



ABSTRACT

STUDIES ON INSTANTIZING AND PROPERTIES OF INSTANTIZED DRY MILKS

by Ken-ichi Mori

The purpose of the study was to determine the effect of various product related factors on the characteristics of the instantized dry milks, especially dispersibility and density. The cost of agglomerating operation also was investigated.

Skimmilk with high and low heat treatments or with various percentages of milk fat was concentrated and spray dried in a horizontal spray drier under controlled conditions. These dry milks were instantized in a Blaw-Knox unit. The particles were wetted with steam, subjected to hot air redrying and conditioned on a belt which delivered the product to the sifter. After sifting, the product was packaged in moisture proof containers and held at room temperature for analysis by common procedures.

In a comparison of instantized high heat and low heat nonfat dry milk the dispersibility was not significantly different (48.0 and 47.6 grams). Average density of 18 trials was higher and moisture increase due to instantizing was 0.37 percent higher in high heat samples. High heat nonfat dry milk shattered more easily as indicated by size of particles separated by the Rotap sieve test.

An 87 percent larger amount of particles passed through 100- and 200-mesh sieves.

Nonfat dry milk tempered to 40^o, 70^o or 90^o F. before entry into the agglomerating chamber gave the following average results on 12 trials of instantized samples, respectively:

- (a) The dispersibilities of 47.4, 48.3 and 47.7 grams were not significantly different.
- (b) The packed bulk density of 0.466, 0.490 and 0.477 gram per ml. was not significantly different.
- (c) The moisture increase during agglomeration and redrying was 1.72, 1.38 and 1.16. These are significantly different.

Instantized dry milks with 1, 2, 5 or 10 percent milk fat varied in dispersibility between 44.4 and 48.0 grams (no significant difference), but dry milk with 26 percent fat was 31.9 grams which was a significantly lower dispersibility. Moisture increase from instantizing was 0.97 percent for 1 percent fat dry milk and inconsistently varied from 1.84 to 2.12 percent for the dry milks with 2, 5, 10 and 26 percent fat. The packed bulk density average decrease of 5 trials was 0.268, 0.237, 0.223, 0.192 and 0.136 gram per ml. for the samples with 1, 2, 5, 10 and 26 percent fat.

Particles separated into groups according to size by sieve retention on 14-, 20-, 28-, 35-, 48-, 60-, 65- and 100-mesh screens did not show a significant difference in dispersibility.

However, particles retained on a 200-mesh screen and in the pan had a slightly lower dispersibility. Packed bulk density ranged from 0.223 to 0.613 gram per ml. as the particle size decreased when separated by retention on 14-mesh to the 200-mesh sieves or in the pan.

A combination of sieve and Coulter electronic counter methods was required to classify particles of agglomerated dry milks. A substantial variation in the percentage of particle sizes was evident in the results of six commercial brands of instantized nonfat dry milk obtained from the East Lansing, Michigan, grocery stores.

The projected cost of instantizing nonfat dry milk in the Michigan State University Dairy Plant was 2.1422 cents per pound of which 0.7230 was fixed and 1.4192 was variable costs. A commercial dry milk plant with an instantizer had fixed cost of 0.7517 cents per pound, variable of 1.6776 and thus total costs of 2.4293 cents.

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
LITERATURE REVIEW	4
I. Production of instant dry milk	4
A. After dehydration	4
1. Agglomeration by wetting	4
2. Coating and other methods	9
B. Single stage process	10
1. Large particle	11
2. Single stage agglomeration	13
C. Foam drying	14
1. Foam mat drying	15
2. Foam spray drying	17
II. Factors affecting instantizing	18
III. Change of properties of nonfat dry milk by instantizing	19
A. Dispersibility	19
B. Flavor	22
C. Color	23
D. Hygroscopicity	24
E. Nutritive value	25
IV. Tests and standards of instant nonfat dry milk	26

	Page
V. Usage of instant nonfat dry milk	26
VI. Costs	27
VII. Packaging	28
EXPERIMENTAL PROCEDURES	30
I. Preparation of nonfat dry milk samples	30
II. Preparation of dry milk samples with various milk fat contents	31
III. Instantizing process	32
IV. Design of experiments	33
V. Methods of testing the dry milks	34
VI. Cost analysis of instantizing operation	38
RESULTS	39
I. Effects of high heat and low heat nonfat dry milk and the temperature of the nonfat dry milk <u>per se</u> for instantizing on the properties of the instantized product	39
II. The influence of milk fat in dry milks on the properties of the instantized products	44
III. Particle size analysis	51
A. Particle size analysis of instantized nonfat dry milk	51
B. Combination sieve and counter methods	52
C. Properties of instant nonfat dry milk of different particle size	53
IV. Cost analysis of instantizing operation	55

	Page
A. Plant A	55
B. Plant B	60
DISCUSSION	64
SUMMARY	69
LITERATURE CITED	71

LIST OF TABLES

Table	Page
1. The effects of high heat and low heat nonfat dry milk and the temperature of nonfat dry milk on the properties of instantized product	40
2. Summation of analyses of variance for dispersibility, moisture increase and bulk density	42
3. Correlation coefficients among properties of instantized nonfat dry milk	43
4. Influence of milk fat in the dry milk on the properties of instantized dry milk	46
5. Comparison of properties of instantized dry milks with various milk fat contents	48
6. Correlation coefficients among properties of instantized dry milk with various milk fat contents ..	49
7. Classification of size and the resulting properties of commercial instant nonfat dry milks	52
8. Particle size analysis of Brand D of instant nonfat dry milk by combination of sieve and counter methods	53
9. Dispersibility and bulk densities of instant nonfat dry milk of various particle sizes	54
10. Shattering test results of low and high heat nonfat dry milk after instantizing	55

LIST OF FIGURES

Figure	Page
1. Regression line between bulk densities, loose and packed, in instantized nonfat dry milk	45
2. Regression line between bulk densities, loose and packed, in instantized fat containing dry milks	50

INTRODUCTION

Since the first instantized nonfat dry milk was marketed in 1954, the consumption of "instant" nonfat dry milk has increased very rapidly. Data giving the total instantized nonfat dry milk production were not available. However, practically all nonfat dry milk for home use is instantized. The reasons may have been attributed to its apparently quick dispersibility and solubility, and also to its ready availability.

It has been widely used not only for beverage purposes, but also for cookery. Industrial uses have been limited probably due to the higher cost. The amount of nonfat dry milk for home use was 141.7 million pounds in 1954, and 255.3 million pounds in 1963. Home use to the total nongovernmental use was 19.7 percent in 1954, and it increased to 28.5 percent in 1963 (3).

Dry whole milk and dry milk with 12 or 8 percent fat also have been available. Sales have been relatively small because of stability problem, cooked or chalky flavor and presumably lack of dispersibility.

In spite of the large amount of instantized nonfat dry milk that is currently produced, there is much that is not known about processing factors which influence the dispersibility and other characteristics of the final instantized product. Published information is lacking. Whatever is known has been restricted to individual

company personnel who may have conducted studies.

A disadvantage has been the increased cost of the agglomerating process. Furthermore the decrease in density results in added packaging expenses.

An objective of this study was to investigate various common product factors that affect agglomeration of dry milks and their influence on the characteristics of the resulting product. Of greatest interest was the effect of fat content, heat treatment, dry milk temperature for instantizing and particle size. Another objective was to ascertain the cost of agglomerating nonfat dry milk.

The term "instantize" refers to altering powder particles so that they disperse readily in water during reconstitution. There are various degrees of effectiveness of instantized products. All products called "instant" are not always strictly qualified. Agglomeration means, in this study, clumping or clustering of particles of powder into large aggregates. Since the single pass process has been less satisfactory for product dispersibility, agglomerating process has been widely employed. This causes two terminologies, instantizing and agglomeration, to be synonymous in trade usage.

Solubility usually refers to the ability of particles to dissolve homogeneously into water, forming a solution. Dispersibility implies the ability of particles to distribute as a colloidal state in water. The dispersed substance remains suspended in the liquid.

Since milk is a complex of many components, some are soluble such as lactose, and others are dispersible such as proteins. Despite the difference, trade usage of terms, solubility and dispersibility, has been interchangeable. In this manuscript, these two terms are used synonymously. Sinkability refers to the ability of the particle to penetrate the water surface and disperse or settle to the bottom of the quiescent container.

LITERATURE REVIEW

I. Production of instant dry milk

A search of the literature indicated that the manufacture of instant dry milk, especially nonfat dry milk, has been developed mainly in the United States. There are many processing techniques. They could be classified into three major groups: A. after dehydration (two-stage process), B. single stage process, and C. foam drying.

A. After dehydration

1. Agglomeration by wetting

Most processings were based on the principle of wetting and redrying. Dry milk with the normal small particles was produced by the conventional spray drier. The instantizing equipment, which might or might not be attached to the drier, formed clumps or clusters from many small particles. Nonfat dry milk was moistened by water or steam under specific conditions. The moistened particles stuck together to form aggregates attaining fluffy, porous, sponge-like structure. These aggregates were redried to the desired moisture level by hot air.

Several patents have been granted to inventors of equipment and methods under this classification. Although the principle was the same, there were many differences in machine design, such as method of wetting and redrying, maximum moisture content of

wetted dry milk and the claimed change of physical and chemical state of lactose and protein.

Peebles (44) has been considered the pioneer in the development of instant dry milk. Product from his process was first introduced extensively throughout the United States in 1954. According to the description of apparatus by Peebles (43) and Havighorst (22), the dry milk was dispersed as it entered the processing chamber. In the chamber, the dry milk came into intimate contact with an air stream containing finely atomized water and steam. The moistened particles stuck together to form aggregates. Their moisture content was adjusted between 10 to 20 percent. The moisture content was reduced to the desired level by means of heated air within a shaker-drier. The inventor claimed that substantial amounts of lactose changed into the crystalline form.

The Cherry-Burrell system was described by Carlson et al. (9). The dry milk was agglomerated in a horizontal chamber with moist air moving at high velocity. The moisture content increased 6 to 10 percent. Wetted particles were redried in a vertical tube of increasing diameter. Warm particles were cooled on a shaker-table, then sized between two stainless steel rolls.

Griffin (15) was granted a patent for the Blaw-Knox method. This machine was cone shaped and very compact. Two balanced

straight -line tubes with jets of steam were directed downward against each other at an angle of about 40 degrees from a vertical plane. Dry milk was passed in a free falling dispersion along this plane into the zone of collision of the two jets. The particles were moistened and dropped through a turbulent heated air drying stream onto a belt. Redried particles were conveyed by an inclined belt, on which cooling occurred to a gyrating sifter for sizing.

Lauder and Hodson (33) developed a modified method for instantizing products. A stream of dry milk containing less than 4 percent moisture was exposed to steam, causing surface moistening and agglomeration. The moisture content of wetted powder might increase to 9 percent, but preferably to 5.5 percent. The aggregates were immediately brought in contact with a hot air stream. The inventors claimed that the instantized product was characterized by a relatively high beta-lactose and a low alpha-lactose content which was thought to improve the dispersibility of the product.

An U.S. patent has been given to Bissell (5) for another modification of instantizing process. Dry milk was fed onto a moving belt from which it fell as a curtain into the path of a row of steam jets. The aggregates fell on the second belt and were carried into a drying chamber. The inventor claimed that a substantial portion of lactose in the dry milk, which was in the beta-anhydrous form, had been changed to the alpha-hydrate form in the instantized dry milk.

Scott (50) received a patent for a novel method of agglomerating wetted milk particles. Dry milk wetted in a hydration chamber with a fine spray of water or milk to a moisture content of 10 to 14 percent was then conveyed to a hammer mill within 15 to 20 seconds. During this time, according to patent claims, protein swelled and lactose was hydrated and absorbed its required water of crystallization. The agglomerates were redried on porous belts which traveled through drying ovens.

In the process invented by Shields (52), nonfat dry milk was moistened by water to approximately 15 percent and held for a sufficient period to convert a substantial portion of the lactose into the alpha-hydrate form. The product was dispersed in a stream of air and mixed with normal nonfat dry milk particles in such proportions that the additional particles occupied about 25 percent of the total solids in the final product. The inventor claimed the resulting clumps were highly soluble in cold water.

At the present time, instantizing has been mostly confined to nonfat dry milk. Hall and Hedrick (17), however, reported that a small amount of instantized dry whole milk, dry milk with 12 percent fat and dry buttermilk were being marketed in the United States, and an 8 percent fat dry milk in Canada.

A patent which provided specifically for the manufacturing of an instant fat containing dry milk product was granted to Peebles (45).

This process comprised the same steps used for instantizing nonfat dry milk (44), followed by spraying a butterfat-water emulsion over the porous agglomerates of the instant nonfat dry milk. Absorption of the butterfat was promoted by heating the fat and applying it in atomized form, and by having the dry milk temperature above the melting point of the fat. The amount of fat added to the instantized nonfat dry milk could be adjusted to as much as 70 percent.

Kennedy (28) reported in his patent the use of a protein modifying enzyme such as rennin or papain in fat containing milk concentrate having a solid content from 5 to 70 percent and a fat content from 12 to 65 percent dry basis. The mix was kept at the enzyme active temperature. The viscosity of the mix decreased first, then increased. Enzyme action was stopped by rapid heating to an enzyme inactivating temperature when the viscosity had risen from a minimum to at least its original value, but not to a point of greatly accelerated increase. Then mix was dried, producing easily reconstitutable fat containing dry milk.

Another patent specifically referring to fat containing dry dairy product was granted to McIntire and Loo (38). Their method comprised the homogeneous mixing of lecithin with a fat containing dry dairy product. Then, individual particles were moistened to an extent sufficient to render them sticky and caused these sticky particles to adhere together in the form of random shaped aggregates

of a size substantially greater than the size of individual particles. Finally excess moisture was removed.

2. Coating and other methods

Sjollemma (54) described a method of coating nonfat dry milk or whole dry milk with a surface-active agent such as oleic acid or soya lecithin to produce a product with instant properties. Warm dry milk was mixed with the liquid surface active agent in an amount of 2 percent by weight for about 5 minutes, then cooled. Inventor claimed that the finished product showed excellent dispersing action in cold water.

Budding (7) also received a British patent for using surface active agents. His process consisted of mixing the dry milk with 0.2 to 4.0 percent of a water-free liquid surface active agent. Suggested surface active agents were 1 percent oleic acid for non-fat dry milk, 2 percent of soya lecithin at 70° C. (158° F.) for dry whole milk, 4 percent of a mixture of 1 part of glyceryl monolaurate and 2 parts of olive oil for dry ice cream mix, and 1 percent of a 20 percent solution of egg lecithin in petroleum ether for dry baby food.

Niro Atomizers, Ltd. (42) developed an instantizing unit mounted under the conical drying chamber. Dry milk was discharged into the unit with a moisture content of approximately 8 to 10 percent. The instantizer was provided with special perforated plates which were divided into three sections. The plates were

vibrated, resulting in a forward movement of the powder particles toward the point of discharge as air passed upwards through the perforations. The first section served as an agglomerating compartment giving the product time to cluster. The second section served for the purpose of redrying the product to the required moisture content. In the last section, cold air was used to cool the instantized product. The atomizer of the drying chamber was provided with double outlets. One set was for concentrate and the other for fines. The fine particles were exhausted back through the atomizer for adherence to the concentrate spray; thus, some pre-agglomeration occurred in the spray drying chamber.

Recently an attempt has been made at TEKNIKA Inc. (47) to utilize sonic energy in agglomerating dry milk. Dry milk was introduced into stainless steel sonic column, in which intense sound was generated. Dry milk was agglomerated by the use of sonic energy and a slight amount of steam. The agglomerates formed blocks which entrained a large amount of air. The exposure to sonic energy was in terms of milliseconds. The block was either cut or ground to the size of particle desired. Since the exposure time was short, the inventor claimed that the final product did not have an overcooked flavor.

B. Single stage process

The single stage process does not require additional reprocessing

equipment. This process could be classified into two groups:

1. large particle dry milk that depends on size and density for reconstitution properties and 2. agglomeration of particles within the drying chamber. Some equipment can perform both to a limited extent.

1. Large particle

In order to dry a larger particle, longer drying time or higher drying temperatures were required. Since heat damage of protein places a limit on the temperatures that can be used, a longer drying time was often employed. A tower-type drier, which allowed the particle to remain suspended in the drying air for longer periods of time, was more ideal for this purpose.

Coulter and Townley (12) were granted a patent for the Coulter spray drier which could be operated to produce a large particle instant dry milk by varying conditions of drying such as large nozzle orifice, lower feeding pressure and a drying temperature adjustment to affect the required drying.

Sanna (48) designed a tower-type spray drier suitable for single stage instantizing. This tower was unique in the method of heating. Two or more heat zones were predetermined, depending upon the moisture content of the drying particles. The drier was tall with a capacity for more than one pressure nozzle delivering the concentrated milk near the top of the drying chamber. The falling particles

passed through at least two heating zones. In the first zone, the heat was more intense. The heating source in the first zone was electromagnetic wave energy as in the microwave range. This included several magnetron tubes arranged at the top of the tower above the spray nozzles. As the particles fell, they passed through an arrangement of baffles which prevented heating energy in the first zone from passing into the next zone. In the second zone, radiant energy was supplied by a series of infrared lamps. If necessary, additional heating zones could be added. The inventor also suggested that the whole system could be held under a partial vacuum to aid in drying products that are easily heat damaged.

The single stage process by Rice (46) involved evaporating milk to total solids of 40 to 45 percent, heating the concentrate to 165° F. for 20 seconds, and cooling to 80° to 95° F. in a cooling vat down to 40° to 45° F. About 1.5 gallons of concentrate containing partly crystallized lactose from a previous batch were added to each 1,000 pounds of concentrate in the vat. The mixture was agitated to produce a high viscosity. The concentrate was introduced into a spray drier having a nozzle with a relatively large orifice at low pressure and at a temperature of concentrate from 140° to 145° F. Inlet drying air temperature was sufficient to obtain an outlet air of 204° to 210° F. Dried particles of relatively large size, but quite dense, were obtained.

2. Single stage agglomeration

The University of Wisconsin drying tower is probably one of the most versatile driers used for milk today. This tower is suitable for the production of large particle instant and/or single stage agglomeration (4). Agglomerates were produced by using a suitable arrangement of five nozzles in the top of the drying chamber. Four of them were arranged horizontally, radiating out 12 inches from the circular common wall and 90 degrees apart. The fifth nozzle was placed 36 inches below the center of the other nozzles. The effect was to subject a mist of relatively dry particles from upper nozzles to a mist of relatively wet particles from the lower nozzle. This resulted in an agglomeration of the particles. Amundson (4) reported that under such an arrangement, moistures ranged from 6 to 7 percent and that further drying was required outside the main drying chamber.

Process described by Spiess and Sullivan (56) involved projecting one stream of an inert gas carrying the powder particles and another stream of an inert gas carrying an atomized wetting liquid into an agglomeration zone at high speed so that the two streams impinged on each other at an angle greater than 90 degrees, preferably 180 degrees. The chamber was designed to maintain these powder particles and liquid in suspension for a sufficient period of time to form agglomerates.

Method by Sharp and Kempf (51) was a single operation without rewetting. The process was comprised of three drying stages; in the initial spray drying stage concentrate containing a predetermined quantity of lactose seed crystals was sprayed through a hot drying air stream. The moisture content of the particle was reduced to 10 to 18 percent at a time when both crystalline lactose and noncrystalline lactose were present in the particle. Intermingling of the particles at this stage caused agglomerates to be formed by virtue of the tackiness of the noncrystalline lactose. These agglomerates then passed through the second and third drying stages where the moisture was reduced to the desired content.

Alfa Laval Co. (1) was granted a patent on a unique drier. The process relied on the recirculation of fine particles through the drying chamber to increase the particle size and, thus, improve the sinkability during reconstitution. In the drier, a suction element was installed above dry milk discharge which evacuated the fines and rediverted them into the atomizer. The atomizer had special openings for dispersing fines above the normal liquid discharge.

C. Foam drying

Foam drying was developed to minimize flavor defects and improve reconstitution of dry whole milk. Foam drying can be divided into two categories: 1. foam mat drying and 2. foam spray drying.

1. Foam mat drying

This process is also called film drying or puff drying.

Sinnamon et al. (53) reported on the manufacture of dry whole milk that was dried under high vacuum and low temperature with a sponge-like structure: milk was homogenized at 145° F. and 2,500 p.s.i., and pasteurized at 162° F. for 16 seconds. It was concentrated to 47 to 50 percent total solids at 85° to 100° F. in a high vacuum falling film evaporator, then heated to 135° F. and homogenized at 4,000 and 500 p.s.i. Before the concentrate was homogenized, nitrogen was entrained in it. The gas-concentrate then flowed over drying pans and was cooled to 55° F. The concentrate expanded as the pressure was reduced. A collapse of the sponge-like expanded structure in the early drying stages was prevented by maintaining quite low temperatures (near freezing point) and allowing some evaporation to take place before applying heat and drying.

Tamsma et al. (59, 60) further studied this type of drying. Milk was standardized to a solids-not-fat to fat ratio of 2.75:1 and preheated in a hot water jacketed vat under continuous agitation at 145° F. for 30 minutes. The milk was concentrated at 115° F. to 16° Baumé and standardized to 50 percent total solids. The concentrate was homogenized at 135° F. and nitrogen was incorporated at the same time by adding approximately 20 ml. of nitrogen (at room temperature and 1 atmospheric pressure) per liter of

concentrate through a fine capillary in the line immediately prior to the homogenizer. The concentrate was cooled to 50° F., dispensed onto a vacuum shelf of a drier and dried for 3 hours at below 1 mm. pressure. The temperature of the product was kept below 120° F. Dry foams were comminuted through a 20-mesh screen.

A patent was granted to Winder and Kielsmeier (63) for foam mat drying. Pasteurized, homogenized milk concentrate was cooled down to approximately 50° F. when substantially all of the fat was solidified. The concentrate was dried by electrical heating while attempting to maintain the fat in the solid state. The temperature of milk concentrate during the drying operation should be maintained below 95° F. until the solid content of the dried particle was at least 70 percent, and then, below the value specified by the equation:

$$Y = 47 - 15.4 \log 10X$$

where Y is the temperature in centigrade and X is the time in minutes, until the solids in the particle reached about 87 percent. This method, however, was not suitable for commercial milk drying as it was a batch method that required 80 minutes drying time.

The Chain Belt Company manufactured suitable equipment for the drying of whole milk. This machine was described by Fixari et al. (14). It was referred to as a vacuum dehydrator and has been used for dehydrating heat sensitive materials. The vacuum dehydrator consisted of a horizontal vacuum chamber, in which an

endless stainless steel belt passed over a heating drum at one end and a cooling drum at the other end. The drying material was sprayed on the belt which moves over or under a series of radiant heaters, over the heating drum, past another series of radiant heaters, each of which could be individually controlled for heating intensity, and then over the refrigerated cooling drum to complete the cycle. The cooled, dried product was scraped off by a blade and fell into a tube. An air lock permitted periodical removal of the product. The dehydrator has been acceptable for the drying of instant coffee and citrus juices. This dehydrator permitted a continuous drying operation. Drying time for milk would be only a few minutes, possible three or four.

Morgan et al. (40) described a modified technique. Milk was concentrated to about 36 percent solids, edible stabilizer was added, the concentrate cooled, whipped to produce a foam which was then spread on a drying tray or belt, dried by heated air at 130° to 190° F., screened and compressed. The inventors claimed that the dried products made by this process had a unique, fine structure and were easily reconstituted in cold water.

2. Foam spray drying

After milk was concentrated to 45 to 60 percent solids, gas such as nitrogen or air was incorporated by high pressure between the pressure pump and the spray nozzle by means of a mixing

chamber in the line. The resulting spray dried particles were very porous with a low density, but were easily dispersed in water.

Hanrahan and Webb (18) reported the above process was suitable for drying of whey with high acidity. Hanrahan et al. (19) also reported on the production of foam spray dried whole milk. Procedures were almost the same as for cottage cheese whey except nitrogen was used. The flow rate of nitrogen into the mixing device was determined by a flow meter and manually controlled by a needle valve. The high pressure pump was equipped with a spring-loaded bypass valve which allowed the utilization of various nitrogen-concentrate ratios, maintaining a constant pressure on the spray head. The resulting particles, although of light density and large size, had improved dispersibility on reconstitution.

II. Factors affecting instantizing

Several factors affect instantizing such as volume and velocity of air current, amount and dryness of steam used, size of chamber, etc.

Takano (58) theorized from the electron-microscopic photographs that regular nonfat dry milk particles with crust (formed by low drying temperatures and longer time) on the surface were difficult to moisten. High drying temperature and short drying time tended to form porous particles. Air bubbles within the particles influenced the density of nonfat dry milk. He stated that if the

particles were light, the particle traveled too fast and the frequency of the collision decreased. If too dense, the particles moved slowly, then faster air velocity and more air would be needed to get sufficient movement. He concluded that there should be a certain range of density of regular nonfat dry milk according to the design of the instantizer.

The bulk density depended upon the shape and inner structure of the powder particles (32). The spherical particles of spray dried milks permitted a closer packing than flaky shape of roller dried milk. The apparent density of spray dried nonfat dry milk ranged from 0.5 to 0.6 gram per ml. The bulk density of spray dried milks varied according to the type of plant and degree of precondensation of milk. Spray dried milk with a minimum of occluded air has a bulk density as high as 0.8 gram per ml.

III. Change of properties of nonfat dry milk by instantizing

A. Dispersibility

The reasons nonfat dry milk is improved in dispersibility and wettability by agglomeration are several in number. Literature review indicated that the improvement could be due to the increase of the weight of agglomerated particle. The water absorbing capacity caused by porous structure of the agglomerate increases dispersibility.

Bockian et al. (6) made a study of factors affecting dispersibility

of nonfat dry milk before and after instantizing. Dispersibility time of particles with various sizes was observed. Dispersibility time was defined as the time lapse between the initial contact of the particle with the water and the complete submergence of the particles beneath the water surface. In this sense, dispersibility meant wettability rather than its usual connotation. They found a general correlation between particle size and wettability. Protein nitrogen distribution, chloride, total alpha- and beta-lactose, sodium, potassium and calcium were investigated. Slight changes in the lactose distribution and in the protein distributions were considered insufficient to account for the increased dispersibility of instantized dry milks. They concluded that the wettability of instant dry milk resulted mainly from the distribution of salts, lactose and proteins, and also particle size. The successive washings of instant dry milk indicated that a reorientation of salts and lactose toward the particle surface occurred. They also concluded that the less soluble components such as calcium and protein were oriented toward the center of particles. The larger size and shape of the particles kept the individual particles farther apart as they reached the surface of the water. These heavier individual particles allowed more rapid breaking through surface tension of the water.

Schulz (49) stated that powder particles with less than 50 microns had in general very poor wettability. The larger the particle

size, the more wettable it was. He suggested particles should be 100 to 250 microns for purely soluble materials such as sugar and detergent. But, dry milk, because of its colloidal structure, needed to contact water as much as possible. He suggested particle size of 30 to 100 microns for dry milk with instant characteristics.

Loftus (34) compared commercial instant dry milks by microscopic study. He found that the particles of the most excellent dispersibility were larger than those of others and contained strong birefringent of many minute lactose crystals uniformly distributed throughout the particle.

Harper et al. (21) investigated the reconstitution rate of instantized nonfat dry milks. They used various times of contact of the dry milks with water and also analyzed the amount of water retained by the particles. Instant nonfat dry milk increased its water retention and usually decreased the rate of the solids passing into solution. They explained that contact between dry milk and water caused at least two reactions, one leading to the dispersion of the milk solids, and the other to the destabilization and insolubility of the milk proteins.

Starey (57) noticed a slight increase of temperature when instant nonfat dry milk was reconstituted in distilled water at 20° C. Instant dry milk of United States origin, other dry milks and lactose monohydrate were used. There was a general tendency for the

change of temperature to vary inversely with the expected degree of hydration. He reported that the samples of instant dry milk showed rapid dispersibility but appeared to be incompletely hydrated.

Howard et al. (25) investigated the surface areas of dry milks produced by various drying methods. The specific surface area, estimated permeametrically, of whole and nonfat dry milk was up to 9,200 cm²/gm. for spray dry milks and 2,400 to 5,600 cm²/gm. for instantized and foam dry milks.

Bockian et al. (6) found that a fairly large amount of anhydrous, amorphous lactose in nonfat dry milk and a ratio of alpha to beta crystallization of 40:60. The amorphous lactose absorbed water and became viscous during instantizing. Lactose was crystallized in instantized nonfat dry milk with the ratio of alpha to beta reversing to 60:40. Amorphous lactose dissolved quickly over the surface of water and increased the surface tension of water, this hindered the rest of the particles from being wetted, lactose in crystalline form such as alpha lactose dissolved more slowly, thus helping the wetting of the rest of the dry milk.

B. Flavor

Keeney and Bassette (27) mentioned that instant nonfat dry milk exhibited a more intense cereal-like flavor in reference to their observations of chemical changes.

Mann and McIntire (35, 36) found that the flavor acceptability

was almost the same for noninstant and for instant nonfat dry milk with a slight decrease during storage. They also performed flavor acceptability tests for paired samples under different storage conditions. Hedonic scores for instant and noninstant nonfat dry milks were initially 5.6 and 5.7 respectively, and were 4.7 and 4.8 after storage at 120° F. Triangular taste test indicated no significant difference either before or after storage at 100° F. and 120° F. They concluded that the instantizing process did not adversely affect the flavor of nonfat dry milk.

The flavor of the instantized nonfat dry milk was affected by preheating temperature of the skimmilk according to McDivitt et al. (37). Instant nonfat dry milk from milks forewarmed at 165° F. and 175° F. were superior to those heated higher or lower in temperatures. Preheating to 155° F. resulted in a product with the maximum scores for off flavors.

C. Color

Bockian et al. (6) observed some browning reaction in the instant dry milk. They thought the carbonyl compounds, the resultants of casein and lactose reaction were more rapidly dispersed than casein itself.

Keeney and Bassette (26, 27) found that the instantizing process promoted the development of browning-type reactions by their analysis of 5-hydroxymethylfurfural, reductone contents and

indophenol reducing values immediately after reconstitution of instant nonfat dry milk.

Kumet et al. (31) also reported that the instantizing process favored the development of the browning reaction. This was concluded by estimating ferricyanide reducing values of the protein. The extent of the browning reaction appeared to correlate with the amount of wetting and the necessary subsequent heating to redry.

Mann and McIntire (35) made a comparative investigation of flavor, acid ferricyanide reducing values, thiobarbituric acid value and color of instant and noninstant nonfat dry milks during storage. The color of noninstant was slightly lighter than that of instant milk. Average initial acid ferricyanide reducing value was 0.471 and 0.232 and the thiobarbituric acid value 0.191 and 0.085 for instant and noninstant, respectively.

Mann and McIntire (36) extended their study on paired samples under various storage conditions. The average thiobarbituric acid values for the instant nonfat samples were 0.210 before and 0.244 after storage at 100° F. The average ferricyanide reducing values were similar to those obtained with the thiobarbituric acid method.

D. Hygroscopicity

Studies in this aspect have been scarce. Sone et al. (55) investigated saturated vapor pressure curves of instant nonfat dry milk at various temperatures. These curves did not show the

hysteresis. This would account for the fact that capillary texture with porous structure was deteriorating. Their research showed that instantized dry milk was less hygroscopic than regular dry milk. The reasons were not explained completely, but the interference of hygroscopicity by the presence of crystalline lactose and/or decrease of undenatured portion of protein were offered as two possibilities.

E. Nutritive value

Hodson (23) reported the investigations of nutritional comparison of paired samples. One was noninstantized and the other was instantized. The results showed that there were no significant differences in thiamin, riboflavin, niacin, pantothenic acid and vitamin B₆ contents between instantized nonfat dry milk and fresh milk; nor did the conversion of a low heat nonfat dry milk into an instantized product by a commercial process affect the content of these vitamins. Only the ascorbic acid content of instant dry milk tended to be lower than that of the regular nonfat dry milk. Rat growth tests indicated that the protein quality in instant dry milk was similar to that in low heat nonfat dry milk or pasteurized milk.

The next year, Hodson and Miller (24) investigated the nutritive value of stored samples of instant nonfat dry milk. They stated that the rat growth tests showed no decrease in the nutritive value of the protein of samples of instant nonfat dry milk stored for periods of

two years. No loss of lysine was observed in samples stored in containers impervious to moisture. Samples stored in a cardboard container where the moisture had increased from 3.8 to 5.8 percent showed a slight loss of lysine, but the rat growth tests indicated no loss in its nutritive value.

IV. Tests and standards of instant nonfat dry milk

The instantizing of nonfat dry milk does not improve the quality of resulting product. Therefore, the manufacturer has to strictly specify the quality of nonfat dry milk to be used. In general, these requirements are: (a) low or medium heat nonfat dry milk with undenatured whey protein nitrogen between 2 to 5 mg. per gm., (b) large particle size, and (c) the U.S. Extra Grade. The American Dry Milk Institute and the U.S. Department of Agriculture have established standards for Extra Grade instant nonfat dry milk (2, 61).

V. Usage of instant nonfat dry milk

Because of its superior dispersibility, usage of instantized dry milk in many kinds of food would be very possible. The disadvantages would be the more expensive price and greater bulk than regular nonfat dry milk. These have not been serious disadvantages for use in the home. Consequently, practically all the more than 250 million pounds used at the retail level have been the instant type.

One report of usage of instant nonfat dry milk in commercial

scale cottage cheese production has been made by Kosikowski (30). Cottage cheese was made from reconstituted skim milk of instant nonfat dry milk. He stated that cottage cheese of good or excellent flavor was obtained. Because of the higher moisture retention (compared with regular low heat dry milk) during cooking, the body characteristics tended to result in a pasty body. Yields of uncreamed cottage cheese curd, adjusting to an 80 percent moisture content, averaged 1.64 and 1.72 pounds per pound of dry milk for low heat and instant nonfat dry milk samples, respectively.

VI. Costs

Hall and Hedrick (17) reported that from past experience, in order to achieve realistic operating costs, a plant had to produce at least 16,000 pounds of instant nonfat dry milk per day. Some plants produced 30,000 pounds a day (with a 2,000 pounds per hour standard unit). With a nominal investment for building, some plants were observing an operating cost of 0.5 to 0.75 cent per pound of finished product for an efficient operation. The estimated total cost of instantizing nonfat dry milk in several plants ranged from 1.5 to 2.0 cents per pound in 1958. The total processing cost was 6.8 cents per pound. The cost for instant nonfat dry milk to consumer in 1958 was approximately 47.2 cents per pound, with the allocation as follows: to producer 6.9; to processor 13.7; to distributor 36.1; to retailer 38.5; and to consumer 47.2 cents.

The operation cost in one commercial company in Japan was obtained (64). The cost of regular nonfat dry milk was 29 cents per pound and instantized nonfat dry milk was 38 cents per pound. The difference of 9 cents was considered to be instantizing cost (including packaging). The breakdown of the costs of instant nonfat dry milk in percentage was as follows: raw material (regular nonfat dry milk) 77.7; packaging materials 15.0; fuel and utilities 0.2; labor 1.5; depreciation 3.5; indirect costs 2.1 percent. These were based on annual production in 1962. The amount of instant nonfat dry milk produced was approximately 7.9 million pounds in a year, 25,000 pounds per day.

VII. Packaging

Packaging in a quantity to reconstitute into one quart is not as popular as it was for regular nonfat dry milk, due to the greater cost because of the lower density. Myrick (41) stated that a popular size for instant type was the 0.6 pound package which makes 3 quarts of nonfat milk at a cost to the housewife of from 23 to 30 cents. Larger packages of 1.6 pounds for 8 quarts, and 2.4 pounds for 12 quarts of reconstituted product have been in demand. For commercial and industrial usage, the powder is placed in fiber drums holding about 100 pounds or in bags holding 25 or 50 pounds. The carton type of retail packages are constructed of bleached, rigid paperboard. They have a separate liner consisting of a

polyethylene laminated paper. Aluminum foil laminated to paper overwaxed with a mixture of polyethylene and wax is another popular liner or overwrap.

EXPERIMENTAL PROCEDURES

I. Preparation of nonfat dry milk samples

Most samples of the nonfat dry milks were manufactured in Michigan State University Dairy Plant using equipment with commercial characteristics. Samples of instant nonfat dry milk on the market were purchased randomly from supermarkets in the East Lansing area. Samples of five different brands with the intention of each representing a different processing system were obtained.

Skimmilk was separated from the milk of a common source, pasteurized at 145° F. for 30 minutes, and divided into two portions. One portion of skimmilk was processed for low heat and the other portion was manufactured to obtain high heat treatment. The skimmilk concentrates were dried using two pressure nozzles, in a tear-drop frame horizontal drier with an auger in the bottom. Two sets of nonfat dry milk from low and high heat treatments were manufactured for the instantizing trials. An attempt was made to dry the milks to 3.0 percent moisture.

Processing details were:

	<u>Low heat</u>	<u>High heat</u>
(a) Skimmilk preheat temperature	145° F.	195° F.
(b) Hotwell temperature	145° F. for 1 min.	190° F. for 20 min.

(c) Evaporator steam chest	$155^{\circ} \pm 5^{\circ} \text{ F.}$	$165^{\circ} \pm 5^{\circ} \text{ F.}$
Vapor chamber	115° F.	115° F.
(d) Total solids of concentrate	38 - 42%	38 - 42%
(e) Concentrate preheat temperature	$125^{\circ} - 145^{\circ} \text{ F.}$	$155^{\circ} - 165^{\circ} \text{ F.}$
(f) Pressure to spray nozzle	2,500 - 2,700 p.s.i.	2,700 - 3,000 p.s.i.
(g) Inlet air temperature	$290^{\circ} \pm 5^{\circ} \text{ F.}$	$295^{\circ} \pm 5^{\circ} \text{ F.}$
(h) Outlet air temperature	$200^{\circ} \pm 5^{\circ} \text{ F.}$	$205^{\circ} \pm 5^{\circ} \text{ F.}$
(i) Nozzle diameter	0.0292 inch	0.0292 inch
(j) Core	No. 20*	No. 20*

To study the effect of dry milk temperature for instantizing, the samples were held at 90° , 70° and 40° F. until temperature equilibrium occurred.

II. Preparation of dry milk samples with various milk fat contents

Preparation of dry milks with different fat percentages was carried out according to the low heat treatment pattern. First, milk was separated into cream and skim milk. Separated skim milk was pasteurized and concentrated in accordance with the conditions in nonfat dry milk sample preparation.

*Spray Systems Co.

Standardization of fat and solids-not-fat was accomplished after concentration. The required amount of cream was added to the concentrated skim milk. The mixture was adjusted to approximately 40 percent total solids, heated to 140° F. and homogenized. Standardized concentrates were spray dried under similar conditions described for nonfat dry milk, except inlet temperature was lowered as the percentage of fat in concentrate increased. Dry milks with 2, 5, 10 and 26 percent fat were manufactured.

Nonfat and 2 percent fat dry milks were sifted through 24-mesh screen and 5, 10 and 26 percent fat dry milks through 12-mesh screen. All dry milks were packaged in 50-pound multi-wall Kraft paper bags with 2-mil polyethylene inner liner. Dry products were stored at room temperature until used for the trial unless otherwise stated.

III. Instantizing process

Instantizing was conducted in the Blaw-Knox Model 350 Instantizer. The instantizer was warmed until outlet redrying air temperature reached 150° F. Dry milk samples of 25 to 30 pounds were used for each trial. These were dumped into the feed hopper at the top of the instantizer and processing started soon thereafter. The control of processing was performed in accordance with the standard operation:

- (a) Dry milk feed rate (rheostat dial setting) 60 - 70

(b) Pressure of steam injection	3 p.s.i.
(c) Inlet redrying air temperature	295° - 305° F.
(d) Outlet redrying air temperature	155° - 165° F.

Difficulty was encountered in obtaining a uniform flow of samples with 26 percent milk fat from the hopper to the vibratory trough. Occasionally manual assistance was necessary to obtain a uniform discharge into the vibratory trough for distributing into the agglomeration chamber.

Preliminary trials indicated that 3 p.s.i. steam pressure was not sufficient for agglomerating dry milks with high fat content, such as 5, 10 and 26 percent. The steam pressure was raised to 4 and 5 p.s.i. Five p.s.i. resulted in excessively high moisture content. Finally, 4 p.s.i. was chosen for 5, 10 and 26 percent fat dry milks to be more comparable to 3 p.s.i. for 1 and 2 percent fat dry milks.

Inlet and outlet redry air temperatures were maintained at the same levels for all trials. During a 3- or 4-hour run, a considerable accumulation of milk solids was observed on the metal lining in the agglomeration section of the unit.

IV. Design of experiments

The first set of experiments was designed to investigate the effects of temperature of the dry milk per se on instantizing process and the properties of the instantized product. High heat and low heat

nonfat dry milks were studied for the same purposes. The next experiments were designed to study the effects of fat content in the dry milk on the agglomeration process and the properties of the resulting product.

Experiments were designed in a way to be able to conduct the analysis of variance. The experiment on heat treatments and temperature of dry milk ahead of agglomeration was designed as a randomized block containing a two-way factorial. Analysis of variance (13) was conducted to find the differences caused by the various factors. In order to determine the difference caused by a change of steam pressure in the trials with dry milks having milk fat the t-test (13) was used. Guenther (16) presented Tukey's method for multiple comparison which was used to compare the difference between the average for each condition in the experiments with dry milk having various amounts of milk fat.

Correlation and regression (8) among properties of instantized products were investigated. The CDC 3600 computer was used for a portion of the statistical analysis.

V. Methods of testing the dry milks

The following tests were conducted on the dry milks: American Dry Milk Institute methods (2) were used for moisture, scorched particle score, dispersibility and solubility. The Cenco method (39) also was used for moisture determination. Bulk density in loose and

packed form was determined by Harland's method (20). For the particle size analysis of dry milks, two methods were utilized; one was the Coulter electronic counter for small particles; the other was the Rotap sieve method for the large particles.

The Coulter counter (11) consisted of a sample stand, an amplifying and counting unit, and a small vacuum pump. A beaker containing the sample suspended in a 4 percent ammonium thiocyanate in isopropyl alcohol (vehicle) was placed on the sample holder in such a manner that a tube with a 280-micron or 400-micron aperture was immersed in it. The tube was filled with the vehicle and was connected to a vacuum system which provided for the flow of a measured volume of vehicle, for instance 500 or 2,000 microliter, through the aperture on the tube. Electrodes were located within and without the tube and a constant voltage maintained between them.

The vehicle flowing through the aperture exhibited a resistance which was changed when a particle passed the sensing zone. This change in resistance was amplified and counted. The size of particles was reflected by the magnitude of change in resistance which was manifested as pulse height on an oscilloscope. The number of particles passing through the aperture was counted electronically. An adjustable threshold setting permitted the counting of only those pulses which exceed a given height on the oscilloscope. In this manner, the minimum size of particles counted was regulated. To

increase the range of pulse height and thus the range of particle size measured, it was possible to decrease the resistance across the electrodes, and to increase the amplification gain. The volume of vehicle passing through the counting aperture was regulated by the vacuum system provided with a traveling mercury column which activated starting and stopping switches preset for known volume displacements.

The apparatus was standardized by determining the half count of an uniform size particle sample of known diameter in microns, such as ragweed pollen. The settings of amplification gain, threshold, resistance across electrodes were adjusted in order to calculate a calibration factor (k) for each aperture tube. This factor which corresponded to the known mean diameter of the standard was in turn used to calculate settings to give other particle diameters.

Counting of particles was then made in an unknown sample at these settings, usually starting with the largest particles. Coincidence of particles passing through the aperture at high counts was compensated by use of a coincidence factor which was a function of the number of particles actually counted, size of aperture and volume of vehicle passing through the aperture. The adjusted counts were corrected to particle volume factor for each interval in diameter. The summation of these factors comprised the total volume of particles in a given volume of vehicle. From these data, the

percentage weight distribution was calculated, assuming a uniform density for all particles.

The Rotap Testing Sieve Shaker was used with 8-inch diameter sieves of six different mesh sizes. The designations as U.S. sieve series were Nos. 40, 50, 60, 70, 100 and 200 which corresponded to 35, 48, 60, 65, 100 and 200 meshes, respectively (62). A 100-gram sample of instantized dry milk was placed on the top sieve. The system was closed and samples were submitted to shaking for 5 minutes with horizontal cycle of 300 and tapping rate of 150 per minute.

The dry milk retained on each sieve and bottom pan was weighed and percentage of the total was calculated. The retained particles on each sieve were considered to be relatively uniform in size. The sample on each sieve was examined for bulk density and dispersibility.

A shattering test was developed because none have been reported in literature. After preliminary study and alteration the following test proved useful: a 100-gram sample was weighed into a Sealright container. It was of 1 quart size and was a resin coated paperboard cylinder. The diameter was 3 1/4 inches and the height was 6 1/2 inches. The containers were sealed with adhesive tape at the joint of cover and body, and wrapped in a polyethylene bag as a precaution against sample loss. The samples were subjected to shattering by

rotation in a wooden butter churn at 35 revolutions per minute for 20 minutes. Inside churn diameter was 18 inches. After subjection to the shattering test the samples were classified for size by Rotap sieve method.

VI. Cost analysis of instantizing operation

The processing cost analysis of instantizing dry milk was conducted in the Michigan State University Dairy Plant (Plant A) and a commercial plant (Plant B). In this study costs were limited to those which occurred only for the instantizing operation. The various items were divided into the fixed or variable costs. Factors considered were: (a) labor cost, (b) utilities, such as steam, electricity and fuel, (c) depreciation, interest, tax, insurance and maintenance of machine and building, (d) miscellaneous supplies, (e) indirect expenses and so forth.

RESULTS

- I. Effects of high heat and low heat nonfat dry milk and the temperature of the nonfat dry milk per se for instantizing on the properties of the instantized product

The regular low heat nonfat dry milk had a moisture of 3.15 percent and 0.515 and 0.770 gram per ml. loose and packed density. The regular high heat nonfat dry milk analysis was moisture 3.05 percent, loose density 0.525 and packed density 0.769 gram per ml. Table 1 presents the analysis of dispersibility, moisture and bulk densities of six instantizing trials. The tests were conducted in duplicate.

Dispersibility of instantized high heat and low heat nonfat dry milk was similar. The average of 18 trials for high heat nonfat dry milk was 48.01 grams and for 18 trials of low heat was 47.61 grams.

Instantized high heat nonfat dry milk had higher loose and packed bulk density than low heat nonfat dry milk. The difference in average bulk densities in the loose form was 0.020 gram per ml. and in the packed form was 0.028 gram per ml.

The moisture increase in high heat nonfat dry milk after agglomeration and redrying averaged 1.60 percent for 18 trials. The low heat nonfat dry milk increased 1.23 percent.

Nonfat dry milk was tempered to 40^o, 70^o and 90^o F. and then instantized by the standard procedure. None of these three

TABLE 1--The effects of high heat and low heat nonfat dry milk and the temperature of nonfat dry milk on the properties of instantized product

Trial (num- ber)	Pre- heat treat- ment	Temper- ature for instan- tizing (deg. F.)	Disper- sibility (gm.)	Moisture increase (percent)	Bulk density	
					Loose (gm./ml.)	Packed (gm./ml.)
1	Low	90	47.35	0.55	0.373	0.510
	Low	70	48.78	0.95	0.338	0.472
	Low	40	47.10	1.10	0.320	0.463
	High	90	48.90	1.35	0.417	0.526
	High	70	48.82	0.95	0.384	0.521
	High	40	44.97	1.90	0.362	0.521
2	Low	90	49.40	1.30	0.342	0.500
	Low	70	47.00	1.20	0.320	0.446
	Low	40	47.10	0.95	0.325	0.442
	High	90	48.27	1.60	0.336	0.471
	High	70	50.15	1.25	0.370	0.503
	High	40	47.49	1.45	0.343	0.495
3	Low	90	48.17	-1.60	0.324	0.446
	Low	70	46.95	1.05	0.324	0.421
	Low	40	48.40	1.65	0.308	0.446
	High	90	49.07	1.35	0.314	0.438
	High	70	48.19	2.80	0.354	0.521
	High	40	46.67	2.15	0.312	0.446
4	Low	90	44.33	1.30	0.331	0.471
	Low	70	45.32	1.05	0.305	0.442
	Low	40	47.40	1.65	0.312	0.454
	High	90	46.12	1.25	0.333	0.520
	High	70	46.62	1.85	0.358	0.510
	High	40	48.07	2.10	0.316	0.458
5	Low	90	49.83	0.35	0.296	0.417
	Low	70	48.78	1.40	0.362	0.537
	Low	40	47.38	1.65	0.333	0.458
	High	90	48.23	1.50	0.324	0.490
	High	70	49.45	1.35	0.348	0.490
	High	40	47.61	1.55	0.336	0.480
6	Low	90	46.70	0.90	0.291	0.454
	Low	70	49.97	1.05	0.347	0.526
	Low	40	47.06	2.50	0.325	0.454
	High	90	46.56	0.95	0.350	0.532
	High	70	49.33	1.60	0.342	0.490
	High	40	49.63	1.95	0.338	0.476

TABLE 1--Continued

Trial (num- ber)	Pre- heat treat- ment	Temper- ature for instan- tizing (deg. F.)	Disper- sibility (gm.)	Moisture increase (percent)	Bulk density	
					Loose (gm./ml.)	Packed (gm./ml.)
Average low		90	47.63	1.00	0.326	0.466
Average low		70	47.80	1.12	0.333	0.474
Average low		40	47.41	1.58	0.321	0.453
Average high		90	47.86	1.33	0.346	0.488
Average high		70	48.76	1.63	0.359	0.506
Average high		40	47.41	1.85	0.335	0.479

temperatures (Table 1) seemed to affect the dispersibility significantly. The average of 12 trials were 47.41, 48.28 and 47.74 grams, respectively.

Nonfat dry milk tempered to 40° F. ranged in moisture increase after agglomeration and redrying from 0.95 to 2.50 percent. The average was 1.72 percent. Under similar conditions a temperature of 70° F. resulted in a moisture increase that averaged 1.38 percent. Nonfat dry milk tempered to 90° F. showed the least moisture increase. The range was 0.35 to 1.60 percent and averaged 1.16 percent.

The decrease in packed bulk density among 12 trials ranged from 0.248 gram per ml. to 0.328 gram and averaged 0.304 gram for the instantized nonfat dry milk tempered to 40° F. At 70° F. the results ranged from 0.233 gram per ml. to 0.349 gram and averaged 0.280 gram. At 90° F. the range was 0.237 gram per ml. to 0.353 gram.

The average was 0.293 gram.

Solubility index of all the samples was less than 0.1 ml.

Scorched particle scores were 15.0 mg. (Disc B) or less.

The results of analyses of variance for each property are shown in Table 2.

TABLE 2--Summation of analyses of variance for dispersibility, moisture increase and bulk density

Factor	D.F.	F values			
		Dispers- ibility	Moisture increase	Bulk density value	
				Loose	Packed
Preheat treatment (A)	1	<1.00	9.13**	10.03**	8.60**
Temperature for instantizing (B)	2	1.44	6.75**	2.91	1.94
A x B	2	<1.00	<1.00	<1.00	<1.00
Trials	5	2.31	3.68*	4.75*	1.71
Error	25				
Total	35				

Note: * Significant at 5 percent level

** Significant at 1 percent level

The degree of freedom for error was 25 and for the total was 35. Both were large compared to those for each factor. This fact indicated that the calculated F value became relatively large, in other words, significant differences of important factors could be

detected effectively. The six trials tended to equalize the processing variations, particularly those factors such as differences of room temperature and of moisture content of steam. Usually these factors are randomized, but they can be separated from the error, thus making the F test more effective. The interaction (A x B in Table 2) was the measurement of the degree of change of one factor affected by the existence of the other factor.

Correlation coefficients among properties are shown in Table 3.

TABLE 3--Correlation coefficients among properties of instantized nonfat dry milk

	Dispersibility	Bulk density		Moisture increase
		Loose	Packed	
Dispersibility	--	0.2202	0.1147	0.0128
Bulk density Loose		--	0.8020**	-0.0502
Bulk density Packed			--	0.0190
Moisture				--

Note: ** Significant at 1 percent level

The correlation between loose and packed densities was significant at 1 percent level. No significant correlations were found between other combinations, for example, dispersibility and packed bulk density.

Regression equation was $Y = 1.067X + 0.1200$. Y was the

packed bulk density in grams per ml. and X was loose bulk density in grams per ml. Regression line is shown in Figure 1.

II. The influence of milk fat in dry milks on the properties of the instantized products

The results of dispersibility, moisture increase and decrease of bulk density are shown in Table 4. Duplicate tests were conducted on five trials.

The dispersibility of dry whole milk (26 percent fat) was very inferior. It ranged from 28.10 to 33.53 grams and averaged 31.90 for five trials. Samples of dry milk with 1, 2, 5 and 10 percent milk fats had averages of 45.45, 46.98, 48.03 and 44.42, respectively. Three of the five samples with 10 percent milk fat failed to comply with the standard of not less than 44 grams.

The moisture increase of instantized nonfat dry milk (1 percent milk fat) averaged 0.97. This was approximately half of the increase of the other dry milks having 2, 5, 10 and 26 percent milk fat. These were 2.07, 1.98, 1.84 and 2.12 percent, respectively.

The loose and packed bulk density of the instantized dry milks with various amounts of milk fat in general had the same trend. The decrease in bulk density was less as milk fat content increased. The packed bulk density change averaged 0.136, 0.192, 0.223, 0.237 and 0.268 gram per ml. for dry milk samples with 26, 10, 5, 2 and 1 percent milk fat. This trend suggests that the effect of

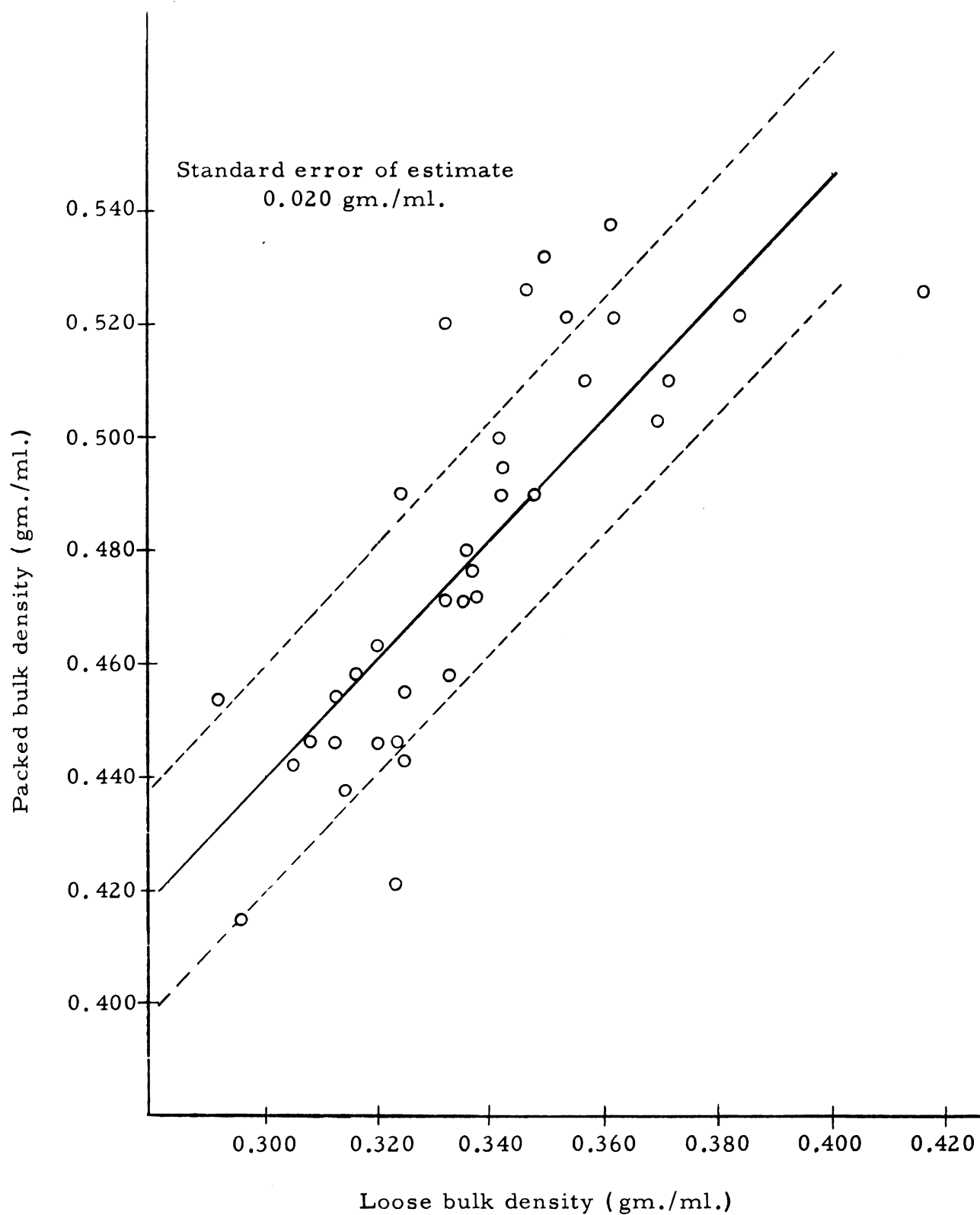


Fig. 1. Regression line between bulk densities, loose and packed, in instantized nonfat dry milk.

TABLE 4--Influence of milk fat in the dry milk on the properties of the instantized dry milk

Milk fat (per- cent)	Test	Number of trial					Aver- age
		1	2	3	4	5	
1 (nonfat)	Dispersi- bility (gm.)	44.58	44.73	45.28	46.18	46.48	45.45
	Moisture increase (percent)	0.95	1.55	0.30	0.95	1.10	0.97
	Decrease of bulk density (gm./ml.)						
	Loose	0.200	0.249	0.242	0.256	0.249	0.239
	Packed	0.227	0.287	0.254	0.287	0.283	0.268
2	Dispersi- bility	48.78	47.73	46.20	43.63	48.55	46.98
	Moisture increase	1.85	1.65	2.35	2.40	2.10	2.07
	Decrease of bulk density						
	Loose	0.100	0.177	0.224	0.220	0.211	0.186
	Packed	0.149	0.192	0.282	0.282	0.280	0.237
5	Dispersi- bility	47.80	49.25	48.95	48.05	46.08	48.03
	Moisture increase	1.93	1.60	1.90	2.40	2.05	1.98
	Decrease of bulk density						
	Loose	0.011	0.125	0.143	0.126	0.135	0.108
	Packed	0.167	0.250	0.225	0.235	0.237	0.223

TABLE 4--Continued

Milk fat (per- cent)	Test	Number of trial					Aver- age
		1	2	3	4	5	
10	Dispersi- bility	45.83	43.33	43.63	43.90	45.40	44.42
	Moisture increase	2.15	1.50	1.35	2.15	2.05	1.84
	Decrease of bulk density Loose	0.062	0.156	0.143	0.188	0.188	0.147
	Packed	0.081	0.191	0.185	0.242	0.260	0.192
26	Dispersi- bility	33.53	33.43	32.10	32.35	28.10	31.90
	Moisture increase	1.65	2.25	2.45	2.50	1.75	2.12
	Decrease of bulk density Loose	0.010	0.081	0.161	0.146	0.102	0.100
	Packed	0.017	0.138	0.165	0.172	0.187	0.136

agglomeration decreased as the milk fat content increased. Statistical evaluation indicated the packed bulk density between dry milk with 1 and 26 percent milk fat was significant.

Solubility index and scorched particle scores were examined before and after instantizing. Solubility index of all the samples was less than 0.5 ml., indicating no detectable change due to instantizing. Scorched particle scores were 15.0 mg. (Disc B) or less. Instantizing

did not increase the score of scorched particle content.

Since the range of percent milk fat in dry milk was large in this experiment, the usual analysis of variance was not adequate to find the differences. The multiple comparison of average values was determined. Results are shown in Table 5.

TABLE 5--Comparison of properties of instantized dry milks with various milk fat contents

Comparison of average of instant dry milk properties										
Fat percent	Dispersibility					Moisture increase				
	1	2	5	10	26	1	2	5	10	26
1	—	-	-	-	*	—	*	*	*	*
2		—	-	-	*		—	-	-	-
5			—	-	*			—	-	-
10				—	*				—	-
26					—					—
Decrease of bulk density										
Fat percent	Loose					Packed				
	1	2	5	10	26	1	2	5	10	26
1	—	-	*	-	*	—	-	-	-	*
2		—	-	-	-		—	-	-	-
5			—	-	-			—	-	-
10				—	-				—	-
26					—					—

Note: * Significant at 5 percent level

- Not significant

The correlation and regression among properties were calculated and results are shown in Table 6.

Only the correlation between loose and packed densities was significant at 1 percent level. No significant correlations were found among other combinations.

TABLE 6--Correlation coefficients among properties of instantized dry milk with various milk fat contents

	Dispersibility	Bulk density		Moisture increase
		Loose	Packed	
Dispersibility	—	-0.0779	-0.2437	-0.1419
Bulk density Loose		—	0.8589**	-0.0639
Bulk density Packed			—	0.0449
Moisture				—

** Significant at 1 percent level

Regression equation was $Y = 1.2056X + 0.1016$, where Y was packed bulk density in grams per ml. and X was loose bulk density in grams per ml. Regression line is shown in Figure 2.

The effect of instantized dry milk with 5, 10 and 26 percent milk fat caused by raising steam pressure 1 p.s.i. was examined. The moisture increase after agglomeration and redrying was greater with higher steam pressures. Bulk densities, loose and packed form, did not vary significantly. The dispersibility of dry milk with 26 percent milk fat increased significantly, from 31.90 grams to

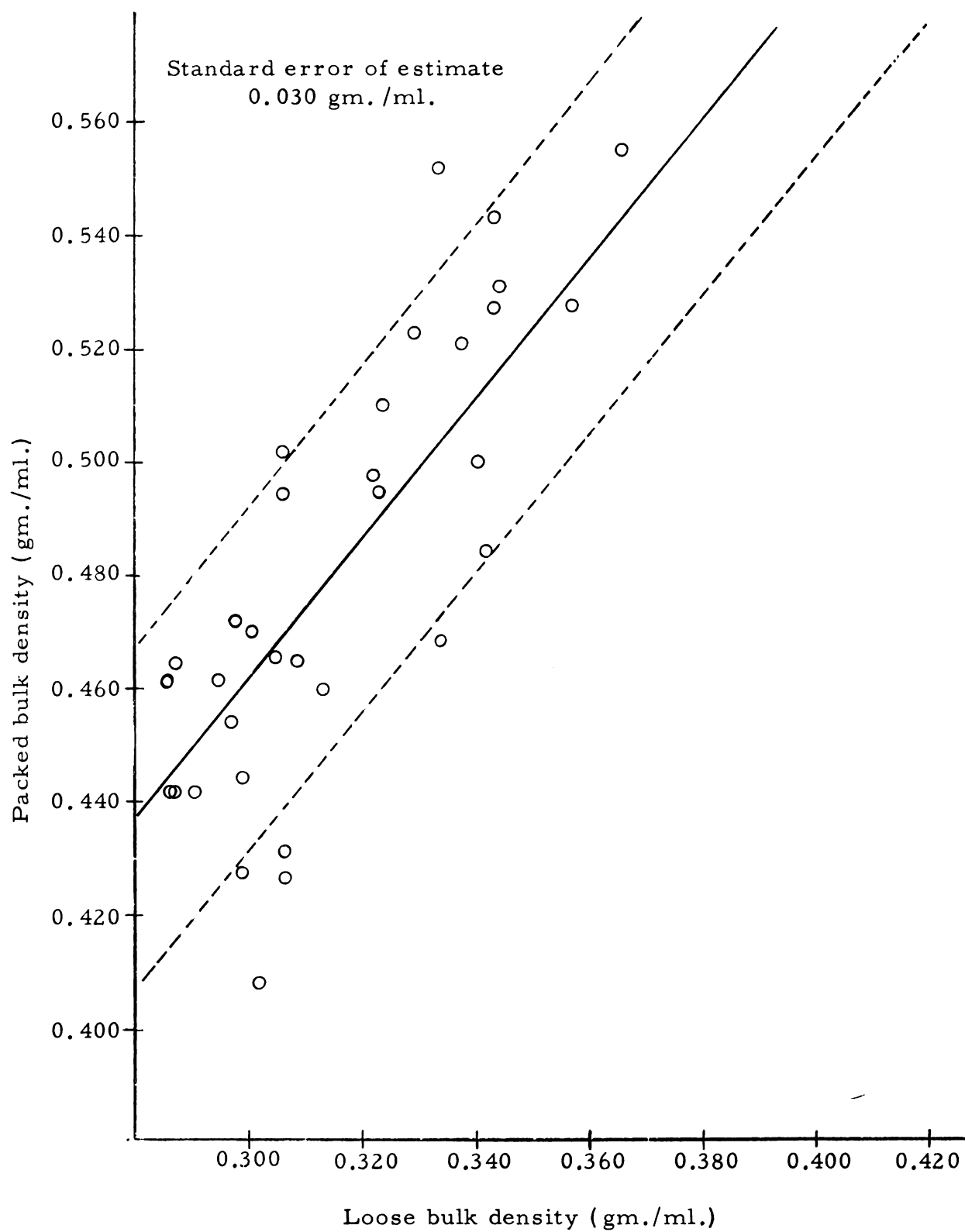


Fig. 2. Regression line between bulk densities, loose and packed, in instantized fat containing dry milks.

37.41 grams when the steam pressure was changed from 4 p.s.i. to 5 p.s.i. Both of these dispersibility values are below the standard of 44.00 grams. Five p.s.i. caused too high a moisture increase.

III. Particle size analysis

A. Particle size analysis of instantized nonfat dry milk

Six different brands of commercial samples including Michigan State University product were classified by the Rotap sieve method. The classification of size and properties of each sample is shown in Table 7.

Data in Table 7 are the average of duplicate determinations. The moisture content of all samples was less than 4.0 percent. Loose bulk density of samples was from 0.255 to 0.450 gram per ml. Packed bulk density also varied from 0.344 to 0.526 gram per ml. Dispersibility of all samples was above 44.00 grams, which was the minimum value designated by American Dry Milk Institute for this factor to qualify for Instant Type, Extra Grade.

Sample A had a large percentage on the sieve No. 200 and the same applied to sample E. Samples B and C showed very similar results. Both contained large percentage of coarse particles that remained on sieve No. 40. They had a second peak that was of relatively small particle size (sieve No. 100). Samples D and F were similar to samples B and C. The difference was that samples D and F contained a higher percent of coarse particles and less

of fine particles than samples B and C. All samples had the least percentage that remained on the sieve No. 70.

TABLE 7--Classification of size and the resulting properties of commercial instant nonfat dry milks

Sieve (num- ber)	Mesh	Brand					
		A	B	C	D	E	F
		Classification (percent)					
40	35	3.5	28.2	23.8	39.7	1.9	43.3
50	48	8.5	21.6	18.6	9.6	4.0	18.3
60	60	4.9	11.3	10.4	7.3	6.3	6.1
70	65	5.5	5.9	5.7	6.7	7.9	3.9
100	100	14.4	13.3	16.6	9.7	25.9	11.7
200	200	39.5	14.3	16.5	15.9	38.3	10.6
Pan		23.7	5.4	8.4	11.1	15.7	6.1
Total		100.0	100.0	100.0	100.0	100.0	100.0
Dispersibility							
(gm.)		45.45	46.70	49.00	47.58	47.53	47.07
Moisture							
(percent)		3.66	3.30	3.80	3.45	3.55	3.30
Bulk density							
Loose (gm./ml.)		0.316	0.291	0.311	0.284	0.450	0.255
Packed (gm./ml.)		0.446	0.373	0.376	0.376	0.526	0.344

B. Combination sieve and counter methods

Since the 400-micron aperture could count and classify only particles with a diameter of 200 to 250 microns or less, the larger particles were sifted out by Rotap for 5 minutes with U.S. sieves Nos. 16, 20, 30, 40, 50 and 60. The particles which passed through

TABLE 8--Particle size analysis of Brand D of instant nonfat dry milk by combination of sieve and counter methods

Sieve number	16	20	30	40	50	60	
Opening (mesh)	14	20	28	35	48	60	
Classification (percent)	16.0	10.8	9.5	7.3	8.7	4.2	
Diameter by counter method (micron)	210	184	146	116	92	74	59
Classification	7.0	9.5	10.0	8.0	3.9	1.8	0.1
Diameter by counter method	47	39	34	29	23	18	14
Classification	1.0	0.3	0.1	0.7	0.1	0.7	0.3

sieve No. 60 were subjected to the Coulter counter analysis. The results are shown in Table 8. Each value is the average of duplicate tests.

C. Properties of instant nonfat dry milk of different particle size

Instantized nonfat dry milk on each sieve was analyzed for the loose and packed bulk densities and dispersibility. Results are shown in Table 9. Each value is the average of duplicate tests of the sample retained on the designated sieve.

The loose and packed bulk densities of instant nonfat dry milk increased as the particle size decreased. Dispersibility of particles on each sieve between 14 and 100 mesh fluctuated between 46.28 and

TABLE 9--Dispersibility and bulk densities of instant nonfat dry milk of various particle sizes

Sieve No.	Mesh	Dispersibility (gm.)	Bulk density	
			Loose (gm./ml.)	Packed (gm./ml.)
16	14	48.56	0.187	0.223
20	20	47.45	0.192	0.237
30	28	49.15	0.211	0.257
40	35	46.28	0.222	0.302
50	48	46.40	0.257	0.338
60	60	49.45	0.284	0.350
70	65	48.53	0.310	0.379
100	100	47.19	0.357	0.441
200	200	44.73	0.394	0.483
Pan	---	44.44	0.500	0.613

49.45 grams with a lack of a consistent pattern in relation to size.

The dispersibilities of the particles held on 200-mesh sieve or collected in the pan were a trifle lower, 44.73 and 44.44 grams, respectively.

The nonfat dry milks with low and high heat treatments were subjected to a shattering procedure and particles were classified for size. The results are shown in Table 10. Each value in Table 10 is the average of tests in triplicate.

Results of low heat nonfat dry milk indicated that the total amount of particles retained on No. 100 sieve or larger in the control sample was 41.8 percent, but the percentage decreased to 27.4

TABLE 10--Shattering test results of low and high heat nonfat dry milk after instantizing

Sieve No.	Mesh	Low heat nonfat dry milk		High heat nonfat dry milk	
		Control (percent)	Shattering (percent)	Control (percent)	Shattering (percent)
40	35	10.3	7.0	1.7	1.3
50	48	9.3	6.0	5.3	2.7
60	60	5.0	2.7	3.0	2.3
70	65	4.0	3.0	3.0	2.0
100	100	13.2	8.7	8.7	7.0
200	200	29.4	30.1	32.3	30.2
Pan	---	28.8	42.5	46.0	54.5
Total		100.0	100.0	100.0	100.0

during the shattering procedure. The high heat control samples without the shattering procedure had a similar percent of fines as the low heat samples with the shattering procedure. Apparently some breakup of agglomerated particles occurred during the screening step of the instantizing operation. The shattering procedure had only a minor effect on breakup of agglomerates of high heat samples because of the high percent of fines in the control.

IV. Cost analysis of instantizing operation

A. Plant A

The cost of operation was projected on the basis of the following conditions:

(a) 8-hour working day with 21.67 days in a month and 260 days in a year.

(b) Time schedule of operation

8:00 - 9:00 a.m. setting up and preparation

9:00 - 12:00 a.m. production

12:00 - 1:00 p.m. lunch

1:00 - 3:30 p.m. production

3:30 - 5:00 p.m. cleaning up.

In other words, 2.5 hours were involved for auxiliary operations. Net production hours were 5.5.

(c) Entire operation including setting up and cleaning up of the instantizer was done by one operator.

(d) Rated production capacity was 300 pounds per hour, consequently, 1,650 pounds per day.

(e) The depreciation of the instantizer and the building was calculated by straight-line method for 10 and 30 years, respectively. Interest, taxes and insurance, and maintenance of equipment were added as 2.5, 2.0 and 3.0 percent of total investments, respectively. The maintenance of building was considered to be 1.5 percent per year.

(f) Allocation of indirect costs such as management, office, sales, laboratory, etc., was estimated on the basis that instantizing required 5 percent of total dairy plant drying operations.

(g) Requirements of utilities and supplies were calculated from the manufacturer's data and augmented by experience:

steam--6.7 pounds for hot water for cleaning per day,
40 pounds for instantizer per hour,
water--100 gallons per day,
electricity--43.6390 KWH--efficiency was assumed to
be 85 percent,
all purpose detergent--0.5 pound per day, and
acid cleaner--0.2 gallon per day.

(h) Prices of equipment, building, etc.:

instantizer total price was \$10,705.00,
ten percent was added as installation costs. Consequently, the initial investment was \$11,775.50,
building cost was \$15.00 per square foot. The space where the instantizer had been installed was 384.4 square feet,
labor cost of \$21.40 per day was used (10),
utilities and supplies:
the cost of a KWH was 1.8 cents,
water was \$0.15 per 100 cubic feet or 750 gallons,
steam at 100 p.s.i. cost \$2.25 per 1,000 pounds,
all purpose detergent was \$22.95 per cwt.,
acid cleaner was \$1.80 per gallon,

indirect costs such as management, office, laboratory,
etc., were taken from Plant A records.

(i) Breakdown of individual cost per day was as follows:

Fixed cost

Instantizer and accessories

Depreciation	\$ 4.529038
Interest	1.132260
Tax and insurance	0.905808
Maintenance	<u>1.358711</u>
Subtotal	\$ 7.925817

Building

Depreciation	\$ 0.739200
Interest	0.554423
Tax and insurance	0.443538
Maintenance	<u>0.332654</u>
Subtotal	\$ 2.069815

Indirect costs

Management	\$ 0.989505
Office	0.403375
Laboratory	0.207660
Maintenance	<u>0.333000</u>
Subtotal	\$ 1.933540

Fixed cost total \$11.929202

Fixed cost per pound of instant dry milk was 0.7230 cent.

Variable cost

Utilities and supplies

Electricity	\$ 0.785498
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Water	0.020000
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Steam for machine	0.585000
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for warm water	0.151200
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Detergent and cleaner	<u>0.474750</u>
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Subtotal	\$ 2.016448
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Labor	\$21.400000
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Variable cost total	\$23.416448
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Variable cost per pound of instantized dry milk was \$0.014192 and the fixed cost \$0.007230. The combined fixed and variable costs were \$35.35 or \$0.021422 per pound of instantized nonfat dry milk.

(j) Package cost

Bulk density of nonfat dry milk decreased approximately 100 percent during instantizing. Therefore, the space occupied by instantized product was twice as much as noninstantized product. This caused the package costs to approximately double.

If a regular 50-pound bag could accommodate only 25 pounds of instantized product, the package cost per pound was \$0.009576 based on the original cost of \$0.23915 per bag.

Same conditions could be extended to retail packagings.

A small operation used the cylinder shaped container of wax coated paperboard with push-in metal lid. It held 5 pounds of regular or 2 pounds of instant type nonfat dry milk. The cost of the container was \$0.12525. The package cost was 2.505 cents for regular and 6.2625 cents per pound for the instant nonfat dry milk.

B. Plant B

Information on instantizing costs for nonfat dry milk was obtained from the plant records that were maintained by a computer system for March 30 to April 25, 1964:

- (a) The data indicated that instantizing time was 97.25 hours per week or 19.45 hours per day. Five working days were considered a week and 260 days constituted a year.
- (b) The instantizing equipment was operated by two persons each shift.
- (c) Production capacity was 650 pounds per hour and 12,643 pounds per day which was an average of a 3-month operation.
- (d) The depreciation of instantizing equipment and building was calculated by straight-line method for 15 and 30 years, respectively. Interest was computed at 2.5 percent and tax and insurance at 2.0 percent of total investment. The maintenance cost was calculated to be 3.0 percent of

equipment and 1.5 percent of initial investment of the building.

- (e) Costs of utilities and supplies were obtained from the bills by allocating 0.7458 KWH per HP. A total of 68 HP was required by the motors. The efficiency of a motor was assumed to be 85 percent. Water used for processing averaged 8 gallons per hour and 1,000 gallons for cleaning which occurred once a week. Light, heat and fuel were estimated to be 70 percent of the monthly operation bills.
- (f) The information on indirect cost included a portion of management, office, sales and laboratory expenses.
- (g) Prices of equipment, building, etc.

The price of instantizing equipment was \$49,692 and installation cost of \$12,000 was in addition giving a total of \$61,692.

Building spaces considered in this study were processing room with 1,850 square feet, warehouse with 1,500 and fan room with 300. Processing room was two story in height. The cost per square foot was \$12.00, \$3.00 and \$10.00 respectively.

Labor cost averaged \$3.00 per hour including fringe benefits.

The cost of a KWH was \$0.012. Water was \$0.15 per

100 cubic feet or 750 gallons. Supplies and miscellaneous items were \$23.07 per day.

(h) Breakdown of costs on daily basis.

Fixed cost

Instantizing equipment

Depreciation	\$15.818615
Interest	5.931923
Tax and insurance	4.745538
Maintenance	<u>7.118308</u>
Subtotal	\$33.614384

Building

Depreciation	\$ 3.807615
Interest	2.855762
Tax and insurance	2.284615
Maintenance	<u>1.713462</u>
Subtotal	\$10.661454

Indirect costs \$50.761422

Total fixed cost \$95.037260

Variable cost

Utilities and supplies

Electricity	\$13.925577
Water	0.023707
Light	13.211814

Heat and fuel	\$ 17.863443
Supplies	<u>23.073373</u>
Subtotal	\$ 68.097914
Labor	\$144.000000
Variable cost total	\$212.097914
Fixed and variable cost total	\$307.135074

Variable cost per pound of instant dry milk was \$0.016776 and the fixed cost was \$0.007517. The combined fixed and variable cost was \$0.024293 per pound.

DISCUSSION

The dispersibility of instant nonfat dry milk was not significantly different between the low heat and the high heat types. However, the dispersibility test was not capable of indicating small differences. Undoubtedly, some factors other than the heat treatment of the skim milk before drying within the range of good practice have an important influence on dispersibility of the resulting instantized nonfat dry milk. Apparently the high heat instantized nonfat dry milk had fragile agglomerates. The sieve classification indicated a much larger amount of fines. However, these were not sufficiently small to affect the dispersibility test.

The analysis of variance denoted that the moisture increased more when instantizing high heat than low heat nonfat dry milk. The difference can be explained by the fact that high heat nonfat dry milk has a greater moisture absorption and adsorption capacity and controlled redrying air had no additional capacity to remove it. The exact nature of water binding capacity is not known.

Lots of nonfat dry milk were tempered to 40^o, 70^o or 90^o F. and then instantized. The analysis of variance indicated a significant increase in moisture retention of the instantized nonfat dry milk from the 40^o F. trial compared to 70^o F. trials and the 70^o F. trials compared to the 90^o F. trials. This trend might be anticipated on the basis of greater condensation on the particles from the humid air

currents in the agglomerating chamber. Since the difference averaged 0.34 percent between 40° F. and 70° F. trials and 0.16 percent between 70° and 90° F. trials the keeping quality of instant nonfat dry milk would be affected to a small extent. Therefore, to reduce moisture variation of the instantized nonfat dry milk the temperature of the powder per se should be controlled. Another possibility would be to adjust steam flow into the agglomerating chamber. The air movement in the chamber is balanced for a predetermined rate of product infeed so that increasing the amount of nonfat dry milk is not a recommended correction.

Despite careful attempts to control the instantizing operations significant differences were observed among the moisture increases of various samples. From a practical standpoint the moisture of instant nonfat dry milk should be limited to not more than 4.5 percent. This is the standard for Extra Grade, Instant Nonfat Dry Milk published in 1963 by the U.S. Department of Agriculture (61). Correlation analysis did not reveal a relationship between moisture increase after redrying and dispersibility of instantized nonfat dry milk.

The dispersibility of instantized nonfat dry milk was independent within limits of the bulk density. Within the classification of particle sizes studied, sieves with 14 to 200 mesh plus pan, the dispersibility did not show a correlation until particles passed

through the 100- and were retained on the 200-mesh sieve. The product in the pan (not collected on the 200-mesh sieve) was only slightly lower in dispersibility. There may be several reasons the difference was not pronounced. The product in the pan may have contained a minimum of the exceedingly small particles. These are known to be detrimental to dispersibility. A representative sample contained 9 percent particles of 92 microns or smaller (fines) in diameter. Plants may add up to 15 percent fines to instant nonfat dry milk for commercial sale. The dispersibility method may not have been sufficiently refined for consistently detecting small differences. The term, dispersibility, has been applied to different phenomena in reconstitution of nonfat dry milk. For example, Bockian et al. (6) reported a general correlation existed between particle size and dispersibility. A scrutiny of their dispersibility method indicated that these authors were actually measuring wettability.

An analysis of the effect of milk fat content of instantized dry milks on dispersibility denotes a lack of significant difference among dry milks with milk fat contents of 1, 2, 5 and 10 percent although the average of all trials is slightly less for the dry milk with 10 percent than the other three dry milks. In fact, more than half of the results were below the minimum of 44 grams. Dry whole milk (26 percent milk fat) was significantly lower in

dispersibility (31.9 grams) than the average of the samples with 1, 2, 5 and 10 percent milk fat that were from 44.4 to 48.0 grams.

The milk fat in large amounts such as dry whole milk undoubtedly retards wetting of the particles during agglomeration. The use of more moist steam during agglomeration was an attempt to overcome the wetting problem. Theoretically milk fat on the surface of the particle would not be expected to have as much adherence during the collision of particles as wetted casein or lactose. The lyophobic property of milk fat also would decrease its dispersion tendency in aqueous solutions. The form of the fat also would have an effect. The free fat should have a larger adverse influence than fat within its natural membrane covering.

A direct influence of increasing amounts of milk fat in the dry milks on bulk density was noticed. The specific gravity of milk fat is definitely lower than the remaining components of milk; however, this fact was offset by the reduced agglomeration of dry milk with the high milk fat contents. The net effect was a higher bulk density of the dry milk with higher percent milk fat. The difference between 1 and 2 percent milk fat in the dry milk was not detectable by bulk density.

The Coulter counter has definite limitations for classifying the particle size of agglomerated dry milks. Separation by the sieve method is necessary for the larger agglomerates; then the Coulter

counter can be used for the remainder which must be within the counting range of the aperture tube. Replications are desirable to assure reliability of results because of the very small quantity of sample used for the Coulter method. Another consideration is the complexity of the calculations of particle size from the data. The use of a computer minimized the required time for the calculations. Kinsman (29) reported that a 12-point curve (data from 12 observations) required 2 minutes with a computer, 7 to 10 minutes with memory type calculator, 10 to 15 minutes with standard calculator and 20 to 30 minutes with slide rule.

Cost analysis of two instantizing operations showed that these expenses are important. The projected cost of 2.14 cents per pound for Plant A and 2.43 cents per pound for commercial Plant B represent 15.3 and 17.4 percent increases over 14 cents for regular non-fat dry milk. In addition, the packaging cost would double approximately for the agglomerated dry milk because of the decrease in bulk density.

The largest item of expense was labor. It constituted more than 50 percent of the instantizing expenses. Large capacity operations should be able to utilize labor more efficiently so the cost per pound should be lower.

SUMMARY

The dispersibility of high heat and low heat nonfat dry milk after instantizing was not significantly different. The difference in bulk density by the loose and packed methods was small, but significantly greater for the high heat nonfat dry milk. This may have been due to the larger amount of small particles. Instantized high heat nonfat dry milk had an 87 percent larger content of small particles (those passing through 100- or 200-mesh sieves); conversely less larger particles were retained on 35- to 65-mesh sieves indicating a greater breakup of agglomerates during sifting or the sieve test than low heat nonfat dry milk. The high heat nonfat dry milk retained more moisture from redrying after agglomeration than the low heat product. The average difference was 0.37 percent.

Nonfat dry milk tempered to 40°, 70° or 90° F. for instantizing showed no significant difference in dispersibility. The same applied to bulk densities. The average moisture increase after agglomerating and redrying was 1.72 percent, 1.38 and 1.16 for 40°, 70° and 90° F. nonfat dry milk, respectively.

The dispersibility of instantized dry milks with 1, 2, 5 or 10 percent milk fat varied (44.4 to 48.0 grams), but all averaged above the minimum standard of 44.0 grams. Dispersibility of dry milk with 26 percent milk fat averaged 31.90 grams. After agglomeration and redrying the moisture increase of nonfat dry milk (1 percent

milk fat) was 0.97 percent. Dry milks with 2, 5, 10 and 26 percent milk fat varied from 1.84 to 2.12 percent increase. The increase was not consistent with the milk fat content increase. The packed bulk density decreased 0.268, 0.237, 0.223, 0.192 and 0.136 gram per ml. with the milk fat content of 1, 2, 5, 10 and 26 percent in the instantized dry milk.

A large variation was observed in the particle sizes of six brands of instantized nonfat dry milk on the local retail market. The sieve method of separating particles with screen mesh of 14, 20, 28, 35, 48, 60, 65 and 100 did not give samples with a significant difference in dispersibility. Particles retained on the 200-mesh sieve and in the pan had a slightly lower dispersibility. The loose bulk density increased from 0.187 to 0.500 and packed bulk density from 0.223 to 0.613 gram per ml. with the above range of particle sizes. A combination of the sieve method and Coulter counter was required to classify particle sizes of agglomerated nonfat dry milk.

Plant A with an instantizer having a capacity of 300 pounds of instantized product per hour had a fixed cost of 0.7230 and variable cost of 1.4192 for a total instantizing cost of 2.1422 cents per pound. Plant B's capacity was 650 pounds per hour. The fixed cost was 0.7517 cent and the variable cost was 1.6776 cents. The total instantizing cost was 2.4293 cents per pound.

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