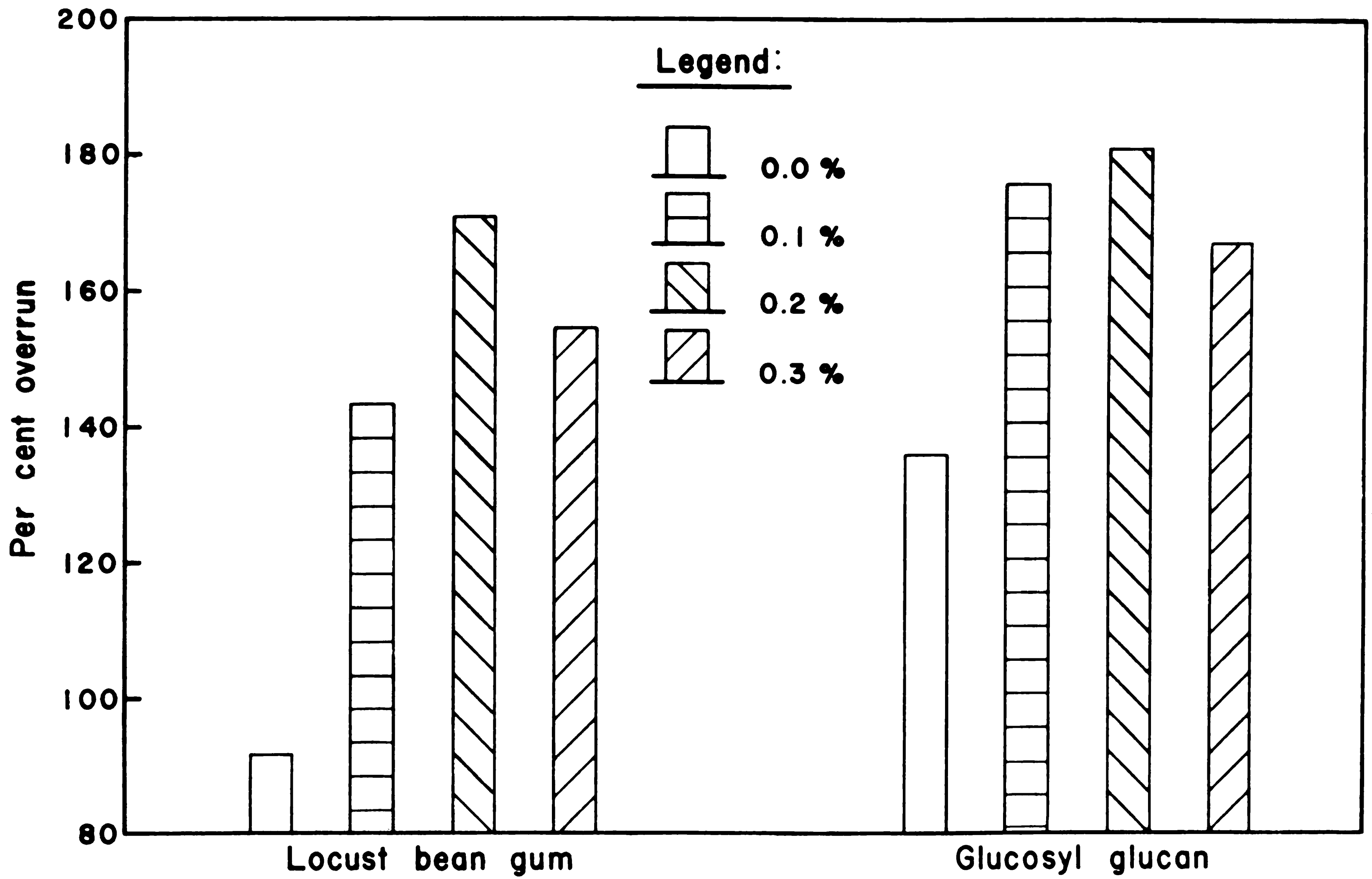

Figure 7. The effect of locust bean gum and glucosyl glucan added to milk upon the percentage overrun attained in whipped Neufchatel cheese.

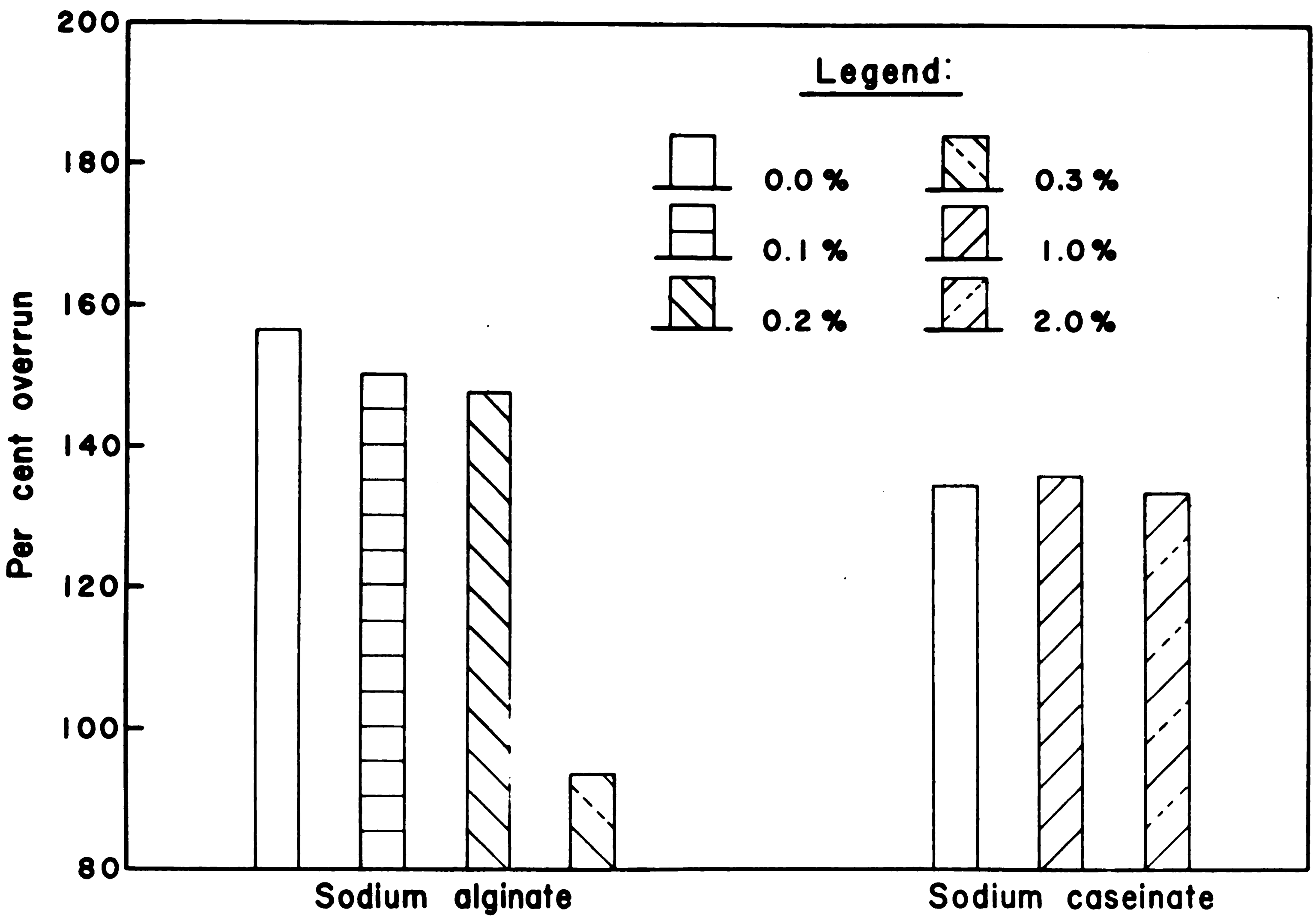

Figure 8. The effect of sodium alginate and sodium caseinate added to milk upon the percentage overrun attained in whipped Neufchatel cheese.

in similar overrun trends after the samples in each trial were whipped by the aeration method (Figure 7). Results of the two trials indicated that each stabilizer at all three levels of addition contributed to an increase in percentage overrun as compared to the whipped control cheese. The optimum concentration of locust bean gum and glucosyl glucan for producing maximum overrun in whipped Neufchatel cheese appeared to be 0.2 per cent. Addition of 0.3 per cent of either of the two stabilizers resulted in decreased overrun. Results in Figure 7 showed that the addition of 0.3 per cent glucosyl glucan produced a lower overrun percentage in the whipped cheese than the addition of 0.1 per cent of this stabilizer. In contrast to this, the cheese prepared from milk containing 0.3 per cent locust bean gum and aerated with the nitrous oxide gas contained an 11 per cent higher overrun than whipped cheese made from milk containing this stabilizer at the 0.1 per cent level. The addition of locust bean gum and glucosyl glucan to milk for Neufchatel cheese that was whipped by aeration produced substantial increases in overrun as compared to the whipped control cheese. The optimum concentration of both locust bean gum and glucosyl glucan to the milk appeared to be 0.1 per cent in order to avoid slow curd drainage, grainy texture and soupy appearance of the prepared cheese, and to attain a suitable overrun increase in Neufchatel cheese whipped by the aeration method.

Results in Figure 8 revealed that the addition of sodium alginate to milk resulted in decreased overrun in the experimental samples of whipped cheese. Also, as the sodium alginate was increased in increments of 0.1 per cent, the overrun in the whipped cheese was decreased. This decrease in the percentage overrun was especially noticeable in the whipped cheese made from milk that contained 0.3 per cent added sodium alginate. A comparison of results in Figures 1 and 8 showed that sodium alginate softened the body and texture of Neufchatel cheese, but decreased the overrun of the whipped product. Therefore, based upon overrun results from this study, the addition of this stabilizer to milk for whipped Neufchatel cheese could not be recommended. Sodium caseinate added to milk at levels of 1.0 and 2.0 per cent did not appear to influence the per cent overrun in the whipped cheese as was shown in Figure 8.

The influence of added monoglycerides upon the overrun of whipped Neufchatel cheese

Three monoglyceride emulsifiers (A, B and C; Table 1, p. 22) having a minimum monoester content of 90 per cent were added by two separate methods in order to study their effect upon the percentage overrun in Neufchatel cheese whipped by aeration. One method consisted of adding the emulsifiers (a 50-50 mixture by weight of the particular emulsifier and 1,2-propanediol) to the milk during the pasteurization process. The other method of emulsifier addition consisted of adding the monoglyceride-propanediol mixture to the cheese during the mixing process as described in the Procedures. Table 8 (p. 41) contains information concerning the coagulum acidity at the beginning of drainage, moisture content and pH of the cheese samples in which the monoglyceride emulsifiers had been added to the milk. Table 12 contains the same information for cheese samples in which the emulsifiers had been added to the cheese.

The effects of the three monoglyceride emulsifiers (A, B and C) added at different levels, to either the milk during pasteurization or to cheese during the mixing process, upon the per cent overrun of the

Table 12. The moisture content and pH of Neufchatel cheese to which monoglyceride emulsifiers were added during the mixing process for overrun studies

Cheese lot (No.)	Monoglyceride added	Acidity of coagulum at beginning of drainage (%)	pH and moisture content of cheese	
			pH	Moisture (%)
I	A	0.78	4.56	63.44
II	B	0.72	4.62	58.69
III	C	0.72	4.61	59.85

whipped cheese are shown in Figures 9, 10 and 11, respectively. The overrun produced in each sample of cheese was accomplished by aerating the product with carbon dioxide gas (87 psi). Aeration with this gas did not result in extremely high overrun, as shown in Figures 9, 10 and 11; however, overrun differences were noted with the addition of different monoglycerides at levels of 0.1, 0.2 and 0.3 per cent and compared to the overrun of the whipped control sample of each trial. The three control samples involving trials in which monoglycerides were added to the cheese differed somewhat in overrun, which was to be expected since the three controls were prepared from different batches of milk and contained different amounts of moisture. Therefore, a more realistic evaluation of the effect of each monoglyceride upon overrun is made by comparing the whipped control cheese to the three experimental batches in each trial.

Previous data in this manuscript have shown that the addition of monoglyceride emulsifiers to milk for Neufchatel cheese preparation

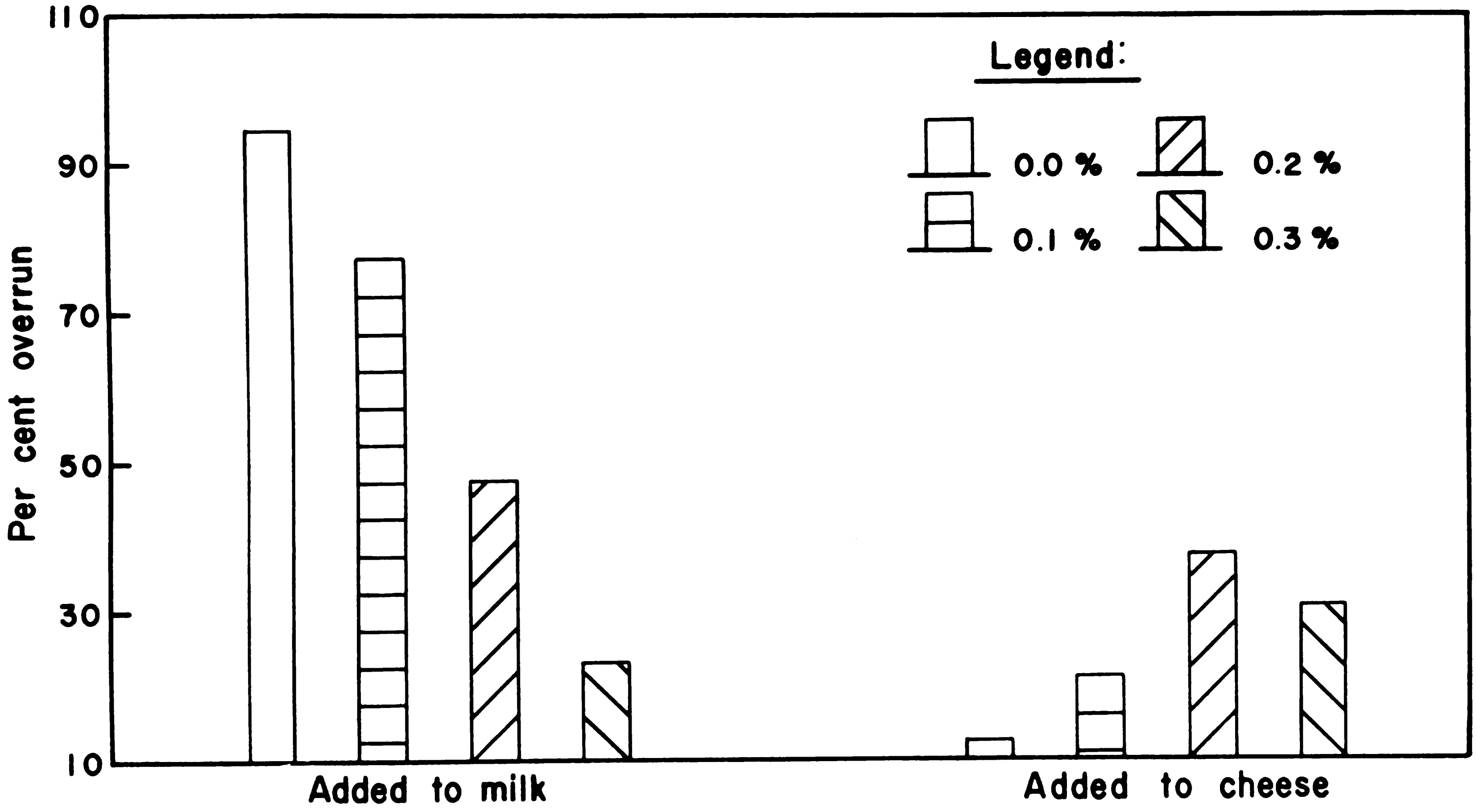

Figure 9. The effect of monoglyceride A upon per cent overrun in whipped Neufchatel cheese.

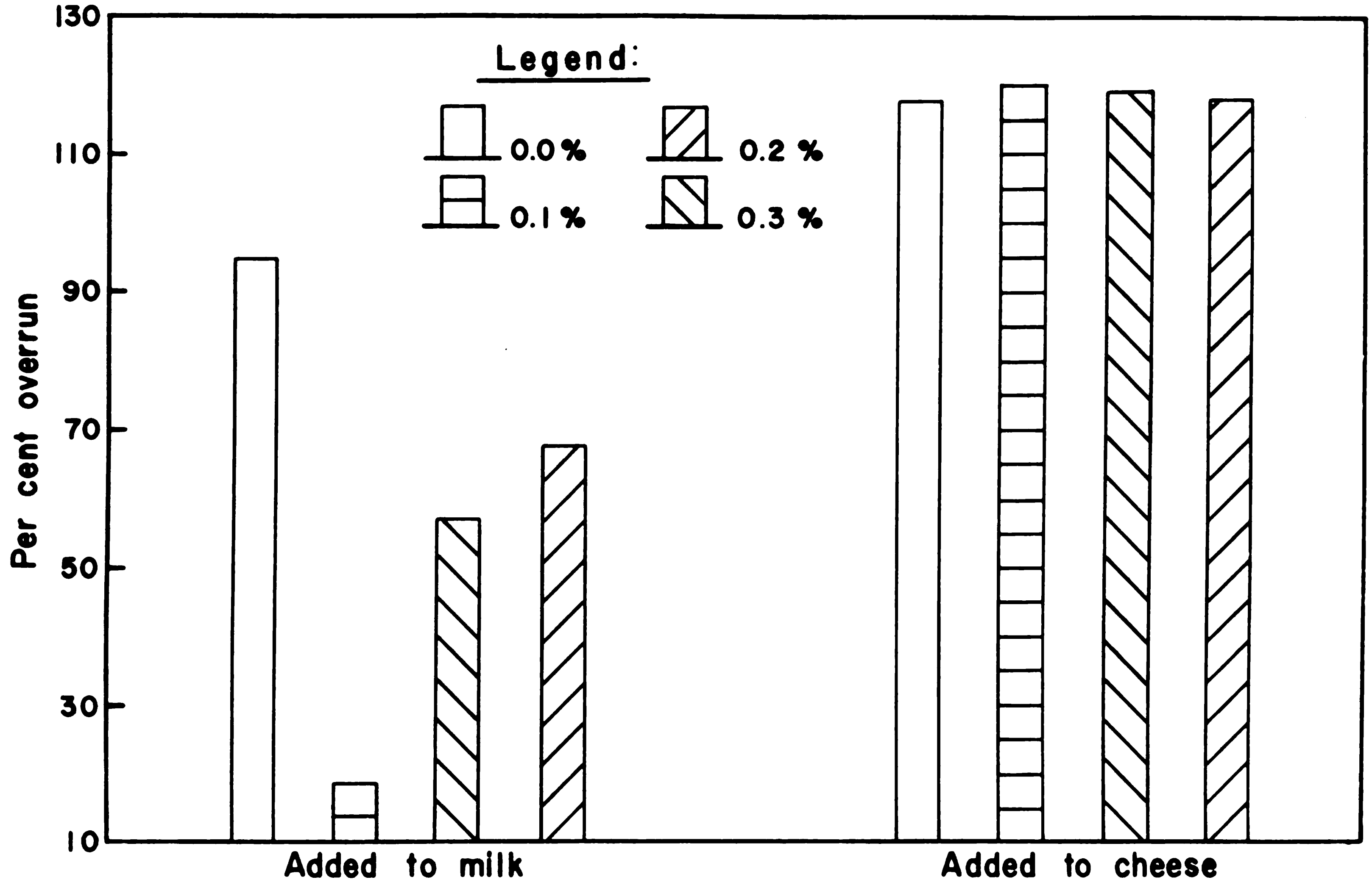

Figure 10. The effect of monoglyceride B upon per cent overrun in whipped Neufchatel cheese.

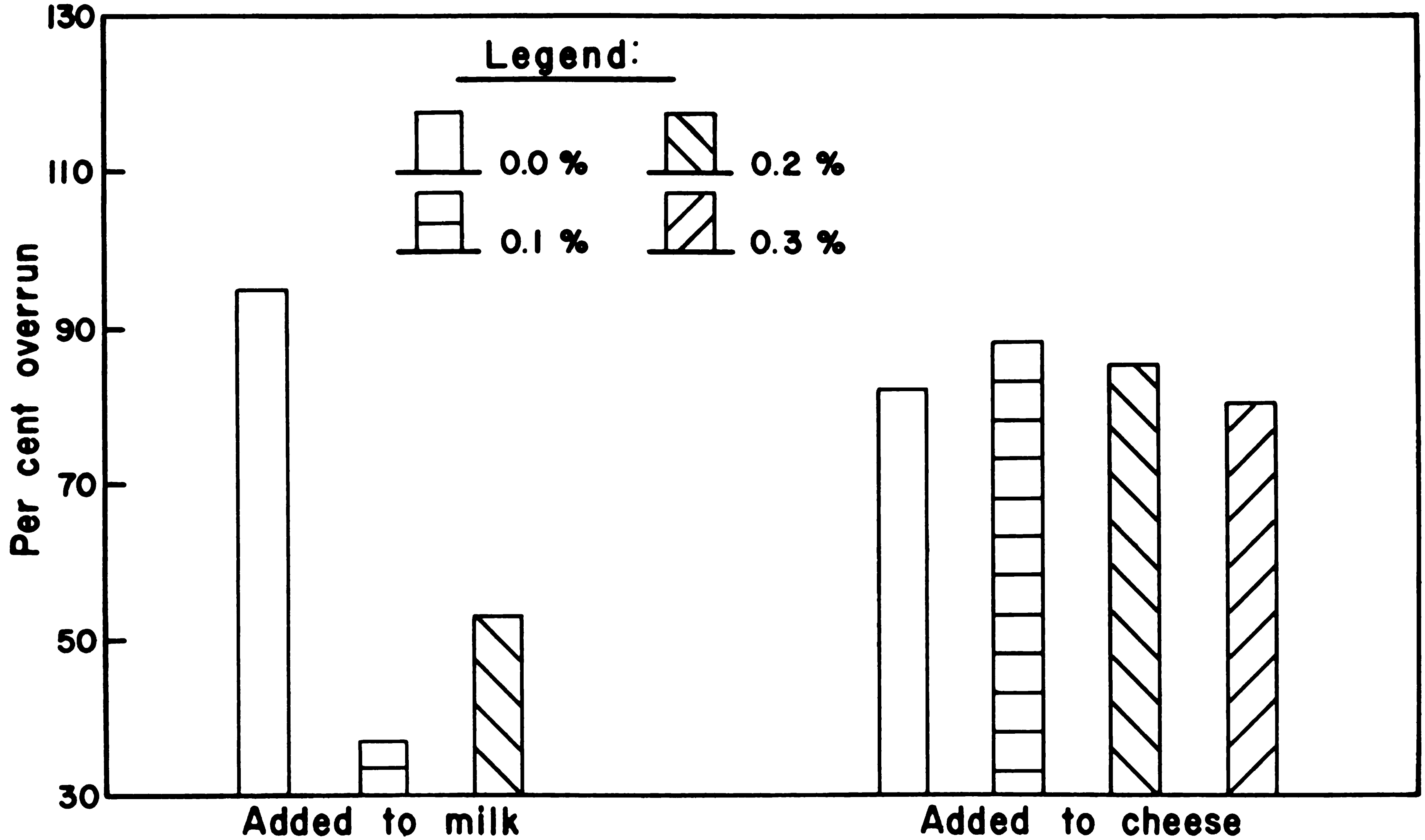

Figure 11. The effect of monoglyceride C upon per cent overrun in whipped Neufchatel cheese.

resulted in a softer cheese which had a smoother body and texture than the corresponding control cheese samples. However, overrun data shown in Figures 9-11 indicated that monoglycerides added to milk decreased the overrun in whipped Neufchatel cheese. As the concentration of the A emulsifier (Table 1, p. 22) was increased in the milk the per cent overrun of the whipped cheese decreased (Figure 9). The A emulsifier was a highly saturated monoglyceride having an iodine value of 3. The B and C monoglycerides had iodine values of 40 and 56, respectively. They reduced the overrun in the cheese to a greater extent when added to the milk at the 0.1 per cent level than when added at levels of 0.2 and 0.3 per cent. For example, the addition of B monoglyceride to milk at concentrations of 0.1, 0.2 and 0.3 per cent resulted in whipped cheese that contained 19, 57 and 68 per cent overrun respectively as compared to an overrun of 95 per cent in the control sample (Figure 10). The cheese made from milk containing 0.3 per cent C monoglyceride was not considered suitable for whipping because of its extreme soupy appearance.

The effects of monoglyceride emulsifiers, added at levels of 0.1, 0.2 and 0.3 per cent to the cheese during the mixing process, upon the overrun in whipped Neufchatel cheese were shown in Figures 9, 10 and 11. Data collected in this study indicated that the B and C monoglycerides (Figures 10 and 11) had a negligible effect upon overrun in the experimental whipped cheese samples as compared to their corresponding controls. The addition to cheese of the highly saturated A monoglyceride at levels ranging from 0.1 to 0.3 per cent appeared to increase the per cent overrun of the whipped product as was shown in Figure 9. The optimum amount of this monoglyceride to add to the cheese in order to reach the maximum overrun level was found to be 0.2

per cent. The whipped cheese that contained 0.2 per cent of the A monoglyceride had an overrun of 38 per cent; whereas, the whipped control sample in this trial contained only 12 per cent overrun.

The data shown in Figures 9-11 indicated that the A emulsifier, added to cheese during the mixing process, was the only monoglyceride that resulted in an increase in per cent overrun as compared to the corresponding whipped control cheese sample. Some of the advantages of adding monoglyceride emulsifiers to the cheese during the mixing process rather than to milk during pasteurization included:

1. less time required in the milk pasteurization process,
2. less time required to drain the Neufchatel cheese to the legal moisture level (not more than 65.0 per cent moisture),
3. better control over individual experiments as the moisture content of the control and experimental samples of a given trial was identical, and
4. a higher per cent overrun resulted in the whipped cheese.

The influence of added high and low HLB emulsifiers upon overrun of whipped Neufchatel cheese

A comparison of the effect of a low HLB emulsifier (E) versus a high HLB emulsifier (G; Table 1, p. 22) upon the overrun in whipped Neufchatel cheese was made after adding the particular emulsifier to the milk and to the cheese in separate trials. The E emulsifier had an HLB rating of 2.8 and the rating of emulsifier G was 10.9. The coagulum acidity at beginning of drainage, moisture content and pH of cheese samples in which the two emulsifiers had been added to the milk are given in Table 10 (p. 45), and the same information concerning cheese samples to which each of the two emulsifiers was added is shown in Table 13. Carbon dioxide gas (87 psi) was dispersed into each cheese sample in these overrun studies. The effects of the E emulsifier added at concentrations of 0.1, 0.2 and 0.3 per cent to milk and to cheese were presented in Figure 12 and the overrun information that involved addition of the G emulsifier at the same levels was shown in Figure 13.

Table 13. The moisture content and pH of Neufchatel cheese to which E and G emulsifiers were added during the mixing process for overrun studies

Cheese lot (No.)	Emulsifier added	Acidity of coagulum at beginning of drainage (%)	pH and moisture content of cheese	
			pH	Moisture (%)
I	E	0.81	4.48	63.92
II	G	0.74	4.61	60.37

Data in Figures 12 and 13 indicated that both the high and low HLB emulsifiers (E and G; Table 1, p. 22) added to milk decreased the overrun in whipped Neufchatel cheese as compared to the control samples in each trial. Addition of the low HLB emulsifier (E) to cheese during the mixing process at concentrations of 0.1, 0.2 and 0.3 per cent appeared to increase the percentage overrun slightly in the aerated cheese. As shown in Figure 12, the E emulsifier proved to be the most effective when added to the cheese at a level of 0.1 per cent. Addition of the G emulsifier to cheese at concentrations above 0.1 per cent increased the percentage overrun of the whipped cheese (Figure 13). This high HLB emulsifier produced the greatest amount of overrun when added to the cheese at the rate of 0.3 per cent.

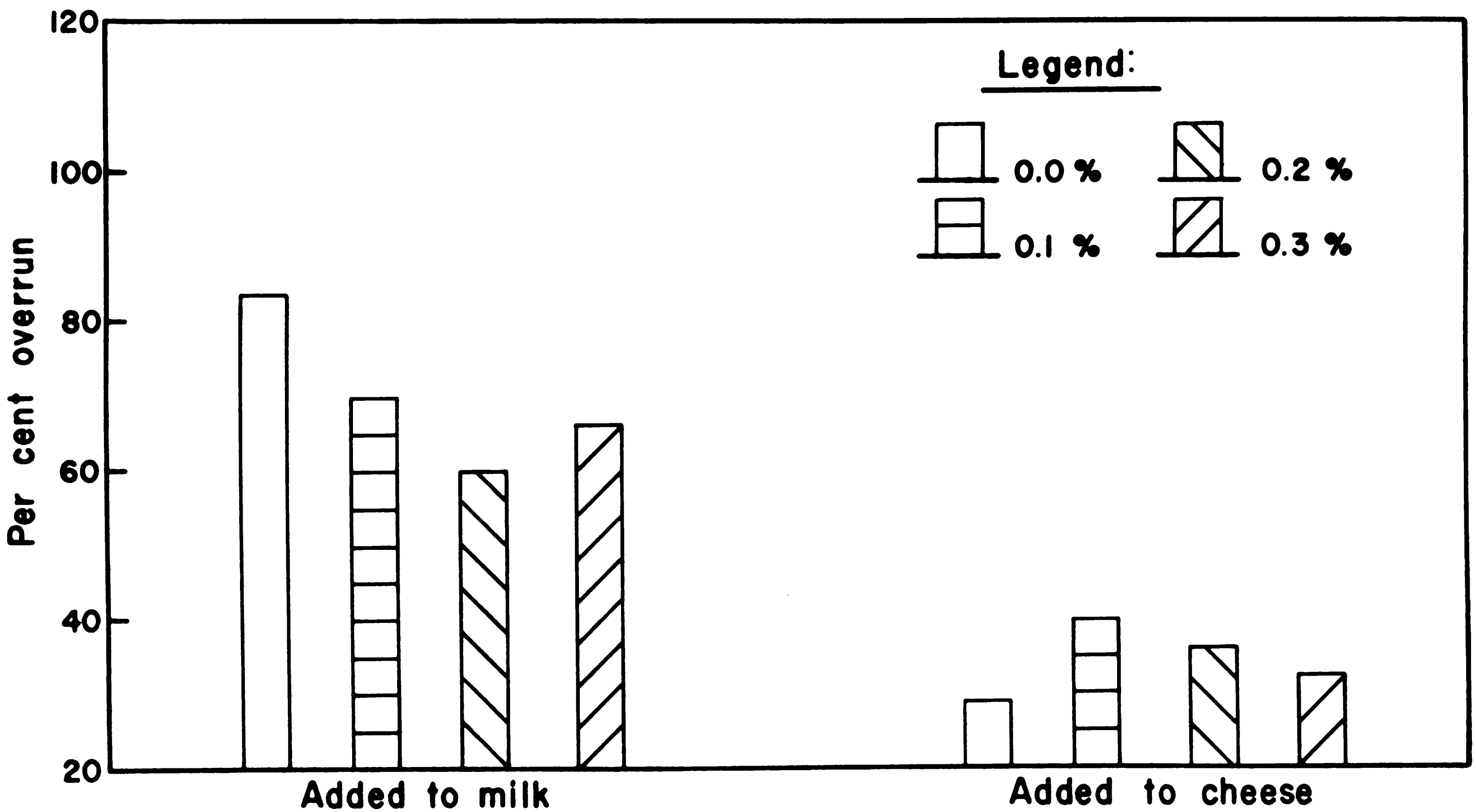

Figure 12. The effect of emulsifier E upon per cent overrun in whipped Neufchatel cheese.

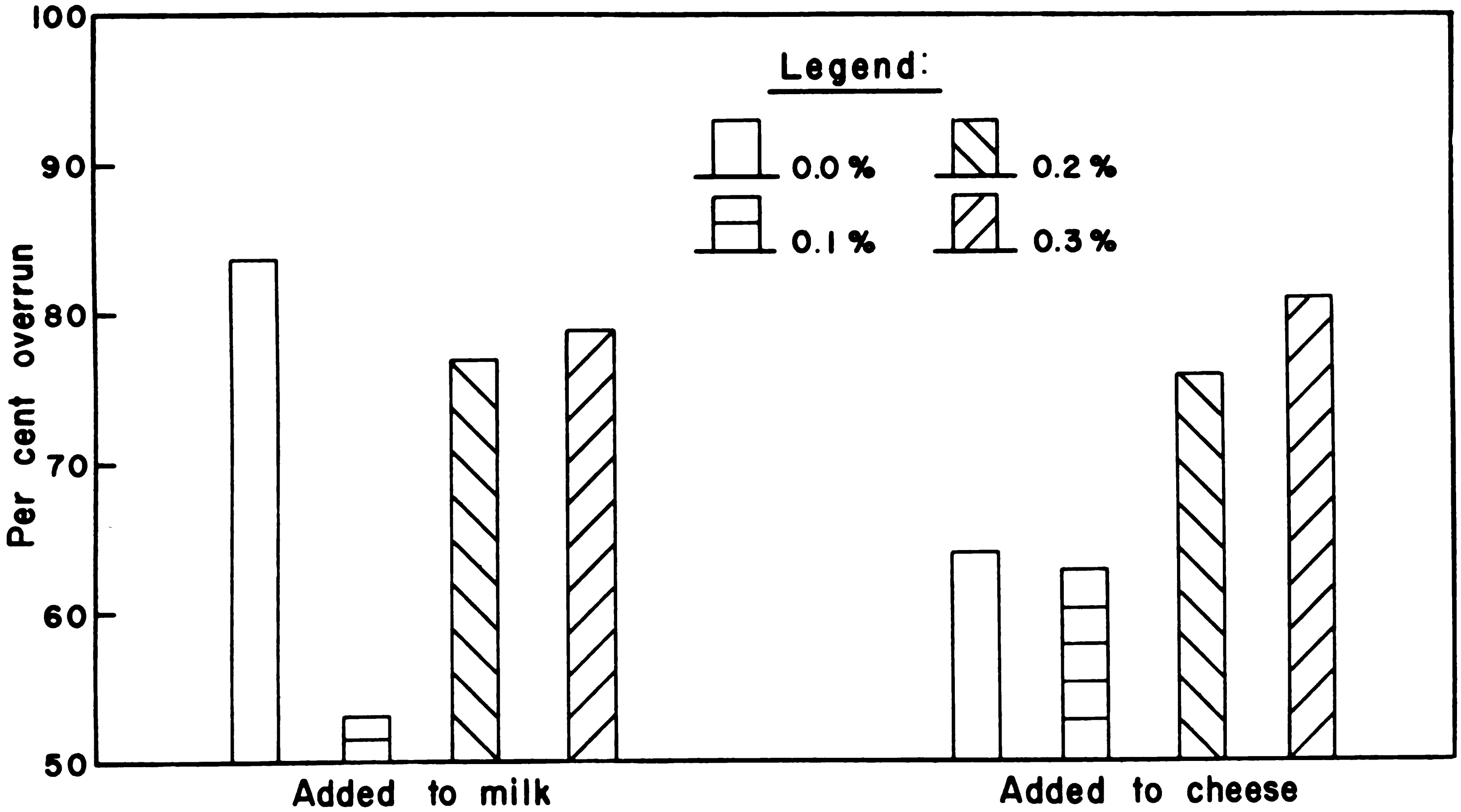

Figure 13. The effect of emulsifier G upon per cent overrun in whipped Neufchatel cheese.

Based upon overrun data recorded in Figures 9-13, the results indicated that addition of emulsifiers to milk was ineffective from the standpoint of increasing the overrun in Neufchatel cheese whipped by the aeration method. Addition of the A and G emulsifiers to cheese during the mixing process were found to be the most effective emulsifiers used in this study to give an increased overrun in the whipped product. The A emulsifier was the most effective when added at the 0.2 per cent level; whereas, G added at the rate of 0.3 per cent produced the highest percentage overrun.

Another overrun investigation involved the addition of high and low HLB emulsifier combinations to the cheese. The emulsifier combinations decreased the overrun tremendously as compared to the overrun in the whipped control and experimental cheese samples containing the individual emulsifiers. As previously noted, the glucosyl glucan stabilizer appeared to increase the overrun in aerated Neufchatel cheese as did the addition of high HLB emulsifiers to the cheese. Therefore, glucosyl glucan (0.2 per cent) was added to whole milk during the pasteurization process and high and low HLB emulsifiers (0.25 per cent) were added individually to the resulting cheese in order to study the effect of emulsifier-stabilizer combinations upon overrun in the whipped cheese. The stabilizer-emulsifier combinations failed to increase the overrun above levels reached when the stabilizers and emulsifiers were added individually.

The influence of emulsifier H added to cheese upon overrun in whipped Neufchatel cheese

Sodium stearoyl 2-lactylate (H; Table 1, p. 22), in addition to other food uses, has been added to improve aeration and stability of whipped toppings. This emulsifier was added to Neufchatel cheese

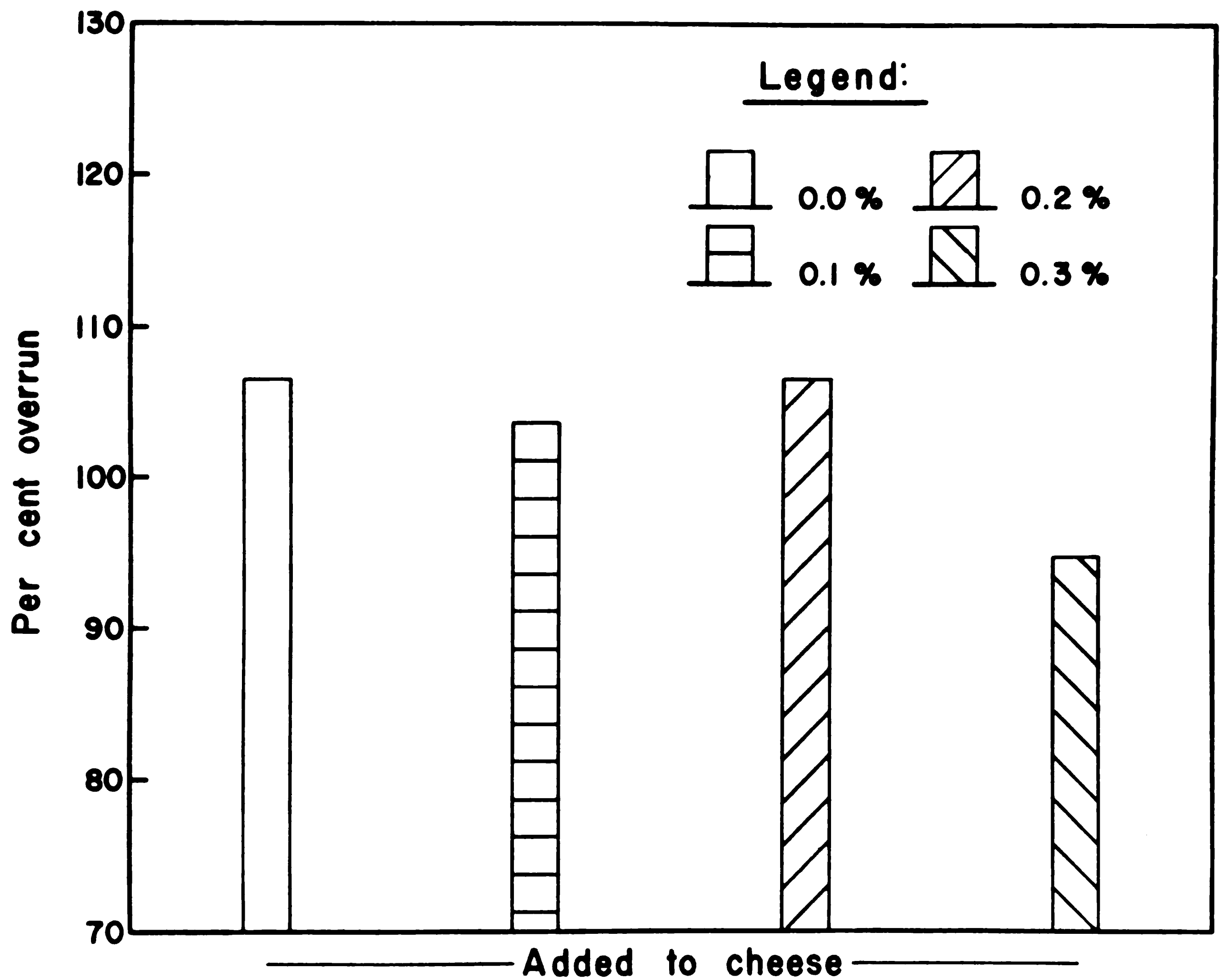

Figure 14. The effect of emulsifier H upon per cent overrun in whipped Neufchatel cheese.

during the mixing process at concentrations of 0.1, 0.2 and 0.3 per cent in order to study its effect upon overrun in the whipped cheese. The cheese used in this trial had a pH of 4.52, contained 60.89 per cent moisture and was aerated with carbon dioxide gas (87 psi). The effects of the H emulsifier were shown in Figure 14.

The data (Figure 14) indicated that sodium stearoyl 2-lactylate did not appreciably lower the overrun in whipped Neufchatel cheese. Data recorded in Figure 14 showed that 0.2 per cent was the optimum amount of H to add to the cheese in order to attain maximum overrun percentages with this emulsifier. From the standpoint of their effect upon overrun in Neufchatel cheese whipped by the aeration method, the results indicated that the A monoglyceride (0.2 per cent), emulsifiers G (0.3 per cent) and H (0.2 per cent) added to the cheese were the most desirable emulsifiers used in this study.

Shrinkage of Whipped Neufchatel Cheese

Numbered containers of whipped Neufchatel cheese were removed from the 40 F refrigerator after four days' storage, and shrinkage of the individual samples was determined by noting the ml petroleum ether required to fill the void formed as a result of shrinkage. Investigations included the effect of different gases, stabilizers added to each milk and cheese, lactic acid fermentation versus direct acidification in cheese manufacture and the fat content of milk for cheese preparation upon shrinkage of whipped Neufchatel cheese. In order to more accurately evaluate each of the variables upon shrinkage, it was necessary in some instances to select samples from different trials which had comparable overruns.

<u>The influence of the percentage of fat upon the shrinkage of whipped Neufchatel cheese</u>

The whipped cheese samples shown in Table 14 were aerated with nitrous oxide gas (150 psi).

Table 14. The influence of the percentage of fat on the shrinkage of whipped Neufchatel cheese

Whipped Cheese	Fat in milk	Shrinkage of whipped Neufchatel cheese of different fat contents and similar overruns		
		Fat content and overrun of whipped Neufchatel cheese		Shrinkage*
(No.)	(%)	Fat (%)	Overrun (%)	(ml/petroleum ether)
I	4.0	20.1	133	86
II	5.0	23.6	134	84

*Shrinkage was determined by restoring the volume of original whipped Neufchatel cheese after four days' storage at 40 F with petroleum ether.

The Neufchatel cheese made from milk containing 5.0 per cent milk fat contained 1.0 per cent higher overrun and the shrinkage was only 2 ml less than the whipped cheese prepared from 4.0 per cent milk (Table 14). Those results suggested that an increase in the fat content of Neufchatel cheese had virtually no effect upon shrinkage of the whipped product.

<u>Direct acidification versus lactic acid fermentation for milk coagulation during Neufchatel cheese preparation</u>

The information in Table 15 pertained to shrinkage differences which resulted from the use of the two different cheese preparation methods used in this study. Each of the two cheese samples listed in the above mentioned table was aerated with nitrous oxide (150 psi). As was shown in Table 15, shrinkage occurred to a greater extent in whipped Neufchatel cheese where direct acidification, rather than lactic acid fermentation, was used in preparation of the cheese. The overrun of the two whipped cheese samples was practically the same; however, the difference in shrinkage expressed as ml petroleum ether was 11. A previous

Table 15. The influence of methods of acidification on the shrinkage of whipped Neufchatel cheese

Whipped Cheese (No.)	Method of cheese preparation	Shrinkage of whipped Neufchatel cheese prepared by different methods, but similar overruns	
		Overrun (%)	Shrinkage (ml/petroleum ether)
I	Direct acidification*	134	96
II	Lactic acid fermentation	135	85

*Food grade lactic acid (50 per cent) added to acidify the whole milk.

discussion in this thesis has noted that Neufchatel cheese prepared by the lactic acid fermentation method possessed a more pleasing flavor and aroma than cheese prepared by the direct acidification method. Hence, in this study, there were two obvious advantages to the lactic acid fermentation method of Neufchatel cheese preparation. One advantage was the more desirable flavor and aroma of the cheese and the other was less shrinkage of the whipped product.

Effect of different gases used in aeration upon shrinkage of whipped Neufchatel cheese

The four gases and injection pressure of each used to aerate Neufchatel cheese in this portion of the research are given in Table 16. Whipped cheese samples containing similar overruns were chosen from separate trials so that a more accurate comparison could be made of the effect of carbon dioxide, nitrogen, nitrous oxide and the nitrous oxide-carbon dioxide mixture (84-16 per cent by weight) upon shrinkage of the whipped Neufchatel cheese. The apparent effects that the four gases had upon shrinkage of whipped Neufchatel cheese are shown in trials 1 and 2 of Table 16.

Table 16. The influence of different gases under pressure aeration on shrinkage of whipped Neufchatel cheese

Whipped Cheese Trial	Gas used in studies		Shrinkage of whipped Neufchatel cheese aerated with different gases, but containing similar overruns	
	Name	Pressure	Overrun	Shrinkage petroleum ether
(No.)		(psi)	(%)	(mls)
I	Nitrogen	300	31	12
	Nitrous oxide	150	30	24
	Carbon dioxide	87	30	27
II	Nitrous oxide	150	158	89
	Nitrous oxide-carbon dioxide mixture	150	152	103

Data in Table 16 indicate that aeration with nitrogen resulted in less shrinkage of the whipped cheese than the other three gases used in this study. Nitrous oxide appeared to result in less shrinkage of the cheese than either carbon dioxide or the nitrous oxide-carbon dioxide gas mixture. As noted previously in this manuscript, aerating the Neufchatel cheese with nitrogen gas resulted in low overrun of the whipped product. The lack of high overrun that resulted from cheese aerated with nitrogen made it impossible to compare the effect of this gas with the other three gases upon shrinkage in high overrun studies.

The influence of different stabilizers added to milk upon shrinkage of whipped Neufchatel cheese

Sodium caseinate, sodium alginate, locust bean gum and glucosyl glucan were the four stabilizers added to milk for cheese preparation and subsequent whipping in this study. Four different trials concerned with the effect of stabilizers added to milk at various levels upon shrinkage of the whipped cheese are given in Table 17.

Table 17. The influence of different stabilizers upon the shrinkage of whipped Neufchatel cheese

Whipped Cheese Trial	Stabilizer added	Shrinkage of whipped Neufchatel cheese containing different stabilizers, but similar overruns	
		Overrun	Shrinkage (ml/petroleum ether)
(No.)	(%)*	(%)	
I	Sodium caseinate-		
	0.0	135	85
	1.0	136	97
	2.0	135	103
II	Sodium alginate-		
	0.0	92	69
	0.3	94	81

Table 17 (Cont'd.)

Whipped Cheese Trial	Stabilizer added	Shrinkage of whipped Neufchatel cheese containing different stabilizers, but similar overruns	
		Overrun	Shrinkage (ml/petroleum ether)
(No.)	(%)*	(%)	
III	Locust bean gum-		
	0.0	149	107
	0.3	149	96
IV	Locust bean gum-		
	0.2	171	112
	Glucosyl glucan-		
	0.2	181	112

*Percentage stabilizer based upon pounds of milk in the particular batch.

The whipped cheese samples listed in trials 1-4 of Table 17 were aerated with nitrous oxide gas (150 psi) which contributed to the large overrun figures seen in this table. Previous results have shown that aeration with nitrous oxide gas gave larger overrun percentages in whipped Neufchatel cheese than carbon dioxide and nitrogen. Sodium caseinate and sodium alginate appeared to increase shrinkage of the whipped cheese; whereas, locust bean gum and glucosyl glucan were found to result in decreased shrinkage of the whipped Neufchatel (Table 17). An increase in sodium caseinate, while not affecting the per cent overrun, resulted in increased shrinkage of the whipped cheese. The data in trial 4 of Table 17 suggested that glucosyl glucan resulted in less shrinkage than locust bean gum where each stabilizer was added to the milk at the rate of 0.2 per cent. The two samples of whipped cheese showed the same amount of shrinkage, but the glucosyl glucan sample contained 10 per cent more overrun than the whipped cheese that contained locust bean gum. As noted previously, the addition of 0.2 per cent locust bean gum to milk resulted in a grainy textured cheese; whereas, this defect was not evident in Neufchatel cheese prepared from milk containing 0.2 per cent glucosyl glucan. Therefore, data presented thus far in the thesis have indicated that glucosyl glucan is a more beneficial stabilizer than locust bean gum.

The influence of monoglyceride emulsifiers upon shrinkage of whipped Neufchatel cheese

Data concerned with the effect of monoglycerides upon shrinkage of whipped Neufchatel cheese consisted of samples selected from separate trials in some instances that had been aerated with the same gas and which possessed similar overruns. The results indicated that there was virtually no difference in shrinkage among whipped samples to which a given monoglyceride had been added to the milk and those to which the same emulsifier had been added to the cheese. Shrinkage data presented in Table 18 are typical of results obtained where monoglycerides had been added to the milk (trials 2 and 3) and to the cheese (trial 1).

The results of this study indicated that the higher the degree of saturation of the monoglyceride, the more effective the monoglyceride is in preventing shrinkage of the whipped cheese (Table 18). Whipped cheese samples that contained either the A or B monoglyceride emulsifier (Table 1, p. 22) usually had less shrinkage than the corresponding whipped control cheese. Addition of monoglyceride C appeared to increase the shrinkage of whipped Neufchatel cheese. The A emulsifier was the most effective monoglyceride added in this research for preventing shrinkage. The A and B monoglycerides tended to decrease shrinkage of whipped Neufchatel cheese as the concentration of each was increased from 0.1 to 0.3 per cent.

Table 18. The influence of different monoglyceride emulsifiers upon the shrinkage of whipped Neufchatel cheese

Whipped Cheese Trial	Monoglyceride emulsifier added		Aerating gas and pressure		Shrinkage of whipped Neufchatel cheese containing different monoglycerides, but similar overruns	
					Overrun	Shrinkage (ml/petroleum ether)
(No.)	(%)*		(psi)		(%)	
I	Control	0.0	N_2O	150	116	80
	A	0.3	"	"	118	71
	C	0.3	"	"	114	84
II	Control	0.0	CO_2	87	23	24
	A	0.3	"	"	24	15
	B	0.1	"	"	18	22
III	Control	0.0	CO_2	87	55	50
	B	0.2	"	"	56	48
	C	0.2	"	"	52	52

*Percentage monoglyceride based upon weight of milk in batch or cheese in sample.

A comparison of the effect of high and low HLB emulsifiers upon shrinkage of whipped Neufchatel cheese

The HLB rating of emulsifiers D, E, F and G (Table 1, p. 22) was 3.2, 2.8, 14.9 and 10.9 respectively. Portions of the data concerned with the effect of high and low HLB emulsifiers upon shrinkage of whipped Neufchatel cheese were shown in Table 19. Trial 2 of this table was an example showing typical shrinkage that resulted when a particular emulsifier was added to milk during pasteurization and to

Table 19. The influence of high and low HLB emulsifiers upon shrinkage of whipped Neufchatel cheese

Whipped Cheese Trial (No.)	Emulsifier added (%)*		Aerating gas and pressure (psi)		Shrinkage of whipped Neufchatel cheese containing different emulsifiers, but similar overruns: Overrun (%)	Shrinkage (ml/petroleum ether)
I	Control	0.00	CO_2	87	107	92
	E	0.30	"	"	103	72
	F	0.30	"	"	99	81
II	G**	0.20	CO_2	87	77	59
	G	0.20	"	"	76	59
III	Control	0.00	N_2O	150	62	53
	D	0.75	"	"	61	44
	G	0.75	"	"	60	49
IV	F	0.20	N_2	300	43	14
	G	0.20	"	"	43	14
V	Control	0.00	N_2O	150	133	86
	Mixture:					
	E	0.38				
	F	0.12	"	"	130	94
	Mixture:					
	E	0.25				
	F	0.25	"	"	134	97

*Percentage emulsifier based upon grams of cheese in sample or weight of milk in batch.

**The only sample in Trials 1-5 in which the emulsifier was added to the milk.

cheese during the mixing process. The results in trial 2 suggested that a particular emulsifier gave similar shrinkage regardless of whether it was added to milk or to the cheese.

Samples listed in trials 1, 3 and 4 of Table 19 involved the addition of individual high and low HLB emulsifiers to the cheese during the mixing process. Addition of the individual emulsifiers appeared to decrease shrinkage of whipped Neufchatel cheese as compared to whipped control samples. There did not appear to be an obvious difference in shrinkage of the whipped products when the same level of emulsifiers F and G were added to the cheese (trial 4, Table 19). The results of this research indicated that the low HLB emulsifiers (D and E) were more effective in preventing shrinkage of the whipped cheese than were the high HLB emulsifiers (F and G). The addition of high and low HLB emulsifier combinations increased shrinkage of the finished product as is shown in trial 5 of Table 19.

A comparison of the influence of emulsifier H with other emulsifiers upon shrinkage of whipped Neufchatel cheese

The effect of emulsifier H on shrinkage of whipped Neufchatel cheese (Table 1, p. 22) was compared to other emulsifiers in Table 20. Previous results have shown that the presence of A and B monoglycerides, low HLB emulsifiers (D and E) and high HLB emulsifiers (F and G), in Neufchatel cheese tended to decrease shrinkage of the whipped product. However, emulsifier H appeared to prevent shrinkage to a greater degree than any of the other added emulsifiers.

Data in trials 2 and 3 of Table 20 indicated a decrease in shrinkage of whipped samples containing emulsifier H. Previously mentioned in this manuscript was that the A emulsifier resulted in less shrinkage of the whipped cheese than other monoglycerides added in this study.

Table 20. A comparison of the influence of emulsifier H with other emulsifiers upon shrinkage of whipped Neufchatel cheese

Whipped Cheese Trial (No.)	Emulsifier added (%)*		Aerating gas and pressure (psi)		Shrinkage of whipped Neufchatel cheese containing different emulsifiers, but similar overruns: Overrun (%)	Shrinkage (ml/petroleum ether)
I	H	0.5	N_2O	150	120	66
	A	0.3	"	"	118	71
	C	0.3	"	"	114	84
II	Control	0.0	CO_2	87	90	60
	H	0.3	"	"	95	56
	E	0.3	"	"	89	58
III	Control	0.0	CO_2	87	104	82
	H	0.1	"	"	104	68
	D	0.2	"	"	105	79

*Percentage emulsifier based upon grams of cheese in sample.

Instances in which whipped samples contained the A and H emulsifiers and had similar overruns, the H emulsifier resulted in less shrinkage than did the A monoglyceride as was shown in trial 1 of Table 20. Shrinkage of whipped cheese that contained the C monoglyceride was greater than in other samples listed in trial 1 and was typical of shrinkage that resulted from addition of this emulsifier. The data in trials 2 and 3 of Table 20 indicated that emulsifier H was also more effective than the low HLB emulsifiers in reducing shrinkage of whipped Neufchatel cheese.

Body Characteristics of Whipped Neufchatel Cheese

On the visco/amylo/graph (VAG) curve, time was represented in minutes on the abscissa and arbitrary Brabender viscosity units, ranging from 0-1000, were represented on the ordinate. The VAG instrument reflects the breakdown of the product with agitation by the decline in viscosity units with time. The rate of breakdown decreased with the time of agitation and the slope of the curve; therefore, it provided an index of resistance to the physical stress.

Use of the VAG instrument afforded the opportunity of determining the rate of breakdown of the Neufchatel cheese samples immediately after whipping. The decrease in viscosity of samples that were aerated with the same gas at the same pressure and which possessed similar overruns were compared in given figures. This made it possible to better evaluate the different processing and additive variables upon body stability of the freshly whipped cheese.

The VAG data showed interesting differences in the breakdown of the body of freshly whipped samples where different treatments were used. Figures 15-22 were indicative of the VAG results obtained in this study that concerned the effect of milk fat content, direct acidification versus lactic acid fermentation in Neufchatel cheese preparation, and stabilizers and emulsifiers added to the milk or cheese upon body stability of the whipped product.

Viscosity measurements of the two whipped samples shown in Figure 15 indicated that the 3.5 per cent higher fat content of Neufchatel cheese made from 5.0 per cent milk, as compared to the cheese made from 4.0 per cent milk, resulted in a more rapid body breakdown due to physical stress. The whipped cheese samples made from 4.0 and 5.0 per cent milk contained 133 and 134 per cent overruns respectively and

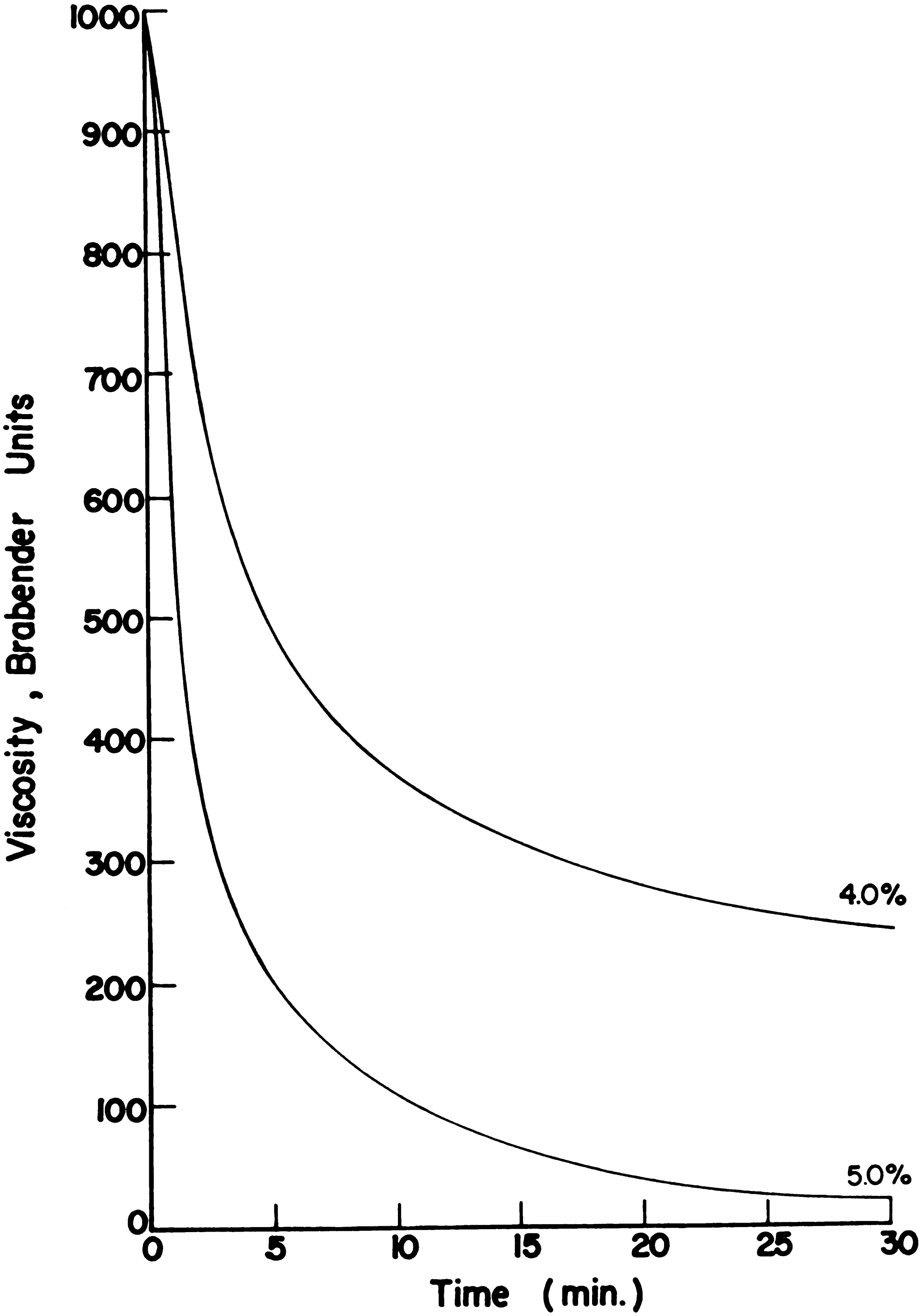

Figure 15. A comparison of the viscosity of whipped Neufchatel cheese prepared from milk containing 4.0 and 5.0 per cent fat.

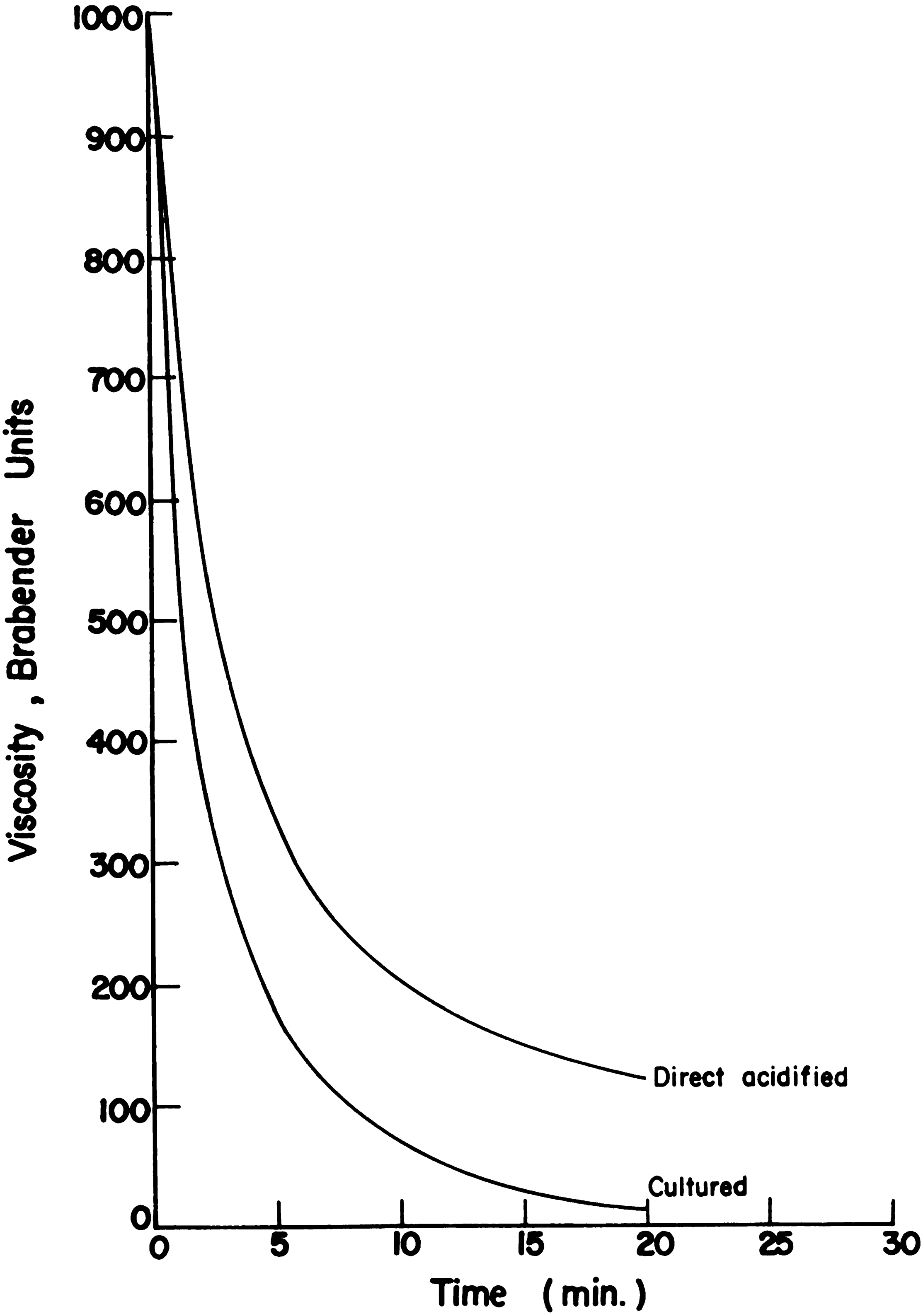

Figure 16. A comparison of the viscosity of whipped Neufchatel cheese prepared by direct acidification or bacterial fermentation.

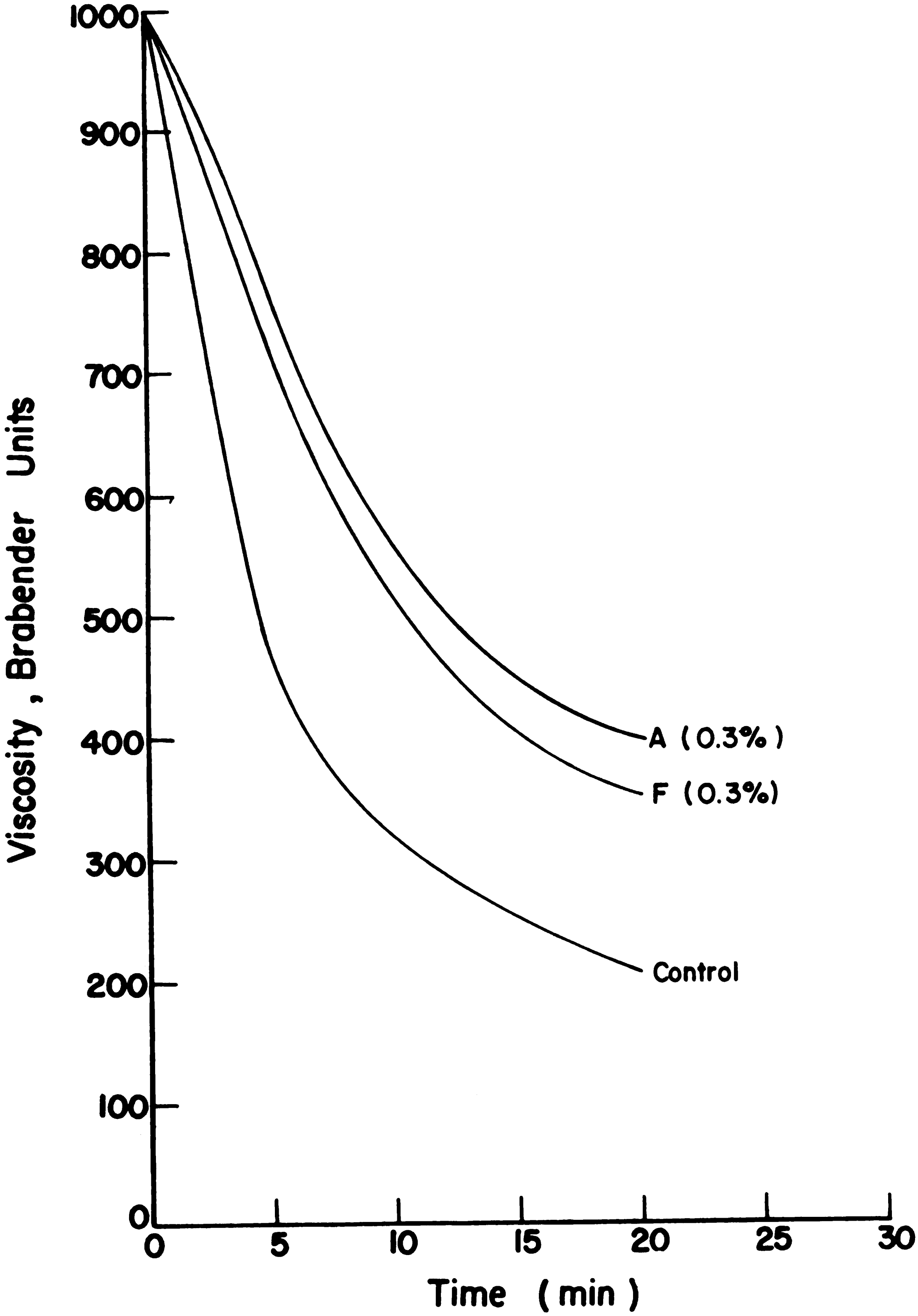

Figure 17. The effect of emulsifiers upon the viscosity of whipped Neufchatel cheese.

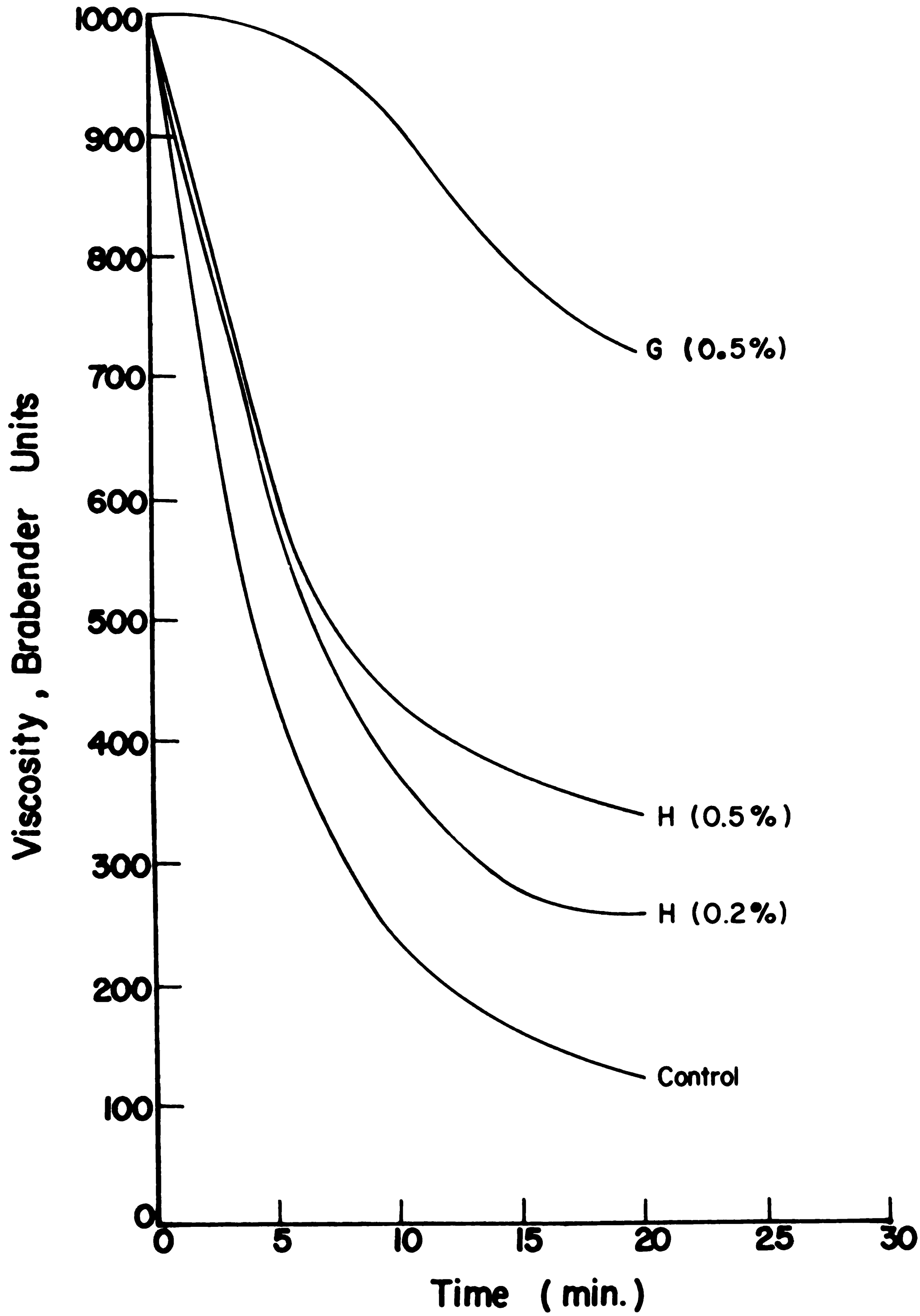

Figure 18. The effect of emulsifiers upon the viscosity of whipped Neufchatel cheese.

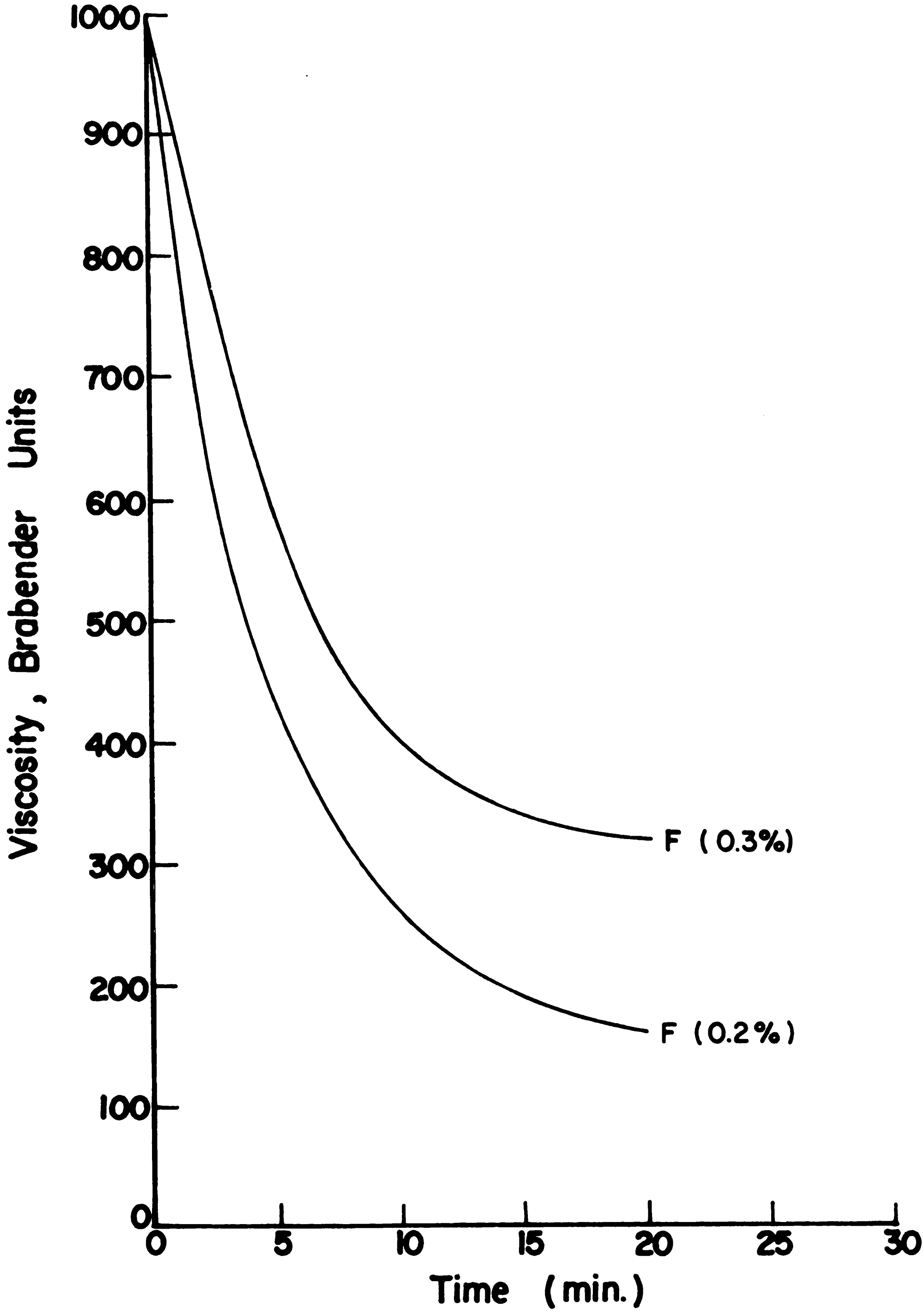

Figure 19. The effect of emulsifier F upon the viscosity of whipped Neufchatel cheese.

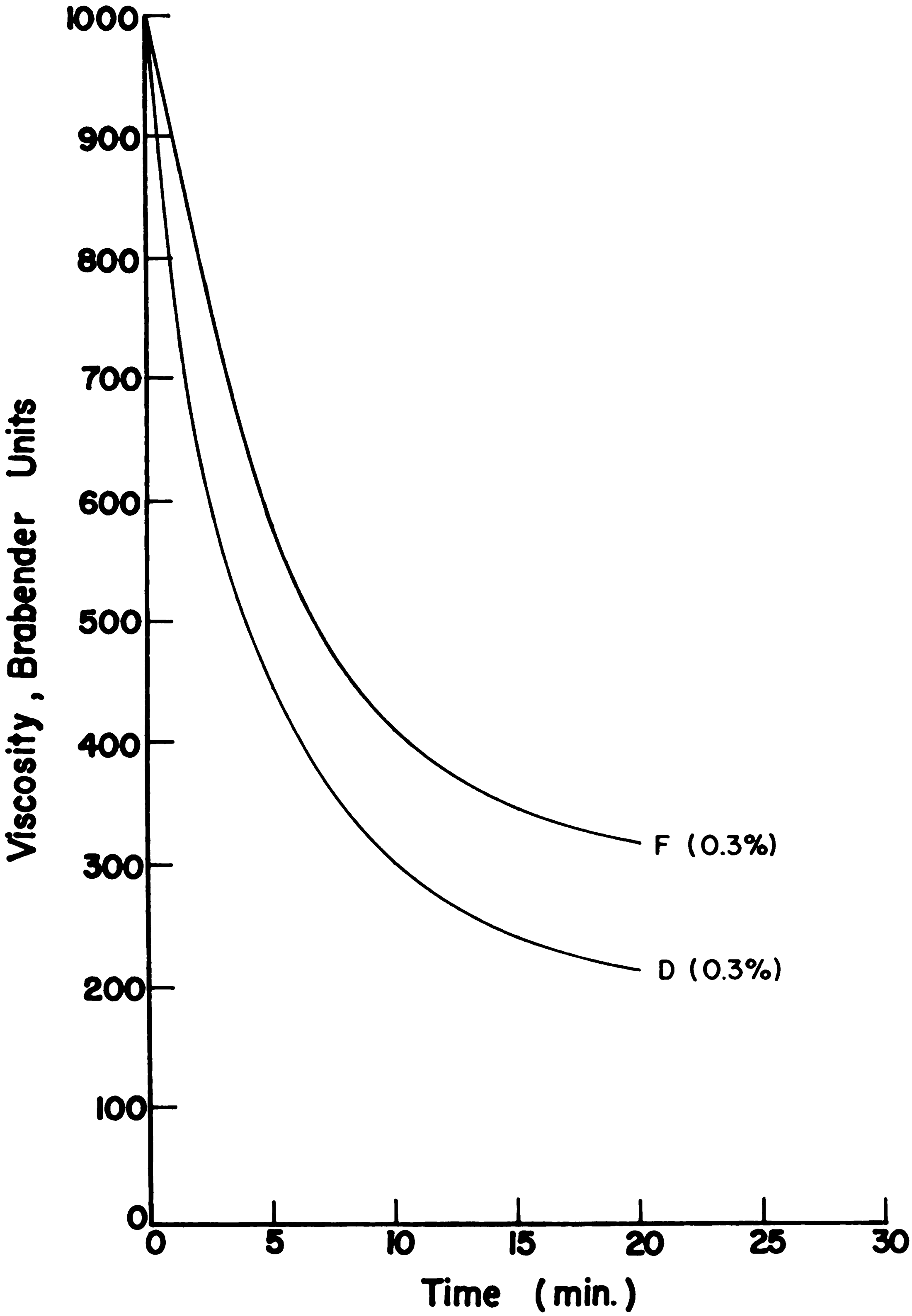

Figure 20. A comparison of the viscosity of whipped neufchatel cheese containing 0.3 per cent of emulsifier D or F.

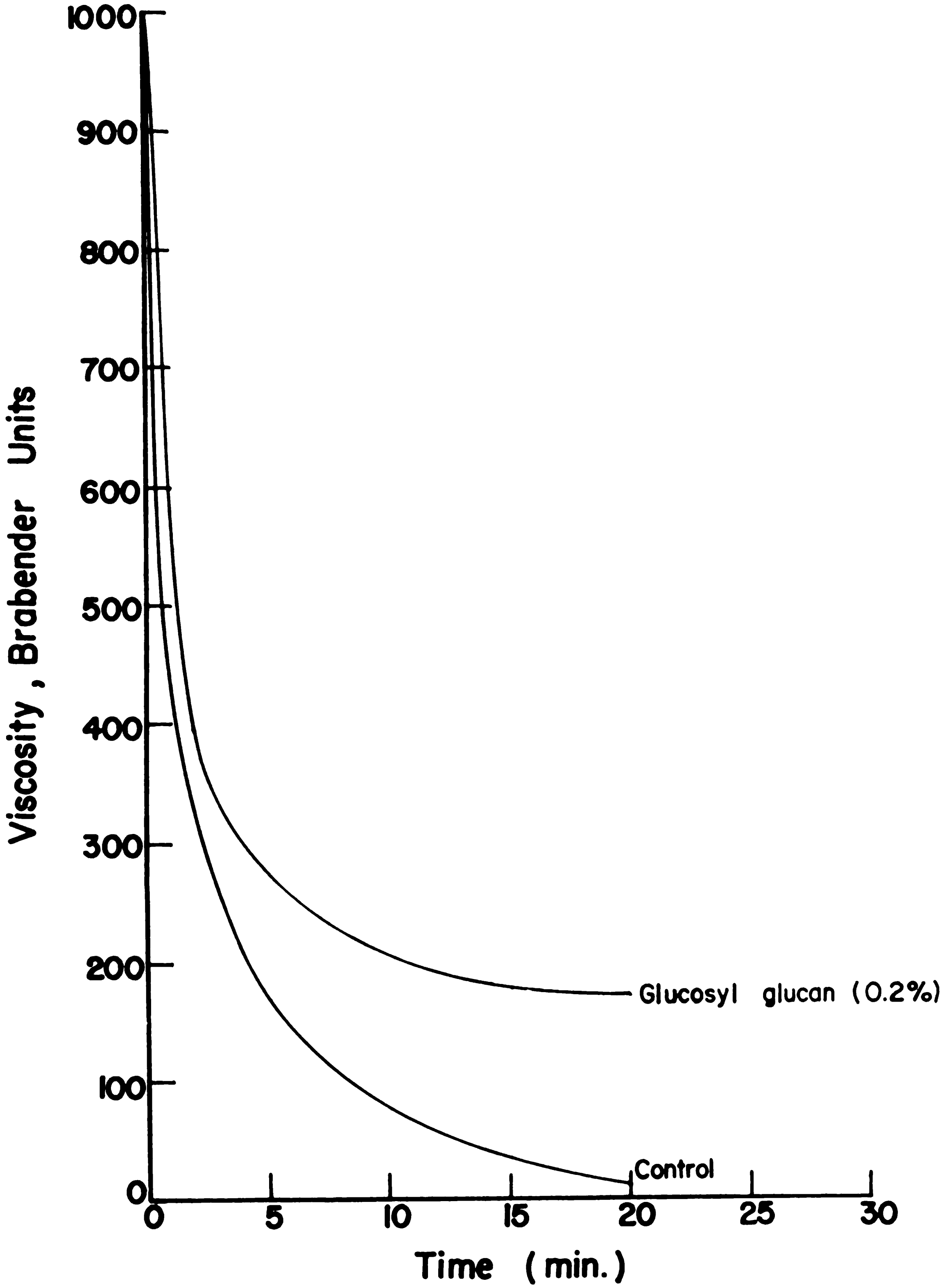

Figure 21. The effect of added glucosyl glucan upon the viscosity of whipped Neufchatel cheese.

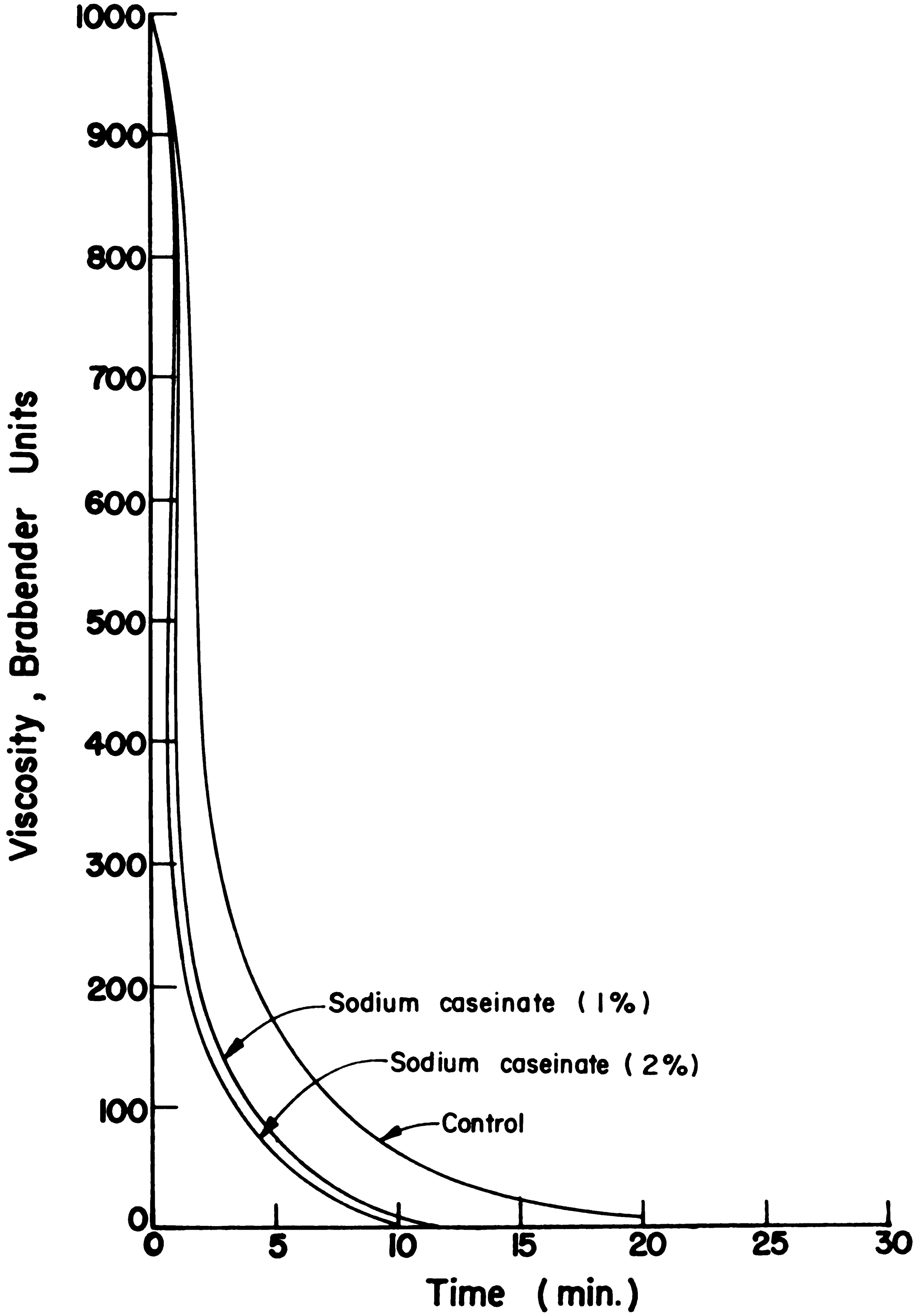

Figure 22. The effect of added sodium caseinate upon the viscosity of whipped Neufchatel cheese.

showed similar amounts of shrinkage. Based upon penetrometer readings, the Neufchatel cheese made from 5.0 per cent milk was softer than the cheese made from milk containing 4.0 per cent milk fat (Table 2, p. 29). These results suggested that the higher the fat content of cheese, the softer the prepared cheese and the weaker the body of the whipped cheese where the overruns of the two aerated samples were practically the same.

Previous data in this manuscript have indicated that Neufchatel cheese prepared by direct acidification was slightly softer than cheese prepared by lactic acid fermentation. Neither method of milk coagulation appeared to show a particular advantage over the other from the standpoint of percentage overrun attained or shrinkage of the whipped cheese. According to Figure 16, the body of the whipped cheese made by direct acidification broke down at a slower rate than the cultured cheese when both samples were subjected to the same physical stress.

Figures 17-20 showed the relative viscosity of whipped control and experimental cheese samples containing added emulsifiers. The whipped cheese samples shown in each of the four figures mentioned above contained essentially the same percentage overrun. Data in the preceding section of this thesis indicated that the addition to cheese of most of the emulsifiers used in this study tended to decrease shrinkage of the whipped samples. The whipped cheese containing emulsifiers A, F, G and H (Table 1, p. 22) at various concentrations showed more resistance to physical stress than did the whipped control samples (Figures 17 and 18).

As shown in Figure 17, the aerated sample containing 0.3 per cent A monoglyceride broke down to a lesser degree than the sample containing the same per cent emulsifier F. The G emulsifier added to cheese at the 0.5 per cent level appeared to result in a more stable whipped product than did the other three emulsifiers shown in Figures 17 and 18. It was previously noted that the H emulsifier appeared to be the most effective emulsifier added in this study to aid in preventing shrinkage of the whipped Neufchatel cheese. It seemed likely that this emulsifier would result in a whipped cheese that would withstand more physical stress than that prepared from other emulsifiers. However, data in Figure 18 showed that emulsifier G gave a more stable whipped product from the standpoint of effects on viscosity.

The data in Figure 20 indicated that the addition of a high HLB emulsifier (F) resulted in a whipped cheese that would withstand more physical stress than the addition of a low HLB emulsifier such as D. Increasing the per cent of emulsifier F from 0.2 to 0.3 gave an aerated product in which the viscosity broke down more slowly when using the VAG instrument (Figure 19).

The effect of glucosyl glucan and sodium caseinate added to milk upon the viscosity of whipped Neufchatel cheese were shown in Figures 21 and 22. Based upon penetrometer readings of the prepared cheese, addition of glucosyl glucan stabilizer to milk resulted in a softer finished cheese. This stabilizer also caused an increase in overrun and a decrease in shrinkage of the whipped cheese. According to the data in Figure 21, the addition of 0.2 per cent glucosyl glucan resulted in a whipped cheese that was more stable under physical stress than a control sample containing the same overrun percentage.

Addition of 1.0 and 2.0 per cent sodium caseinate to whole milk for Neufchatel cheese preparation appeared to decrease overrun and increase shrinkage of the whipped samples as compared to control cheese samples. According to penetrometer readings, the addition of 2.0 per cent sodium caseinate to milk gave cheese with a firmer body than the corresponding control cheese. The VAG results shown in Figure 22 indicated that sodium caseinate decreased the stability of the whipped cheese to physical stress. Also, an increase in the sodium caseinate content of milk resulted in a decrease in body stability of the resulting whipped cheese as measured by the VAG instrument.

Concerning the effect of additives upon the viscosity of whipped Neufchatel cheese (Figures 17-22), it was noteworthy that the addition of emulsifiers to the cheese appeared to improve the physical stability of the whipped product. The same emulsifiers were found to decrease shrinkage of the aerated cheese. The glucosyl glucan stabilizer resulted in whipped Neufchatel cheese that demonstrated less shrinkage and more stability to physical stress than whipped control samples having similar overruns. The addition of sodium caseinate to milk decreased body stability and increased shrinkage of whipped Neufchatel cheese.

SUMMARY AND CONCLUSIONS

The softness of Neufchatel cheese varied directly with fat content as measured by penetrometer values and subjective observations. Cheese of higher fat content was also smoother in body and texture. Decreasing the milk pasteurization temperature was found to result in cheese with a softer and smoother body and texture. Of the various stabilizers evaluated in this research glucosyl glucan added to the milk during pasteurization resulted in cheese with the most desirable softness. Propylene glycol proved to be a suitable vehicle for incorporation of emulsifiers into the cheese milk. The emulsifiers used improved the softness and smoothness of the cheese.

Aeration proved to be a successful method for producing high overrun in whipped Neufchatel cheese. Nitrous oxide and a mixture of nitrous oxide-carbon dioxide produced the highest percentage overrun in such cheese. Increasing the fat content of milk resulted in cheese that whipped to a higher overrun. There was an inverse relationship between milk pasteurization temperature and overrun in the whipped cheese.

Glucosyl glucan and locust bean gum stabilizers added to milk increased the overrun of whipped Neufchatel cheese, whereas sodium alginate and sodium caseinate significantly decreased the overrun. Emulsifiers, added separately to milk, decreased the overrun in the whipped cheese. However, certain emulsifiers increased overrun when added to the cheese during the final mixing process.

Total elimination of the shrinkage problem of whipped Neufchatel cheese was not attained by the treatments used in this study. Cheese aerated with nitrous oxide showed less shrinkage than high overrun cheese that had been aerated with other gases. Added emulsifiers decreased shrinkage of the whipped cheese.

The visco/amylo/graph results showed that an increase in the fat content of Neufchatel cheese caused a decrease in the body stability of the freshly whipped product. Whipped cheese prepared by direct acidification had more resistance to physical stress than whipped cheese prepared by the lactic acid fermentation method. Emulsifiers added to cheese during the mixing process resulted in improved body stability of the whipped product over control samples. The VAG results indicated that glucosyl glucan increased stability of the whipped cheese, whereas sodium caseinate decreased the stability of the whipped product.

In conclusion, a whipped Neufchatel cheese with sufficient overrun and desirable physical properties was prepared by the addition of certain stabilizers to the milk or certain emulsifiers to the cheese and aerating with nitrous oxide or the nitrous oxide-carbon dioxide gas mixture.

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