THE EFFECT OF PROCESSING VARIATIONS ON THE FREE-FAT, SELF-DISPERSION, AND FLAVOR OF WHOLE MILK POWDER

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Eugene F. Reinke

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by

Eugene F. Reinke

AN ABSTRACT

Submitted to the College of Agriculture of
Michigan State University of Agriculture and Applied Science
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ABSTRACT

Eugene F. Reinke

Thirty-nine samples of whole milk powder, involving 29 processing variations, were manufactured with commercial size equipment. All of the processing variations could easily be adapted to present commercial operations.

The lowest initial values of free-fat were observed in the whole milk powders of reduced fat (17 - 20%) content. Higher values of free-fat were observed in the full-cream powders (22 - 32% fat). Increased heat treatment of the fluid and/or concentrated whole milk; recombination of concentrated skimmilk with cream or butteroil; treatment of the concentrated skimmilk with a proteolytic enzyme followed by recombination with butteroil; and the use of fluid homogenized milk resulted in even higher initial values of free-fat. The small increase in free-fat observed after storage was not statistically significant.

High initial self-dispersion values were observed in the whole milk powders in which the concentrated skimmilk was treated with a proteolytic enzyme and recombined with butteroil. The decrease in the self-dispersion values following storage was observed to be statistically significant, but there was no correlation between the quantity of free-fat and the self-dispersion values of the whole milk powder while fresh or after storage.

ABSTRACT

Eugene F. Reinke

Increased heat treatment of the fluid and/or concentrated whole milk resulted in initially high flavor scores. A statistically significant decrease in the flavor scores of the whole milk powder following storage was observed. There was no correlation between the quantity of free-fat and the flavor scores of the whole milk powder while fresh or after storage.

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INTRODUCTION

The importance of butterfat on the flavor deterioration of whole milk powder is widely recognized. During the 1920's several workers observed that a portion of the fat in dried whole milk powder was extractable with certain solvents. This extractable fat was referred to as "free-fat"; the predominant theory being that it was not protected by the fat-globule membrane. Though some significance was attached to the quantity, very little research was conducted to observe the effect of free-fat on whole milk powder. Recent work by Shipstead and Tarassuk (1953) has shown that the free-fat in spray-dried milk oxidized first during storage. Also, Litman and Ashworth (1957) and Nickerson, Coulter, and Jenness (1952) reported that the free-fat adversely affects the ease of reconstitution of whole milk powder.

The objectives of this study were:

1) to observe the effect of processing variations on the formation of free-fat in whole milk powder, and
2) to observe the effect of the quantity of free-fat on the self-dispersion values and flavor scores of whole milk powder.

REVIEW OF LITERATURE

The term "free-fat", as related to whole milk powder, was first reported by Holm, Greenbank, and Deysher (1925), who defined it as "fat not protected by a protein film" and extractable with carbon tetrachloride. They were interested in determining the correlation between increased values of free-fat during storage and susceptibility to oxidation.

Probably the first worker to point out the relationship of the fat globule and its membrane to oxidation was Dr. Storch, who, according to Washburn (1922), found that each and every fat globule is surrounded by a minute but definite gelatinous envelope, which protects the fat from oxidation as long as it is unbroken.

According to Coulter, Jenness, and Geddes (1951), work by Lendrich indicated that aging of the powder in the atmosphere caused the lactose to crystallize and allowed up to 88 per cent of the fat to be extracted with benzene. Lampitt and Bushill (1931) made similar findings, stating that at a critical moisture content of 8.6 to 9.2 per cent in the powder, the liberation of free-fat correlated with lactose crystallization. King (1948, 1955, 1956), who has done considerable work in this field, also attributed the formation of free-fat to lactose crystallization, as he believed the lactose crystals would mechanically injure or pierce the fat globule membrane. Choi, Tatter, and O'Malley (1951) reported the presence of 'free' fat but considered it to be a result of protein coagulation rather than lactose crystallization.

Though the presence of free-fat has been shown by the above workers, very little research has been conducted to correlate the effect of various manufacturing treatments and the formation of free-fat with its resultant effect on flavor and dispersion.

Holm et al. (1925) did notice a decrease in free-fat after homogenization of the fluid milk. Litman and Ashworth (1957) found that with few exceptions powders stored at 85° F. (29.4° C.) contained less free-fat than those stored at 45° F. (7.2° C.). The decrease in free-fat was not clearly understood but they postulated that at the higher storage temperature it might be absorbed within the powder granule itself. Their work also showed that the amount of free-fat is related to the total fat in the powder, with a definite relationship between free-fat and dispersion. They observed a sharp increase in free-fat for powder with about 26 per cent fat, which agrees with the work of Holm et al. (1925).

Nickerson et al. (1952) also found that homogenization reduced the amount of free-fat in freeze-dried whole milk, although the total amount of free-fat extracted, with or without homogenization, was considerably higher than for spray-dried milk. Also, he observed that the presence of free-fat decreased the wettability of the resultant powders. More recent work by Tamsma, Edmondson, and Vettel (1959) with foam-dried milk powders also substantiated the effect of "superior homogenization" in reducing the free-fat slightly. Other factors reported as affecting the free-fat were particle size, indicating an increase in free-fat with decreased particle size; drying temperature did not affect the free-fat; no correlation between free-fat and storage was noted. Improved keeping quality was reported for powders high in free-fat, whereas the dispersibility decreased. Greenbank and Hufnagel (1953), however, reported that the keeping quality increased as the carbon tetra-chloride extractable fat decreased.

The effect of variations in manufacturing upon the keeping quality and reconstitutability of whole milk powder has received considerable attention.

Holm, Greenbank, and Deysher (1926) and Holm, Wright, and Greenbank (1927) reported that clarification of the fluid milk is beneficial in improving the keeping quality of whole milk powder, while Lea, Findlay, and Smith (1945) did not agree with this.

Preheat treatment of the fluid milk has probably received more attention than any other processing variation. Several workers - Hollender and Tracy (1942), Holm *et al.* (1926), and Manus and Ashworth (1948a) - have suggested a temperature of 170 to 181° F. (76.7 to 83° C.) for 30 minutes. Lea *et al.* (1945) found that increasing the preheat treatment from 160° to 190° F. (71° to 87.6° C.) improved the keeping quality. This was later confirmed by White, Smith, and Lea (1947). Manus and Ashworth (1948a) reported that milk preheated to 170° F. (76.7° C.) for ten to thirty minutes kept much better than milk preheated to 160° F. (71° C.) for 30 minutes. Similarly, Christensen, Decker, and Ashworth (1951) noted an improvement in the keeping quality as the preheat treatment was increased from 140° to 160° F. (59.8° to 71° C.), with an even greater improvement as the preheat temperature was increased from 160° to 170° F. (71° to 76.7° C.). White, Waite, Hawley, Clark, and Henry (1952) concluded that there was no advantage in preheating at 230° F. (110° C.) as compared to 190° F. (87.6° C.).

Palmer and Dahle (1922) stated that the general improvement in keeping quality of dried whole milk manufactured at the higher preheat treatments is considered to be due to:

1. Greater destruction of natural enzymes.
2. Increased antioxidant.
3. Greater destruction of bacteria.

Holm *et al.* (1925), Manus and Ashworth (1948a) and Haller and Holm (1947) have shown that precondensation helps to improve the keeping quality of dried milk.

Holm *et al.* (1925) found that homogenization gave better keeping quality.

The effect of spraying pressure and orifice size has been studied by Hetrick and Tracy (1944) who concluded that the finer powders made with a small nozzle had poor keeping quality, while later work by Tracy, Hetrick, and Krienke (1951) showed that the size of the particle was not as important as some other factors.

Holm and Greenbank (1923) found that a moisture content of three per cent was optimum for preventing tallowy flavor. Holm *et al.* (1927) considered the optimum moisture content to be two to three per cent, and found that a high moisture content, especially at high storage temperature, increased the rate of oxidation. Lea and Smith (1949) and Bryce and Pearce (1946) agreed that a moisture content of not over three per cent is preferred. Hollender and Tracy (1942) stated that a high moisture content (5% or more) and a high storage temperature (20° C.) increased the rate of oxidation. Coulter, Jenness, and Crowe (1948) found that increasing the moisture content from 1.5 to 5 per cent increased the rate of loss in flavor score. Radema (1954) reported that low moisture contents encouraged the development of tallowy flavors, while high moisture content encouraged the glue-like flavor. Range of moisture content was approximately 1.7 to 4.2 per cent.

Dahle and Palmer (1924) recorded little change in the keeping quality of powdered milk stored at 4° and 20° C., but found a decided difference at 37° C. Holm et al. (1927) found a rapid decrease in keeping quality for powders stored above 0° C. Bryce and Pearce (1946) noted that the palatability of whole milk powder deteriorated when stored at 60° F. (15.5° C.) or higher, and found that a storage temperature of 80° or 120° F. (26.6° or 48.8° C.) was not as satisfactory as 100° F. (55.5° C.) Christensen et al. (1951) reported that air packed samples stored at 45° F. (7.2° C.) were slightly superior in flavor to nitrogen packed samples stored at 85° F. (29.4° C.), and he postulated the improved flavor was due to the loss of the heated flavor. Lea et al. (1945) have found that powder stored at 37° C. kept two to three times as long as powder stored at 47° C. Radema (1954) and Hunziker (1949) agreed that the keeping quality decreases with an increase in storage temperature, while Hollender and Tracy (1942) concluded that storage temperature is more important than moisture in determining the keeping quality.

Increasing the fat content, according to Holm et al. (1925) decreased the flavor stability. Greenbank and Hufnagel (1953) reported that the keeping quality was increased as the fat content was decreased below 20 per cent. Lea and Smith (1943a) noted that a powder containing 2.4 per cent fat and 1.4 per cent moisture had only a very slight taste of staleness when fresh and was highly palatable and did not develop the typical tallowy flavor nearly as fast as full-cream milk powder.

According to Swanson (1955), reconstitution of milk powder involves three factors: 1) wettability, 2) dispersibility, and 3) solubility.

Wettability, according to Ashworth (1952), is the initial phase of dispersion and refers to that characteristic of the milk powder which allows water to penetrate the mass without mechanical agitation.

Gibson (1952) described dispersibility as the ability of the powder to mix readily with water when stirred a few times.

Solubility is defined by Supplee and Bellis (1925) as the ability of the dried milk, when mechanically mixed with water, to form a solution, suspension, or emulsion similar to natural milk.

High preheating temperatures (190° F. - 87.6° C. - for 20 seconds) did not appreciably affect the resulting solubility of the milk powders, according to Lea _et al._ (1945); Crossley (1945), and Hunziker (1949) concluded that the slight loss in solubility due to high preheat treatment is more than offset by the increased keeping quality. Manus and Ashworth (1948b) both agreed that preconcentration improved the solubility. Ashworth (1955) reported that a solids content of 30 to 40 per cent gave maximum wettability.

Coulter _et al._ (1951) believed that excessive heating of the condensed milk before drying could affect the

solubility of the powder due to the shorter time required to cause protein coagulation in the higher solids product.

Homogenization improved wettability of powder containing 4 to 28 per cent fat when stored at 85° F. (29.4° C.) according to Ashworth (1955), and Manus and Ashworth (1948b) noted a direct relationship between high solubility indices and efficient homogenization.

Janzen and McGugan (1953) reported that particle size had no appreciable influence on wettability and dispersion, but found that removal of surface fat was effective in more rapid wetting and dispersion although it did not maintain this characteristic after storage for two months. Gibson and Raithby (1954) found that when reconstituting skim milk powder the particles of 15 to 25 micron diameter were easier to reconstitute than those of less than 15 microns. Panasenkov and Boistsun (1953) noted that particles of 30 micron diameter absorbed and retained more moisture than those of 18 microns. Sinnanon, Aceto, Eskew, and Schoppet (1957) reported that for puff-dried whole milk powder, 20 mesh screening was superior to 40 mesh screening for dispersion properties; while Tamsma _et al._ (1959) observed that foam-dried milk comminuted through a 40 mesh screen followed by sieving on a 60 mesh screen to remove the fine particles gave a more dispersible powder than comminution through a 20 mesh screen. Swanson (1955) found that for non-fat dry milk a particle size of 30 to 50 micron diameter gave the best wettability and dispersion, but that for whole milk powder factors other than particle size are important.

Work by Tamsma *et al.* (1959) showed that for foam-dried whole milk powder, dispersion decreased 0.11 per cent for each one per cent increase of free-fat, and also noted that the free-fat increased with decreased particle size.

Stone, Conley, and McIntire (1954) found that as the fat content of the powder increased dispersion decreased, but concluded that factors other than the fat content affected dispersion, as stated by Swanson (1955).

Proteolytic treated milks were found by Hibbs and Ashworth (1951) to be less soluble initially, but decreasing in solubility during storage at a slower rate than the control. Julien and Baker (1957), using Rhozyme P11, however, found slight proteolysis to be beneficial in improving the wettability of milk powder. Bullock and Winder (1958) found that they could improve the sinkability of dried whole milk by 10 to 40 per cent by subjecting the powder to a post drying temperature treatment.

Supplee and Bellis (1925) reported that a moisture content of three to five per cent causes no appreciable change in solubility during storage. Lea and Smith (1943b) noted that the change in solubility for low moisture content powders (less than 3%) stored at ordinary temperature when gas-packed is very small.

EXPERIMENTAL PROCEDURES

Drying Trials

The milk used throughout this study was from a mixed herd source obtained at the Michigan State University dairy plant.

Fresh standardized-clarified milk was forewarmed to 155° - 165° F. (68.5° - 74° C.) for 20 seconds in a tubular heater, condensed to approximately 47 per cent solids - range of 40 to 53% - in a Rogers single effect evaporator, using a vapor temperature of approximately 92° F. (33.4° C.) - range of 86° to 102° F. (30° to 38.9° C.). The concentrated product was preheated to 135° F. (57.2° C.) in a tubular heater prior to drying in a Rogers 250 lb./hr. spray-dryer using 2200 p.s.i. nozzle pressure with a single No. 69/20 nozzle and outlet air temperature of approximately 188° F. (86.5° C.) - range 170° to 205° F. (76.7° to 96° C.). Whenever practical control samples were manufactured prior to drying of the experimental sample. A total of 29 trials, involving 39 samples, was manufactured under commercial plant conditions.

Variations in the processing treatment included:

1) Forewarming
2) Recombination of concentrated skimmilk with cream or butteroil

3) Treatment of concentrated whole milk

4) Nozzle size

5) Nozzle pressure

6) Treatment of the concentrate with a proteolytic enzyme mixture

7) Composition (fat percentage)

8) Homogenization conditions

For purposes of this study, the word "concentrate" is used to identify either condensed skimmilk or condensed whole milk. "Forewarming" refers to the heat treatment the fluid milk received prior to concentration; and the word "preheat" is used to designate the temperature treatment the concentrated product received prior to drying.

High forewarming temperatures - 240° to 300° F. (115.5° to 149° C.) - were attained by using a two-stage heating system. The fluid milk was heated to at least 165° F. (74° C.) in a tubular heater, followed by heating in a Rogers-Terret steam injection heater.

Samples of the powder were collected in plastic bags and representative portions were packaged in No. 2 cans filled one-half to three-fourths full. The packaged powder was then subjected to a vacuum of 27 inches Hg for two minutes which was displaced with nitrogen before sealing with a drop of solder. Samples were stored at 33°, 70°, and 90° F. (0.6°, 21.1°, and 32.2° C.).

All samples of powder were analyzed for total fat, free-fat, self-dispersion, flavor, moisture, whey-protein nitrogen, particle size, and specific volume when fresh; and for free-fat, self-dispersion, and flavor after storage for one, three, and six months.

The analyses and packaging of samples were normally completed within 48 hours of manufacturing. Duplicate analyses were made on total fat, free-fat, and self-dispersion.

Analytical Methods

Fat. The method of Mojonnier and Troy (1925) was used to determine fat in the dried milk powder.

Free-fat. The method of Thomas, Holgren, Jokay, and Bloch (1957) was used for this purpose. The solvent was prepared by mixing equal parts of petroleum and ethyl ether. Special equipment included a No. 15 rubber stopper with two widely separated holes. Through one of the holes was inserted the stem of a medium porosity (10 to 15 microns) Buchner (60 milliliter capacity) fritted-glass filter; the other hole was connected by tubing to a vacuum source. Also used were Mojonnier fat dishes, hot plate, vacuum oven, and cooling dessicator.

A 20-gram sample of dried milk was weighed into a 125 milliliter Erlenmeyer flask and shaken vigorously for 20 seconds with 40 milliliters of the solvent. The flask was unstoppered and the contents allowed to settle for at least one minute. The filtering assembly; i.e., the fritted-glass filter and rubber stopper with tubing, was then placed on a previously weighed fat dish and vacuum applied. The solvent was carefully decanted into the funnel to prevent any excessive amount of powder flowing into the funnel. Thirty milliliters of solvent were added to the flask and shaken, and, with the vacuum applied, as much of the powder and solvent as possible were poured into the funnel. The flask was rinsed with 20 milliliters of solvent. The vacuum was then released and the solvent poured into the funnel. This was followed by rinsing the flask twice with 10 milliliters of solvent. The sides of the funnel were rinsed with 20 milliliters of solvent and vacuum applied until all of the solvent was pulled into the dish.

The solvent was evaporated on a hot plate at 135° C., placed in a vacuum oven (at least 20 inches of vacuum) for ten minutes, cooled in a desiccator for five to seven minutes, and weighed. Results were calculated as follows:

$$\text{mg. free-fat/g. of fat} = \frac{\text{g. free-fat/g. powder} \times 1000}{\text{g. fat/g. powder}}$$

<u>Self-dispersion</u>. The method of Stone <u>et al</u>. (1954) was used for this purpose. A 15-gram sample of milk powder, tempered to room temperature, was screened over 90 milliliters of distilled water at 75° F. (23.9° C.) in a Buchner funnel of approximately 82 millimeters inside diameter. The powder was allowed to remain undisturbed on the surface

of the water for a period of three minutes before the solution was drawn through a coarse (40 - 60 micron) fritted-glass filter into a suction flask by applying vacuum for one minute. The solution was diluted to 200 milliliters and a 20 milliliter aliquot was pipetted into a previously weighed solids dish. The liquid was then evaporated on a hot plate at 180° C., placed in a vacuum oven at 100° C. for ten minutes with not less than 20 inches of vacuum, cooled in a desiccator for five minutes, and weighed. Results were calculated as:

g. powder self-dispersed/15 g. of powder = wt. of residue x 10

Flavor score. A panel of four judges using the hedonic preference rating with a high of nine and a low of one was employed. Samples were reconstituted according to the method of the American Dry Milk Institute (1955) using 13 grams of powder to 100 milliliters of distilled water.

Particle size. Particle size distribution was determined microscopically using a calibrated eyepiece and observing five fields of ten particles per field for each powder sample.

Slides were prepared using the vacuum chamber as illustrated, Figure 1. A clean glass slide (A) was placed on the base of the chamber (B) and a small amount of powder placed inside the glass tube (C) by removing the rubber stopper (D). The chamber was then placed centrally over the slide on the base with air lines (E and F) closed. The vacuum line to (G) was opened long enough to get a vacuum of approximately 15 inches and then closed. The clamp on line (F) was then slowly opened, allowing air to enter and thereby dispersing the powder out of hole (H) in a fine spray and onto the slide. The slide was removed from the chamber and a cover glass supported by scotch tape was used to protect the powder particles while being handled for viewing.

Specific volume. The specific volume of the powder was determined by using a 100 milliliter graduated cylinder in conjunction with a 100-gram weight which fit snugly but freely into the cylinder. A ringstand with two clamps was used to guide and control the verticle lift of the cylinder. Five 10-gram samples of the powder were individually weighed out. After placing 10 grams of powder in the cylinder, the 100-gram weight was gently lowered into the cylinder with a string until it came to rest on the powder. The powder was then tamped for thirty times by raising the cylinder one inch each time, using the bottom clamp as a stop guide. This procedure was repeated for each 10-gram lot until all 50 grams were tamped. Results were expressed as milliliters of powder per 50-gram sample.

Moisture. The toluene distillation method as outlined by the A. D. M. I. (1955) with modifications in the equipment as suggested by Kennedy and Stribley (1956) was used for this purpose.

Whey-protein nitrogen. The procedure of the National Dairy Products Corporation (1957), employing a turbidimetric method of estimating the undenatured serum proteins, was used for this purpose. The preparation of the whey-protein was based on the procedure of Harland and Ashworth (1945).

Statistical analysis. Snedecor's (1956) method of analysis of variance - at the 5% significance level - was used to determine if there were any significant differences between the fresh and stored samples or between the samples stored at 33°, 70°, and 90° F. (0.6°, 21.1°, and 32.2° C.). Also, a statistical study - at the 5% significance level - was made to observe any correlation between the quantity of free-fat and self-dispersion values or between the quantity of free-fat and flavor scores while fresh and following storage, using a correlation co-efficient of 0.482.

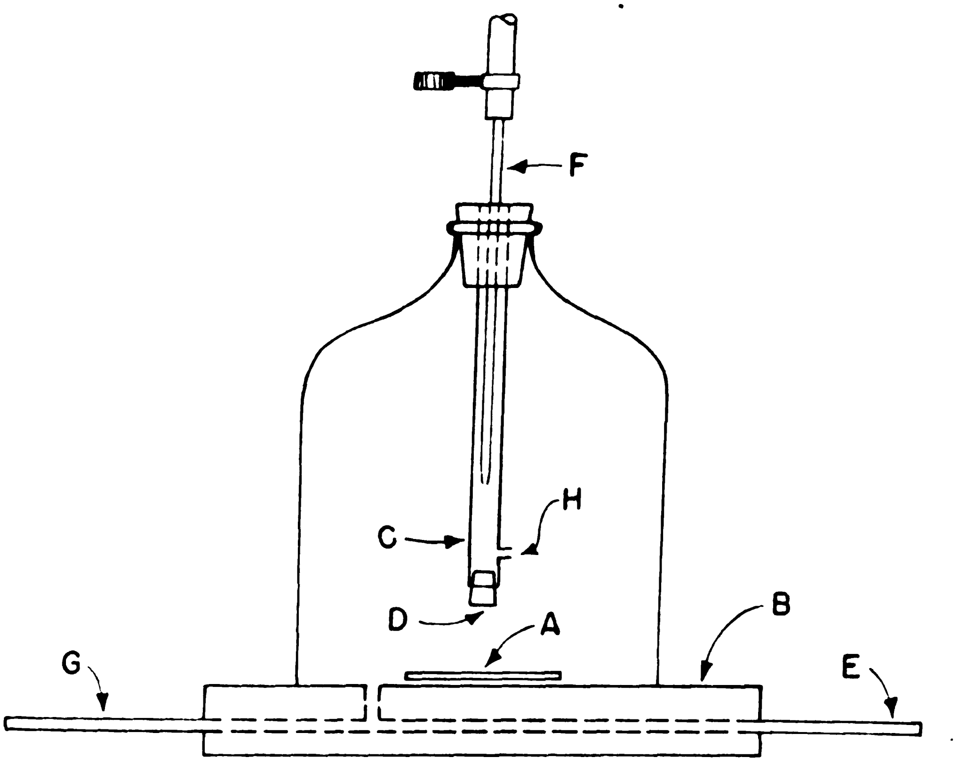


Figure 1. Diagram of vacuum chamber used for preparation of slides in determining particle size distribution.

RESULTS

The effects of variations in the processing treatment on the free-fat, self-dispersion, and flavor of whole milk powder while fresh and following storage at 33°, 70°, and 90° F. (0.6°, 21.1°, and 32.2° C.) are presented in tables 1 through 8, while figures 2 through 30 represent the graphical relationship of these values.

The whey-protein nitrogen values, specific volume, and particle size distribution are given in the detailed tables in the appendix.

A comparison of the composite averages of free-fat values following storage showed that the samples stored at 70° F. (21.1° C.) exhibited the highest free-fat value. The experimental data of the free-fat and self-dispersion values and flavor scores for samples stored at 33° and 90° F. (0.6° and 32.2° C.) will be considered in the section devoted to statistical analysis.

Free-Fat

The initial free-fat values varied from 10.7 to 69.0 milligrams per gram of fat for powders with a fat content of 11 to 32 per cent. Following storage for six months, the values varied from 10.2 to 64.3 milligrams per gram of fat.

The experimental data show that the following processing variations resulted in an increase in the initial free-fat value.

1. Increased forewarming temperatures and/or holding time of the fluid milk. (Table 1)
2. Recombination of the concentrated skimmilk with cream or butteroil. (Table 2, trials 6 and 7)
3. Increased preheating temperature of the concentrated whole milk. (Table 3, trials 10 and 11)
4. Spray-drying with a large size nozzle. (Table 4, trials 13, 15, 16, and 17)
5. Treatment of the concentrated whole or skimmilk with a proteolytic enzyme. (Table 6, trials 20, 21, 22, 23, 24, and 25)
6. Homogenization of the fluid milk. (Table 8)

Though some processing variations resulted in an increase in the initial amount of free-fat, other processing variations were effective in reducing the amount of free-fat as compared to the control. These included:

1. Homogenization of the concentrated whole milk. (Table 3, trial 8)
2. Spray-drying with a small size nozzle. (Table 4, trial 14)

3. Spray-drying with reduced nozzle pressure. (Table 5, trial 18)
4. Treatment of the concentrated skimmilk with a proteolytic enzyme. (Table 6, trials 26 and 27)
5. Reduced fat content of the fluid milk. (Table 7)

Although the over-all change in free-fat values following storage was increased, a large number of samples showed a decrease. Those exhibiting a decrease received the following processing treatments:

1. Recombination of the concentrated skimmilk with cream. (Table 2, trial 5)
2. High temperature forewarming in conjunction with homogenization of the concentrated whole milk. (Table 3, trial 10)
3. High temperature preheating of the concentrated whole milk. (Table 3, trial 11)
4. Spray-drying with a large size nozzle. (Table 4, trials 13, 16, and 17)
5. Spray-drying with reduced nozzle pressure. (Table 5, trial 18)
6. Treatment of the concentrated whole or skimmilk with a proteolytic enzyme. (Table 6, trials 20, 21, 22, 23, 25, and 27)

Self-Dispersion

Initial self-dispersion values varied from 0.346 to 2.412 grams per 15 grams of powder. Following storage for six months, the values ranged from 0.325 to 0.851.

Incomplete experimental data on the initial self-dispersion values of a number of samples precludes a complete analysis. Increased heat treatment of the fluid or concentrated whole milk; i.e., increased temperature and/or holding time, resulted in slightly lower self-dispersion values. The effect of homogenization of the whole milk concentrate on the self-dispersion of the powder was not clearly defined.

Recombination of the concentrated skimmilk with cream or butteroil, or treatment of the concentrated skimmilk with a proteolytic enzyme, resulted in greater self-dispersion. This was particularly true when the concentrated skimmilk was treated with a proteolytic enzyme and recombined with butteroil. Reduction of the fat content or use of pasteurized homogenized fluid milk did not enhance the initial self-dispersion.

All powder samples decreased in self-dispersion during storage, with a few still exhibiting a relatively high value despite the decrease. These included samples with the following processing variations:

1. Homogenization of the concentrated whole milk. (Table 3, trial 8)

2. Spray-drying with a large size nozzle. (Table 4, trials 13 and 16)
3. Spray-drying with reduced nozzle pressure. (Table 5, trials 18 and 19)
4. Treatment of the concentrated skimmilk with a proteolytic enzyme. (Table 6, trial 26)

Flavor

Initial flavor scores of the reconstituted whole milk powder ranged from a high of 6.0 to a low of 3.5 on the hedonic scale. Following storage for six months, values ranged from 3.0 to 6.5.

Though the initial data on the flavor scores are not complete, the experimental data generally indicate that the samples manufactured with high heat treatment had a higher initial flavor score than the control. Other processing variations either did not produce any change in flavor or resulted in a lower flavor score.

As was expected, most of the samples decreased in flavor during storage. This was particularly true of those exhibiting a high initial flavor score; i.e., trials 11 and 12 in which the concentrated whole milk received a higher preheat treatment. A good proportion of the samples with reduced fat content maintained a relatively high flavor score following storage.

Whey-protein Nitrogen

Whey-protein nitrogen values varied from 3.5 to 8.5 milligrams per gram of powder and correlated with the fore-warming heat treatment of the fluid milk. Increased pre-heating temperature of the concentrated whole milk and increased inlet air temperature of the drier did not result in any appreciable change of whey-protein nitrogen values as compared to the controls. Similarly, homogenization of the concentrated whole milk, nozzle size, nozzle pressure, and treatment of the concentrated whole or skimmilk with a proteolytic enzyme resulted in no change in the whey-protein nitrogen values.

Specific Volume

Values ranged from 61.8 to 89 milliliters per 50 grams of powder. The lower values were observed in spray-drying with a large size nozzle or use of reduced nozzle pressure, particularly for low fat powders. Treatment of the concentrated whole or skimmilk with a proteolytic enzyme resulted in an increase of specific volume values except in the case where the treated concentrated skimmilk was recombined with butteroil.

Particle Size Distribution

Of the four distribution groups; i.e., 3.6 to 14, 15 to 36, 37 to 72, and greater than 72 microns, the 15 to 36

micron group generally contained the largest percentage of particles.

The effect of the processing variations on the particle size distribution was not clearly defined. Even in samples spray-dried with large or small size nozzles, the resulting particle size did not always correspond to the expected value.

Recombination of the concentrated skimmilk with cream or butteroil produced a powder with a greater percentage of large particles.

Statistical Analysis

The average values of free-fat, self-dispersion, and flavor scores as used in the analysis of variance are given in table 9.

No interaction between storage periods and processing variations on the free-fat values was found; i.e., storage at 70° F. (21.1° C.) had no effect on the free-fat regardless of the method of manufacture. There were significant differences, however, between the free-fat values and processing variations.

Samples of powder stored at 70° and 90° F. (21.1° and 32.2° C.) had significantly greater amounts of free-fat than those stored at 33° F. (0.6° C.). There was no significant difference in free-fat for samples stored at 70° and 90° F. (21.1° and 32.2° C.).

No interaction between storage periods and processing variations on the self-dispersion values was found. There were significant differences between self-dispersion values and processing variations, and between the fresh and stored samples. There was no significant difference for storage at three and six months.

There was a significant difference in self-dispersion values for samples stored at 33° and 70° F. (0.6° and 21.1° C.) and 70° and 90° F. (21.1° and 32.2° C.), while there was no difference between those stored at 33° and 90° F. (0.6° and 32.2° C.).

There was no correlation between the quantity of free-fat and self-dispersion values when fresh or following storage at 70° F. (21.1° C.) for six months.

No interaction between storage periods and processing variations on the flavor scores was found. Also, there were no significant differences between samples due to processing variations. A significant difference between the fresh and stored flavor scores was found although there was no significant difference between the third and sixth month.

There were no significant differences in flavor scores for samples stored at 33° and 70° F. (0.6° and 21.1° C.). There were significant differences in flavor scores for samples stored at 33° and 90° F. (0.6° and 32.2° C.), and for those stored at 70° and 90° F. (21.1° and 32.2° C.).

There was no correlation between the quantity of free-fat and the flavor scores when fresh or following storage at 70° F. (21.1° C.) for six months.

TABLE 1

The effect of forewarming temperatures and/or holding time on the free-fat, self-dispersion, and flavor of whole milk powder

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
1. Forewarming			
a) Forewarmed to 160° F. for 20 seconds (Average of samples 1, 9c, 10c, 11c, and 13c)	1	27 - 28	33 70 90
b) Forewarmed to 240° F. for 20 seconds (Average of samples 2 and 12c)	2	28 - 29	33 70 90
c) Forewarmed to 300-305° F. for 20 seconds (Sample 15c)	3	27	33 70 90
d) Forewarmed in hotwell at 185° F. for 15 to 20 minutes (Average of samples 5 and 8c)	4	28 - 30	33 70 90

TABLE 1 (continued)

	Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
	Storage period (months)											
	Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
		19.2	22.7	22.9		0.667	0.637	0.681		4.1	3.8	3.7
a)	18.7	20.6	21.3	21.8	0.809	0.698	0.600	0.605	4.7	4.7	3.6	3.4
		21.0	23.4	21.5		0.660	0.630	0.646		4.4	3.6	3.2
		24.0	23.3	23.0		0.714	0.731	0.644		4.8	5.0	4.0
b)	23.5	25.0	23.5	23.8	0.987	0.708	0.699	0.707	5.4	4.7	4.7	4.2
		24.8	24.2	24.6		2.228	0.662	0.637		4.8	4.4	4.4
		24.4	27.1	26.8		0.481	0.508	0.625		4.0	4.3	3.7
c)	26.1	23.8	28.3	27.0	0.743	0.487	0.469	0.538	5.5	4.2	3.7	3.0
		24.0	27.7	26.6		0.497	0.357	0.389		3.8	2.3	3.0
		23.0	29.1	26.4		0.619	0.663	0.669		4.7	4.9	5.7
d)	27.7	28.7	26.4	28.5	0.643	0.558	0.593	0.541	--	3.6	4.0	5.0
		29.4	30.3	29.6		0.835	0.443	0.469		3.8	4.1	5.4

TABLE 2

The effect of recombination of concentrated skimmilk with cream or butteroil on the free-fat, self-dispersion, and flavor of whole milk powder

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
2. Recombination			
a) Concentrated skimmilk recombined with cream (Sample 25c)	5	26	33 70 90
b) Concentrated skimmilk recombined with cream - reduced fat content (Sample 18c)	6	20	33 70 90
c) Concentrated skimmilk recombined with fresh butteroil (Sample 26c)	7	32	33 70 90

TABLE 2 (continued)

	Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
	Storage period (months)											
	Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
		21.6	24.3	24.7		0.755	0.606	0.611		4.2	4.0	4.0
a)	32.4	32.3	32.4	31.2	0.910	0.768	0.695	0.627	4.5	4.0	4.8	4.3
		29.6	34.3	33.9		0.704	0.558	0.481		4.4	3.3	4.3
		16.5	15.3	15.8		0.683	0.497	0.426		4.3	3.6	4.0
b)	13.3	17.5	21.5	15.7	1.628	0.621	0.393	0.367	4.4	4.7	3.8	4.7
		18.8	18.5	17.2		0.544	0.498	0.403		4.3	3.6	3.5
		26.6	26.2	--		0.793	0.684	--		5.0	3.8	--
c)	27.0	28.8	27.4	--	0.980	0.685	0.626	--	5.0	4.8	3.5	--
		28.4	27.5	--		0.670	0.563	--		4.8	4.3	--

TABLE 3

The effect of treating the concentrated whole milk on the free-fat, self-dispersion, and flavor of whole milk powder

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
3. Treatment of the Concentrated Whole Milk			
a) Concentrate heated to 150 - 155° F. and homogenized at 2500 and 500 p.s.i. (Average of samples 9 and 10)	8	28	33 70 90
b) Concentrate heated to 160° F. and homogenized twice at 2500 and 500 p.s.i. (Sample 11)	9	28	33 70 90
c) Fluid milk forewarmed to 240° F. for 20 seconds, concentrate heated to 155° F. and homogenized at 2500 and 500 p.s.i. (Sample 12)	10	28	33 70 90
d) Concentrate heated to 185° F. (Sample 13)	11	28	33 70 90
e) Fluid milk forewarmed to 300 - 305° F. for 20 seconds, concentrate heated to 183° F. (Sample 15)	12	28	33 70 90

TABLE 3 (continued)

	Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
	Storage period (months)											
	Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
		19.6	18.7	18.8		0.886	0.804	0.851		4.9	3.1	3.7
a)	17.9	18.2	17.5	17.9	0.928	0.920	0.796	0.797	4.5	5.0	3.6	4.1
		18.6	18.9	18.2		0.882	0.793	0.850		4.2	3.7	3.5
		19.3	20.0	20.6		0.692	0.628	0.854		4.2	4.6	4.5
b)	19.7	18.8	20.6	19.9	0.689	0.561	0.638	0.704	4.5	5.0	3.8	3.7
		20.0	19.2	19.8		0.716	0.651	0.748		5.0	4.0	4.0
		24.8	26.2	25.2		0.557	0.632	0.657		5.2	5.0	--
c)	29.0	26.2	26.1	23.4	0.716	0.587	0.707	0.596	5.6	3.8	4.8	--
		27.0	26.6	25.0		0.618	0.630	0.619		3.8	4.2	--
		23.8	23.8	20.9		0.632	0.658	0.668		4.0	4.3	3.0
d)	26.3	24.0	23.6	24.1	0.788	0.620	0.597	0.716	6.0	4.4	3.3	3.0
		25.1	24.1	24.7		0.609	0.601	0.646		4.0	2.8	2.7
		26.4	27.5	29.4		0.576	0.663	0.608		3.6	4.6	3.7
e)	25.7	26.0	29.0	28.8	0.734	0.610	0.593	0.453	6.0	3.8	3.0	3.3
		26.4	27.7	31.2		0.533	0.509	0.379	.	4.0	3.0	2.3

TABLE 4

The effect of nozzle size on the free-fat, self-dispersion, and flavor of whole milk powder

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
4. Nozzle size			
a) Large nozzle (No. $\frac{1}{4}$SBC5) with nozzle pressure of 600 p.s.i. (Sample 17)	13	22	33 70 90
b) Small nozzle (No. 72/17) with nozzle pressure of 1000 p.s.i.; using concentrated pasteurized homogenized milk (Sample 23)	14	23	33 70 90
c) Large nozzle (No. $\frac{1}{4}$SBC5) with nozzle pressure of 1500 p.s.i.; using concentrated skimmilk recombined with cream (Sample 6)	15	22	33 70 90
d) Large nozzle (No. $\frac{1}{4}$SBC5) with nozzle pressure of 1000 p.s.i.; using concentrated skimmilk recombined with cream (Sample 7)	16	11	33 70 90
e) Large nozzle (No. 63/425) with nozzle pressure of 2200 p.s.i., fluid milk forewarmed to 185° F. for 15 to 20 minutes (Sample 8)	17	28	33 70 90

TABLE 4 (continued)

	Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
	Storage period (months)											
	Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
		10.3	14.9	13.6		0.884	0.808	0.746		4.2	4.0	4.2
a)	14.4	14.0	15.7	12.9	0.822	0.766	0.565	0.745	4.0	4.2	4.5	4.0
		14.8	14.3	15.0		0.757	0.746	0.672		4.4	3.5	3.8
		63.0	61.6	53.7		0.452	0.491	0.456		3.6	4.3	4.0
b)	22.3	60.6	65.6	60.7	0.944	0.445	0.407	0.440	3.8	3.8	3.7	3.5
		58.0	60.7	48.5		0.385	0.367	0.359		3.6	3.3	3.7
		51.0	52.7	54.0		0.682	0.689	0.686		5.4	5.8	6.0
c)	49.0	53.7	56.8	58.4	--	0.709	0.629	0.637	--	4.8	5.5	6.0
		54.7	58.3	60.8		0.982	0.576	0.612		3.6	3.0	4.0
		16.6	18.5	19.5		0.783	0.892	0.686		5.2	5.0	6.0
d)	22.5	16.0	20.7	18.8	--	0.820	0.797	0.834	--	5.2	5.7	6.5
		17.7	20.4	19.4		0.876	0.845	0.837		3.4	3.5	3.5
		41.4	50.3	46.2		0.562	0.426	0.550		4.4	4.6	5.4
e)	69.0	58.5	61.5	64.3	--	0.543	0.420	0.353	--	4.4	6.0	4.7
		52.0	63.9	61.5		0.805	0.346	0.393		3.8	5.6	3.7

TABLE 5

The effect of nozzle pressure on the free-fat, self-dispersion, and flavor of whole milk powder

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
5. <u>Nozzle pressure</u>			
a) Nozzle pressure of 500 p.s.i. (Sample 4)	18	19	33 70 90
b) Nozzle pressure of 1000 p.s.i., using concentrated skimmilk recombined with cream (Sample 18)	19	20	33 70 90

TABLE 5 (continued)

	Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
	Storage period (months)											
	Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
a)	10.7	10.4	9.9	10.2	--	0.989	0.964	1.036	--	4.8	4.2	3.2
		10.5	10.5	10.2		1.055	0.979	0.838		5.2	4.0	4.8
		9.5	11.0	10.5		1.099	1.052	1.211		4.4	3.3	3.8
b)	14.4	12.2	11.1	11.1	1.653	1.331	1.043	1.027	4.6	4.3	4.8	4.0
		14.1	14.4	14.6		1.251	0.953	0.851		5.7	4.8	4.3
		14.7	15.1	12.9		1.525	0.815	0.887		5.3	4.4	4.5

TABLE 6

The effect of treatment of the concentrate with a proteolytic enzyme mixture on the free-fat. self-dispersion, and flavor of whole milk powder

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
6. Treatment of the concentrate with a proteolytic enzyme (lactivase) mixture			
a) Concentrated pasteurized homogenized milk treated with proteolytic enzyme for 10 minutes (Sample 22)	20	26	33 70 90
b) Concentrated pasteurized homogenized milk treated with proteolytic enzyme for 5 minutes (Sample 24a)	21	28	33 70 90
c) Concentrated pasteurized homogenized milk treated with proteolytic enzyme for 10 minutes (Sample 24b)	22	28	33 70 90
d) Concentrated pasteurized homogenized milk treated with proteolytic enzyme for 15 minutes (Sample 24d)	23	28	33 70 90

TABLE 6 (continued)

	Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
	Storage period (months)											
	Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
a)	49.0	48.8	49.4	46.4	0.577	0.434	0.444	0.407	6.0	4.2	4.0	3.0
		48.3	45.7	49.7		0.383	0.342	0.325		4.0	3.8	3.7
		44.5	49.8	46.4		0.390	0.281	0.317		4.4	4.2	3.5
b)	19.2	18.6	--	--	0.416	0.230	--	--	4.5	4.3	--	--
		18.4	--	15.3		0.280	--	0.335		3.3	--	3.5
		17.8	--	17.4		0.218	--	0.312		3.7	--	3.7
c)	19.3	19.0	--	--	0.346	0.296	--	--	4.8	4.7	--	--
		17.5	--	16.1		0.315	--	0.368		3.7	--	3.7
		17.0	--	17.6		0.294	--	0.344		3.3	--	3.5
d)	18.7	17.9	--	17.7	0.379	0.372	--	0.379	4.3	4.7	--	3.8
		17.6	--	17.7		0.336	--	0.379		4.0	--	3.8
		19.1	--	17.4		0.249	--	0.309		4.0	--	4.0

TABLE 6 (Page 2)

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
6. Treatment of the concentrate with a proteolytic enzyme (lactivase) mixture (continued)			
e) Concentrated skimmilk treated with proteolytic enzyme for 5 minutes and recombined with cream (Sample 25a)	24	27	33 70 90
f) Concentrated skimmilk treated with proteolytic enzyme for 10 minutes and recombined with cream (Sample 25b)	25	28	33 70 90
g) Concentrated skimmilk treated with proteolytic enzyme for 5 minutes and recombined with fresh butteroil (Sample 26a)	26	31	33 70 90
h) Concentrated skimmilk treated with proteolytic enzyme for 15 minutes and recombined with fresh butteroil (Sample 26b)	27	32	33 70 90

TABLE 6 (continued)

Page 2.

	Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
	Storage period (months)											
	Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
e)	34.6	24.2	30.8	29.3	1.072	0.745	0.510	0.624	3.5	5.2	3.8	5.0
		33.0	38.8	40.9		0.673	0.625	0.485		4.8	4.3	4.8
		34.4	39.4	43.4		0.554	0.630	0.514		3.6	3.5	3.3
f)	40.3	21.6	29.4	30.9	0.967	0.751	0.630	0.487	4.3	4.2	4.3	5.5
		32.3	40.4	40.5		0.591	0.585	0.498		4.6	4.3	4.3
		29.6	41.5	43.0		0.689	0.537	0.588		4.2	4.5	2.8
g)	18.9	16.1	16.1	--	2.119	1.134	0.890	--	5.3	4.5	3.8	--
		20.8	20.6	--		1.301	0.796	--		5.3	3.5	--
		19.2	21.0	--		1.087	0.881	--		4.3	3.3	--
h)	23.6	19.2	18.3	--	2.412	0.978	0.807	--		4.0	3.8	--
		25.1	27.1	--		0.853	0.661	--		4.5	4.0	--
		26.4	26.8	--		0.892	0.773	--		4.3	3.5	

TABLE 7

The effect of composition on the free-fat, self-dispersion, and flavor of whole milk powder

Processing treatment	Trial number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
7. Composition			
Reduced fat content (Average of samples 3 and 17c)	28	17 - 18	33 70 90

TABLE 7 (continued)

Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
Storage period (months)											
Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
	13.7	13.0	13.6		0.746	0.686	0.564		4.1	4.6	3.6
11.9	12.8	13.1	12.7	0.763	0.707	0.630	0.537	5.0	3.7	3.9	3.7
	13.8	13.6	14.2		0.793	0.657	0.597		3.5	3.0	3.4

TABLE 8

The effect of homogenization conditions upon the free-fat, self-dispersion, and flavor of whole milk powder

Processing treatment	Trial Number	Fat content of whole milk powder (%)	Storage Temperature (°F.)
8. <u>Homogenization conditions</u>			
Pasteurized (HTST) homogenized milk (Average of samples 22c, 23c, and 24c)	29	26 - 27	33 70 90

TABLE 8 (continued)

Free-fat (mg./g. of fat)				Self-dispersion (g./15g. powder)				Flavor (hedonic rating)			
Storage period (months)											
Fresh	One	Three	Six	Fresh	One	Three	Six	Fresh	One	Three	Six
29.0	32.5	40.9	41.1	0.654	0.456	0.378	0.382	5.0	4.2	3.9	3.2
	32.1	40.5	31.0		0.418	0.259	0.372		3.7	3.2	3.4
	31.7	40.6	32.4		0.402	0.369	0.388		4.0	3.7	3.3

TABLE 9

Average values of free-fat, self-dispersion, and flavor scores used in the analysis of variance

Property	Storage Temperature (°F.)	Storage period (months) Fresh	One	Three	Six	Average of all Storage Periods*
Free-fat (mg./g. fat)	33 70 90	27.30	28.24	30.17	29.50	27.24 29.46 28.72
Self-dispersion (g./15g. powder)	33 70 90	0.858	0.635	0.570	0.562	0.667 0.624 0.656
Flavor (hedonic rating)	33 70 90	4.8	4.4	3.8	3.8	4.3 4.3 3.8

*Average of samples stored for one, three, and six months.

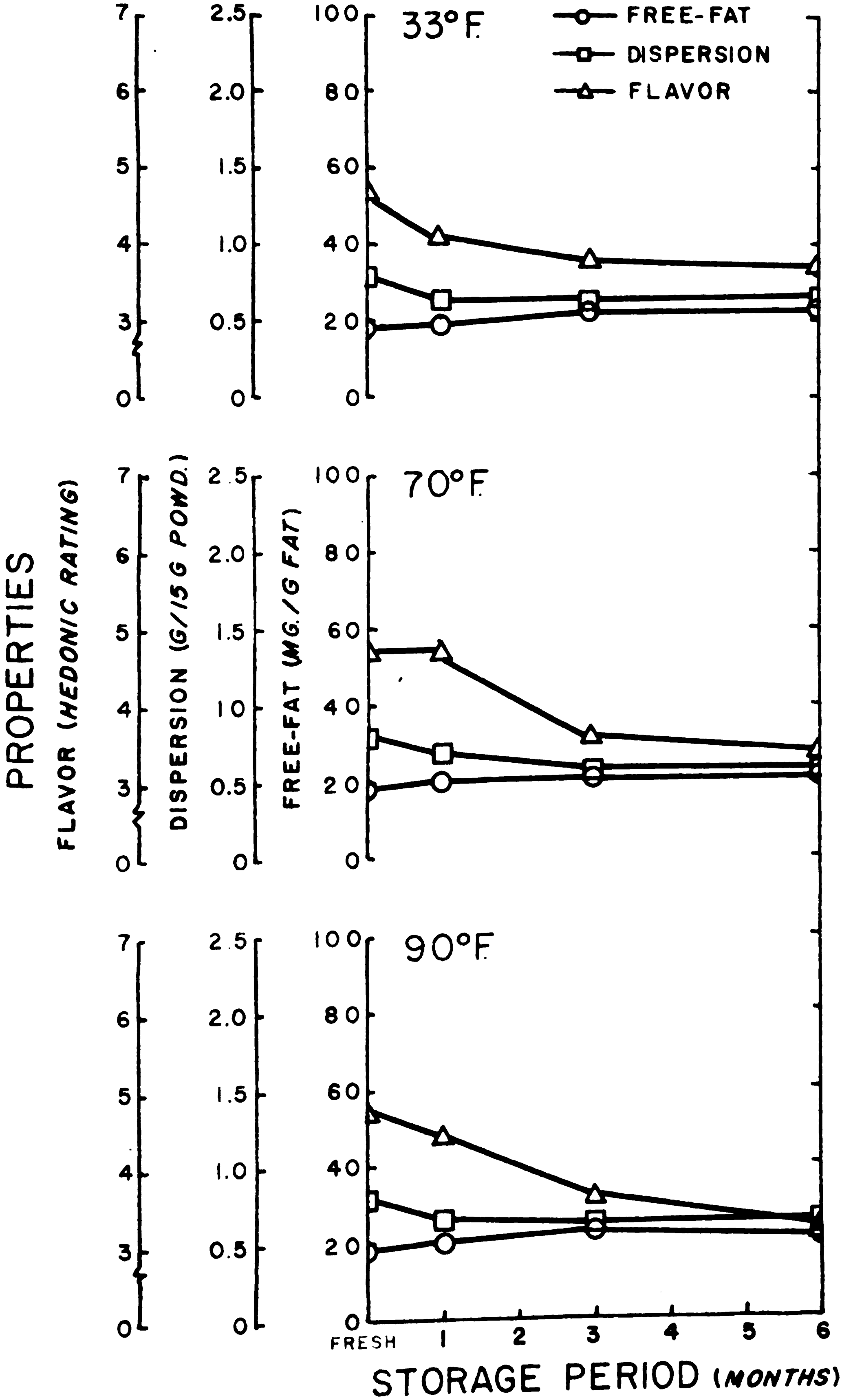


Figure 2. The effect of forewarming to 160° F. for 20 seconds on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 1, trial 1)

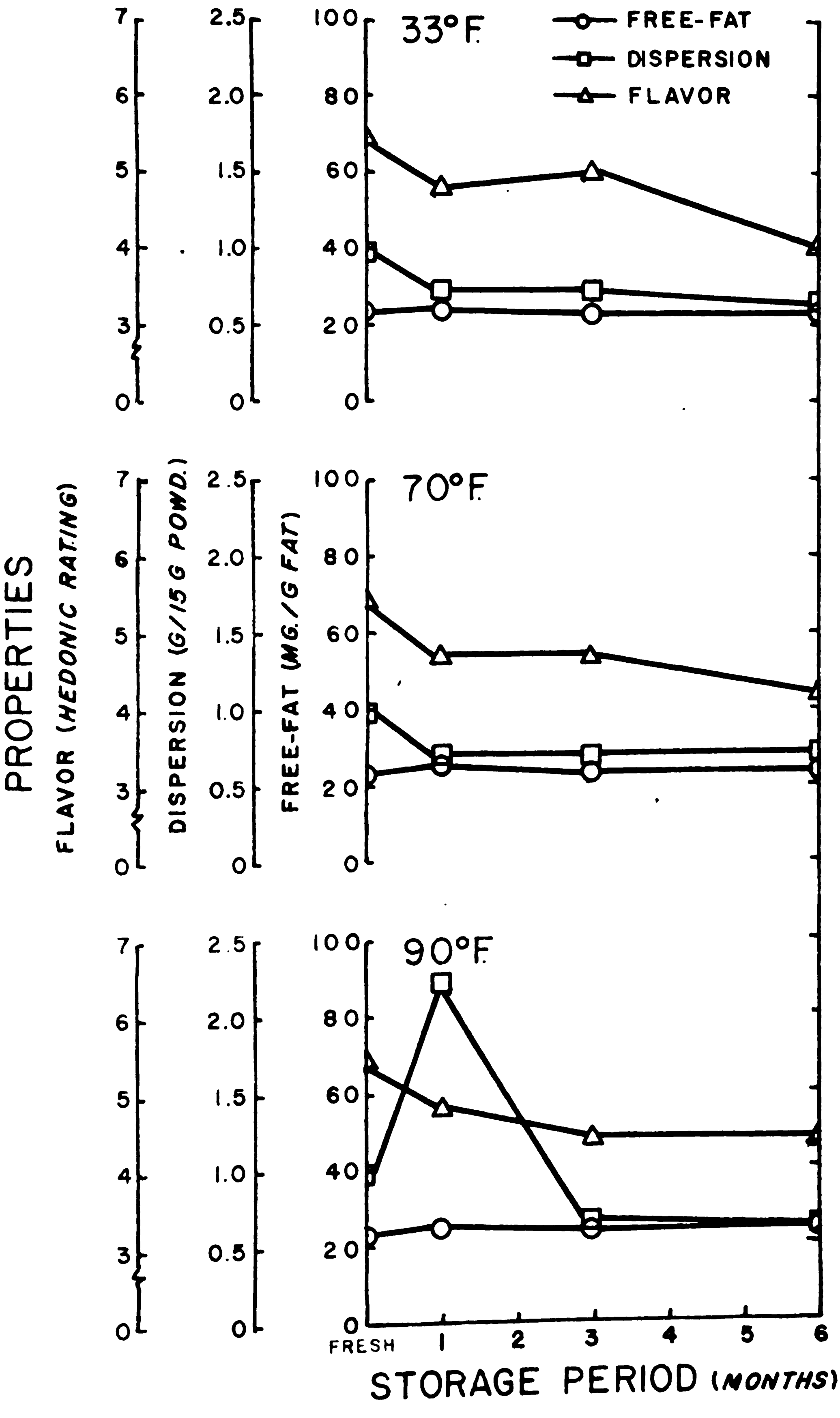


Figure 3. The effect of forewarming to 240° F. for 20 seconds on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 1, trial 2)

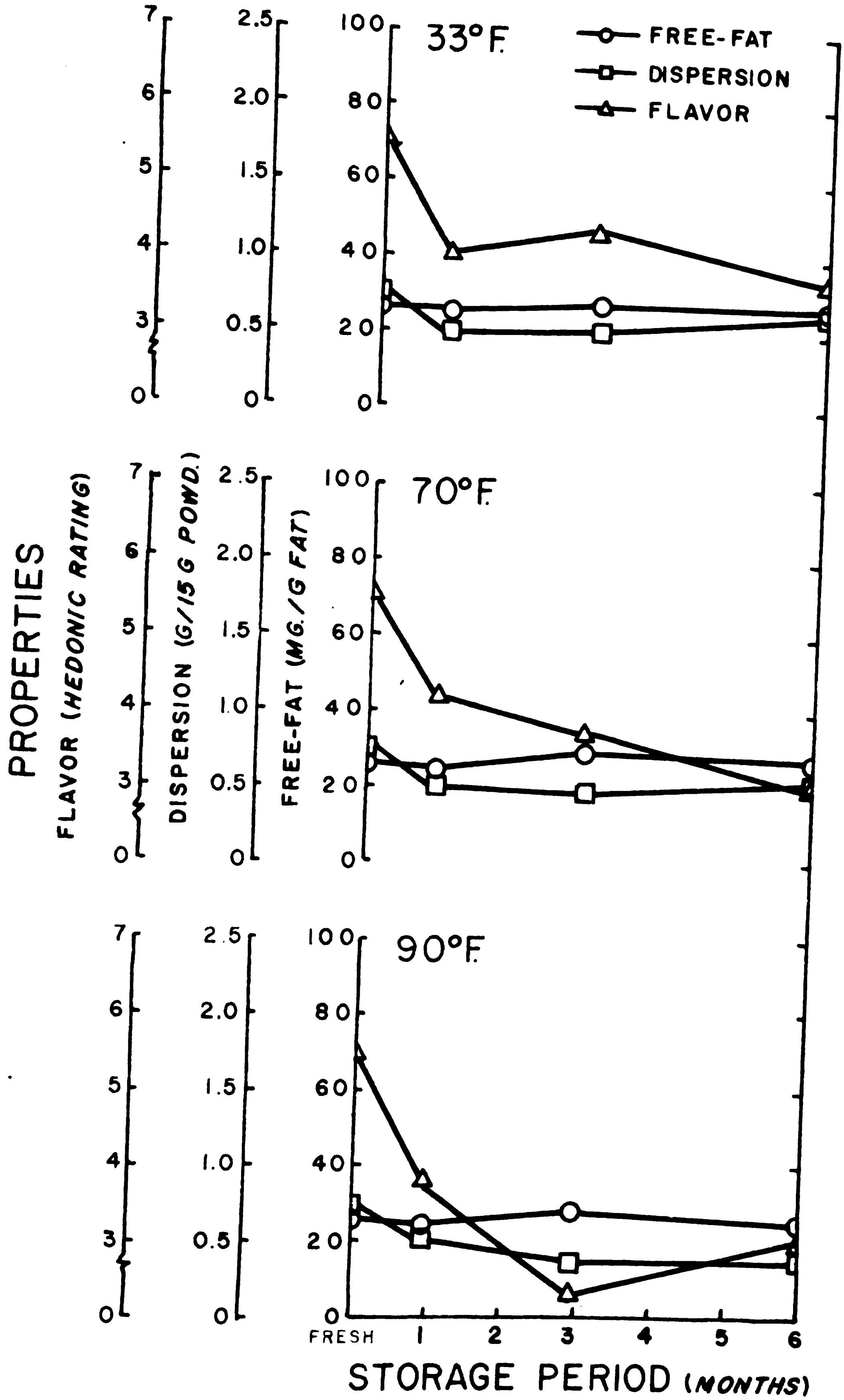
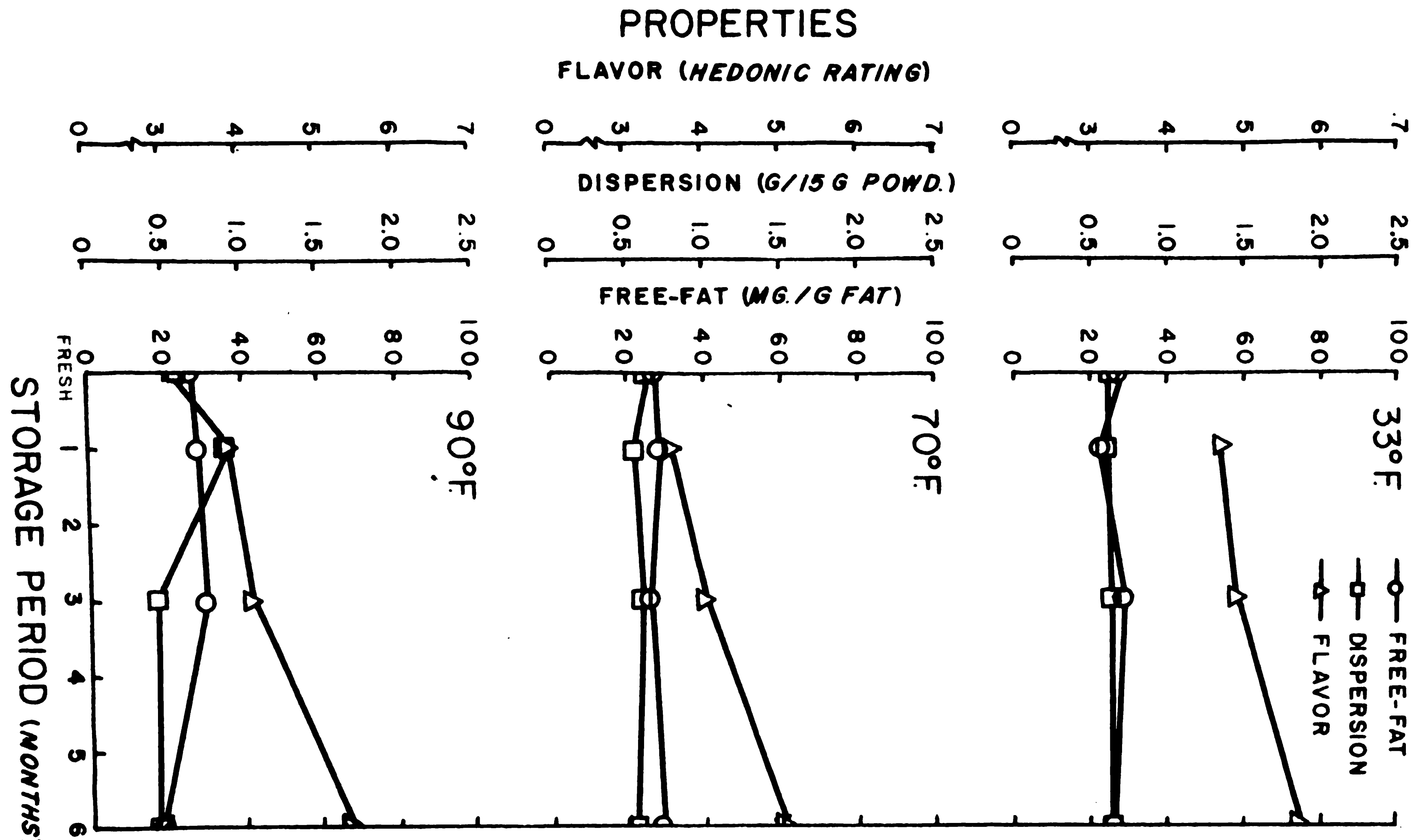


Figure 4. The effect of forewarming to 300-305° for 20 seconds on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 1, trial 3)

Figure 5. The effect of forewarming to 135° F. for 15 to 20 minutes in a hotwell on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 1, trial 4)



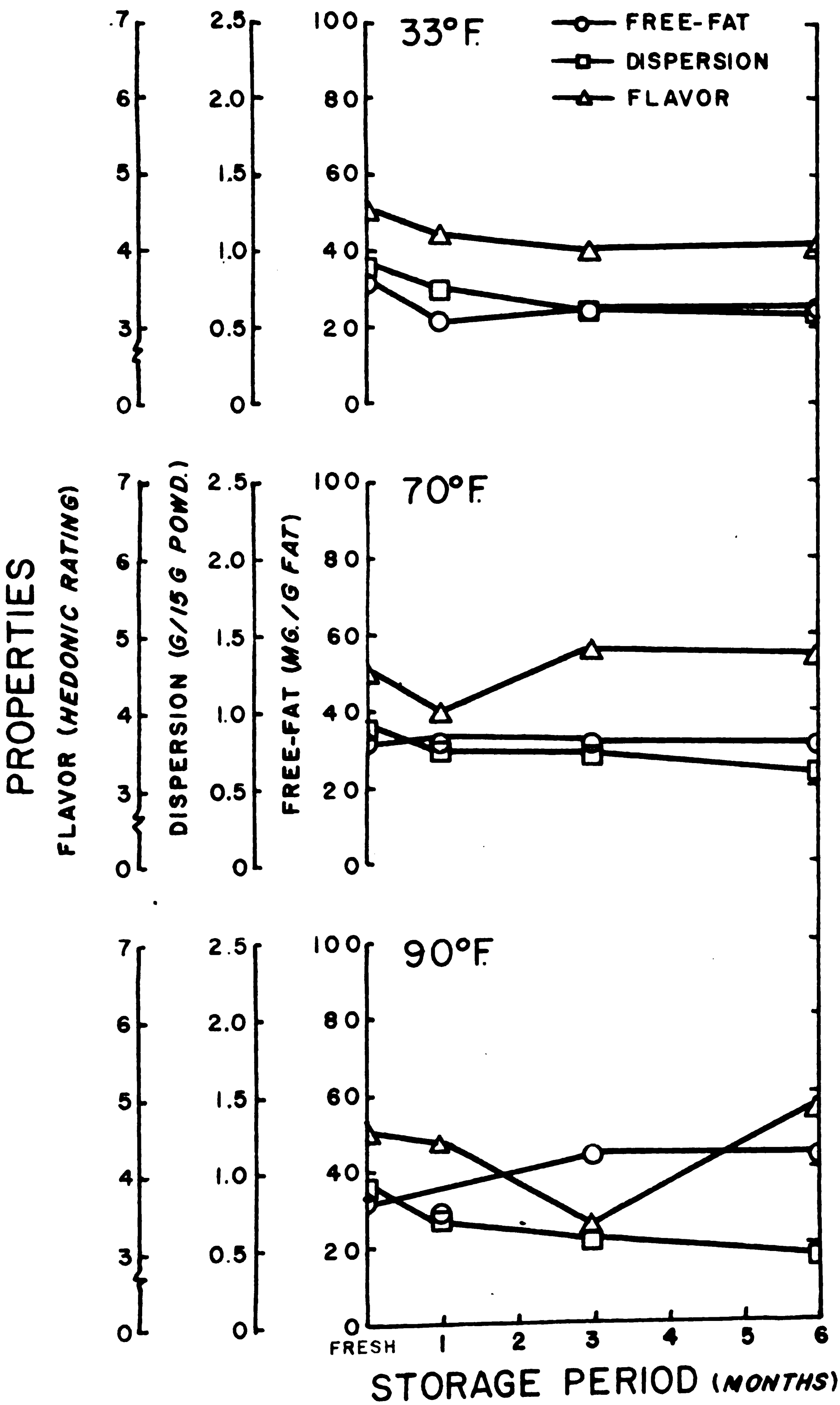


Figure 6. The effect of recombining concentrated skimmilk with cream on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 2, trial 5)

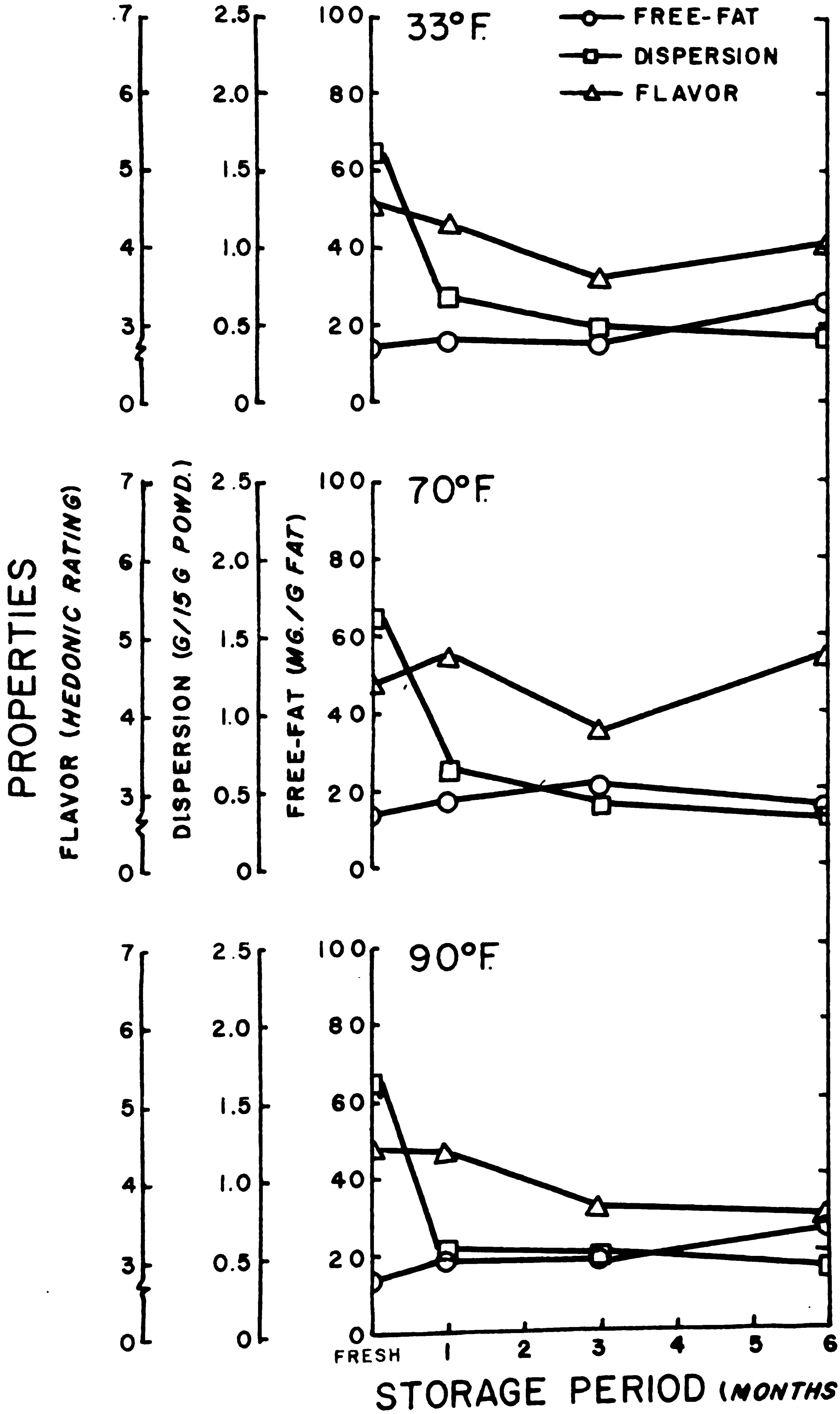


Figure 7. The effect of recombining concentrated skimmilk with cream (reduced fat content) on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 2, trial 6)

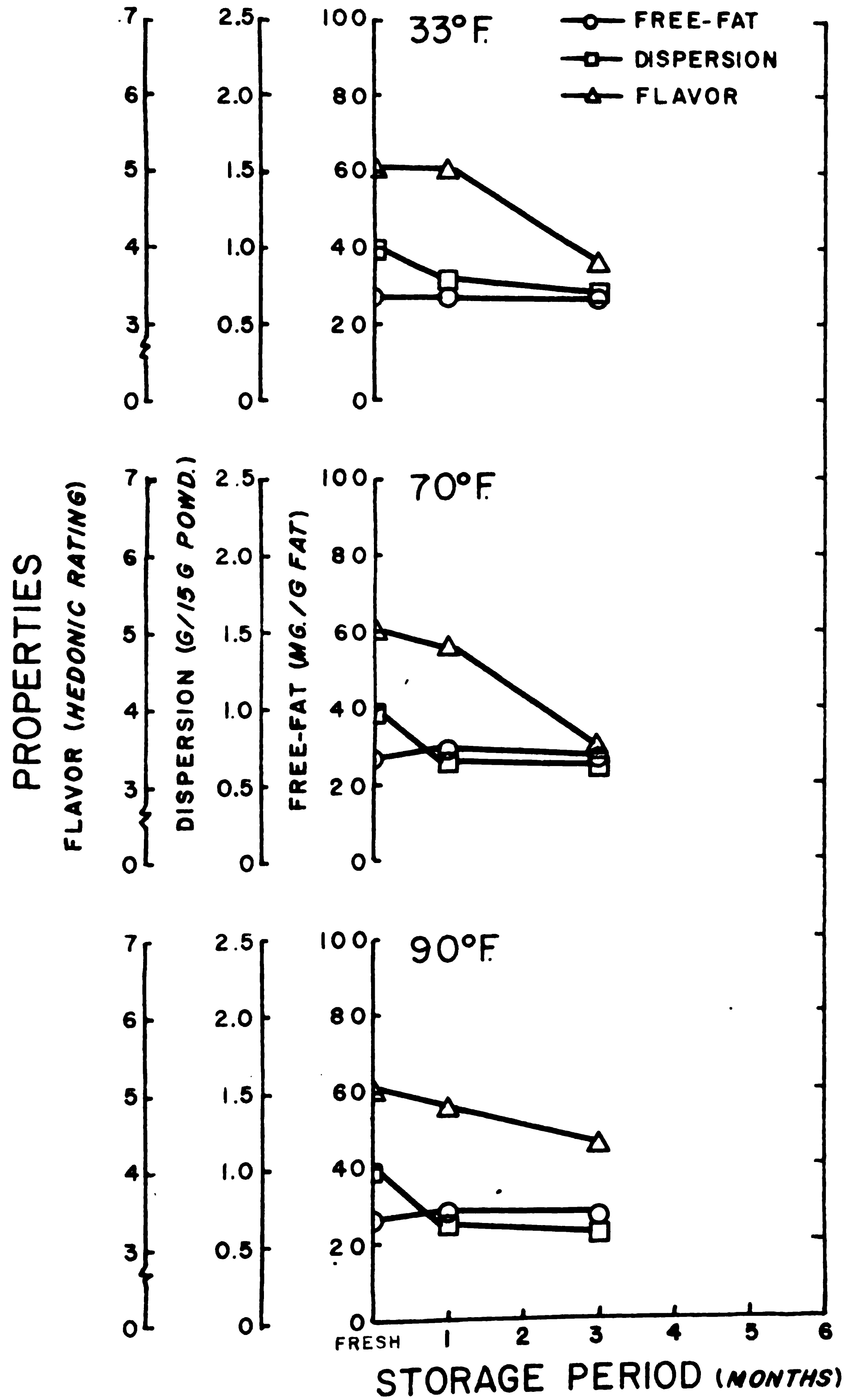


Figure 8. The effect of recombining concentrated skimmilk with fresh butteroil on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 2, trial 7)

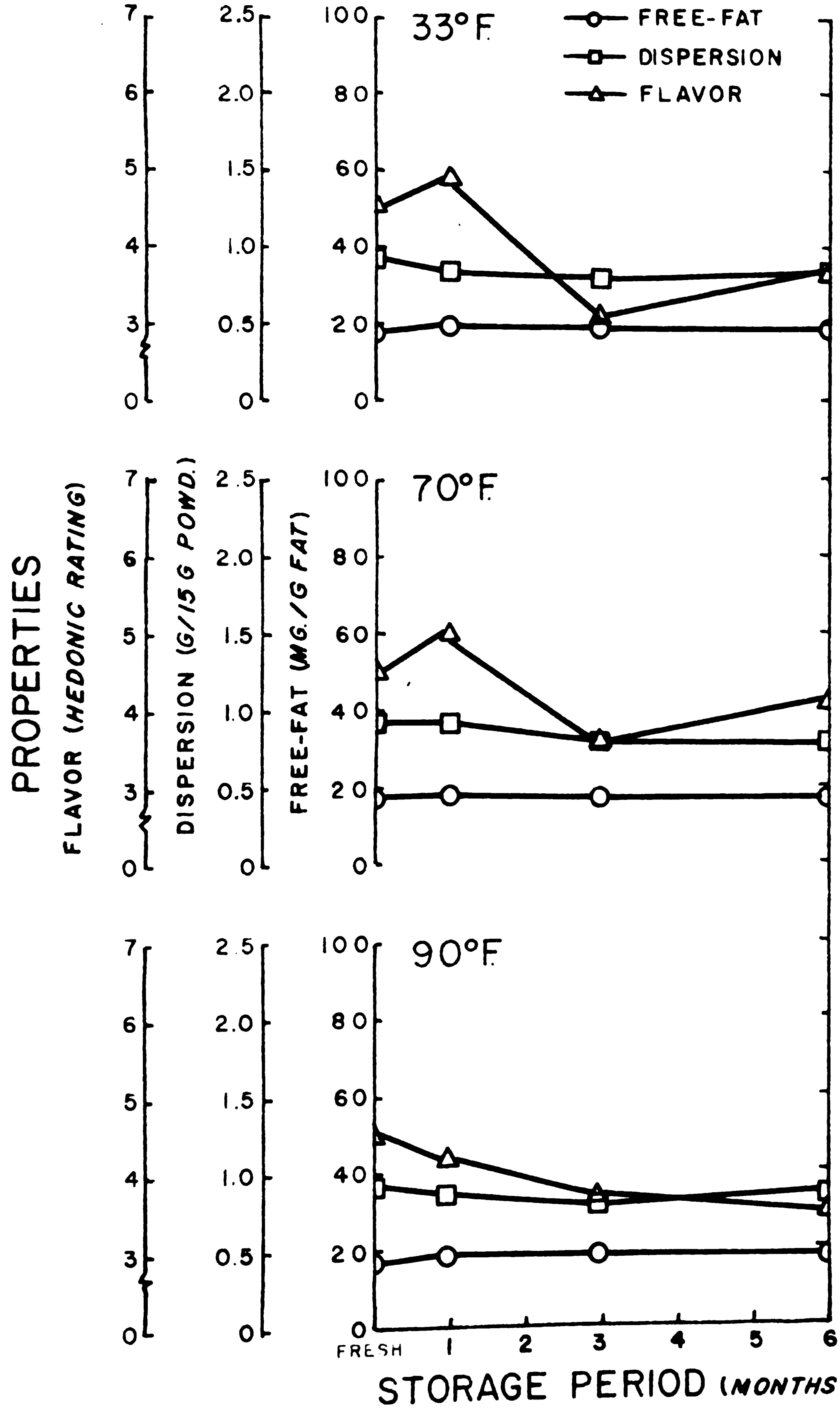


Figure 9. The effect of homogenization of the concentrated whole milk at 2500 and 500 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. Concentrate heated to 150-155° F. prior to homogenization. (See table 3, trial 8)

Figure 10. The effect of homogenizing the concentrated whole milk twice at 2500 and 500 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. Concentrate heated to 160° F. prior to homogenization. (See table 3, trial 9)

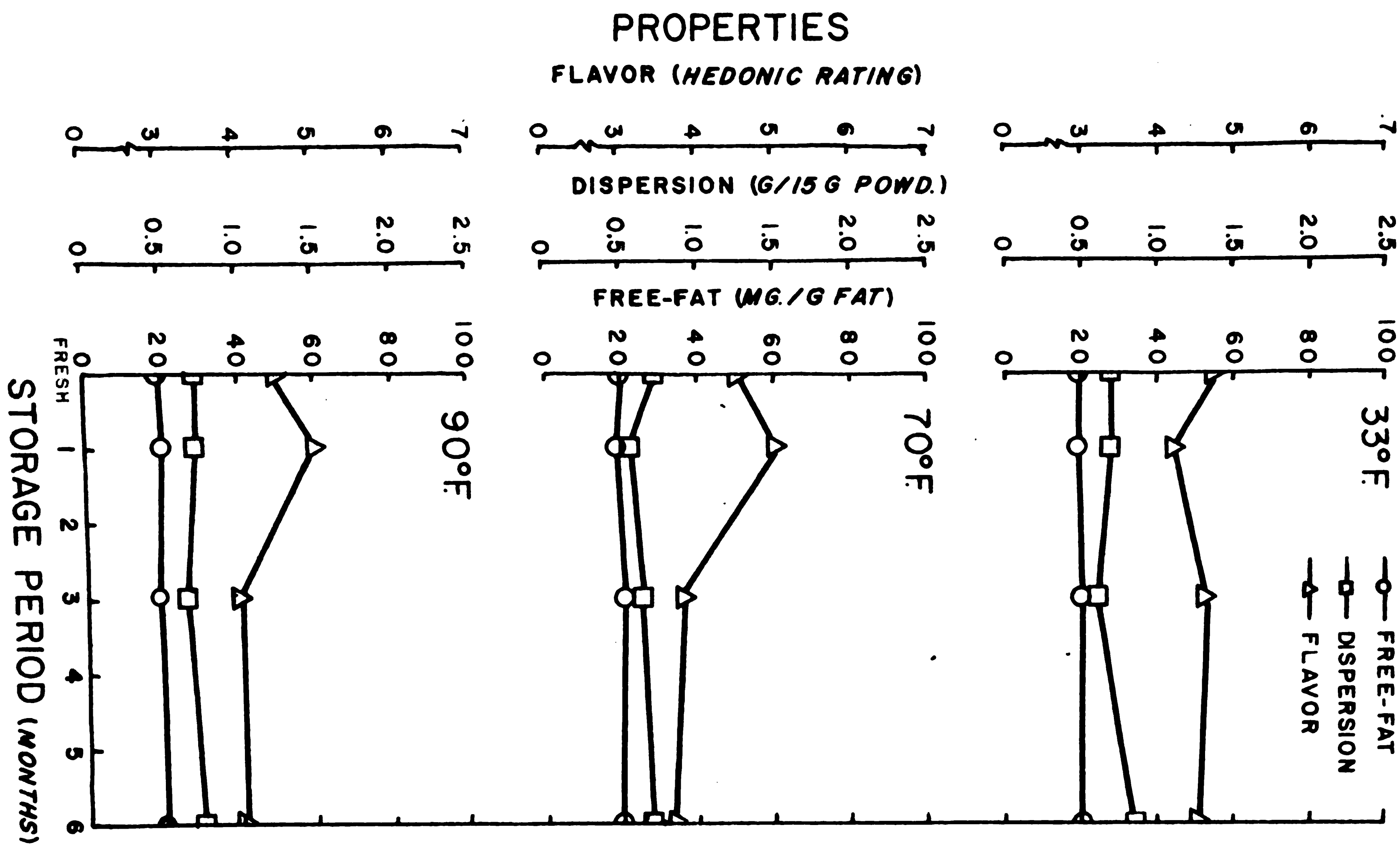
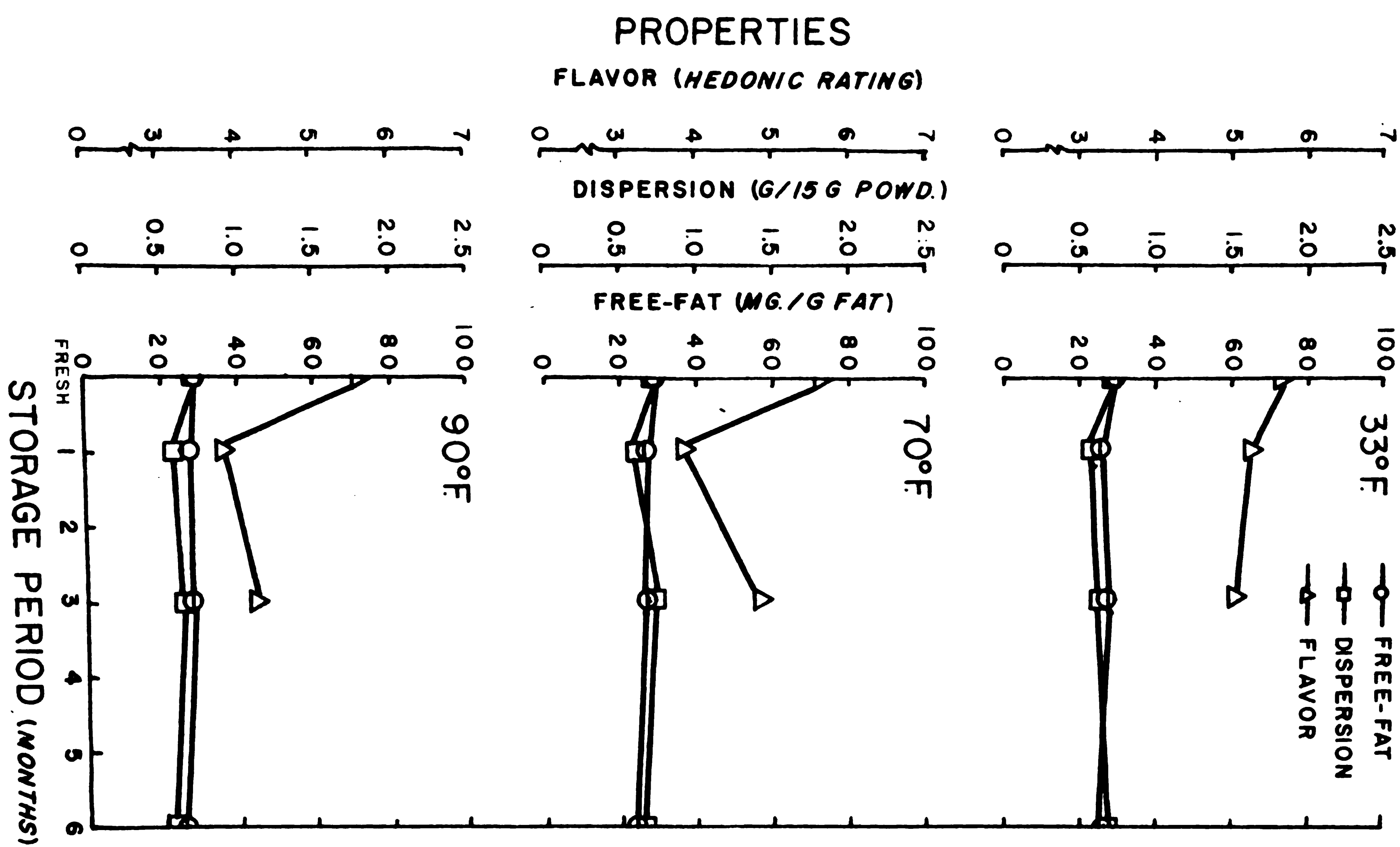


Figure 11. The effect of homogenizing the concentrated whole milk at [illegible] and 500 p.s.i. [illegible] milk powder. [illegible]

Figure 11. The effect of homogenizing the concentrated whole milk at 2500 and 500 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. Fluid milk forewarmed to 240° F. for 20 seconds, concentrate heated to 155° F. prior to homogenization. (See table 3, trial 10)



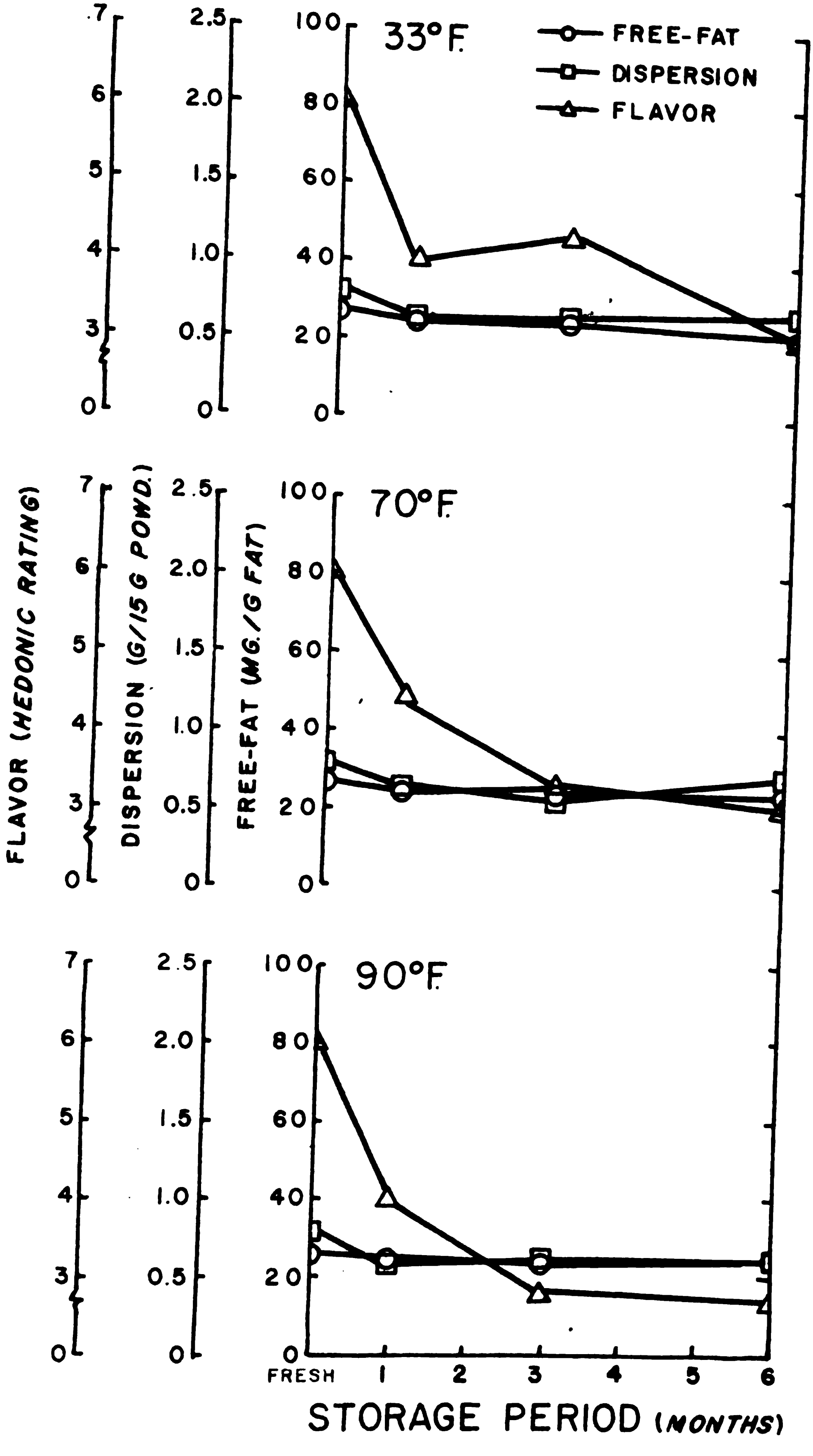


Figure 12. The effect of heating the concentrated whole milk to 185° F. on the 'free-fat, self-dispersion, and flavor of whole milk powder. (See table 3, trial 11)

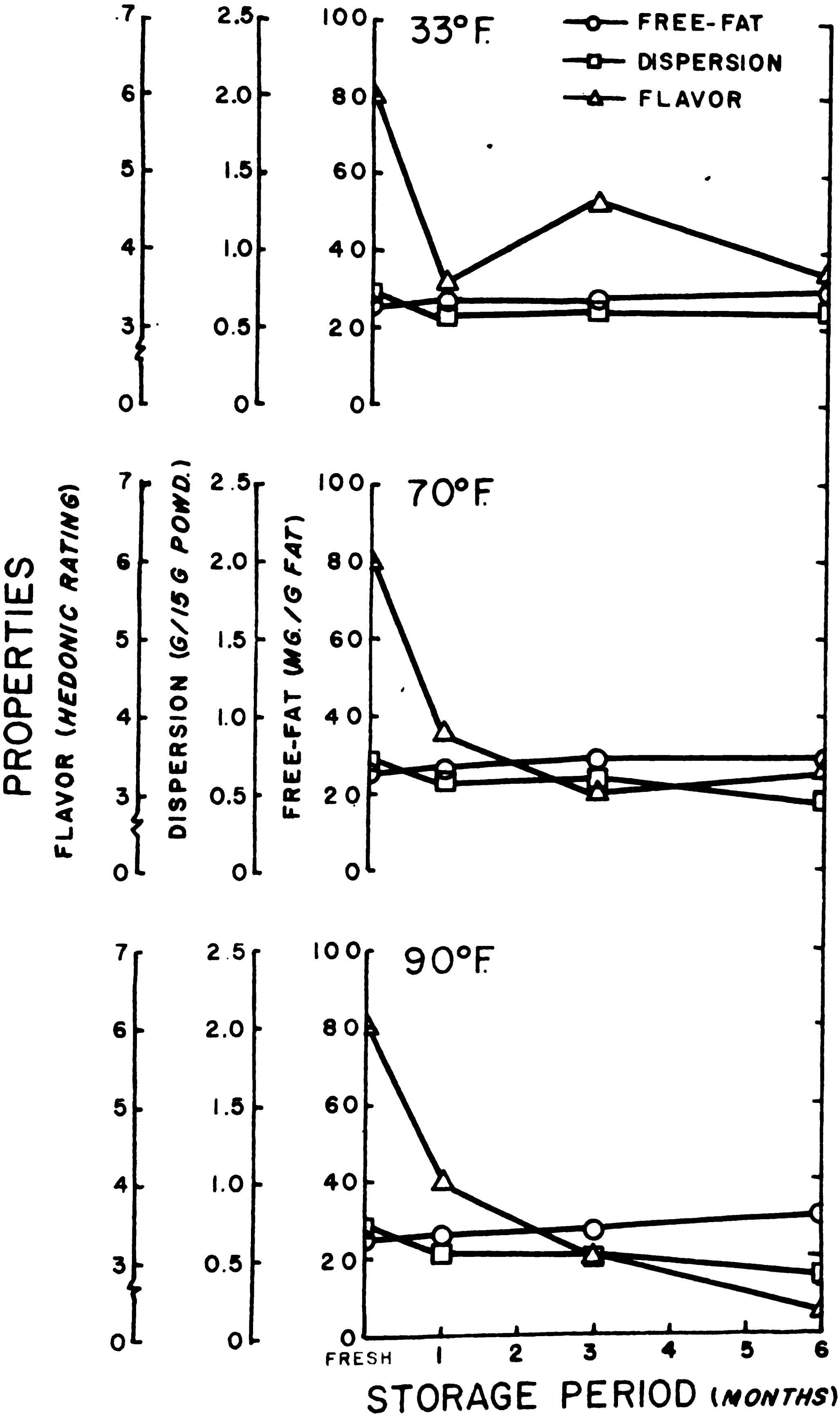


Figure 13. The effect of heating the concentrated whole milk to 183° F. on the free-fat, self-dispersion, and flavor of whole milk powder. Fluid milk forewarmed to 300-305° F. for 20 seconds. (See table 3, trial 12)

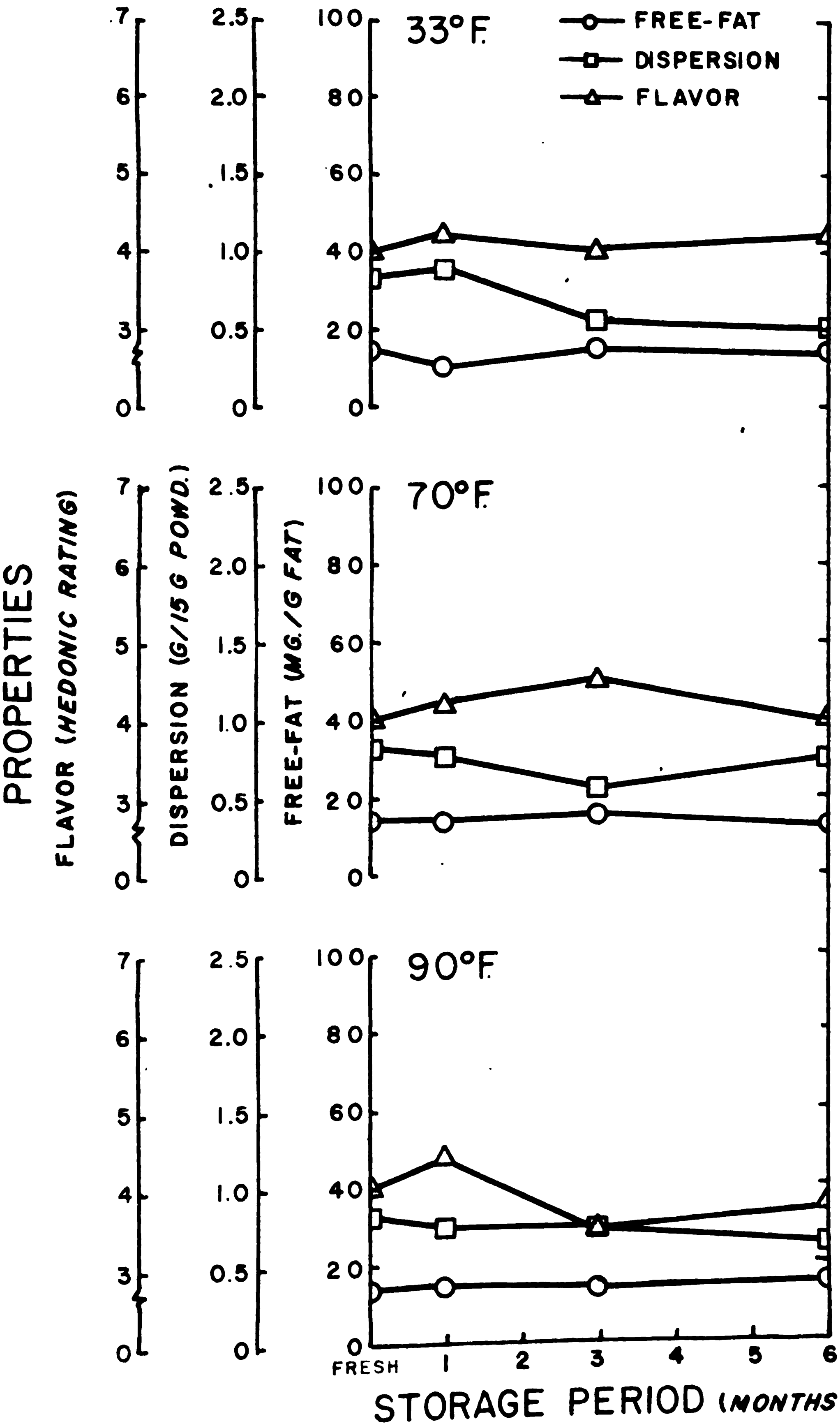


Figure 14. The effect of spray-drying with a large size nozzle (No. 1SBC5) at 600 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 4, trial 13)

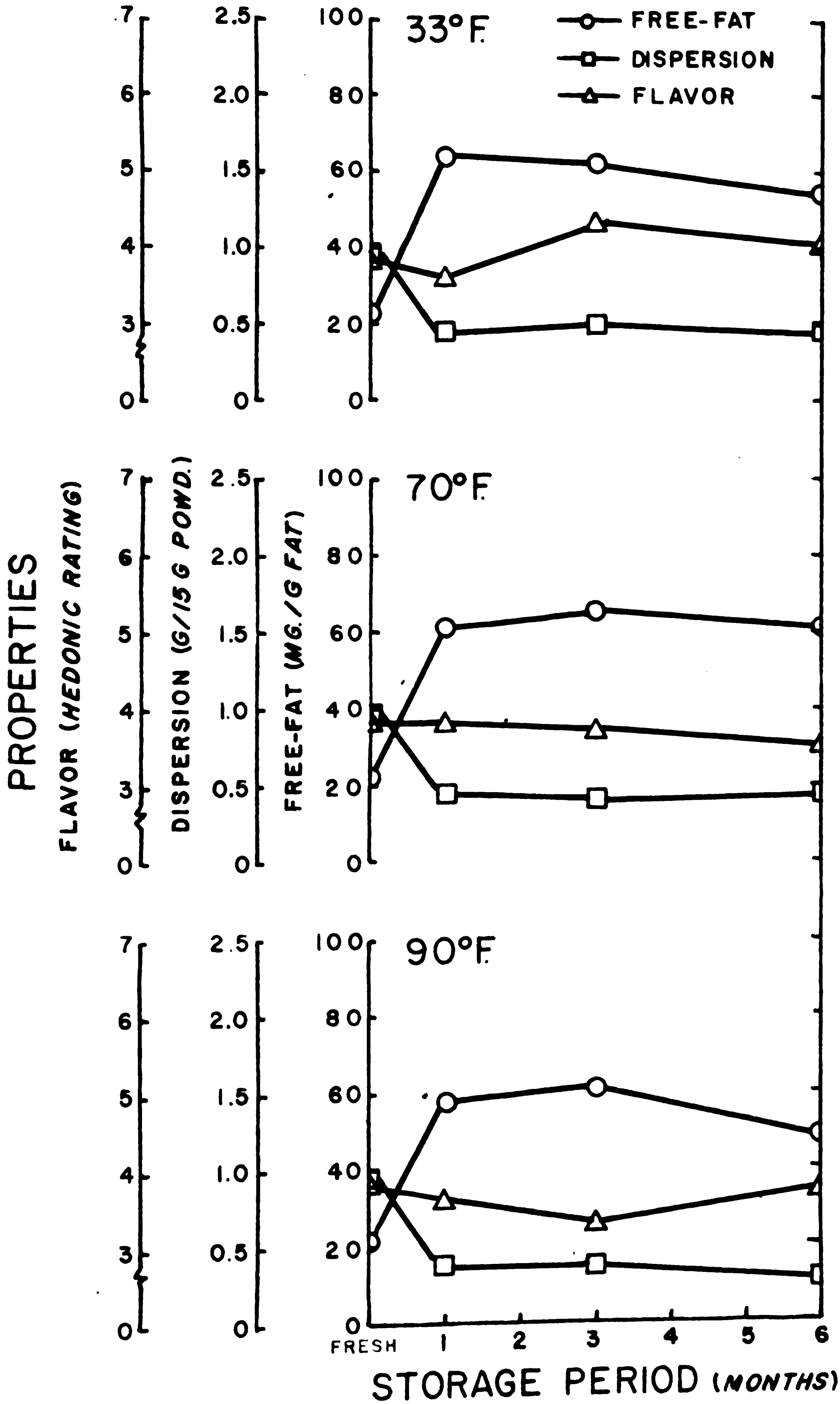


Figure 15. The effect of spray-drying concentrated pasteurized homogenized milk with a small size nozzle (No. 72/17) at 1000 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 4, trial 14)

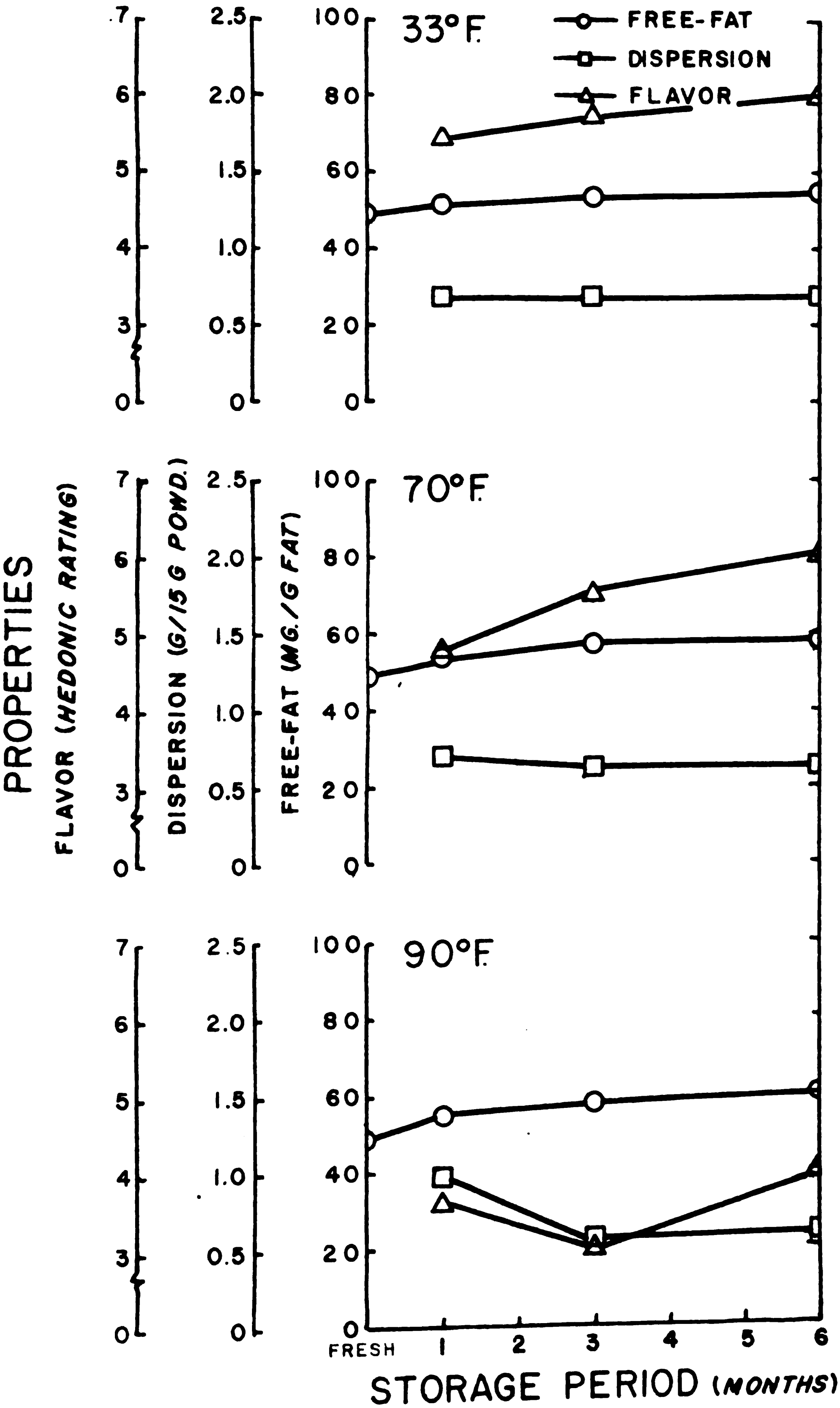


Figure 16. The effect of spray-drying concentrated skimmilk recombined with cream with a large size nozzle (No. ¼SBC5) at 1500 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 4, trial 15)

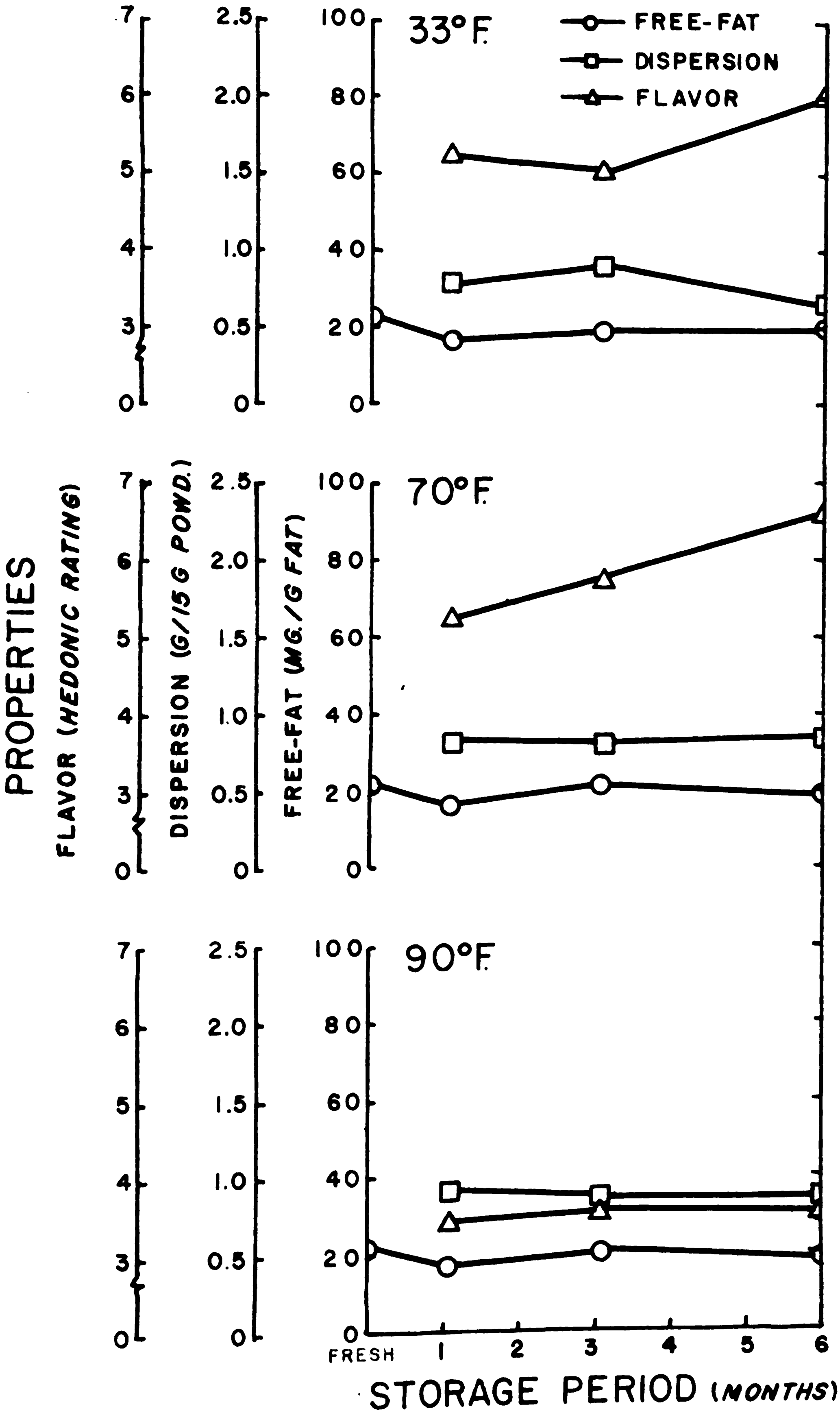


Figure 17. The effect of spray-drying concentrated skimmilk recombined with cream with a large size nozzle (No. 4SBC5) at 1000 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 4, trial 16)

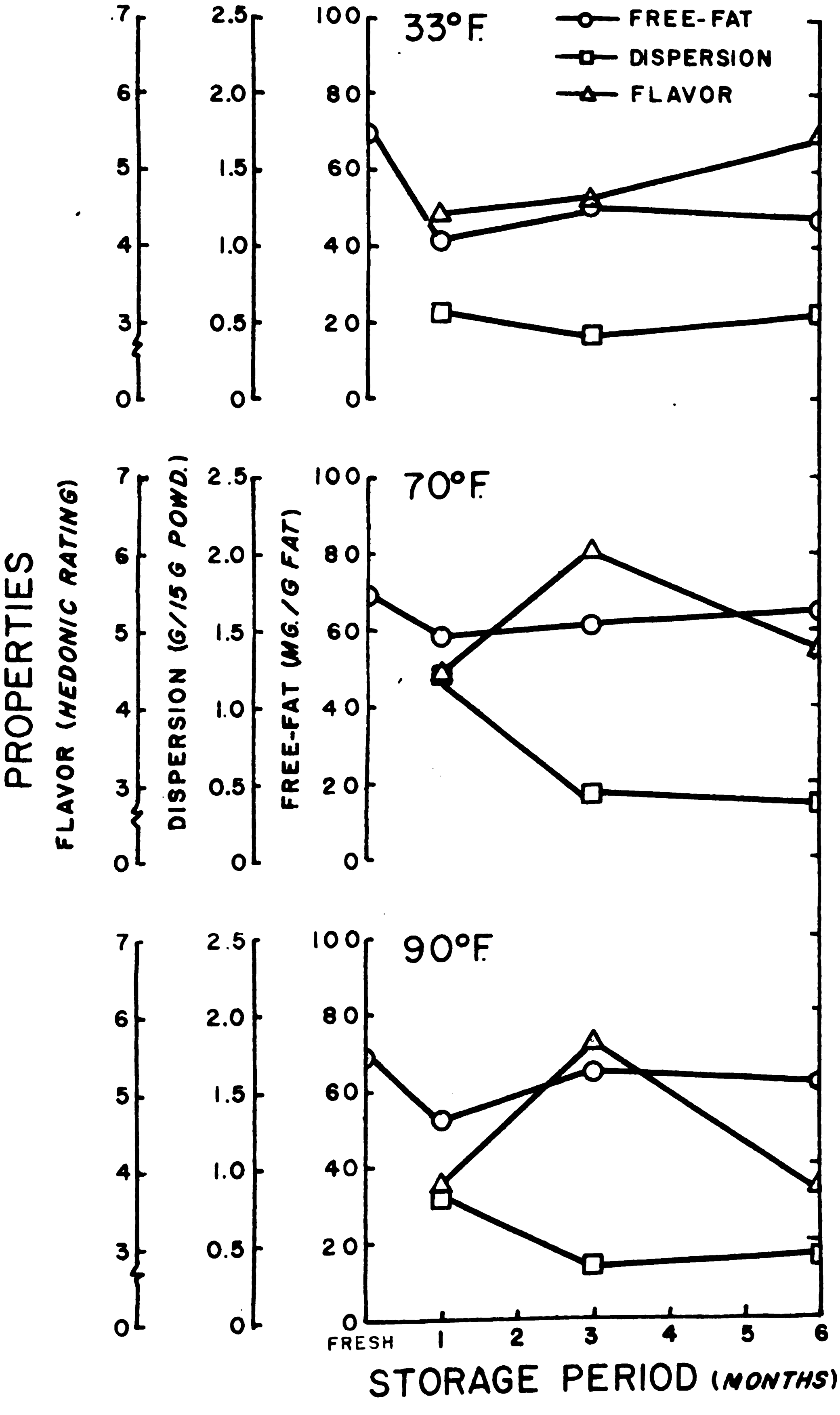


Figure 13. The effect of spray-drying concentrated whole milk with a large size nozzle (No. 63/425) at 2200 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. Fluid milk forewarmed to 135° F. for 15 to 20 minutes in a hotwell. (See table 4, trial 17)

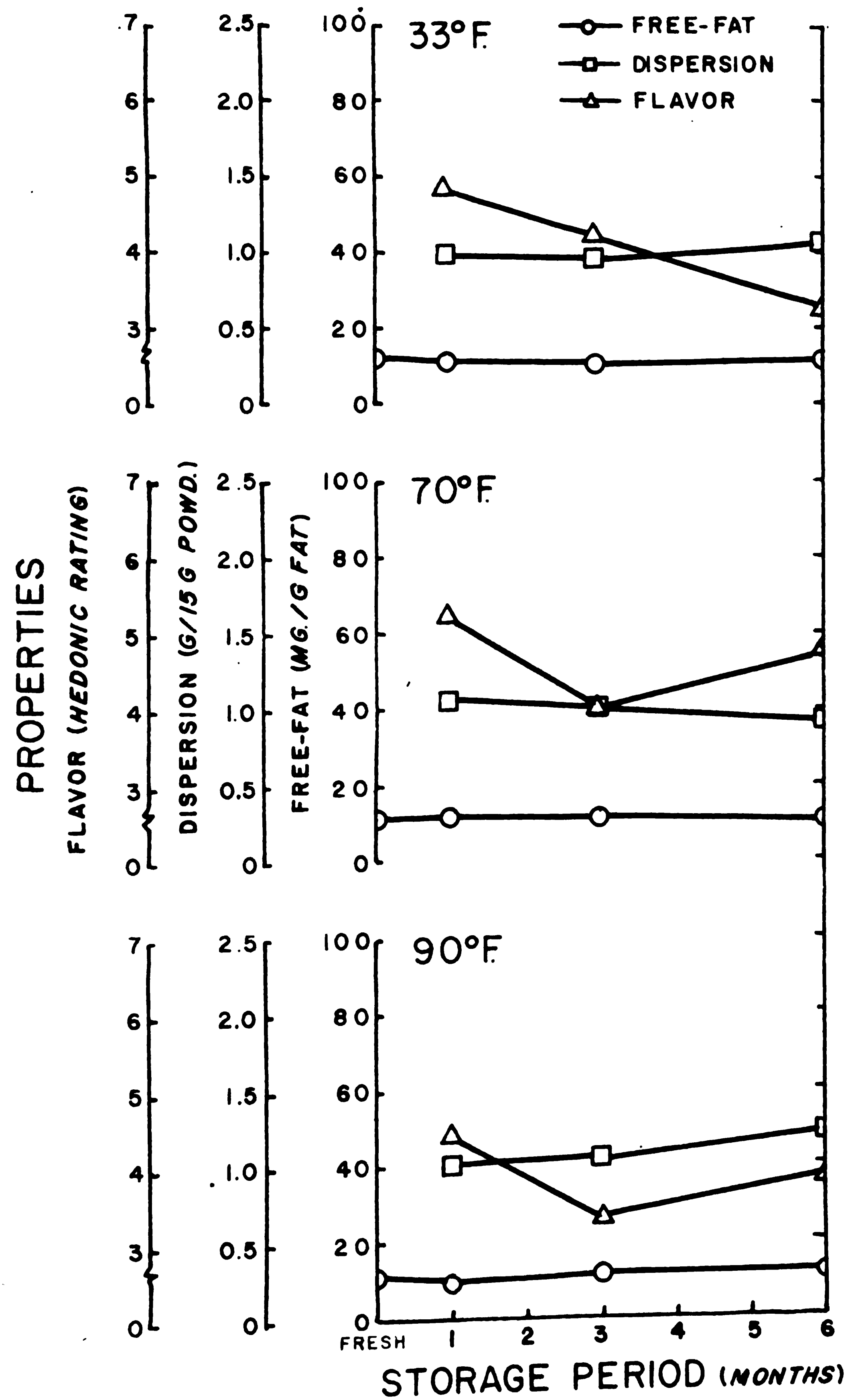


Figure 19. The effect of using reduced nozzle pressure (500 p.s.i.) on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 5, trial 18)

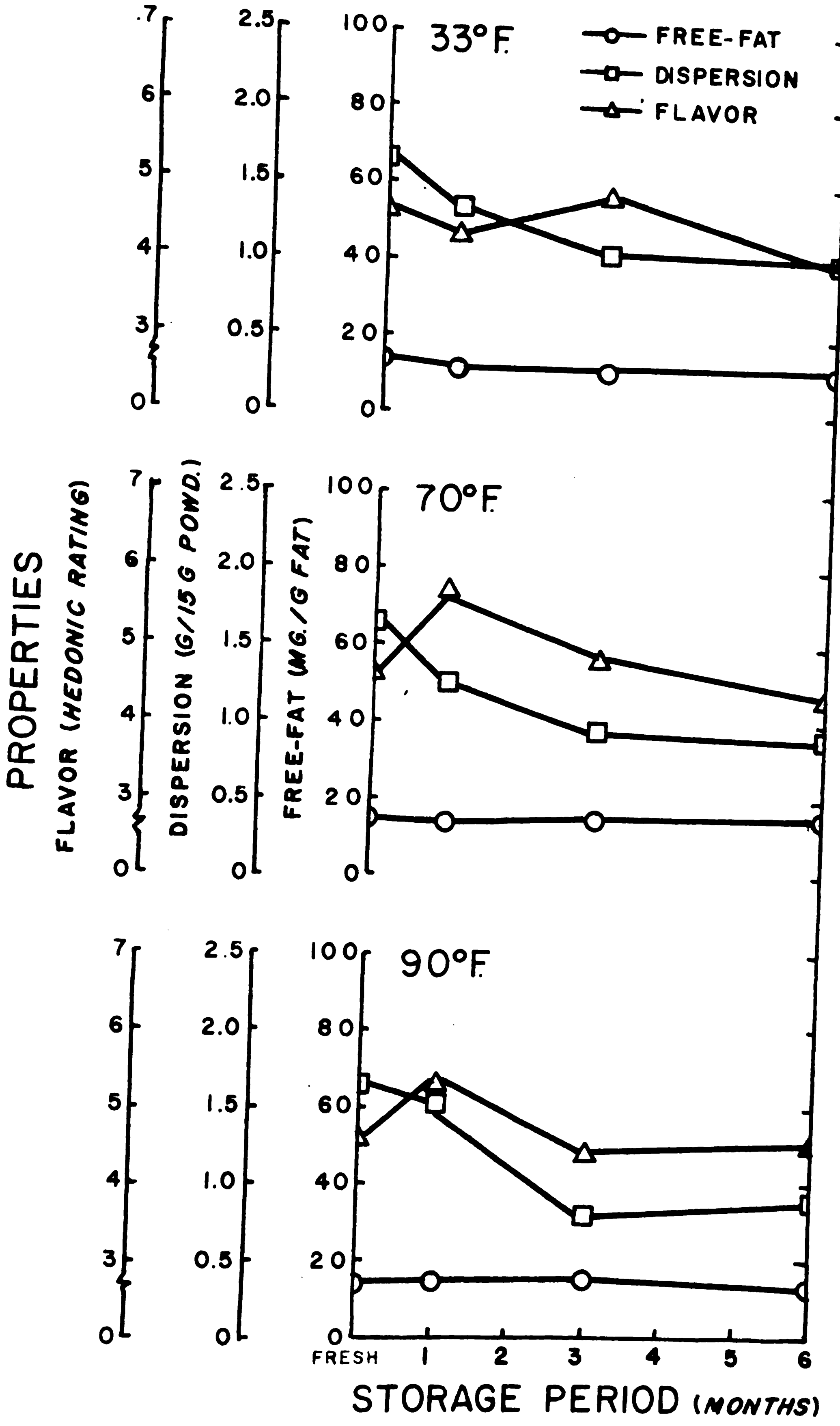


Figure 20. The effect of spray-drying concentrated skimmilk recombined with cream at a reduced nozzle pressure of 1000 p.s.i. on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 5, trial 19)

Figure 21. The effect of treating concentrated pasteurized homogenized milk with proteolytic enzyme for 10 minutes on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 20)

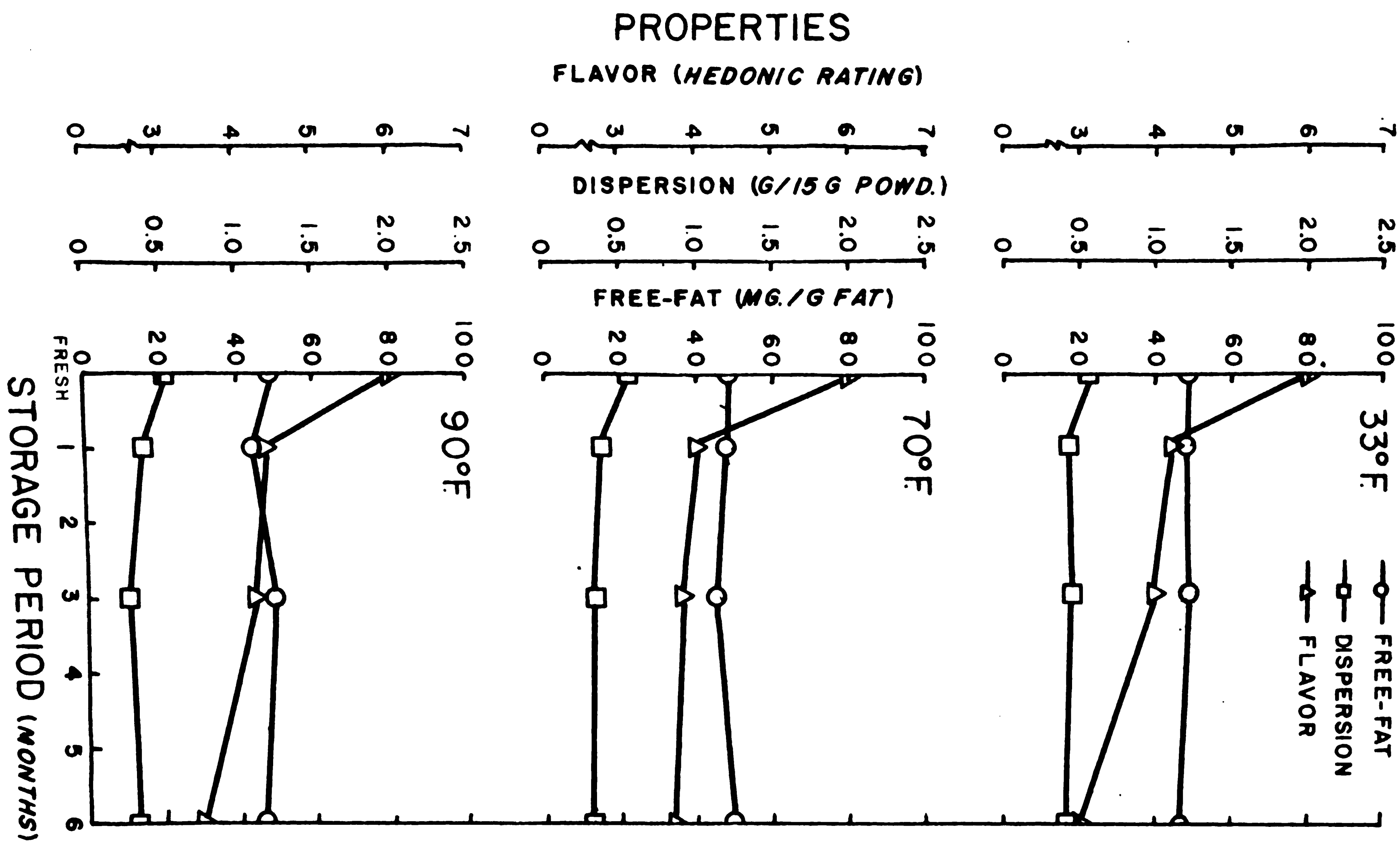
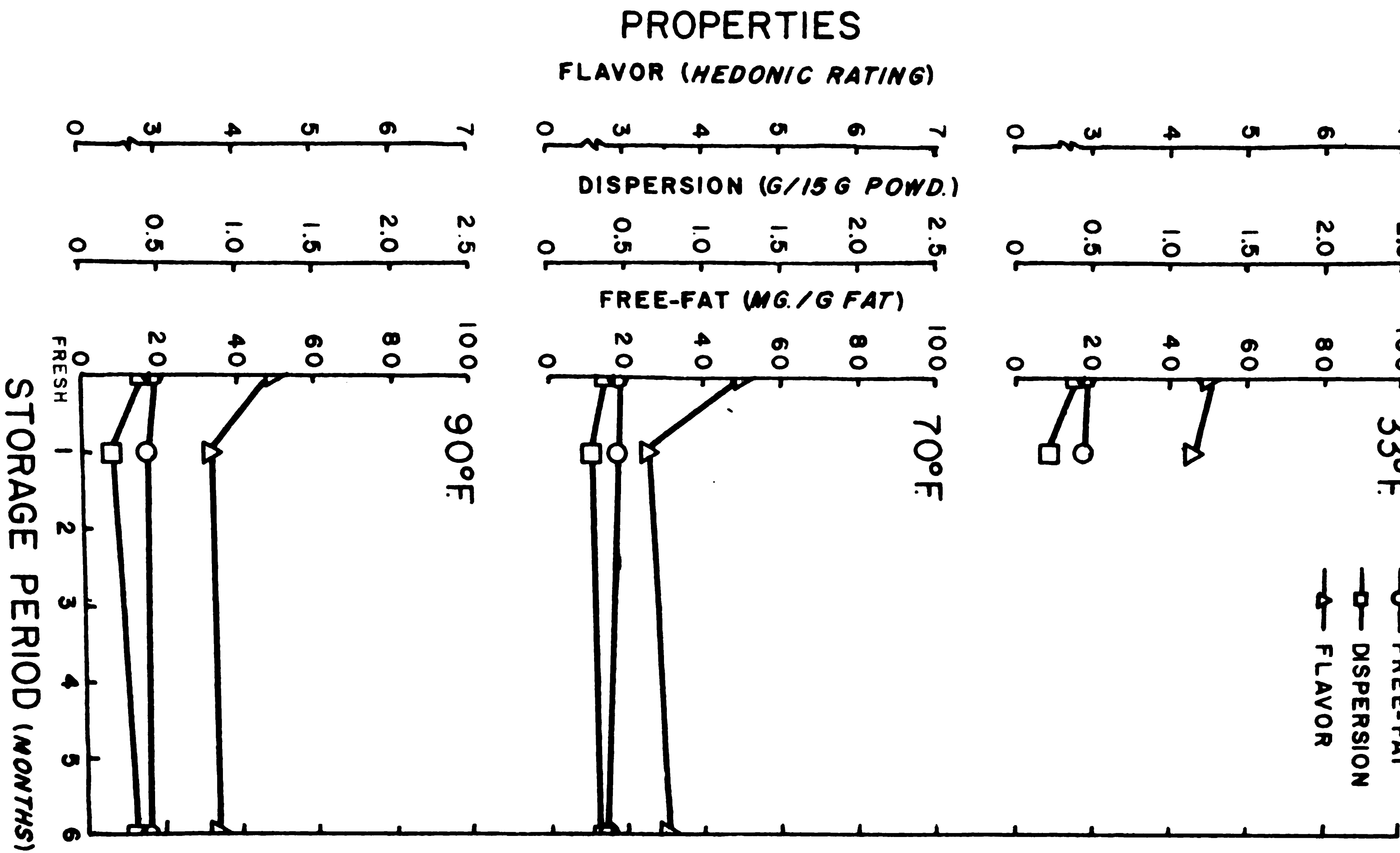


Figure 22. The effect of treating concentrated pasteurized homogenized milk with proteolytic enzyme for 5 minutes on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 21)



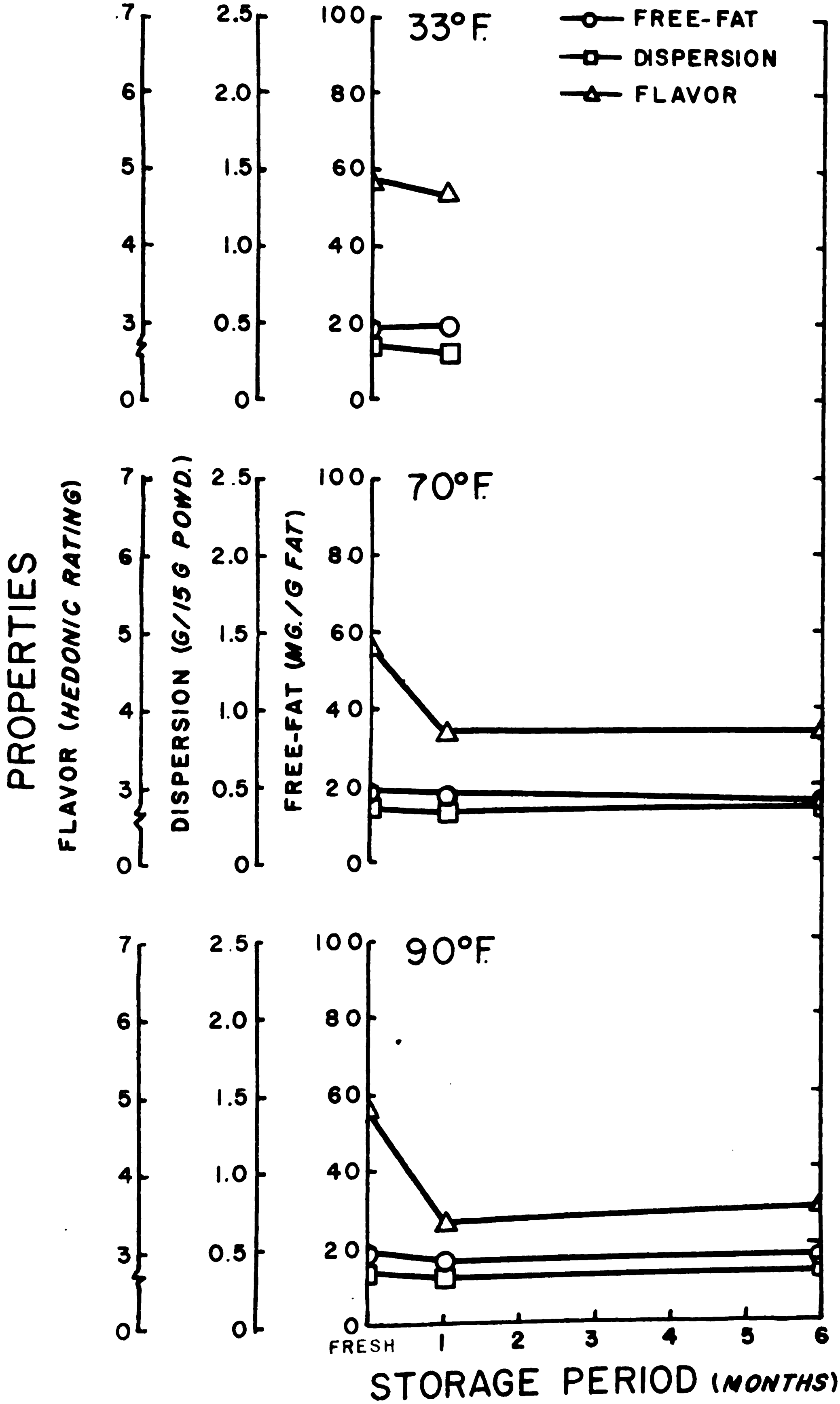
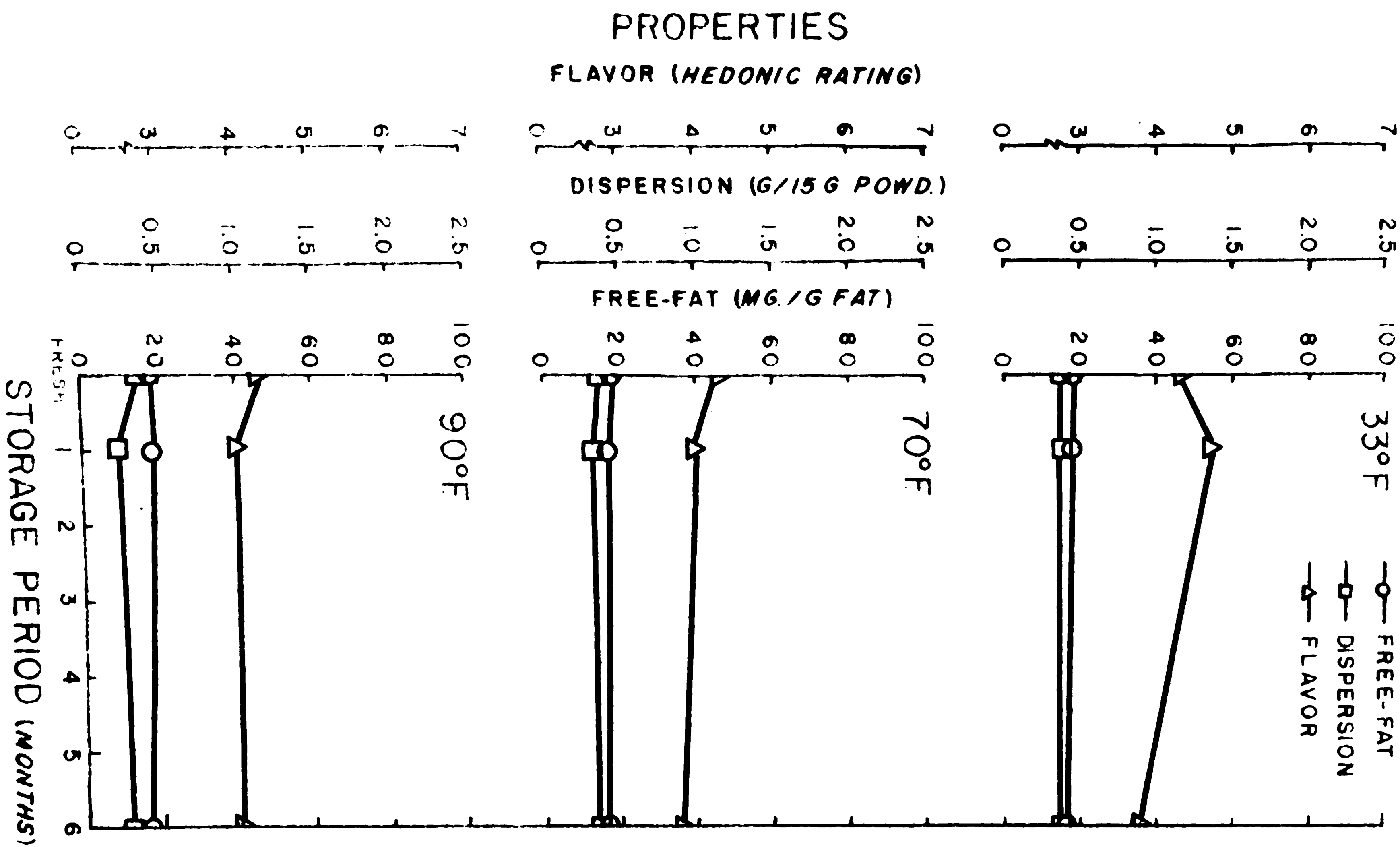


Figure 23. The effect of treating concentrated pasteurized homogenized milk with proteolytic enzyme for 10 minutes on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 22)

Figure 24. The effect of treating concentrated pasteurized homogenized milk with proteolytic enzyme for 15 minutes on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 23)



[illegible] concentrated skimmilk with proteolytic enzyme for

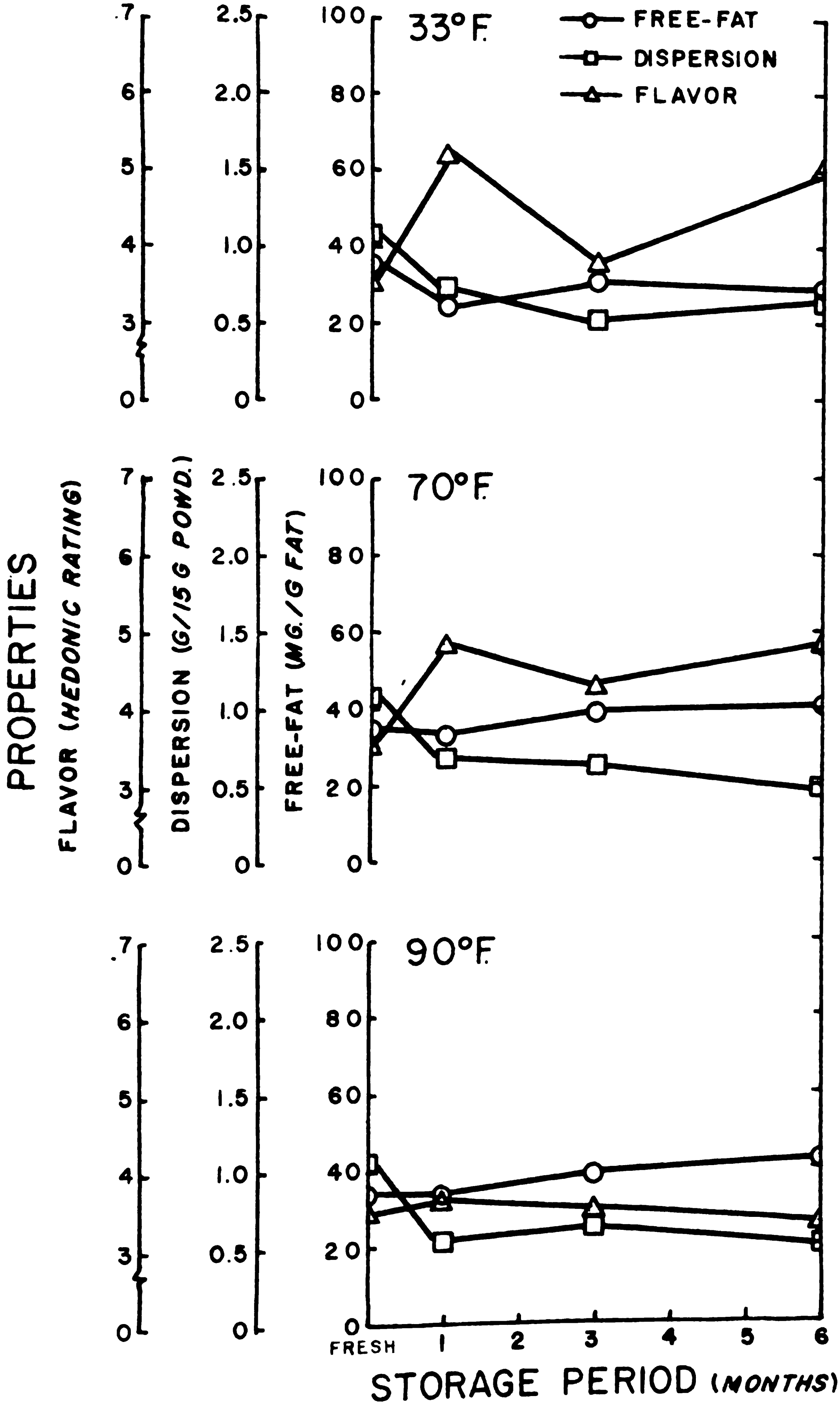


Figure 25. The effect of treating concentrated skimmilk with proteolytic enzyme for 5 minutes, and recombining with cream, on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 24)

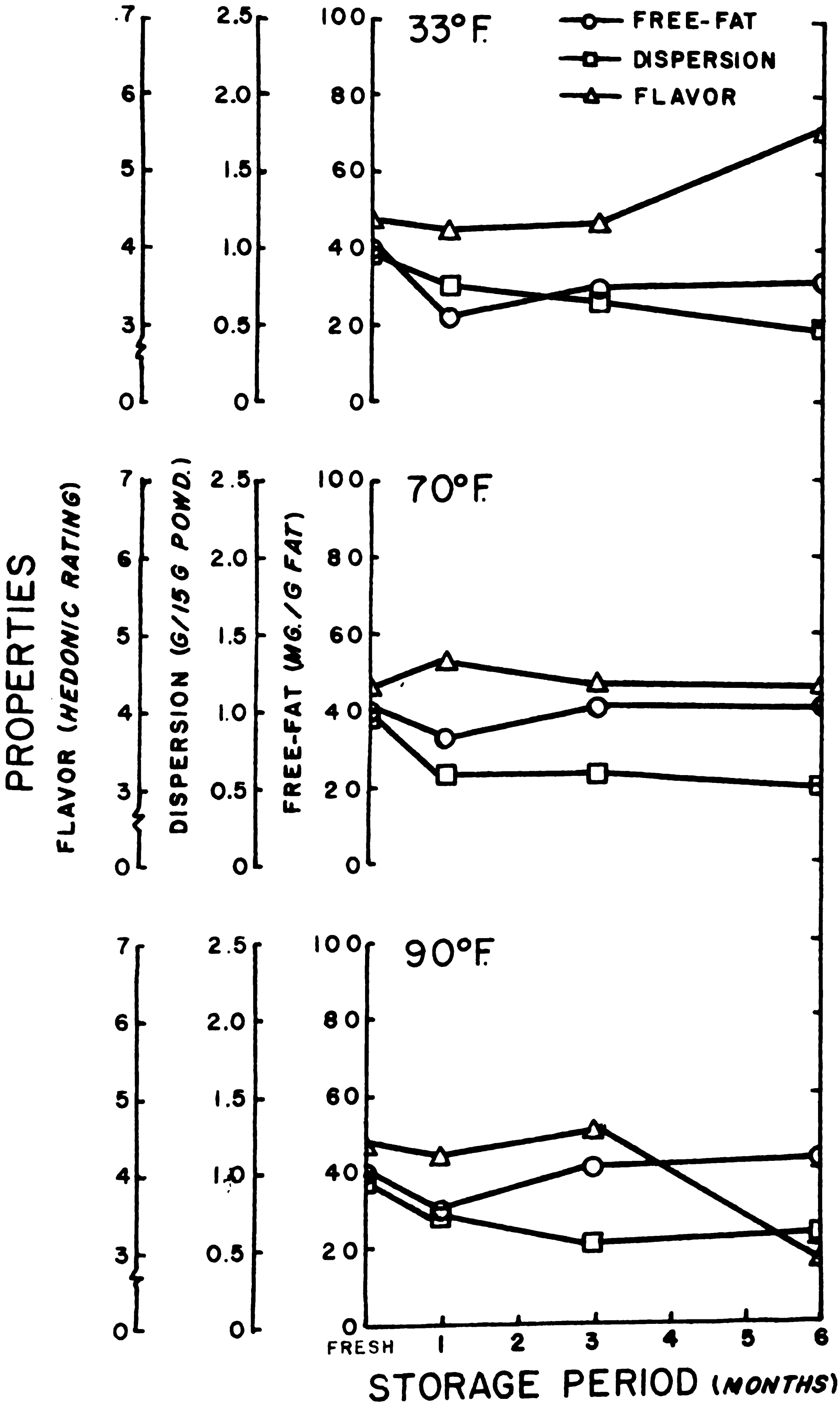


Figure 26. The effect of treating concentrated skimmilk with proteolytic enzyme for 10 minutes, and recombining with cream, on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 25)

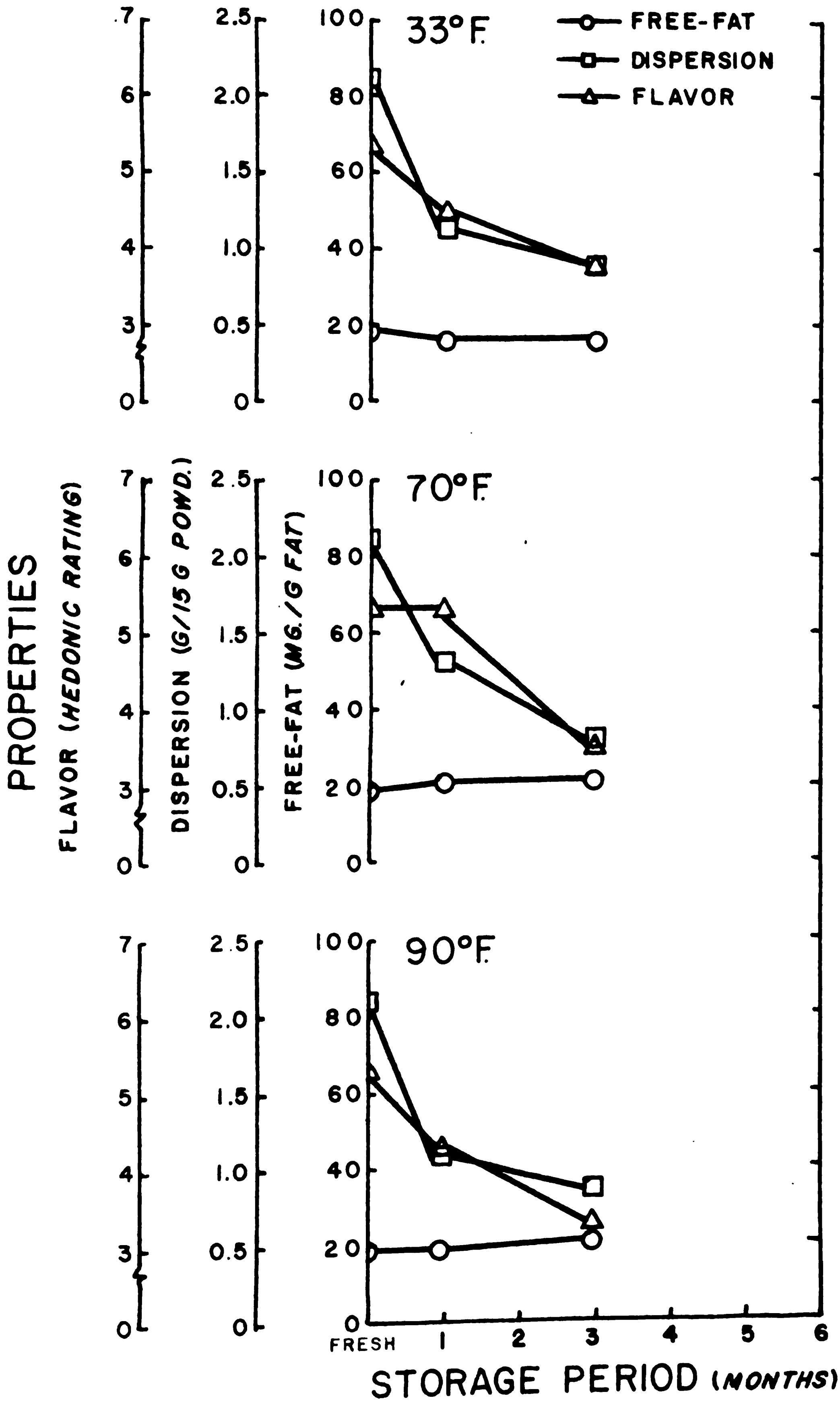
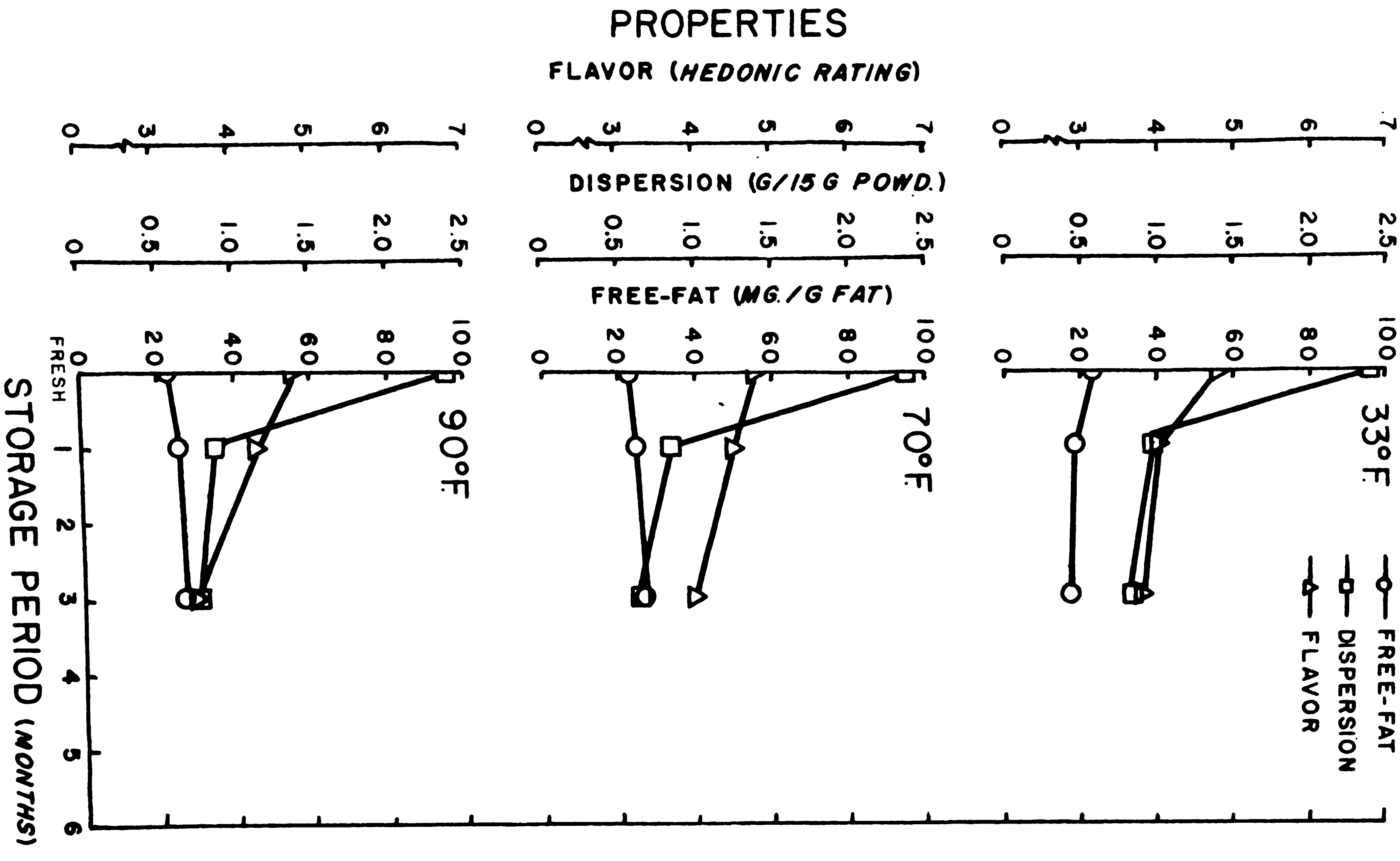


Figure 27. The effect of treating concentrated skimmilk with proteolytic enzyme for 5 minutes, and recombining with fresh butteroil, on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 26)

Figure 28. The effect of treating concentrated skimmilk with proteolytic enzyme for 15 minutes, and recombining with fresh butteroil, on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 6, trial 27)



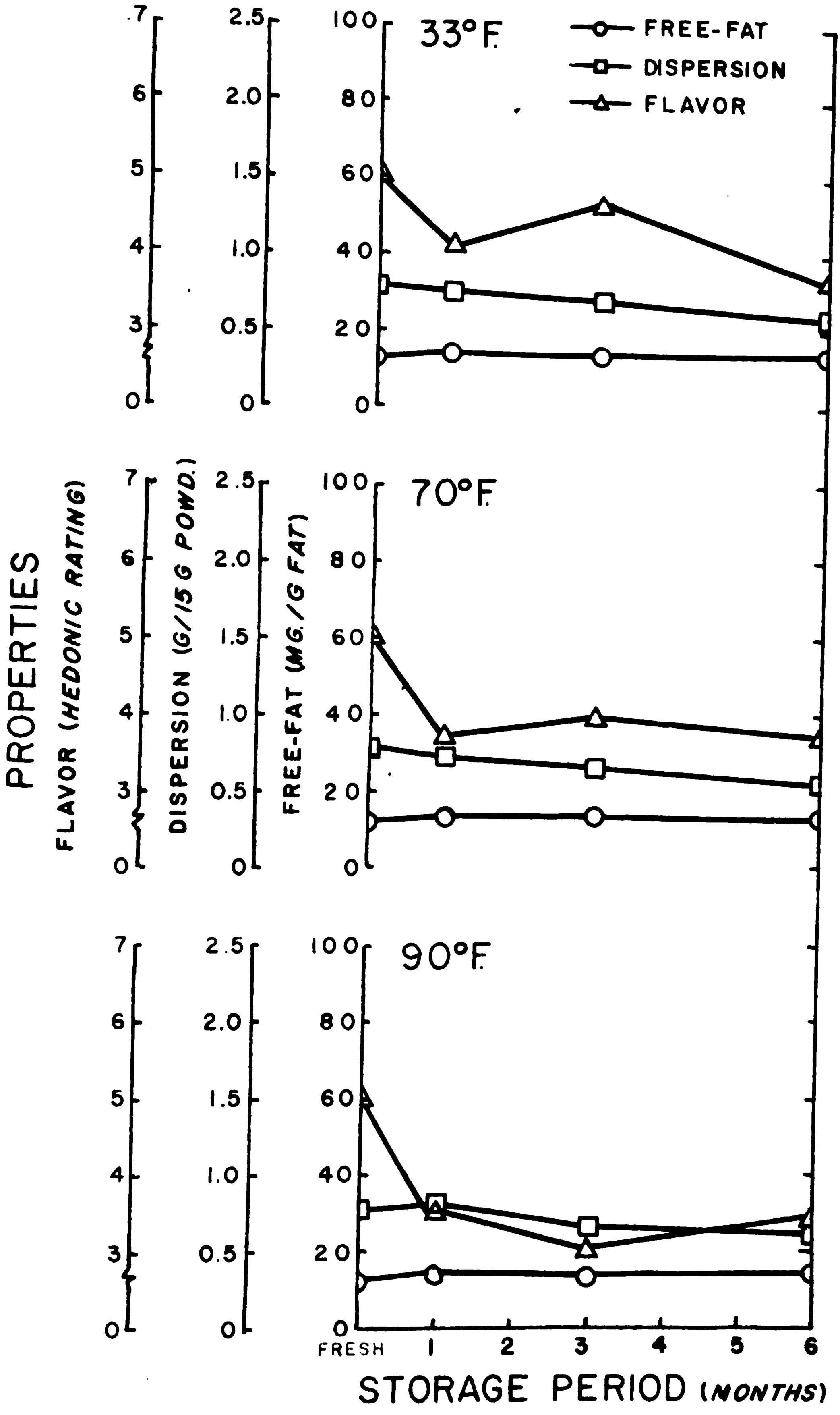


Figure 29. The effect of reducing the fat content of the fluid milk on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 7, trial 28)

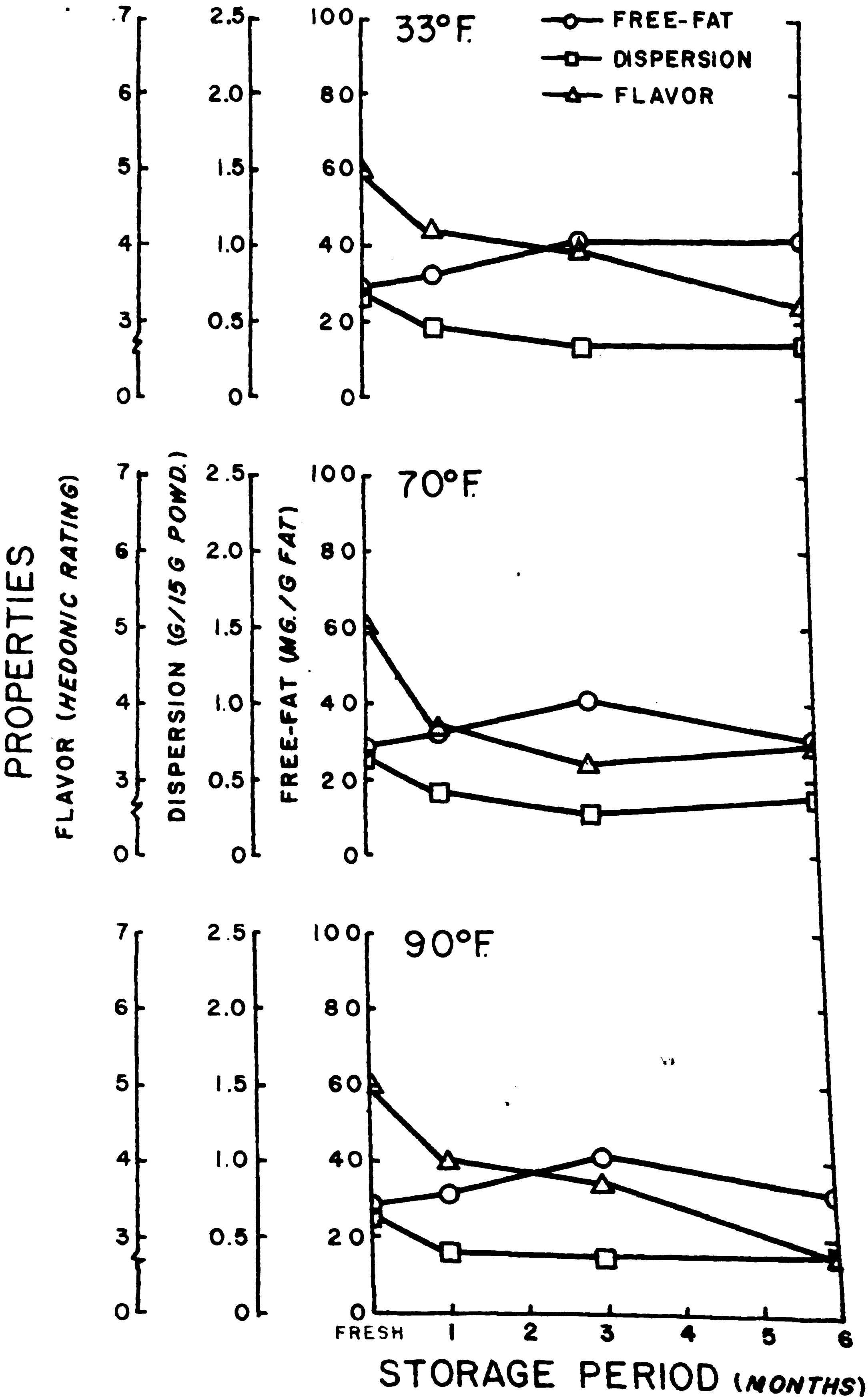


Figure 30. The effect of using pasteurized homogenized milk on the free-fat, self-dispersion, and flavor of whole milk powder. (See table 8, trial 29)

DISCUSSION

Experimental trials of powder for this study were manufactured under commercial conditions and covered approximately one and one-half years. This practice introduced variables in the composition and quality of the fluid milk which could not be controlled. However, Pearce and Bryce (1947) showed that the flavor scores of reconstituted milk powder manufactured in the fall or spring season were equal. Also, Ashworth and Prouty (1958) reported that a stale flavor developed in milk powder regardless of the original raw milk quality.

Free-Fat

The initial values of free-fat reported in this study (10.7 to 69.0 mg./g of fat) agree reasonably well with the results of King (1956) who reported a range of three to twenty per cent free-fat in "restored milk" made from spray-dried powder; this is equivalent to 7.8 to 52 milligrams of free-fat on the basis of a 26 per cent fat powder. Litman and Ashworth (1957) reported free-fat values of less than one per cent to approximately eighteen per cent for milk powders of five to thirty-five per cent, which again would be in the same general range of values reported in this study. Values of 12 to 18 per cent of free-fat were reported by Nickerson _et al._ (1952) which would tend to be in the middle ranges of values of this study.

Forewarming. As was expected, increased heat treatment of the fluid milk - i.e., increased temperature and/or holding time - resulted in higher initial values of free-fat. The free-fat values were inversely related to the whey-protein nitrogen values. Choi _et al._ (1951) observed that alcohol liberated some of the fat in the milk powder, and postulated that coagulation of the protein by alcohol was responsible. Possibly the additional heat treatment would likewise coagulate some of the protein, resulting in the same effect.

Recombination. The initial increase observed in the free-fat in the recombined samples - particularly the full-cream powders - is not clearly understood. The original assumption was that concentration of the fluid skimmilk would reduce the heat treatment the fat would normally receive during forewarming and condensing, and therefore result in a product with less free-fat. The powder manufactured by recombining the concentrated skimmilk with butteroil exhibited less free-fat than when recombined with cream; churning and washing of the butteroil may have removed some of the free-fat.

Treatment of concentrated whole milk. Homogenization of the concentrated whole milk, in conjunction with a high forewarming temperature of the fluid milk, resulted in an increase of free-fat over the control which was not homogenized. This is in contradiction to the results of King (1956) and Tamsma et al. (1959). Perhaps the combination of high temperature forewarming of the fluid and homogenization of the concentrated whole milk were responsible, but this was not conclusive.

The reduction in free-fat observed when homogenizing the concentrated whole milk is in general agreement with Nickerson et al. (1952), King (1956), and Tamsma et al. (1959). Although homogenization increases the surface area of the fat, King (1956) postulated that "surface active plasma-substances (albumen)" are adsorbed which protects the fat.

Nozzle size. The increased values of free-fat observed when spray-drying with a large size nozzle were considered to be due to the higher inlet air temperatures required in the drier to produce a relatively low moisture powder. Similarly, the lower free-fat values observed when spray-drying with a small size nozzle could be attributed to the lower inlet air temperatures.

However, other factors may be involved since the whey-protein nitrogen values did not correlate with the inlet air temperatures. A somewhat similar effect was observed by Ashworth (1955) when heating the concentrated whole milk prior to drying. He noted that, although the wettability of the powder decreased, the whey-protein denaturation was actually less.

Treatment of concentrate with a proteolytic enzyme. This generally resulted in a small increase of free-fat, except for trial 20 which showed an abnormally high increase. This greater increase may have been due partly to the method of heating the concentrated whole milk. For this particular sample, the concentrated whole milk was heated by steam in a jacketed kettle, whereas the control was not. An increase in free-fat was observed whether treating the concentrated whole or skimmilk with a proteolytic enzyme, so no conclusions could be drawn. The electrophoretic pattern of the proteins of the concentrated skimmilk treated with the enzyme exhibited no discernible change. Treatment of the concentrated skimmilk with a proteolytic enzyme followed by recombination with butteroil resulted in a decrease of free-fat.

Composition. The relatively high ratio of SNF/F in low fat powders (17 to 18%) possibly offers sufficient protection to the fat and results in lower free-fat values. Litman and Ashworth (1957) and Holm et al. (1925) agree that reducing the total fat content will decrease the quantity of free-fat.

Homogenization. Holm et al. (1925) reported a reduction in free-fat when using homogenized fluid milk; the results of the present study do not corroborate this.

Probably this can best be explained by Ashworth's (1955) observation that homogenization efficiency was reduced by concentration and, accordingly, the beneficial effect of homogenization on the free-fat would be reduced.

Effect of storage. Many of the samples exhibited an increase in free-fat following storage, however, the reason for this increase is not understood. King (1948, 1955, 1956) believed the powder absorbed moisture during storage which caused the lactose to crystallize and mechanically pierce the fat globule to produce free-fat. Lampitt and Bushill (1931) agreed with this explanation and stated further that at 8.6 to 9.2 per cent moisture in the powder the free-fat values correlated with lactose crystallization. This observation, however, does not explain the increase in free-fat in low moisture powders. The decrease in free-fat for a number of samples is even more difficult to explain. Litman and Ashworth (1957) suggested the possibility of a fat-protein complex which would possibly reduce the amount of free-fat extracted. Additional work is needed to clarify the reason for the variations in free-fat values following storage.

Self-Dispersion

Stone *et al.* (1954), using the same procedure for self-dispersion, reported values of 0.303 to 1.448 grams per 15 grams of powder. These values were obtained from powders with a fat content of from 10 to 35 per cent; no other processing variations were mentioned. Since the powders reported in this study involved a number of processing variations, it seems likely that a greater range of self-dispersion values, as reported in the study, would be obtained. Although not included in the experimental data, self-dispersion values were determined on several commercial samples of "instant" non-fat dry milk powder. Values of 10 to 12 grams per 15 grams of powder were observed, indicating the wide range of values attainable with this method.

Forewarming. The relationship between increased heat treatment of the fluid on the self-dispersion value was not conclusive, however, powders exhibiting the lowest whey-protein nitrogen value had the lowest self-dispersion values. This is in general agreement with the observations of Swanson (1955) who reported that increased forewarming temperatures had a detrimental effect on solubility.

Recombination. Concentrated skimmilk recombined with cream or butteroil resulted in a relatively high initial value of self-dispersion, with an inverse relationship between free-fat and self-dispersion.

Treatment of concentrate. The effect of homogenization of the concentrated whole milk on the self-dispersion characteristics of the powder was inconclusive. In one case, trial 8, the self-dispersion was improved; while in trials 9 and 10 it was reduced. Ashworth (1955) concluded that homogenization of the concentrated whole milk improved wettability by reducing the free-fat content; i.e., wettability and free-fat are interrelated. Assuming such to be true, the variations in the above dispersion values are readily explained. In trial 8, the free-fat decreased, while in trials 9 and 10 it increased.

Treatment of the concentrate with proteolytic enzyme. Treatment of the concentrated skimmilk with a proteolytic enzyme, followed by recombination with cream or butteroil, resulted in improved self-dispersion values. This was most evident in the treated samples recombined with butteroil where the self-dispersion values were more than doubled. Perhaps concentration of the separated product reduced the formation of a fat-protein complex which is considered detrimental to self-dispersion.

Powder manufactured from fluid homogenized milk which was concentrated and treated with a proteolytic enzyme exhibited decreased self-dispersion values. Hibbs and Ashworth (1951) reported similar results.

Composition. Reducing the fat content of the powder did not improve self-dispersion. Hibbs and Ashworth (1951) did not observe any correlation between the fat content and initial solubility. Stone *et al.* (1954) noted a relationship between total fat and self-dispersion, but concluded that other factors - such as rate of cooling of the powder - were more important.

Homogenization. Powder manufactured from fluid homogenized milk exhibited lower self-dispersion values.

Effect of storage. Lea and Smith (1943b), Hetrick and Tracy (1945), and Hibbs and Ashworth (1951), reported little change in the solubility index of whole milk powder, while the results of the present study show a decrease in self-dispersion with increased storage time. Possibly the self-dispersion test is more critical and would show changes in powdered milk following storage more readily than the solubility test which employs a high degree of mechanical agitation.

Flavor

All freshly reconstituted samples exhibited what was considered to be a "typical" whole milk powder flavor. Although chemical tests would have been more objective in detecting oxidation of the fat, a number of workers - Hollender and Tracy (1942), Pearce (1944 and 1945), and Loftus (1955), - have attested to the greater sensitivity of organoleptic judging as employed in this study.

Forewarming. Remaley (1946), Gibson (1952), and Patton and Co-workers (1952) suggested the use of low forewarming or processing temperatures as a means of improving the flavor score. Results of the present study do not substantiate their findings. Apparently, the higher heat treatment of the fluid liberated sufficient sulphydryl groups to retard any initial oxidation of the fresh sample.

Treatment of the concentrate with a proteolytic enzyme. Powder samples manufactured by treating the concentrated whole or skimmilk with a proteolytic enzyme were judged to be bitter. Probably this defect could be overcome by reducing the amount of proteolysis.

Effect of storage. The general decrease in flavor scores following storage agrees with the results of other workers - Pyenson and Tracy (1946), Pearce and Bryce (1947), and Coulter *et al.* (1948). Low fat powder manufactured by recombining the concentrated skimmilk with cream and spray-dried with a large size nozzle scored relatively high in flavor after storage. This was attributed to the larger particle size, which, according to Tracy, Hetrick, and Krienke (1951), means less entrapped air within the powder particle. King (1948) was of the opinion that low levels of entrapped air would retard fat oxidation.

Statistical Analysis

After considerable study of the experimental data, it was evident that a statistical analysis would simplify the interpretation of the results. Accordingly, the data of the individual samples, excluding those with incomplete data, tabulated in the appendix were used. No attempt was made to test for difference between individual samples since many of the trials did not involve more than one replication.

The data of this study (Table 9) did not show any significant change in the quantity of free-fat for samples of whole milk powder stored at 33° F. (0.6° C.). Litman and Ashworth (1957) made a similar observation for samples stored at 45° F. (7.2° C.).

Hollender (1955) reported greater values of self-dispersion for samples of whole milk powder stored at 86° F. (30° C.) than for those stored at 32° F. (0.6° C.). The results of this study showed there was no significant difference in self-dispersion values for samples stored at 33° F. (0.6° C.) or 90° F. (32.2° C.). Though no correlation between the quantity of free-fat and self-dispersion was found, Tamsma <u>et al</u>. (1959) reported an 0.11 per cent decrease in dispersion for each one per cent increase in fat for foam-dried milk. The values of free-fat in foam-dried milk were considerably higher than reported in this study.

Coulter <u>et al</u>. (1948) reported that flavor deterioration occurred most rapidly during the initial storage period. The experimental data for this study substantiates this, since no change in flavor scores was observed after the third month of storage. Also, there was no significant difference in flavor scores for samples stored at 33°

and 70° F. (0.6° and 21.1° C.). This is in agreement with the work of Dahle and Palmer (1924).

SUMMARY AND CONCLUSION

The primary objectives of this study were:

1) to observe the effect of processing variations on the formation of free-fat in whole milk powder, and

2) to observe the effect of free-fat on self-dispersion and flavor in whole milk powder, while fresh and following storage.

A total of 29 trials involving 39 samples were manufactured. The samples were nitrogen packed for storage at 33°, 70°, and 90° F. for periods of one, three, and six months.

The processing variations included:

1) Forewarming
2) Recombination of condensed skimmilk with cream or butteroil
3) Treatment of the concentrate
4) Nozzle size
5) Nozzle pressure
6) Treatment of the concentrate with proteolytic enzyme mixture
7) Composition (fat percentage)
8) Homogenization of the fluid milk

Low initial values of free-fat were observed in samples of whole milk powder of low fat content (17 - 20%) when using low forewarming temperatures (160° F. - 71° C. - for 20 sec.); or recombining the concentrated skimmilk with cream; or spray-drying the concentrated whole milk with a large size nozzle; or spray-drying the concentrate at reduced nozzle pressure.

Higher values of free-fat were observed in the full-cream powders (26 - 32% fat). Increased heat treatment of the fluid and/or concentrated whole milk; recombination of the concentrated skimmilk with cream or butteroil; treatment of the concentrated skimmilk with a proteolytic enzyme followed by recombination with butteroil; and the use of fluid homogenized milk resulted in even higher values of free-fat.

The small increase in free-fat observed after storage was not statistically significant. Samples of whole milk powder stored at 70° and 90° F. (21.1° and 32.2° C.) had significantly greater amounts of free-fat than those stored at 33° F. (0.6° C.). There was no significant difference in the free-fat values for the samples stored at 70° and 90° F. (21.1° and 32.2° C.).

The highest initial self-dispersion values were observed in the whole milk powders in which the concentrated skimmilk was treated with a proteolytic enzyme and recombined with butteroil. Also, the low fat (20%) powder manufactured by recombining the concentrated skimmilk with cream exhibited a relatively high initial self-dispersion value.

A significant decrease in the self-dispersion values, at the five per cent significance level, was observed following storage. There was no significant difference in self-dispersion values between samples stored for three and six months. There was a significant difference between samples stored at 33° and 70° F. (0.6° and 21.1° C.) and between 70° and 90° F. (21.1° and 32.2° C.). No correlation was observed between the quantity of free-fat and the self-dispersion values when fresh or following storage at 70° F. (21.1° C.) for six months.

The initial flavor scores were generally highest for the samples of whole milk powder in which the fluid and/or concentrated whole milk received the highest heat treatment.

A significant decrease in the flavor scores, at the five per cent significance level, was observed following storage. There was no significant difference in flavor scores between samples stored for three and six months. There was a significant difference in flavor scores for samples stored at 33° and 90° F. (0.6° and 32.2° C.) and for samples stored at 70° and 90° F. (21.1° and 32.2° C.). No significant difference was observed in the flavor scores for samples stored at 33° and 70° F. (0.6° and 21.1° C.).

No correlation was observed between the quantity of free-fat and the flavor scores while fresh or following storage for six months at 70° F. (21.1° C.).

Since there was no statistically significant correlation between the quantity of free-fat and the self-dispersion values or flavor scores, it may be concluded that: a) high temperature forewarming of the fluid milk such as used in the hotwell, b) treatment of the concentrated skimmilk with a proteolytic enzyme followed by recombination with cream or preferably butteroil, and c) low fat powders spray-dried with a large size nozzle or at reduced nozzle pressure, would be variations that would improve the flavor and/or self-dispersion of whole milk powder.

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APPENDIX

(Detailed tables listing processing variations and observed properties of individual whole milk powder samples. Tables 10 through 48.)

TABLE 10

Observed properties of whole milk powder (Sample 1)

Property	Fresh	Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	27.73									
Moisture (percentage)	1.50									
Free-fat (mg./g. fat)	15.6	18.5	19.5	20.2	22.0	20.6	21.1	23.3	22.1	23.4
Self-dispersion (g./15g. powder)	--	0.661	0.637	--	0.693	0.664	0.723	0.575	0.522	0.567
Flavor (hedonic rating)	--	--	--	--	4.3	4.0	3.0	3.2	2.6	3.0
Specific volume (ml./50g.)	70.0									
Whey-protein nitrogen (mg./g. powder)	7.5									
Particle size distribution	28% = 3.5 to 14μ; 42% = 15 to 36μ; 22% = 37 to 72μ; 8% = greater than 72μ									

Standardized-clarified raw milk forewarmed to 166° F. for 21 sec., condensed to 52% t.s. at vapor temperature 89° F. Concentrate preheated to 135° F., spray-dried with No. 59/20 nozzle at 2200 p.s.i., inlet air temperature 248° F., outlet air 135° F.

TABLE 11

Observed properties of whole milk powder (Sample 2)

Property	Fresh	Storage period (months): One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	29.04									
Moisture (percentage)	1.60									
Free-fat (mg./g. fat)	23.9	26.3	26.9	26.4	25.4	26.4	27.8	26.6	27.8	27.7
Self-dispersion (g./15g. powder)	--	0.848	0.785	3.850	0.676	0.683	0.635	0.655	0.731	0.681
Flavor (hedonic rating)	--	5.0	5.4	5.4	5.0	5.4	4.0	4.0	4.2	4.4
Specific volume (ml./50g.)	71.2									
Whey-protein nitrogen (mg./g. powder)	4.3									
Particle size distribution	24% = 3.6 to 14µ; 72% = 15 to 36µ; 4% = 37 to 72µ; 0% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 240° F. for 20 sec. with Rogers-Terret direct steam injector, condensed to 52% t.s. at vapor temperature 94° F.. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 245° F., outlet air 180° F.

TABLE 12

Observed properties of whole milk powder (Sample 3)

Property	Fresh	Storage period (months): One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	18.39									
Moisture (percentage)	1.75									
Free-fat (mg./g. fat)	13.3	15.2	14.7	15.1	14.0	13.5	13.9	15.5	14.3	16.1
Self-dispersion (g./15g. powder)	--	0.908	0.916	1.084	0.707	0.680	0.854	0.705	0.710	0.869
Flavor (hedonic rating)	--	4.6	4.2	3.8	5.0	4.5	2.8	3.6	3.4	3.2
Specific volume (ml./50g.)	66.0									
Whey-protein nitrogen (mg./g. powder)	8.1									
Particle size distribution	37½% = 3.6 to 14μ; 60% = 15 to 36μ; 2½% = 37 to 72μ; 0% = greater than 72μ									

Standardized-clarified raw milk forewarmed to 165° F. for 20 sec., condensed to 46% t.s. at vapor temperature 86° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 248° F., outlet air 180° F.

TABLE 13

Observed properties of whole milk powder (Sample 4)

Property	Fresh	One: 33	One: 72	One: 90	Three: 33	Three: 72	Three: 90	Six: 33	Six: 72	Six: 90
		Storage period (months) / Storage temperature (°F.)								
Fat (percentage)	19.08									
Moisture (percentage)	2.02									
Free-fat (mg./g. fat)	10.7	10.4	10.5	9.5	9.9	10.5	11.0	10.2	10.2	10.5
Self-dispersion (g./10g. powder)	--	0.989	1.055	1.099	0.964	0.979	1.052	1.036	0.838	1.211
Flavor (hedonic rating)	--	4.8	5.2	4.4	4.2	4.0	3.3	3.2	4.8	3.8
Specific volume (ml./50g.)	61.8									
Whey-protein nitrogen (mg./g. powder)	8.5									
Particle size distribution	24 % = 3.4 to 14µ; 72 % = 14 to 38µ; 4 % = 38 to 72µ; 0 % = greater than 72µ									

Standardized-clarified raw milk forewarmed to 163° F. for 20 sec., condensed to 46% t.s. at vapor temperature 95° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 500 p.s.i., inlet air temperature 225° F., outlet air 180° F.

FIGURE 14

TABLE 14

Observed properties of whole milk powder (Sample 5)

Property	Fresh	One 33	One 70	One 90	Three 33	Three 70	Three 90	Six 33	Six 70	Six 90
		Storage period (months)								
		Storage temperature (°F.)								
Fat (percentage)	29.96									
Moisture (percentage)	1.38									
Free-fat (mg./g. fat)	30.0	24.3	29.7	31.0	32.6	24.6	30.7	27.2	28.6	30.9
Self-dispersion (g./15g. powder)	0.643	0.348	0.271	0.274	0.427	0.312	0.289	0.341	0.239	0.206
Flavor (hedonic rating)	--	4.5	3.0	3.5	4.4	3.6	3.4	--	--	--
Specific volume (ml./50g.)	75.0									
Whey-protein nitrogen (mg./g. powder)	3.1									
Particle size distribution	66% = 3.6 to 14μ; 30% = 15 to 36μ; 4% = 37 to 72μ; 0% = greater than 72μ									

Standardized-clarified raw milk forewarmed to 185° F. for 20 minutes in hotwell, condensed to 42% t.s. at vapor temperature 93° F. Concentrate preheated to 165° F., spray-dried with No. 69/20 nozzle at 2500 p.s.i., inlet air temperature 300° F., outlet air 198° F.

TABLE 15

Observed properties of whole milk powder (Sample 6)

Property	Fresh	Storage period (months) One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	21.94									
Moisture (percentage)	2.66									
Free-fat (mg./g. fat)	49.0	51.0	53.7	54.7	52.7	56.8	58.3	54.0	58.4	60.8
Self-dispersion (g./15g. powder)	--	0.682	0.709	0.982	0.689	0.629	0.576	0.686	0.637	0.612
Flavor (hedonic rating)	--	5.4	4.8	3.6	5.8	5.5	3.0	6.0	6.0	4.0
Specific volume (ml./50g.)	71.8									
Whey-protein nitrogen (mg./g. powder)	7.9									
Particle size distribution	30% = 3.6 to 14µ; 60% = 15 to 36µ; 10% = 37 to 72µ; 0 % = greater than 72µ									

Raw skimmilk forewarmed to 160° F. for 20 sec., condensed to 45% t.s. at vapor temperature 90° F. Concentrated skimmilk recombined with cream and preheated to 135° F., spray-dried with ¼SBC5 nozzle at 1500 p.s.i., inlet air temperature 330° F., outlet air 184° F.

TABLE 16

Observed properties of whole milk powder (Sample 7)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (^{o}F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	10.68									
Moisture (percentage)	2.64									
Free-fat (mg./g. fat)	22.5	16.6	16.0	17.7	18.5	20.7	20.4	19.5	18.8	19.4
Self-dispersion (g./15g. powder)	--	0.783	0.820	0.876	0.892	0.797	0.845	0.876	0.854	0.837
Flavor (hedonic rating)	--	5.2	5.2	3.4	5.0	5.8	3.5	7.0	6.5	3.5
Specific volume (ml./50g.)	68.8									
Whey-protein nitrogen (mg./g. powder)	8.3									
Particle size distribution	30% = 3.6 to 14μ; 60% = 15 to 36μ; 10% = 37 to 72μ; 0% = greater than 72μ									

Pasteurized skimmilk forewarmed to 160° F. for 20 sec., condensed to 49% t.s. at vapor temperature 90° F. Concentrated skimmilk recombined with cream and preheated to 135° F., spray-dried with No. ½SBC5 nozzle at 1000 p.s.i., inlet air temperature 315° F., outlet air 205° F.

TABLE 17

Observed properties of whole milk powder (Sample 8)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	27.80									
Moisture (percentage)	2.04									
Free-fat (mg./g. fat)	69.0	41.4	58.5	52.0	50.3	61.5	63.9	46.2	64.3	61.5
Self-dispersion (g./15g. powder)	--	0.562	0.543	0.805	0.426	0.420	0.346	0.550	0.353	0.393
Flavor (hedonic rating)	--	4.4	4.4	3.8	4.6	6.0	5.6	5.4	4.7	3.7
Specific volume (ml./50g.)	69.0									
Whey-protein nitrogen (mg./g. powder)	3.5									
Particle size distribution	18% = 3.6 to 14µ; 30% = 15 to 36µ; 26% = 37 to 72µ; 26% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 185° F. for 15 min. in hotwell, condensed to 46% t.s. at vapor temperature 92° F. Concentrate preheated to 140° F., spray-dried with No. 63/425 nozzle at 2200 p.s.i., inlet air temperature 330° F., outlet air 200° F.

TABLE 18

Observed properties of whole milk powder (Sample 8c - control)

Property	Fresh	Storage period (months) One			Three			Six		
		Storage temperature (°F.) 33	70	90	33	70	90	33	70	90
Fat (percentage)	27.80									
Moisture (percentage)	1.98									
Free-fat (mg./g. fat)	25.5	21.8	27.7	27.9	25.6	28.2	29.8	25.6	28.4	28.3
Self-dispersion (g./15g. powder)	--	0.890	0.845	1.397	0.899	0.874	0.597	0.998	0.843	0.733
Flavor (hedonic rating)	--	4.8	4.2	4.2	5.5	4.5	4.8	5.7	5.0	5.4
Specific volume (ml./50g.)	69.8									
Whey-protein nitrogen (mg./g. powder)	3.8									
Particle size distribution	24 % = 3.6 to 14µ; 72% = 15 to 36µ; 4 % = 37 to 72µ; 0 % = greater than 72µ									

Standardized-clarified raw milk forewarmed to 185° F. for 15 minutes in hotwell, condensed to 46% t.s. at vapor temperature 92° F. Concentrate preheated to 140° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 265° F., outlet air 198° F.

TABLE 19

Observed properties of whole milk powder (Sample 9)

Property	Fresh	One: 33	One: 70	One: 90	Three: 33	Three: 70	Three: 90	Six: 33	Six: 70	Six: 90
		Storage period (months) / Storage temperature (°F.)								
Fat (percentage)	28.63									
Moisture (percentage)	1.40									
Free-fat (mg./g. fat)	19.8	21.2	20.3	21.0	19.6	19.1	20.0	21.5	20.0	19.5
Self-dispersion (g./15g. powder)	0.888	0.709	0.753	0.806	0.695	0.639	0.667	0.593	0.568	0.614
Flavor (hedonic rating)	--	4.8	4.8	4.5	3.0	3.5	3.6	4.0	4.5	3.3
Specific volume (ml./50g.)	70.6									
Whey-protein nitrogen (mg./g. powder)	7.8									
Particle size distribution	24 % = 3.6 to 14µ; 58% = 15 to 36µ; 18% = 37 to 72µ; 0 % = greater than 72µ									

Standardized-clarified raw milk forewarmed to 160-165° F. for 20 sec., condensed to 53% t.s. at vapor temperature 92° F. Concentrate heated to 150° F. and homogenized at 2500 and 500 p.s.i., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 235° F., outlet air 190° F.

TABLE 20

Observed properties of whole milk powder (Sample 9c - control)

Property	Fresh	Storage period (months) One			Three			Six		
		Storage temperature ($^{o}F.$) 33	70	90	33	70	90	33	70	90
Fat (percentage)	28.63									
Moisture (percentage)	1.54									
Free-fat (mg./g. fat)	19.8	20.4	22.4	23.0	22.2	23.5	23.2	23.0	24.0	23.0
Self-dispersion (g./15g. powder)	0.774	0.626	0.714	0.733	0.605	0.533	0.574	0.542	0.524	0.555
Flavor (hedonic rating)	--	4.5	4.8	4.0	3.0	3.4	5.6	3.8	3.8	3.8
Specific volume (ml./50g.)	69.8									
Whey-protein nitrogen (mg./g. powder)	7.8									
Particle size distribution	24 % = 3.6 to 14µ; 60% = 15 to 36µ; 16% = 37 to 72µ; 0% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 160-165° F. for 20 sec., condensed to 53% t.s. at vapor temperature 92° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 235° F., outlet air 190° F.

TABLE 21

Observed properties of whole milk powder (Sample 10)

Property	Fresh	Storage period (months) One: 33 °F.	One: 70 °F.	One: 90 °F.	Three: 33 °F.	Three: 70 °F.	Three: 90 °F.	Six: 33 °F.	Six: 70 °F.	Six: 90 °F.
Fat (percentage)	28.13									
Moisture (percentage)	1.40									
Free-fat (mg./g. fat)	16.0	18.0	16.1	16.3	17.8	15.9	17.8	16.2	15.8	17.0
Self-dispersion (g./15g. powder)	0.969	1.063	1.088	0.959	0.914	0.953	0.919	1.164	1.026	1.086
Flavor (hedonic rating)	4.5	5.0	5.2	4.0	3.3	3.8	3.8	3.4	3.8	3.8
Specific volume (ml./50g.)	72.8									
Whey-protein nitrogen (mg./g. powder)	7.7									
Particle size distribution	26% = 3.6 to 14µ; 64% = 15 to 36µ; 10% = 37 to 72µ; 0% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 155° F. for 20 sec., condensed to 53% t.s. at vapor temperature 90° F. Concentrate heated to 150-155° F. and homogenized at 2500 and 500 p.s.i., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 260° F., outlet air 190° F.

TABLE 22

Observed properties of whole milk powder (Sample 10c - control)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	28.13									
Moisture (percentage)	1.38									
Free-fat (mg./g. fat)	19.2	19.8	21.8	20.9	20.4	20.7	20.2	19.7	19.7	20.4
Self-dispersion (g./15g. powder)	0.926	0.876	0.895	0.801	0.727	0.801	0.773	0.954	0.866	0.899
Flavor (hedonic rating)	4.0	3.8	5.3	4.0	3.8	3.5	2.8	3.2	3.8	2.6
Specific volume (ml./50g.)	70.4									
Whey-protein nitrogen (mg./g. powder)	7.9									
Particle size distribution	28% = 3.6 to 14µ; 66% = 15 to 36µ; 6% = 37 to 72µ; 0% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 155° F. for 20 sec., condensed to 53% t.s. at vapor temperature 90° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 276° F., outlet air 191° F.

TABLE 23

Observed properties of whole milk powder (Sample 11)

Property	Fresh	One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	28.27									
Moisture (percentage)	1.80									
Free-fat (mg./g. fat)	19.7	19.3	18.8	20.0	20.0	20.6	19.2	20.6	19.9	19.8
Self-dispersion (g./15g. powder)	0.689	0.692	0.561	0.716	0.628	0.638	0.651	0.854	0.704	0.748
Flavor (hedonic rating)	4.5	4.2	5.0	5.0	4.6	3.8	4.0	4.5	3.8	4.0
Specific volume (ml./50g.)	78.8									
Whey-protein nitrogen (mg./g. powder)	7.5									
Particle size distribution	54 % = 3.6 to 14µ; 44% = 15 to 36µ; 2 % = 37 to 72µ; 0 % = greater than 72µ									

Storage period (months): One, Three, Six.

Standardized-clarified raw milk forewarmed to 165° F. for 20 sec., condensed to 49% t.s. at vapor temperature 91° F. Concentrate heated to 160° F. and homogenized twice at 2500 and 500 p.s.i., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 258° F., outlet air 191° F.

TABLE 24

Observed properties of whole milk powder (Sample 11c - control)

Property	Fresh	Storage period (months): One, Storage temperature (°F.): 33	One, 70	One, 90	Three, 33	Three, 70	Three, 90	Six, 33	Six, 70	Six, 90
Fat (percentage)	28.27									
Moisture (percentage)	1.40									
Free-fat (mg./g. fat)	19.4	18.8	20.2	21.4	20.3	22.6	22.6	19.9	22.2	21.3
Self-dispersion (g./15g. powder)	0.719	0.641	0.626	0.570	0.585	0.484	0.539	0.793	0.578	0.620
Flavor (hedonic rating)	5.0	4.0	5.0	5.4	4.0	4.2	3.8	4.8	3.8	3.8
Specific volume (ml./50g.)	71.5									
Whey-protein nitrogen (mg./g. powder)	7.6									
Particle size distribution	58 % = 3.6 to 14µ; 40 % = 15 to 36µ; 2 % = 37 to 72µ; 0 % = greater than 72µ									

Standardized-clarified raw milk forewarmed to 165° F. for 20 sec., condensed to 49% t.s. at vapor temperature 91° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 270° F., outlet air 192° F.

TABLE 25

Observed properties of whole milk powder (Sample 12)

Property	Fresh	Storage period (months): One — Storage temperature (°F.): 33	One: 70	One: 90	Three: 33	Three: 70	Three: 90	Six: 33	Six: 70	Six: 90
Fat (percentage)	28.48									
Moisture (percentage)	1.96									
Free-fat (mg./g. fat)	29.0	24.8	26.2	27.0	26.2	26.1	26.6	25.2	23.4	25.0
Self-dispersion (g./15g. powder)	0.716	0.557	0.587	0.618	0.632	0.707	0.630	0.657	0.596	0.619
Flavor (hedonic rating)	5.6	5.2	3.8	3.8	5.0	4.8	4.3	--	--	--
Specific volume (ml./50g.)	76.5									
Whey-protein nitrogen (mg./g. powder)	4.6									
Particle size distribution	14% = 3.6 to 14μ; 44% = 15 to 36μ; 38% = 37 to 72μ; 4% = greater than 72μ									

Standardized-clarified raw milk forewarmed to 240° F. for 20 sec. with Rogers-Terret direct steam injector, condensed to 46% t.s. at vapor temperature 100° F. Concentrate heated to 155° F. and homogenized at 2500 and 500 p.s.i., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 263° F., outlet air 192° F.

TABLE 26

Observed properties of whole milk powder (Sample 12c - control)

Property	Fresh	One			Three			Six		
		Storage period (months)								
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	28.48									
Moisture (percentage)	1.80									
Free-fat (mg./g. fat)	23.2	21.8	23.0	23.3	21.1	20.5	20.6	19.3	19.8	21.4
Self-dispersion (g./15g. powder)	0.987	0.581	0.632	0.606	0.786	0.715	0.689	0.633	0.684	0.594
Flavor (hedonic rating)	5.4	4.6	4.0	4.2	5.0	4.0	4.8	--	--	--
Specific volume (ml./50g.)	72.4									
Whey-protein nitrogen (mg./g. powder)	4.8									
Particle size distribution	14% = 3.6 to 14µ; 58 % = 15 to 36µ; 26% = 37 to 72µ; 2 % = greater than 72µ									

Standardized-clarified raw milk forewarmed to 240° F. for 20 sec. with Rogers-Terret direct steam injector, condensed to 46% t.s. at vapor temperature 100° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 261° F., outlet air 191° F.

TABLE 27

Observed properties of whole milk powder (Sample 13)

Property	Fresh	Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	28.40									
Moisture (percentage)	1.44									
Free-fat (mg./g. fat)	26.3	23.8	24.0	25.1	23.8	23.6	24.1	20.9	24.1	24.7
Self-dispersion (g./15g. powder)	0.788	0.632	0.620	0.609	0.658	0.597	0.601	0.668	0.716	0.646
Flavor (hedonic rating)	6.0	4.0	4.4	4.0	4.3	3.3	2.8	3.0	3.0	2.7
Specific volume (ml./50g.)	71.0									
Whey-protein nitrogen (mg./g. powder)	6.4									
Particle size distribution	26% = 3.6 to 14µ; 58% = 15 to 36µ; 16% = 37 to 72µ; 0% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 160° F. for 20 sec., condensed to 47% t.s. at vapor temperature of 90° F. Concentrate preheated to 185° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 233° F., outlet air 192° F.

TABLE 28

Observed properties of whole milk powder (Sample 13c - control)

Property	Fresh	One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	28.40									
Moisture (percentage)	1.50									
Free-fat (mg./g. fat)	19.6	18.6	19.3	19.5	18.4	19.0	19.8	18.7	20.8	19.4
Self-dispersion (g./15g. powder)	0.819	0.532	0.567	0.535	0.574	0.522	0.535	0.538	0.553	0.588
Flavor (hedonic rating)	5.0	4.0	3.8	4.0	3.3	2.8	2.8	3.7	3.3	3.0
Specific volume (ml./50g.)	70.0									
Whey-protein nitrogen (mg./g. powder)	8.0									
Particle size distribution	20 % = 3.6 to 14μ; 54% = 15 to 36μ; 22% = 37 to 72μ; 4% = greater than 72μ									

Storage period (months): One, Three, Six.

Standardized-clarified raw milk forewarmed to 160° F. fcr 20 sec., condensed to 47% t.s. at vapor temperature 90° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 262° F., outlet air 191° F.

TABLE 29

Observed properties of whole milk powder (Sample 15)

Property	Fresh	Storage period (months): One			Three			Six		
		Storage temperature ($^{\circ}$F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	28.15									
Moisture (percentage)	1.38									
Free-fat (mg./g. fat)	25.7	26.4	26.0	26.4	27.5	29.0	27.7	29.4	28.8	31.2
Self-dispersion (g./15g. powder)	0.734	0.576	0.610	0.533	0.663	0.593	0.509	0.608	0.453	0.379
Flavor (hedonic rating)	6.0	3.6	3.8	4.0	4.6	3.0	3.0	4.0	3.3	2.3
Specific volume (ml./50g.)	72.0									
Whey-protein nitrogen (mg./g. powder)	3.9									
Particle size distribution	18 % = 3.6 to 14μ; 60% = 15 to 36μ; 22% = 37 to 72μ; 0 % = greater than 72μ									

Standardized-clarified raw milk forewarmed to 300-305° F. for 20 sec. with Rogers-Terret direct steam injector, condensed to 45% t.s. at vapor temperature 92° F. Concentrate preheated to 183° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 250° F., outlet air 190° F.

TABLE 30

TABLE 30

Observed properties of whole milk powder (Sample 15c - control)

Property	Fresh	One			Three			Six		
		Storage temperature (^{o}F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	27.22									
Moisture (percentage)	1.44									
Free-fat (mg./g. fat)	26.1	24.4	23.8	24.0	27.1	28.3	27.7	26.8	27.0	26.6
Self-dispersion (g./15g. powder)	0.473	0.481	0.487	0.497	0.508	0.469	0.357	0.625	0.538	0.389
Flavor (hedonic rating)	5.5	4.0	4.2	3.8	4.3	3.7	2.3	3.7	3.0	3.0
Specific volume (ml./50g.)	72.0									
Whey-protein nitrogen (mg./g. powder)	4.0									
Particle size distribution	34% = 3.6 to 14µ; 46% = 15 to 36µ; 12% = 37 to 72µ; 8% = greater than 72µ									

Storage period (months): One, Three, Six.

Standardized-clarified raw milk forewarmed to 300-305^{o} F. for 20 sec. with Rogers-Terret direct steam injector, condensed to 45% t.s. at vapor temperature 92^{o} F. Concentrate pre-heated to 135^{o} F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 255^{o} F., outlet air 191^{o} F.

TABLE 31

TABLE 31

Observed properties of whole milk powder (Sample 17)

Property	Fresh	Storage period (months): One, Storage temperature (°F.) 33	One, 70	One, 90	Three, 33	Three, 70	Three, 90	Six, 33	Six, 70	Six, 90
Fat (percentage)	17.51									
Moisture (percentage)	4.56									
Free-fat (mg./g. fat)	14.4	10.3	14.0	14.8	14.9	15.7	14.3	13.6	12.9	15.0
Self-dispersion (g./15g. powder)	0.822	0.884	0.766	0.752	0.808	0.565	0.746	0.746	0.745	0.672
Flavor (hedonic rating)	4.0	4.3	4.3	4.4	4.0	4.5	3.5	4.2	4.0	3.8
Specific volume (ml./50g.)	67.0									
Whey-protein nitrogen (mg./g. powder)	8.4									
Particle size distribution	32% = 3.6 to 14µ; 50% = 15 to 36µ; 14% = 37 to 72µ; 4% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 165° F. for 20 sec., condensed to 40% t.s. at vapor temperature 89° F. Concentrate preheated to 135° F., spray-dried with No. ¼SBC5 nozzle at 600 p.s.i., inlet air temperature 268° F., outlet air 190° F.

TABLE 32

Observed properties of whole milk powder (Sample 17c - control)

Property	Fresh	One 33	One 70	One 90	Three 33	Three 70	Three 90	Six 33	Six 70	Six 90
		Storage period (months)								
		Storage temperature ($^{o}F.$)								
Fat (percentage)	17.51									
Moisture (percentage)	2.34									
Free-fat (mg./g. fat)	10.6	12.2	10.8	12.5	12.0	12.7	13.4	11.7	11.2	12.2
Self-dispersion (g./15g. powder)	0.763	0.584	0.498	0.503	0.666	0.580	0.450	0.423	0.365	0.325
Flavor (hedonic rating)	5.0	3.6	3.2	3.2	4.3	3.3	3.5	3.6	4.0	3.6
Specific volume (ml./50g.)	72.5									
Whey-protein nitrogen (mg./g. powder)	8.5									
Particle size distribution	24% = 3.6 to 14µ; 62% = 15 to 36µ; 12% = 37 to 72µ; 2% = greater than 72µ									

Standardized-clarified raw milk forewarmed to 165° F. for 20 sec., condensed to 40% t.s. at vapor temperature 89° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 270° F., outlet air 192° F.

TABLE 33

Observed properties of whole milk powder (Sample 18)

Property	Fresh	Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	19.81									
Moisture (percentage)	2.78									
Free-fat (mg./g. fat)	14.4	12.2	14.1	14.7	11.1	14.4	15.1	11.1	14.6	12.9
Self-dispersion (g./15g. powder)	1.653	1.331	1.251	1.525	1.043	0.953	0.815	1.027	0.851	0.887
Flavor (hedonic rating)	4.6	4.3	5.7	5.3	4.8	4.8	4.4	4.0	4.3	4.5
Specific volume (ml./50g.)	75.5									
Whey-protein nitrogen (mg./g. powder)	8.1									
Particle size distribution	12% = 3.6 to 14μ; 58% = 15 to 36μ; 20% = 37 to 72μ; 10% = greater than 72μ									

Pasteurized skimmilk forewarmed to 115° F., condensed to 50% t.s. at vapor temperature 89° F. Concentrated skimmilk recombined with cream, preheated to 135° F., spray-dried with No. 69/20 nozzle at 1000 p.s.i., inlet air temperature 230° F., outlet air 180° F.

TABLE 34

TABLE 34

Observed properties of whole milk powder (Sample 18c - control)

Property	Fresh	One 33	One 70	One 90	Three 33	Three 70	Three 90	Six 33	Six 70	Six 90
		Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	19.81									
Moisture (percentage)	2.10									
Free-fat (mg./g. fat)	13.8	16.5	17.5	18.8	15.3	21.5	18.5	15.8	15.7	17.2
Self-dispersion (g./15g. powder)	1.628	0.683	0.621	0.544	0.497	0.393	0.498	0.426	0.367	0.403
Flavor (hedonic rating)	4.4	4.3	4.7	4.3	3.6	3.8	3.6	4.0	4.8	3.5
Specific volume (ml./50g.)	79.0									
Whey-protein nitrogen (mg./g. powder)	8.2									
Particle size distribution	10% = 3.6 to 14μ; 60% = 15 to 36μ; 26% = 37 to 72μ; 4% = greater than 72μ									

Pasteurized skimmilk forewarmed to 115° F. condensed to 50% t.s. at vapor temperature 89° F. Concentrated skimmilk recombined with cream, preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., inlet air temperature 256° F., outlet air 193° F.

TABLE 35

Observed properties of whole milk powder (Sample 22)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (^{o}F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	26.00									
Moisture (percentage)	2.25									
Free-fat (mg./g. fat)	49.0	48.8	48.3	44.5	49.4	45.7	49.8	46.4	49.7	46.4
Self-dispersion (g./15g. powder)	0.577	0.434	0.383	0.390	0.444	0.342	0.281	0.407	0.325	0.317
Flavor (hedonic rating)	6.0	4.2	4.0	4.4	4.0	3.8	4.2	3.0	3.8	3.5
Specific volume (ml./50g.)	70.5									
Whey-protein nitrogen (mg./g. powder)	6.9									
Particle size distribution	46% = 3.6 to 14μ; 48% = 15 to 36μ; 6 % = 37 to 72μ; 0 % = greater than 72μ									

Pasteurized homogenized milk forewarmed to 125° F., condensed to 44% t.s. at vapor temperature 93° F. Concentrate treated with proteolytic enzyme lactivase (1 level tbsp./40 gal. whole milk) for 10 min., preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 190° F.

TABLE 36

Observed properties of whole milk powder (Sample 22c - control)

Property	Fresh	One			Three			Six		
		Storage period (months)								
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	25.90									
Moisture (percentage)	1.98									
Free-fat (mg./g. fat)	20.0	25.7	24.2	24.5	26.3	27.8	25.6	26.4	24.7	24.8
Self-dispersion (g./15g. powder)	0.805	0.518	0.450	0.487	0.413	0.437	0.482	0.491	0.350	0.381
Flavor (hedonic rating)	5.8	4.6	3.8	3.8	3.8	3.2	3.4	2.8	2.8	3.0
Specific volume (ml./50g.)	73.0									
Whey-protein nitrogen (mg./g. powder)	6.9									
Particle size distribution	18% = 3.6 to 14µ; 70% = 15 to 36µ; 12% = 37 to 72µ; 0% = greater than 72µ									

Pasteurized homogenized milk forewarmed to 125° F., condensed to 44% t.s. at vapor temperature 93° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 190° F.

TABLE 37

Observed properties of whole milk powder (Sample 23)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (^{o}F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	23.33									
Moisture (percentage)	2.22									
Free-fat (mg./g. fat)	22.3	63.0	60.6	58.0	61.6	65.6	60.7	53.7	60.7	48.5
Self-dispersion (g./15g. powder)	0.944	0.452	0.445	0.385	0.491	0.407	0.369	0.456	0.440	0.359
Flavor (hedonic rating)	3.8	3.6	3.8	3.6	4.3	3.7	3.3	4.0	3.5	3.8
Specific volume (ml./50g.)	67.0									
Whey-protein nitrogen (mg./g. powder)	7.1									
Particle size distribution	20 % = 3.6 to 14µ; 70% = 15 to 36µ; 10% = 37 to 72µ; 0% = greater than 72µ									

Pasteurized homogenized milk forewarmed to 125^{o} F., condensed to 45% t.s. at vapor temperature 91^{o} F. Concentrate preheated to 135^{o} F., spray-dried with No. 72/17 nozzle at 1000 p.s.i., outlet air temperature 170^{o} F.

TABLE 38

Observed properties of whole milk powder (Sample 23c - control)

Property	Fresh	Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	25.65									
Moisture (percentage)	2.36									
Free-fat (mg./g. fat)	48.8	54.0	54.5	54.3	55.5	53.3	55.6	55.8	53.0	56.0
Self-dispersion (g./15g. powder)	0.509	0.402	0.338	0.279	0.342	0.282	0.257	0.273	0.268	0.237
Flavor (hedonic rating)	3.8	3.8	4.0	3.2	4.0	3.3	4.0	3.8	4.0	3.3
Specific volume (ml./50g.)	67.5									
Whey-protein nitrogen (mg./g. powder)	7.0									
Particle size distribution	40 % = 3.6 to 14µ; 52% = 15 to 36µ; 6 % = 37 to 72µ; 2 % = greater than 72µ									

Pasteurized homogenized milk forewarmed to 125° F., condensed to 45% t.s. at vapor temperature 91° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 190° F.

TABLE 39

Observed properties of whole milk powder (Sample 24a)

Property	Fresh	One			Three			Six		
		Storage period (months)								
		Storage temperature (^{o}F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	27.57									
Moisture (percentage)	1.50									
Free-fat (mg./g. fat)	19.2	18.6	18.4	17.8	--	--	--	--	15.3	17.4
Self-dispersion (g./15g. powder)	0.416	0.230	0.280	0.218	--	--	--	--	0.335	0.312
Flavor (hedonic rating)	4.5	4.3	3.3	3.7	--	--	--	--	3.5	3.8
Specific volume (ml./50g.)	89.0									
Whey-protein nitrogen (mg./g. powder)	6.9									
Particle size distribution	76% = 3.6 to 14μ; 16% = 15 to 36μ; 4% = 37 to 72μ; 4% = greater than 72μ									

Pasteurized homogenized milk forewarmed to 125° F., condensed to 45% t.s. at vapor temperature 93° F. Concentrate treated with proteolytic enzyme lactivase for five minutes (1 tbsp./40 gal. whole milk), preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 185-188° F.

TABLE 40

Observed properties of whole milk powder (Sample 24b)

Property	Fresh	Storage period (months) / Storage temperature (°F.): One, 33	One, 70	One, 90	Three, 33	Three, 70	Three, 90	Six, 33	Six, 70	Six, 90
Fat (percentage)	27.57									
Moisture (percentage)	1.80									
Free-fat (mg./g. fat)	19.3	19.0	17.5	17.0	--	--	--	--	16.1	17.6
Self-dispersion (g./15g. powder)	0.346	0.296	0.315	0.294	--	--	--	--	0.368	0.344
Flavor (hedonic rating)	4.8	4.7	3.7	3.3	--	--	--	--	3.8	3.5
Specific volume (ml./50g.)	84.0									
Whey-protein nitrogen (mg./g. powder)	7.2									
Particle size distribution	14% = 3.6 to 14µ; 66% = 15 to 36µ; 16% = 37 to 72µ; 4% = greater than 72µ									

Pasteurized homogenized milk forewarmed to 125° F., condensed to 45% t.s. at vapor temperature 93° F. Concentrate treated with proteolytic enzyme lactivase for 10 minutes (1 tbsp./40 gal. whole milk), preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i, outlet air temperature 185-188° F.

TABLE 41

Observed properties of whole milk powder (Sample 24d)

Property	Fresh	Storage period (months) One			Three			Six		
		Storage temperature (°F.) 33	70	90	33	70	90	33	70	90
Fat (percentage)	27.57									
Moisture (percentage)	1.60									
Free-fat (mg./g. fat)	18.7	17.9	17.6	19.1	--	--	--	17.7	17.7	17.4
Self-dispersion (g./15g. powder)	0.379	0.372	0.336	0.249	--	--	--	0.379	0.379	0.309
Flavor (hedonic rating)	4.3	4.7	4.0	4.0	--	--	--	3.8	3.8	4.0
Specific volume (ml./50g.)	84.5									
Whey-protein nitrogen (mg./g. powder)	7.3									
Particle size distribution	26% = 3.6 to 14μ; 52% = 15 to 36μ; 18% = 37 to 72μ; 4 % = greater than 72μ									

Pasteurized homogenized milk forewarmed to 125° F., condensed to 45% t.s. at vapor temperature 93° F. Concentrate treated with proteolytic enzyme lactivase for 15 minutes (1 tbsp./40 gal. whole milk), preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 185-188° F.

TABLE 42

Observed properties of whole milk powder (Sample 24c - control)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (^{o}F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	27.57									
Moisture (percentage)	1.66									
Free-fat (mg./g. fat)	18.2	17.8	17.7	16.3	--	--	--	--	15.3	16.4
Self-dispersion (g./15g. powder)	0.649	0.447	0.467	0.439	--	--	--	--	0.497	0.547
Flavor (hedonic rating)	5.5	4.3	3.3	5.0	--	--	--	--	3.5	3.8
Specific volume (ml./50g.)	73.5									
Whey-protein nitrogen (mg./g. powder)	7.2									
Particle size distribution	14% = 3.6 to 14μ; 72% = 15 to 36μ; 12% = 37 to 72μ; 2% = greater than 72μ									

Pasteurized homogenized milk forewarmed to 125° F., condensed to 45% t.s. at vapor temperature 93° F. Concentrate preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 185° F.

TABLE 43

Observed properties of whole milk powder (Sample 25a)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	26.99									
Moisture (percentage)	1.56									
Free-fat (mg./g. fat)	34.6	24.2	33.0	34.4	30.8	38.8	39.4	29.3	40.9	43.4
Self-dispersion (g./15g. powder)	1.072	0.745	0.673	0.554	0.510	0.625	0.630	0.624	0.485	0.514
Flavor (hedonic rating)	3.5	5.2	4.8	3.6	3.8	4.3	3.5	5.0	4.8	2.3
Specific volume (ml./50g.)	74.5									
Whey-protein nitrogen (mg./g. powder)	7.8									
Particle size distribution	16% = 3.6 to 14μ; 60% = 15 to 36μ; 18% = 37 to 72μ; 6% = greater than 72μ									

Pasteurized skimmilk forewarmed to 125° F., condensed to 43% t.s. at vapor temperature 92° F. Concentrated skimmilk treated with proteolytic enzyme lactivase for 5 min. (1 tbsp./40 gal. whole milk), recombined with cream, and preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 185° F.

TABLE 44

Observed properties of whole milk powder (Sample 25b)

Property	Fresh	Storage period (months) One: Storage temperature (°F.) 33	One 70	One 90	Three 33	Three 70	Three 90	Six 33	Six 70	Six 90
Fat (percentage)	27.74									
Moisture (percentage)	1.66									
Free-fat (mg./g. fat)	40.3	21.6	32.3	29.6	29.4	40.4	41.5	30.9	40.5	43.0
Self-dispersion (g./15g. powder)	0.967	0.751	0.591	0.689	0.630	0.585	0.537	0.487	0.498	0.588
Flavor (hedonic rating)	4.3	4.2	4.6	4.2	4.3	4.3	4.5	5.5	4.3	2.8
Specific volume (ml./50g.)	73.0									
Whey-protein nitrogen (mg./g. powder)	7.6									
Particle size distribution	14 % = 3.6 to 14μ; 56% = 15 to 36μ; 24% = 37 to 72μ; 6% = greater than 72μ									

Pasteurized skimmilk forewarmed to 125° F., condensed to 43% t.s. at vapor temperature 92° F. Concentrated skimmilk treated with proteolytic enzyme lactivase for 10 min. (1 tbsp./40 gal. whole milk), recombined with cream, and preheated to 135° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 185° F.

TABLE 45

Observed properties of whole milk powder (Sample 25c - control)

Property	Fresh	Storage period (months): One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	25.97									
Moisture (percentage)	1.60									
Free-fat (mg./g. fat)	32.4	21.6	32.3	29.6	24.3	32.4	34.3	24.7	31.2	33.9
Self-dispersion (g./15g. powder)	0.910	0.755	0.768	0.704	0.606	0.695	0.558	0.611	0.627	0.481
Flavor (hedonic rating)	4.5	4.2	4.0	4.4	4.0	4.8	3.3	4.0	4.3	4.3
Specific volume (ml./50g.)	72.0									
Whey-protein nitrogen (mg./g. powder)	7.7									
Particle size distribution	16 % = 3.6 to 14μ; 68 % = 15 to 36μ; 12% = 37 to 72μ; 4 % = greater than 72μ									

Pasteurized skimmilk forewarmed to 125° F., condensed to 43% t.s. at vapor temperature 92° F. Concentrated skimmilk recombined with cream, preheated to 144° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 185° F.

TABLE 46

Observed properties of whole milk powder (Sample 26a)

Property	Fresh	Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	31.05									
Moisture (percentage)	1.36									
Free-fat (mg./g. fat)	18.9	16.1	20.8	19.2	16.1	20.6	21.0	--	--	--
Self-dispersion (g./15g. powder)	2.119	1.134	1.301	1.087	0.890	0.796	0.881	--	--	--
Flavor (hedonic rating)	5.3	4.5	5.3	4.3	3.8	3.5	3.3	--	--	--
Specific volume (ml./50g.)	70.5									
Whey-protein nitrogen (mg./g. powder)	6.0									
Particle size distribution	34 % = 3.6 to 14µ; 54% = 15 to 36µ; 12% = 37 to 72µ; 0% = greater than 72µ									

Pasteurized skimmilk forewarmed to 135° F., condensed to 42% t.s. at vapor temperature 88° F. Concentrated skimmilk treated with proteolytic enzyme lactivase for 5 min. (1 tbsp./40 gal. whole milk), recombined with fresh butteroil and homogenized; preheated to 150° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 190° F.

TABLE 47

Observed properties of whole milk powder (Sample 26b)

		Storage period (months)								
		One			Three			Six		
		Storage temperature (°F.)								
Property	Fresh	33	70	90	33	70	90	33	70	90
Fat (percentage)	31.65									
Moisture (percentage)	1.40									
Free-fat (mg./g. fat)	23.6	19.2	25.1	26.4	18.3	27.1	26.8	--	--	--
Self-dispersion (g./15g. powder)	2.412	0.978	0.853	0.892	0.807	0.661	0.773	--	--	--
Flavor (hedonic rating)	4.8	4.0	4.5	4.3	3.8	4.0	3.5	--	--	--
Specific volume (ml./50g.)	71.0									
Whey-protein nitrogen (mg./g. powder)	6.0									
Particle size distribution	18% = 3.6 to 14µ; 66% = 15 to 36µ; 16% = 37 to 72µ; 0% = greater than 72µ									

Pasteurized skimmilk forewarmed to 135° F., condensed to 42% t.s. at vapor temperature 88° F. Concentrated skimmilk treated with proteolytic enzyme lactivase for 15 min. (1 tbsp./40 gal. whole milk), recombined with fresh butteroil and homogenized; preheated to 150° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 190° F.

TABLE 48

Observed properties of whole milk powder (Sample 26c - control)

Property	Fresh	Storage period (months): One			Three			Six		
		Storage temperature (°F.)								
		33	70	90	33	70	90	33	70	90
Fat (percentage)	32.26									
Moisture (percentage)	1.30									
Free-fat (mg./g. fat)	27.0	26.6	28.8	28.4	26.2	27.4	27.5	--	--	--
Self-dispersion (g./15g. powder)	0.980	0.793	0.685	0.670	0.684	0.626	0.563	--	--	--
Flavor (hedonic rating)	5.0	5.0	4.8	4.8	3.8	3.5	4.3	--	--	--
Specific volume (ml./50g.)	76.0									
Whey-protein nitrogen (mg./g. powder)	5.9									
Particle size distribution	18% = 3.6 to 14μ; 54% = 15 to 36μ; 28% = 37 to 72μ; 0% = greater than 72μ									

Pasteurized skimmilk forewarmed to 135° F., condensed to 42% t.s. at vapor temperature 88° F. Concentrated skimmilk recombined with fresh butteroil and homogenized; preheated to 150° F., spray-dried with No. 69/20 nozzle at 2200 p.s.i., outlet air temperature 190° F.