RECENT DEVELOPMENTS IN MANUFACTURING,
STORING AND PACKAGING OF DRIED MILKS

by

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INTRODUCTION

History of the Industry

Although the dry milk industry originated shortly after
1900 in the United States, reference to dried milk products
dates back to the thirteenth century. Marco Polo (1254-1324)
upon his return to Venice in 1295, reported that the soldiers
of Genghis Khan were reputed to have carried sun dried milk
products as part of their ration (37).

In 1810, dried milk, in tablet form, was made by the French
scientist Nicolas Appert (12). The drying of milk by applica-
tion of heat was first accomplished by a process invented by
Grimwade to whom a British patent was issued in 1855. By this
method milk was condensed in an open kettle to a dough, sugar
was added and the mixture was pressed into ribbons and dried.
This process, however, was never used extensively (37).

The beginning of milk drying on a commercial scale dates
back to the last half of the nineteenth century. The first suc-
cessfully dried milk product manufactured commercially in the
United States was malted milk. The process was invented by
Horlick in 1883, and the product first placed on the market in
1887 (37).

Freeze drying of milk, initiated by Mac Intyre, in 1894,
(37) was first accomplished by centrifugally removing ice crys-
tals or by causing them to sublime in the drying chamber. As
the ice was separated by centrifugation, concentration of the
milk resulted. The concentrate thus formed was refrozen and re-

separated to recover a heavy paste-like dried mass, which had to be dried under vacuum. One of these procedures employed the principle of sudden freezing and drying by injecting the material to be dried into a rotating drum where the small particles were quickly frozen and dried (25).

The "flake" process developed by Campbell (12), was based upon the general principle of the dough process. This method did not gain public acceptance and was never used extensively.

The experimental work of the past century provided the technology by which milk could be dried on a large scale. It made possible the appearance of the first commercial production of unadulterated dried milk and nonfat dried milk in the United States in 1903. By 1906 all of the present commercially used processes were in operation (12).

The roller film or drum drying method was first used in 1893 and 1894 by the Merrell-Soule Company for drying infant cereal food (12). This method later became the now famous drum drying process for drying milk. The milk is dried by coating a single or double heated drum with the product, revolving the drums and scraping off the dried material after a partial revolution has been completed. The drums are steam heated and may be operated at atmospheric pressure or under vacuum. Almost all products are concentrated in a vacuum pan before they are dried. Roller drying can be profitably conducted on a smaller scale than spray drying. Double drum dryers occupy only a small space in the plant and can remove from 1,000 to 6,000 pounds of water per hour from various types of milk products.

The process of spray drying was invented by Percy in 1872, and is described in U. S. Patent No. 125,406 (37). Originally this method was not used for drying milk, and it was not until 1901 that Stauf applied the Percy process for this purpose. The basic principle set forth in this patent is still in existence today (37). Spray drying of milk is carried out by spraying the partially concentrated product centrifugally and/or under 2,000 to 5,000 pounds per square inch pressure into a chamber through which a current of heated air is directed. The finely atomized particles are dried almost instantly and are quickly separated from the hot air, making the dried milk particles drop into hoppers while the moisture laden air escapes through a mill gauze, woolen material.

Two types of spray drying processes are in use in the United States. In one system the product is sprayed into a large rectangular chamber where upon contact with heated air it dries and falls to the floor. In the second type the product is dried as it is sprayed into a cyclone of heated air. The powder is removed from the bottom of a cone-shaped drying chamber after the fine particles have been separated from the air. The capacity of these drying units is usually between 30,000 and 150,000 pounds of fluid products daily with an hourly production of 200 to 1,000 pounds of powder (37).

The Growth of the Industry

The manufacture of dry milk products represent a major branch of the dairy industry in the United States. According to

statistics compiled by the U. S. Department of Agriculture for
1958 (63), production of dry whole milk, nonfat dry milks and
dry buttermilk amounted to 1,847.45 million pounds. Of this to-
tal, 85.5 million pounds were dry whole milk, 1,689.85 million
pounds were nonfat dry milk and 72.1 million pounds were dry
buttermilk solids. As a comparison, and in order to show the
growth of the industry, the annual production figures of the
principal dry milk products for 1906-1957 inclusive are presented
in Table 1.

Table 1. Annual production figures of the principal dry milk
products for 1906-1957, inclusive.

Year	Dry whole milk 1,000 pounds	Nonfat dry milks 1,000 pounds	Dry buttermilk 1,000 pounds
1906[a]	35	2,625	*
1916	2,123[a]	16,463[a]	324[b]
1926[b]	10,768	91,718	31,378
1936[b]	18,180	349,550	50,781
1946[b]	188,153	666,254	38,082
1957[c]	97,300	1,692,000	69,200

* - Not available
a - Coulter, S. T. Dry Milk Manufacture, J. Dairy Sci. 39(6)
843-846. 1956
b - Hunziker, O. F. Condensed Milk and Milk Powder, 7th. ed.
Publ. by the Author, La Grange, Ill. Feb. 1949.
c - Production report by the American Dry Milk Institute for 1957.

Nonfat Dry Milk. The greatest increase in production and
utilization of a single dairy product during the past decade has

occurred in the area of nonfat dry milk. The tremendous growth
of the nonfat dry milk industry can probably be attributed to the
following developments:

1. Caloric consciousness on the part of the American con-
sumer, with the resultant shift to a higher protein and lower fat
diet.

2. Technological progress of the dry milk industry to make
nonfat dry milk more palatable, available at a low cost, and ac-
cessible in a small unit consumer package.

3. The development of the instantizing process for nonfat
dry milk by Peebles (52), in 1954, increased consumer acceptance
of this product. The Peebles' process produced an ice water
soluble, free flowing crystals, non-foaming, nonfat dry milk
with a flavor approaching that of fresh milk (51).

The instantizing process consists of converting spray-dried
skimmilk into an instantly soluble dried milk particle by ex-
posing it to warm steam at 80° - 120° F. causing it to form po-
rous aggregates containing 10 - 20 per cent moisture, and then
removing the excess moisture from the aggregates. The final
product contains 3.5 - 4.0 per cent moisture. There is substan-
tially no crushing of the aggregates (52). This method of man-
ufacture was found to have no appreciable effect on the gross
composition of the finished products, so that for any given prod-
uct, the instant milk was found to be comparable to its non-
instant counterpart. The introduction of instant powder aroused
the interest of many large dairy companies and competition made
imperative the instantanizing of virtually all packaged nonfat

milks. Today most dairy companies have profited from the intro-
duction of this modified process for making nonfat milk solids.

Dry Whole Milks. The production of a satisfactory dry whole
milk product has been very difficult. Success would provide the
industry with a great opportunity for expansion. The volume of
dry whole milk produced today is substantial and the growth has
been uniform and continuous, except for the war and post war pe-
riods, during which consumption was increased, (Table 1). This
increase has not been lost completely and production seems to be
stabilized. Efforts have been made to produce a dry whole milk
which on reconstitution would be identical with fresh milk, and
have the physical properties of dissolving instantly and com-
pletely in water. Although an instant dry whole milk has not
been developed, certain information has been accumulated which
may help in its eventual development (33). Such factors as the
influence of certain processes, wetting, surface active agents,
particle size, water and powder temperature and free fat are
better understood and may lead to a solution. No increase in
consumption of dry whole milk can be made until the whole milk
powder is protected against poor keeping qualities, development
of rancid and tallowy flavor and the inactivation of agents re-
sponsible for fat spoilage.

Recently, with expanding utilization of dry milk products,
there has been emphasis not only in improving the product, but
also in making dry milks with specific properties for different
applications. As a result, a variety of dry milk products is

commercially available. The future of dry whole milks is very promising if the present problems can be solved.

The purpose of this report is to study the recent developments in manufacturing, storage and packaging of dry milk products and to present this information for those interested in increasing their knowledge of dried milks.

MANUFACTURING PROCESSES OF DRY MILK PRODUCTS

Milk Quality

There are many things to consider in the selection and preparation of milk for drying. Considerable emphasis must be given to the freshness and bacteriological quality of milk intended for manufacturing. Milk used in the manufacturing of powders should be free from decomposition resulting from the growth of microorganisms. It should also be free from chemical or biochemical degradation of its natural components (38). Hunziker (37) indicated that some drying plants have arranged for twice a day rather than daily milk delivery in order to shorten the time between production and processing. There is no doubt that milk to be acceptable for drying should be also suitable for fluid consumption.

Clarification

Most plants clarify milk used for the manufacture of whole milk powder in order to remove extraneous cellular materials and sediment from the milk. Clarification is not necessary in the

manufacture of nonfat dry milk solids since this is accomplished by the separation of the milk.

Homogenization

Homogenization before drying disperses the fat and facilitates reconstitution. The high pressure spraying that precedes spray drying is in itself a mild homogenization treatment, being equivalent to homogenization at 500 to 1,000 pounds per square inch pressure. Homogenization appears to help to protect the fat in dried milk products from oxidation. In the case of dried whole milk, this protection is attributed by Holm, Greenbank and Deysher (36) to a better coverage of the fat by adsorbed protein in the homogenized product. They found that as the fat content of the powder was raised, the amount of free fat increased sharply at 22 per cent; but when the product was homogenized before drying, a sharp rise in free fat did not take place until the fat content of the powder reached 26 per cent. The large amount of free fat in an unhomogenized dried milk of 26 per cent fat made it quickly susceptible to oxidation.

The three major steps involved in converting fluid separated milk into powder dry milks are preheating of the fluid milk, condensing, and drying. Each of these three steps can, in various degrees, produce definite effects on the characteristics of the finished product. Of the three, preheating of the fluid separated milk prior to condensing has been utilized to the greatest extent to obtain desired properties in the finished product.

Preheating

In addition to certain physico-chemical changes created by this initial heat treatment, preheating includes pasteurization, which involves the heating of milk at not less than 145° F. for a holding period of 30 minutes, or at 161° F. for not less than 15 seconds, or for any temperature time combination which will give equivalent results in bacterial destruction. All milks to be processed into dry milk products must be pasteurized. Depending upon the use intended for the dry milk, the temperature of the preheat treatment may vary from those required for pasteurization as outlined above to as high as 220° to 250° F. for a matter of seconds (28). In the manufacture of nonfat dry milks for beverage purposes and cottage cheese it is necessary to avoid as much denaturation of the milk protein as possible (54). For this reason preheat treatment is generally held to 145° F. for 30 minutes. This type of nonfat dry milk is referred to as low heat or cottage cheese type nonfat dry milk and is made by the spray process.

For bread making, milk must be preheated to a 185 to 205° F. from 20 to 30 minutes (54). In some continuous operations a preheating temperature as high as 250° F. for a matter of seconds has been employed. Nonfat dry milk manufactured by this process is generally known as high heat or bakery type milk powder.

A significant proportion of nonfat dry milk is manufactured with preheat treatments in between those for the cottage cheese type and the bakery type. This type of dry milk is suitable for

most uses, such as in prepared mixes, confections, and sausage.
In many cases the preheat treatment may not be of significant
importance. The term medium-heat has been used to refer to spray-
process nonfat dry milk made from milk which has received an in-
termediate preheat treatment.

Depending upon the amount of heat applied, a multiplicity
of physico-chemical changes occur in the milk during the process
of preheat treatment. Stated briefly, among these changes are:

1. destruction of bacteria

2. inactivation of certain enzymes

3. denaturation of the heat labile whey proteins

4. slight increase in viscosity

5. definite increases in sulfhydryl and other types of re-
ducing substances

6. interaction between protein components, and

7. limited reaction of lactose with proteins and other
constituents in the so-called browning reaction.
Some of these changes have been studied by White et al. (65) and
Mattick et al. (47) as a means of assessing dry milk products
with respect to the degree of preheat treatment.

Condensing

Greenbank et al. (27) stated that dried milk made from con-
centrated fresh milk has better keeping qualities than that made
from unconcentrated milk. In the manufacture of dry milk the op-
timum solids concentration of the condensed milk is from 35 to 45
per cent (3). Ashworth (3) stated that condensing the preheated

milk in a vacuum pan has a marked effect on wettability. It also aids in the removal of some of the volatile substances which may include substances that act as catalysts for oxidation. The degree of heat treatment of the milk during condensing will vary with the equipment used and the processing procedure. Milk in the evaporator may be exposed to a temperature ranging from about 80° F. in the Mojonnier low temperature evaporator to over 185° F. in the first effect of triple effect evaporators. The length of time the milk is in the evaporator also varies, depending on the efficiency of the equipment.

Except in some roller-drying operations, the milk after preheat treatment is condensed under reduced pressure to remove as much water as possible before drying. This is done to increase the capacity of the drying equipment and reduce operating costs. Spray-dried milk is almost invariably made from precondensed milk. This is due to the greater economy of evaporating water in a vacuum pan or evaporator as compared with spray-drying and to the greater density of the powder made from precondensed milk.

Spray-Drying

By far the largest proportion of dry milk products manufactured in this country are made by the spray process.

This process has the distinct advantage over roller drying in that it minimizes heat damage (46). Spray drying produces a product consisting of spherical particles which are more or less hollow depending on the material and on certain operational variables (46). It is very hard to produce spherical particles by

spray drying. Hollow particles are the rule; solid particles are the exception. Probably the most important single characteristic of a spray dried product other than particle size is its bulk density. Bulk density influences the size and cost of storage bins, the type and cost of containers, shipping costs and marketing requirements.

Spray dried whole milk has some limitations for beverage purposes. The powder is not readily miscible with water and many reconstituted samples leave a greasy film in the containers. Normal whole milk powder, even when fresh, has a typical cooked and astringent flavor. During storage there is a rather rapid initial decrease in flavor quality and even under the best conditions may not disperse readily when stirred into water.

Tracy et al. (62) concluded that a higher percentage of solid particles was found in the powder containing the smaller size particles, but the volume of the oxygen trapped was greater in these than in powders containing large size particles. An increase in the spray pressure as well as a reduction in the size of the spray nozzle orifice reduced the packing density (62).

There was some tendency during storage for the smaller size powder particle to deteriorate to a greater extent than larger particle powders. The difference was not consistent nor as marked as differences resulting from variations in storage temperature (62). Inasmuch as a reduction in spray pressure results in an appreciable reduction of drier capacity, the economic advantage to be obtained from the slight improvement in keeping

quality of the larger size powder particles that will result from such a manipulation is not in itself sufficient to justify the change (62).

Although there are different types of spray dryers, varying in shape, size, method of atomization and collection of the dry product, they are all based in three essential operations:

1. atomization of the condensed milk into the drying chambers

2. evaporation of the water from the droplets by means of a stream of dry heated air, and

3. separation of the dry particles from the gases (46).

Atomization is not a particularly pertinent factor insofar as the ultimate quality is concerned. Ordinarily, milk is atomized either with pressure spray or with a centrifugal atomizer. Equivalent results can be obtained with both pressure spray and centrifugal atomizer. Coulter (13) has used a two-fluid atomizer on an experimental basis. There has been considerable interest in this method of atomizing because it offers a very rapid and complete mixing of the spray and the air system. Coulter (13) concluded that this atomizer worked successfully in a pilot plant but has never been very successful on a commercial scale.

Pressure nozzles are less expensive to operate than centrifugal atomizers, but they have certain disadvantages when compared with a good centrifugal atomizer. Pressure nozzles will usually produce particles which vary greatly in size. This is a serious disadvantage because the small particles overheat

or scorch, and the large particles do not dry sufficiently and tend to deposit on the walls of the chamber. Ideal drying conditions require all particles to be of uniform size. The dried product obtained from nozzle spraying varies in particle size. Slurries or very viscous products cannot be atomized by nozzles (13).

The centrifugal atomizers handle the product in different ways. Some pass the product through rotating nozzles, or throw a film over a revolving disc, or pass it over rotating vanes (67).

The rotating nozzle does not give a fine spray as the particles are thrown from a half moon shaped jet and not from a film which is broken at the periphery of the pipe. Further, as a large surface per unit of the product is not formed, the time of drying is prolonged and the size of the chamber must be increased considerably.

The revolving discs, which are flat or bell shaped, can atomize satisfactorily only small amounts of not very viscous material, as there is a considerable slip between the fluid and the walls of the pipe, the plate or disc.

With rotating vanes, no slip arises and a very large capacity can be obtained. A thin film is formed which can be reduced in thickness if the vanes have a specially designed profile. Experiments with such an atomizer have shown that even with the high velocity at which the particles leave the atomizer, the size of the particle is so small that due to the resistance of the atmosphere within the chamber the velocity is reduced a great

deal in a very short distance from the atomizer (67). Improve-
ment of this latter basic design represents a high peak in the
development of atomization by the centrifugal process because it
is a more generally adaptable method of spraying fluids.

The method of introducing the drain air relative to the spray
is very important in the design of spray drying equipment. Ash-
worth (3) concluded that if the inlet air temperature were in-
creased from about 220° F. to 320° F. that not much effect upon
wettability would be obtained. Modern designs tend to have a
vertical movement of the air, preferably downward and concur-
rently with the direction of the liquid. Some manufacturers,
however, believe that upward concurrent introduction, both air
and spray entering at the bottom of the chamber, is preferable
for certain purposes. The drying air should be introduced as
close to the spray as possible. Coulter (13) stated that dryers
can normally be classified with respect to air powder flown as
either concurrent or counter-current. Actually, no dryers are
in use or have been developed which provide strictly counter-
current flow of air to milk. Considerable numbers are in use
that provide at least partially counter-current air-milk flow.
With strictly parallel air-milk flow, the temperature of the
particle will never exceed that of the exit temperature from
the dryer, which may be in the order of 170° to 180° F. or pos-
sibly 190° F. If, however, there is partial counter-current
air-milk flow, the temperature of the particles may approach
rather closely that of the inlet air, which may be as high as
300-400° F.

Coulter (13) also stated that dryers may be classified as either updraft, downdraft or horizontal with respect to air flow, or as straight line or rotary flow. Rotary flow has been used with the idea of increasing the flight time of the particles in the air stream. Virtually every combination of these general principles has been used in dryer design. Since all of them have been used, it should be obvious that no one design offers maximum advantage in all respects. Unfortunately, dryer design is still largely on a "cut-and-try" basis. It would be extremely difficult to evaluate all variables which are possible.

Recovery Systems

The method of separation of the entrained powder from the outgoing air is of great importance because the economy of the drying process depends on the satisfactory recovery of powder. If inefficient, the powder loss becomes great thus adding to the cost of production. There are three common types of recovery systems:

1. bag filters
2. cyclones
3. wet scrubbers.

Bag filters are extremely efficient separators of dust but are difficult to maintain clean and free from microorganisms. Furthermore, when hygroscopic products are being dried, warm air must be kept circulating in the unit even during shutdowns to prevent the powder in the bags from taking up water and clogging the filter. The big disadvantage in bag type filters,

however, lies in the variations of the pressure drop across the
filter due to gradual clogging up of the interstices of the
bags. This in turn leads to variations in the efficiency of the
dryer, and to greater loads on the fan motors.

Cyclone collectors are commonly cylindrical containers with
cone-shaped bottoms. The air leaving the drying chamber at a
high velocity enters the cyclone tangentially. It then assumes
a rotary motion forming a cyclonic vortex. Centrifugal force
throws the solids to the peripheral wall of the cylinder, along
which the material then works down into the hopper. Cyclone
collectors are simple, require practically no maintenance and
are easy to keep clean. The modern trend is to build batteries
of a large number of units with small diameters giving very ef-
ficient separation. Certain cyclones of this type reduce the
overall powder loss to less than one per cent of the net weight
put into the drying system. By the use of cyclones, the power
load of the plant and the pressure drop are always constant and
the output of the plant will remain unaltered (67).

A wet scrubber consists of a closed tank into which the in-
coming fresh milk is pumped through a series of suitably dis-
tributed spray jets. The spent air leaving the drying chamber
passes through the fresh milk spray in the collector tank. The
milk dust entrained in the spent air from the drying chamber is
deposited in the incoming fresh milk and becomes an integral
part of it. The milk dust collector thus makes a highly effi-
cient dust recovery, and in addition it precondenses the fresh
milk and uses a greater portion of the heat units contained in

the spent air. Wet scrubbers are only used when atmospheric pol-
lution is of importance or when a combination using the scrubber
as a preconcentrator unit is necessary (67).

The modern belief is that the powder should be removed with-
out the use of mechanical devices such as scrapers or screw con-
veyors, since the impact of these may be deletrious to the phys-
ical condition of the powder. The separation of the powder
should be by gravity and the bottom of the chamber where the
milk is to be collected should be conical in section.

Types of Spray Dryers

The first successful pressure spray process plant in this
country was established by the Merrell-Soule Company (12).
This company bought the rights of U. S. Patent No. 660,711 from
Robert Stauf. The assignees of the patent secured a new patent
(No. 860,929) on a modification of the Stauf process with a
claim of concentrating the milk before drying. The Swenson
Gray-Jensen process originated about 1914, and employed a cy-
clonic countercurrent drying chamber on a wet collector for
prevention of entraiment loss and precondensing (12). The orig-
inal Rogers pressure dryer, which was a large box with spray
nozzles located near the top of all four sides, received U. S.
Patent No. 1,226,001 in 1917 (37). The original design and
process have undergone many changes and improvements within the
past years.

The first dryer using a centrifugal atomizer was patented
in Germany by Krause in 1912 (12). Instead of atomizing the

milk by the use of high pressure spray nozzles, the milk was
atomized by centrifugal force, using a rapid rotating metal spray
disc. Other dryers using the centrifugal spray processes are the
Kestner spray dryer, the Dick Process dryer, the Scott spray dryer,
the Luwa spray dryer, the Bowen spray dryer (see figure 1) and
the Niro spray dryer (37). Many different types of spray dryers
have been developed and are in use.

Drying by the Roller Process

Fluid or condensed milk (2:1 concentrate), after proper heat
treatment, is fed into a trough formed by two rollers revolving
in opposite directions and heated by steam under pressure. The
speed of rotation and temperature of the roller, as controlled
by the steam pressure, is regulated in such a manner that the
milk dries in a thin film before the roller completes a revolu-
tion. This film is continuously scraped off and pulverized into
a fine powder. Figure 2 presents a diagram of the roller process
(27).

Roller process particles are irregular in shape, generally
not so fine as those of the spray product and are relatively
more insoluble because of the high degree of protein destabiliza-
tion. A common and serious defect in quality is the presence in
the powder of charred particles.

Aided by the lubricating action of the fat, whole milk is
dried with comparative ease, but skimmilk presents a much harder
surface film to the knife edge on the drum and unless knives and
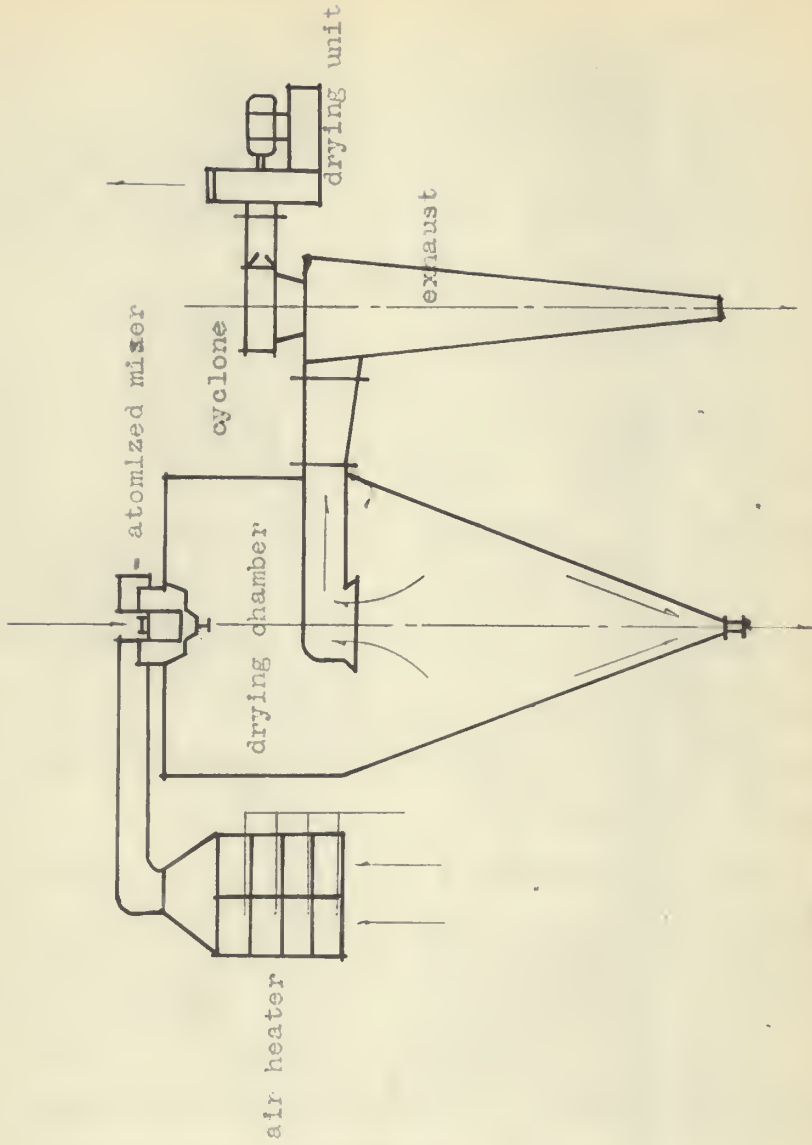rollers are kept in good condition, much burning will take place

Figure 1

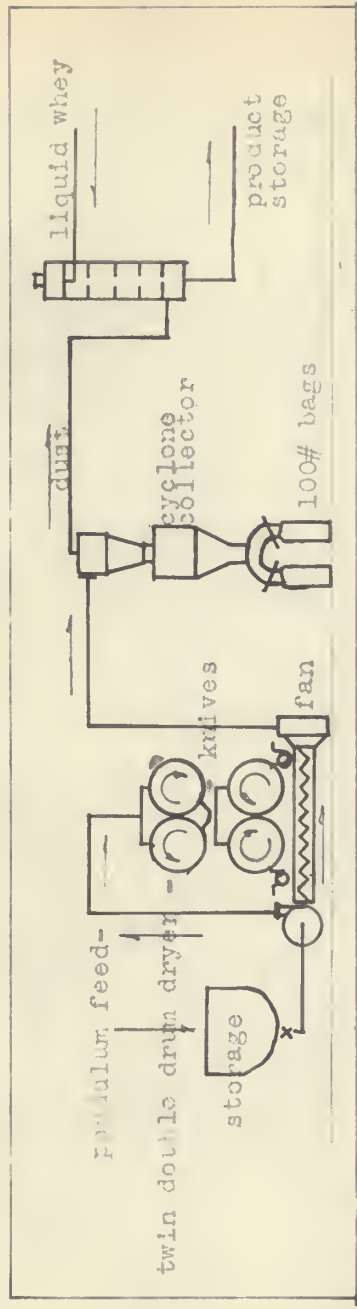THE BOWEN SPRAY DRYER (37).

Figure 2

ROLLER - DRYING PROCESS (37).

on the rollers. The build-up of film on the roller will lift
the knives thus aggravating the problem and accumulating heavy
deposits of burnt powder behind them.

The rollers must be set up in perfect alignment with each
other and with the machine frame so that the film of dried milk
can be removed cleanly by an even pressure along the knife blade
(67). Uneven spreading of the film may result in overheating
of the thinner part of the film before it is removed from the
rollers. Incomplete removal of the dried milk film may be
caused by unequal length and setting of the rollers, uneven
spread of the films of milk, poor adjustment of knives, and un-
even pressure applied along the length of the knives.

In the early days of the dry milk industry, the roller
process was used almost exclusively because it could be accom-
plished on a small scale and required little space in the plant.
In recent years this method has been steadily losing ground to
the spray-drying process. In 1957, less than ten per cent of
the total dry milk production was made by the roller process (63).

Although the film of milk on the roller dries in a matter
of seconds, the milk in the trough is continuously boiling.
Therefore, the temperature of the milk is slightly above 212° F.
and increases somewhat as the milk is concentrated during the
drying process. At this high temperature and concentration,
the proteins coagulate with some loss of solubility.

Instant Nonfat Dry Milk

The instantizing process is a recent development designed
specifically to increase the dispersability of spray process

dry milks. Although ordinary spray process nonfat dry milk is over 99 per cent soluble in water, a certain shaking or agitation is necessary for complete dispersal of the product because of its tendency to lump, a condition which prevents other particles from making contact with water.

Two methods have been used for making nonfat dry milk "instant" or highly soluble. The most common and the original one was invented by D. D. Peebles in 1953 and received U. S. Patent No. 2,835,586 in 1958 (52). This process is quite simple. Figure 3 presents a schematic diagram of the Peebles drying process.

By this process, normal spray dried nonfat dry milk is rewetted with warm steam at 80-120° F. and allowed to form porous aggregates containing 10-20 per cent of moisture. Shortly thereafter the wetted product falls into a countercurrent flow of cool air and on to a conveyor belt. The humid milk powder is then conveyed to a shaker type dryer. In this unit the moisture is reduced to between 3.5-4.0 per cent by forcing heated air through a moving bed of the product. A specially designed vibrating screen serves as a conveyor and air inlet for this redryer. After the moisture is removed the product is standarized into large particles or clusters and is then ready for packing (52) (51).

The new product produced by the Peebles method has granular form, excellent flavor, and long shelf life and is readily and conveniently reconstituted. It also possesses good pouring characteristics and is non-caking. The ease of wetting is outstanding (51).
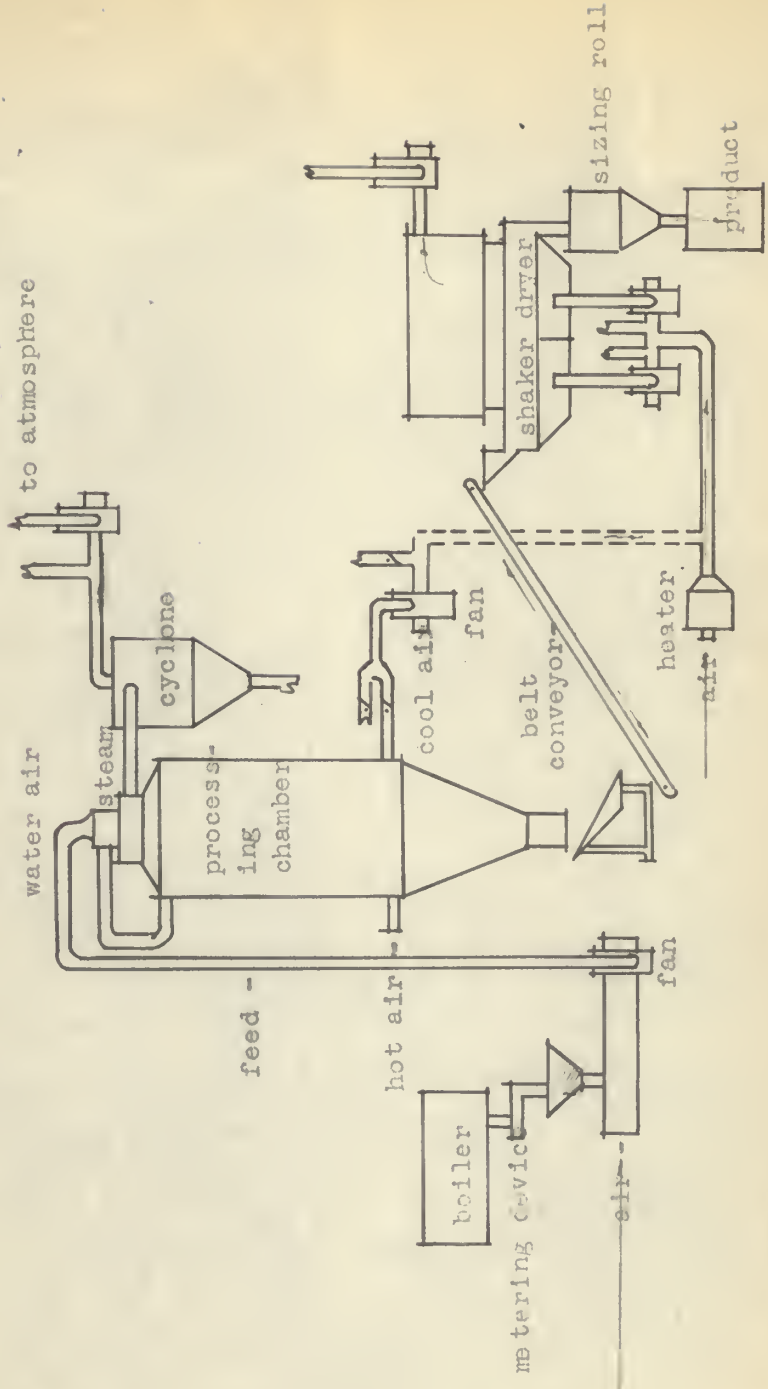
Figure 3

PEEBLES DRYING PROCESS (51)

The other method of instantizing milk solids was developed
by the Cherry-Burrell and Blaw Knox Companies (61). By this proc-
ess, the larger particles are spray-dryed directly by means of a
special or modified spray-dryer, in which drying and agglomera-
tions are accomplished in one operation (61). The powder is in-
troduced into the agglomerating section to wet it to clump par-
ticles, which are then carried to a collector by a high velocity
stream of moist air. Then the product is picked up by fast moving
stream of heated air, and dried to the desired moisture content
in a vertical tube that expands as it feeds into another collec-
tor. The clumped powder is discharged through a rotary air valve
onto a vibrating table, below which cool air is continuously in-
troduced. The cooled powder is fed through adjustable sizing
rollers that reduce it to uniform-sized pellets, ready for pack-
aging (7) (49).

The developers of the process reported that the powder dis-
solved instantly and possessed a good flavor rating after several
months of storage. The keeping qualities of the product stored
up to six months were equal to, or better than, similarly stored
regular milk powders, and did not cake (7) (61). The final milk
solids are made up of firmly held cluster particles that do not
break up during packaging and handling. This process can be
used to make highly wettable instant chocolate milk, malted
milk, and baby food cereals (61).

In regard to defects of instant milks, Loftus-Hill (45)
concluded in his tests that only one of three brands of milks
obtained from the United States fully substantiated the claims

made, although the others dispersed more readily than the usual
spray dried milks. All the powders showed a cooked flavor.
When the samples were stored in the laboratory for fifty days,
the two less desirable brands had caked while the third brand
was still free flowing. Microscopic examination of the three
powders showed that the particles of the most acceptable brand
were larger than those of the other two, and contained a large
number of minute lactose crystals uniformly distributed through-
out the particles.

The instantizing process has been confined mainly to nonfat
dry milk, but considerable work is being done and continuous re-
search is being conducted in attempts to instantize dry whole
milk.

Sinnamon et al. (57) have produced a new form of dried
whole milk by the Puff-drying process. In this process milk is
homogenized, pasteurized at 162° F. for 16 seconds, and concen-
trated to 47-50% total solids at 85°-100° F. in a high vacuum,
falling film evaporator. The milk is then heated to 135° F.,
homogenized in a two stage homogenizer at 4,000 and 500 pounds
per square inch pressure. As it is discharged from the homo-
genizer, nitrogen gas is bubbled through the concentrate after
which it is spread thinly (1/16 of an inch) over stainless steel
drying pans, cooled to 55° F. or below and dried as a foam in a
vacuum shelf dryer. The resulting dried mass is crushed lightly
and passed through stainless steel screens. Variations in the
rate of vacuum applications were found to affect the foam struc-
ture. Using a modification of the dispersability method of

Stone, Sinnamon et al. (57) found that foam dried whole milk dispersed much more readily in cold water than did commercial dried milks. The reconstituted product possessed an excellent flavor. No differences were found in the ultra-centrifugal patterns between the whey proteins of fresh whole milk and those of foam-dried milk (57).

PACKAGING OF DRY MILK PRODUCTS

The problem of packaging nonfat dry milk is largely one of preventing the absorption of moisture from the air, since dried milk is very hygroscopic. In order to avoid the absorption of water, bulk powder is packaged in tongue and groove barrels or special fiber drums (16). The powder is enclosed in a heavily paraffined durable liner or a waxed inner liner with an outer liner of two sheets of kraft paper laminated with essentially odorless asphalt or other suitable material. Despite this protection, some moisture may be picked up under normal storage conditions (16). When powder is exposed to severe temperature and high humidity, hermetically sealed tin cans or metal drums may be used. The cost of packaging in tins is much higher per pound of powder than other materials available but this additional cost is well justified (11), since tin gives complete protection of the product from manufacturer to consumer. The only contact with air or moisture in tin cans is the amount left in the tin at packing. A container commonly used for small packages is the wax paper bag inclosed in cartons. These are further packed with cloth fittings, cellophane or similar mate-

rial. Today the basic package for merchandising skimmilk powder is more or less standard. It is made up of a carton with an aluminum pouring spout, overwrapped with an aluminum foil paper laminate (18). The attractive variety of appearances achieved on the store shelves arises from rotogravure printing in various colors on the foil. Today there is a general trend toward larger packages for retail sale of a number of dairy products.

The packaging requirements for dry whole milk vary with the intended period and conditions of storage and distribution. At present, the hermetically sealed metal container from which most of the oxygen has been removed constitutes the most desirable package available. Quartermaster Corps specifications for packaging dry milk call for the use of airtight sealed tin cans in which the air is replaced by an inert gas before sealing (53). Nitrogen, carbon dioxide, or mixtures of these two gases are commonly used for this purpose. The free oxygen content seven days after packaging must not exceed 3.0 per cent of the volume of the gas space present for extra grade dry whole milk and 2.0 per cent for dry ice cream mix. The examination for free oxygen is always made seven days after packaging because oxygen is held in the powder during vacuumizing and later is desorbed to increase the oxygen content of the head space gas (44).

Milk powders differ not only in the amount of oxygen retained during vacuumizing, but also in the rate at which the oxygen is desorbed. Equilibrium is generally attained within seven days but the state of balance is complicated by the fact

that while oxygen is being desorbed from the powder, principally by diffusion from air cells within the powder particles, oxygen is being taken up by the milk constituents at a rate which depends upon the temperature of storage and the moisture content of the powder (44). In 1948 Henry et al. (29) concluded that nonfat milk solids absorb oxygen at rates which are dependent upon their temperature and moisture content. In 1948 Coulter et al. (17) found that dry whole milk absorbs oxygen at a rate exponentially related to its moisture content. Since it is not known whether the oxygen taken up by milk powder before packaging is as harmful as free oxygen in the head space in causing deterioration, requirements should limit the time between production of the powder and packaging (15).

Some powders retain so much oxygen in the head space of the package that specifications cannot be met by a single gassing. Multiple gassing was found to be necessary and was accomplished by allowing a 20-24 hour period between gassings. Three methods commonly used are:

1. The Schibsted (55) method holds the cans in a vacuum box either under vacuum or a slight pressure of inert gas for the time interval desired before the final evacuation, gassing and sealing.

2. The Shipstead and Brant method evacuates and holds the powder in bulk either under a vacuum or in an inert gas for an appropriate time interval, followed by canning and conventional vacuumizing, gassing and sealing (56).

3. The Coulter and Jenness method displaces the air in the

bulk container of the powder with carbon dioxide furnished by subliming dry ice. This method is reasonably effective, but is subject to less accurate control than either of the others (14).

Nitrogen and carbon dioxide are equally satisfactory as inert gases for gas packing insofar as maintaining a low oxygen level is concerned. The effect of these gases upon keeping quality, however, is contradictory. In 1943 Lea et al. (44) found the keeping quality of powders stored in nitrogen and carbon dioxide to be similar. In 1949 Greenbank and Wright (26) showed that sufficient carbon dioxide may be absorbed by powder held at 50 pounds carbon dioxide pressure for three hours or more so that on final gassing the powder will contain carbonic acid which acts synergistically with antioxidants present to prolong the storage life.

Carbon dioxide alone cannot be used to gas powder which has not been previously exposed to carbon dioxide because the decrease in pressure resulting from absorption of this gas by the powder is usually sufficient in cans five pounds or larger to cause their partial collapse, referred to as "paneling" (26). A mixture of equal parts of nitrogen and carbon dioxide is just as effective as pure nitrogen in preventing the development of tallowiness in milk powder (14).

Lea et al. (44) have suggested compressing milk powder as another means of reducing the oxygen content of the packaged powder and also for saving space in shipment and storage. By using a hydraulic pressure of several tons per square inch, they were able to compress dry whole milk to densities ranging from

1.1 to 1.2 grams per milliliter without an appreciable loss of
fat. The denser blocks required grinding before reconstitution.
Data were presented indicating that by high compression the ox-
ygen content of the powder in hermetically sealed packages could
be reduced to a sufficiently low level to secure satisfactory
keeping qualities. Without hermetic sealing, however, compression
does not improve the keeping quality of dry whole milks.

Packing Roller-Dried Powder

Lea et al. (44) concluded that the gas packing of roller-
processed powders, whether whole or nonfat dry milks, presented
no particular difficulty. In a small experimental cabinet
filled with 25 cans of powder, the pressure could be rapidly re-
duced to three millimeters with a vacuum pump, but could only
with difficulty be induced to fall below this point. A large
part of the residual pressure was undoubtedly due to the vapor
pressure of the moisture which was usually present in amounts
of about three per cent. With the employment of nitrogen con-
taining less than 0.01 per cent of oxygen, one cycle reduced
the oxygen content of the head space gas to about 0.1 per cent.
After standing for 24 hours this value invariably was found to
have increased slightly, but after that the oxygen content re-
mained constant for several weeks.

The small desorption of oxygen from roller powders during
24 hours after packing must be due to the escape of entrapped
air, but there is much less air and it is much less firmly
bound than in the case of spray powders. Regassing a sample of

gas packed roller whole powder 22 hours after the first cycle
gave a product in which no free oxygen could be detected (44).

Packing Spray-Dried Powders

Lea et al. (44) examined powders produced by two modifica-
tions of the spray-drying process and found that the powders
were very similar in general properties, but quite different in
the way they responded to gas packing. Packing was carried out
in the way previously described for roller powders. After
standing, the oxygen content of the head space gas increased
rapidly at first and then more slowly to maximum values which
varied from 1.3 to 5.4 per cent. It then began to decrease
slowly as a result of the normal absorption of oxygen. This
latter process is very slow at 15° C. under a low pressure of
oxygen. They concluded that very little of the entrapped oxy-
gen could be drawn off from a spray-dried powder by submission
to a high vacuum, two millimeters pressure, even for as long as
one hour.

Of a number of powders investigated, those dried by the
pressure spray process tended to contain less entrapped oxygen
and to release it more rapidly than those dried by centrifugal
spray. This observation by no means establishes the way of in-
troducing the spray into the dryer as the critical factor,
since some other steps in the procedure may well influence the
product. Thus batches of powder, even from the same factory,
have been found to differ appreciably (44). They also con-
cluded that if a high standard is to be maintained, double gass-

ing must be used in the case of spray-dried powders.

THE STORAGE OF DRY MILKS

The keeping qualities of milk powders depend upon the initial quality of the milk and the conditions of manufacture. In general, storage life in air at ordinary temperatures under the best conditions is three to seven months for spray-whole milk powder, six to twelve months for roller whole milk powder, and twelve months or longer for nonfat dry milks (44). The storage life of milk powders has been extended to more than three years by packing it in containers filled with nitrogen and carbon dioxide.

Bacterial spoilage will not occur, unless water is absorbed by exposure to air. The bacteriological quality of spray dried milk was found by Mattick, Hiscox and Crossley (47) to be determined by three important factors: plant cleanliness, preheating temperature, and the bacteriological quality of raw milk. The plate count of a powder can be lowered by maintaining a low bacterial count throughout the process, by the use of high preheating temperatures before drying, and by using milk of high bacterial quality. Ashworth et al. (4) concluded that raw, whole milk, with high bacterial counts, due to different types of spoilage bacteria, produced a stale flavor, a drop in pH and proteolysis. Good plant management should be encouraged in order to reduce all sites of infection in the plant that produce an increase in the plate count of milk powder. The plate counts of both roller and spray dried products tend to decrease during

storage.

The physical and chemical changes that occur in dried milk products during storage are associated primarily with three of its constituents: fat, proteins and lactose.

Deterioration of the Lipids

Hydrolytic Rancidity. The hydrolysis of the fat in dry milks by lipases is not a common occurrence because sufficient preheating treatment is applied to the milk to inactivate the enzyme. Powder made from milk treated at 73.8° C. for 30 minutes is usually free from this defect (38). Christensen et al. (10) concluded that milk not preheated became rancid in the vacuum pan, and powder made from it was very rancid in taste.

Oxidative Rancidity. The rate of oxidation of the fat in dry milk products depends in part upon the quality of the milk from which the dried material was prepared. These products should be low in bacterial count and should be dried as soon as possible after the milk is drawn from the cow. The presence of metal catalysts, especially copper and iron, greatly accelerate the rate of oxidation (38). All equipment with which milk comes in contact during the course of its processing should be of stainless steel. Exposure of milk powder to light has been shown by Pearce and Bryce (50) to increase the rate at which deterioration of milk flavor occurs during storage in air. Either sunlight or ultraviolet irradiation was shown to produce oxidative rancidity. It appeared that the extent of flavor deterioration was more closely related to total light energy fall-

ing on the material than to the specific wave length of the light.

Some attempts have been made to prolong the storage life of dry whole milk by the use of antioxidants instead of gas packing (20). Direct addition of antioxidants has been tried as a means of prolonging storage life (34). Some materials which show promise as practical antioxidants are: gallic acid and its esters, nordihydroguaiaretic acid, thiourea, wheat germ oil and ascorbic acid. Antioxidants probably function by breaking the chain reaction by which unsaturated fatty acids are degraded by peroxides. The antioxidant molecule is inactivated by this process and eventually becomes exhausted (24). Findlay et al. (24) observed no decrease in the concentration of ethyl gallate in dry whole milk during the induction period. In a series of experiments White et al. (65) found that the presence of 0.06% to 0.08% ethyl gallate combined with a preheating treatment at 87.8° C. for five minutes prolonged the keeping quality of dry whole milk, when stored in air, by factors of about 3.0, 4.0 and 8.0 for storage at 47°, 37° and 15° C. respectively.

Since the oxidative reaction is relatively slow at room temperature, the determination of keeping quality often is accelerated by increasing the temperature. A number of workers used temperatures of 47°, 37°, and 15° C. in studying keeping quality, and they found that the rate of oxidative deterioration is about doubled by raising the temperature 10° C. (44, 37, 24, 65).

The oxidative degradation may be followed by measurements of the oxygen uptake. In spite of some complications due to uptake of the oxygen by the solids-non-fat, there is a general

correlation between oxygen utilization, peroxide formation and the tallowy flavor in air-packed powder (31).

The removal of oxygen from the container has proved to be the most effective method of preventing oxidation. Lea et al. (44) demonstrated that oxidation does not develop if the oxygen level is reduced to 0.01 milliliter or less per gram of powder. This is equivalent to about one per cent in the interstitial gas (44). It is well known that tallowiness does not develop as long as the container is tightly closed. The small amount of oxygen available will be utilized and will shorten the induction period so that, if the can is opened, tallowiness will develop more rapidly than it would in fresh powder (44).

Reducing the oxygen content of the dry whole milk to levels low enough to prevent oxidation is complicated by the fact that the powder consumes some of the oxygen rapidly and releases it only slowly at low oxygen levels. This desorption of oxygen represents diffusion from occluded air, release of oxygen dissolved in the fat and liberation of absorbed oxygen (44). The technique of double gassing with holding periods between evacuations of four to seven hours must usually be employed to reduce the oxygen content to safe levels (14).

Deterioration of the Nonlipid Constituents

The deterioration of the lipids in dry milk has received major attention in the past. A number of changes occur which do not involve the lipids, consequently with the reduction of lipid oxidation by gas-packing, these have taken a position of supreme

importance.

Coulter, Jenness and Crowe (15) summarized the non-lipid changes that occur in dried whole milk in storage as follows:

"development of stale or burnt feather flavor, browning, production of extractable fluorescent materials, production of carbon dioxide, production of water, increase in acidity, increased reducing capacity, loss in protein solubility, and utilization of oxygen."

All these changes were found to increase in rate with an increase in moisture content and temperature.

Staling. The stale flavor is a defect that is likely to occur in both whole and nonfat powders. This defect is believed to be associated with the protein fraction of the milk, and is more marked in powders of high moisture content. It is said to be prevented most successfully by protection of the powder against incorporation of air and moisture and by avoiding high or very low (below 0° C.) storage temperatures (44).

Lea et al. (44) noted in dry whole milk stored for some time at 47° and 37° C. the appearance of a flavor variously described as heated, scorched or cooked. This flavor was considered to consist of two components:

1. the burnt flavor, associated with proteins or carbohydrates, and

2. a butter-toffee flavor associated with the fat.

Henry et al. (29) in a study of nonfat dry milk solids, reported the development in air-packed powder at high moisture of a stale flavor which gradually increased to a nauseating and undesirable gluey flavor. Nitrogen packed powder at high mois-

ture levels generated only a heated or slightly stale flavor.
At low moisture levels air-packed powder changed in flavor more
than gas-packed, and it was suggested that this was produced by
the oxidation of the lipids in nonfat powder, although a tallowy
flavor could not be identified specifically (29).

Coulter et al. (15) noticed a flavor described as burnt
feathers, which was produced in high-moisture but not in low-
moisture dry whole milk, nonfat dry milk solids and spray-dried
simplified systems of calcium phosphocaseinate and lactose. If
stored at high temperature and moisture for a sufficient period,
the powder browns and produces a typical burned or caramelized
flavor.

Whitney and Tracy (66) made crude separation of reconsti-
tuted stale dry whole milk, into different fractions and found
that the stale flavor component was distributed in proportion
to the quantity of fat present in each fraction. They concluded
that the stale flavor component was concentrated in the butter
oil. Whitney et al. (66) have recently found that the stale
flavor component is extracted with the fat by ethyl or petroleum
ether and that it may be steam distilled from the fat. Suffi-
cient information appears to be available to conclude that the
typical flavor of stale dry whole milk is a composite flavor
which arises from oxidation of lipids and the browning reaction.

Browning. Browning of dry whole milk or of nonfat dry milk
solids during storage is of great importance. It also occurs
during the storage of dry whey. The mechanism by which browning
occurs in any milk product has long been the subject of contro-

versy; one group holding that it results from caramelization of the lactose, and another maintaining that a sugar-protein inter-action is involved. Webb (64) proposed that perhaps both mecha-nisms play a role in the overall process. According to Stadtman (58) browning involves the decomposition of sugar to fulfural-dehydes which condense with nitrogen compounds to form brown products.

The pathways of the browning reaction during storage are not readily followed. Tarassuk and Jack (60) used arbitrary dry color standards for estimating the extent of the reaction. Ex-traction of the brown pigment is difficult, but Choi et al. (9) have shown that the efficiency of interaction is improved by a preliminary tryptic digestion.

Webb (64) found that copper and iron slightly catalyzed browning in lactose solutions during heating. Hollender and Tracy (35) stated without direct proof that browning of dry milk is accelerated by the presence of copper. However, it has not yet been established that copper is involved in promoting the browning reaction in milk and milk products.

Hodges (32) outlined the possible pathways of the browning reaction. Not all the mechanisms of browning can be explained by the scheme proposed by Hodges (32). Seven stages of reaction that occur during browning are:

"A. In the initial colorless stage (no U.V. absorption)
    1. Sugar amine condensation
    2. Amadori rearrangement
B. Intermediate, colorless or yellow (U.V. absorption)
    3. Sugar dehydration
    4. Sugar fragmentation
    5. Amino acid degradation

C. Final stages, highly colored
6. Aldol condensation
7. Aldehyde-amine polymerization."

Once the first reaction is completed, the rest takes place spontaneously (32).

Fluorescence, production of carbon dioxide, production of water, changes in acidity, measurement of reducing capacity and insolubility have been used by Coulter et al. (15) to indicate milk powder deterioration by means of the browning reaction.

Fluorescence. Since fluorescent materials are produced by the interaction of aldehydes with either protein or amino groups, any method for following changes in fluorescence should differentiate between the interaction of aldehydes with protein. Jenness and Coulter (39) devised an empirical fractionation procedure which partially differentiates the fluorescent changes. This included ascertaining the fluorescence of the following fractions of milk:

a. materials soluble in 67 per cent aqueous acetone

b. materials insoluble in 67 per cent aqueous acetone but soluble in 20:80 acetone-ether

c. those insoluble in (a) or (b) but soluble in ten per cent potassium chloride.

Even when normal processing of dry whole milk had no effect on the fluorescence of these extracts, the fluorescence of (a) and (c) increased during storage at rates which depended on the temperature and moisture (15). At 60° C. and at over four per cent moisture, the fluorescence of (c) rose to a maximum and then was

lowered. The fluorescence of the lipid fraction (b) was less affected by storage.

Production of Carbon Dioxide. Henry et al. (29) stated that carbon dioxide is produced from the nonlipid constituents of milk at a rate which is dependent upon the moisture content and the temperature. Some evidence has been obtained that oxygen accelerates the rate of production of carbon dioxide (29). There is no doubt that carbon dioxide is produced by products which result from the Maillard reaction, but the mechanism by which it is formed and the significance of oxygen in the reaction have not been explained.

Production of Water. Water is known to be a by-product of the Maillard reaction. Coulter et al. (15) have demonstrated that the moisture content of a powder increases during storage under conditions which permit this reaction to occur.

Changes in Acidity. The tying up of amino groups of the protein would be expected to cause a decrease in pH and increase in titratable acidity. This effect has been said to occur during storage of dry milk (15).

Reducing Capacity. The capacity of the system for the production of acid ferricyanide and indophenol reducing substances is increased during storage of dried milk. Crowe et al. (17) have shown that this increase results from interaction of lactose with protein and probably also from decomposition of the lactose catalyzed by the buffer salts of milk. Chapman and McFarlane

(8) have obtained indications that these reducing materials pro-
tect butterfat against oxidation. Any such protection is only
of academic interest because of the off-flavors which accompany
formation of the reducing substances.

Insolubility. Insolubility accompanies the browning reac-
tion in milk. The degree of insolubility is dependent on both
moisture content and temperature. Lea et al. (44) have shown
that insolubility can be inhibited for all practical conditions
of storage by maintaining the moisture level below three per
cent. Both casein and milk serum proteins are involved in de-
creasing solubility, but because of its greater concentration,
the former is of greater quantitative importance (29).

Lea (43) found that storage of dry milk protein at 37° C.
and at a relative humidity of 55 per cent caused it to lose solu-
bility in cold water but not in hot water. The influence of
sugar on milk powder solubility is complex. Thus glucose reacts
very rapidly with milk protein with a resulting loss of powder
solubility. Lea's work indicates that the development of pro-
tein insolubility during storage of dried milk products would be
accelerated by the presence of glucose. The glucose induced
changes could probably be retarded by the inclusion of sucrose
in the formula.

Relation of Oxygen to the Sugar-Protein Interaction. Non-
fat dry milks absorb oxygen at rates which are dependent upon
the temperature and moisture of the stored powder (29). Coulter
et al. (15) found oxygen to be utilized at a rate exponentially

related to the moisture content of dry whole milk. In general, the oxygen level has much less effect than the moisture level on deteriorative changes involving the nonlipid constituents.

Tarassuk and Jack (60) found the oxygen content of the storage atmosphere to have very little effect in browning in the production of carbon dioxide. Coulter et al. (15) found the rates of change of fluorescence and reducing substances to be comparable for air and nitrogen packed samples, while carbon dioxide was produced at a faster rate in air packs. Henry et al. (29) found no difference between air and nitrogen packed samples, in the rates of development of any of the manifestations of the Maillard reaction except in flavor deterioration and in the production of carbon dioxide.

Keeney and Bassette (41) concluded that instant nonfat dry milks exhibited more intensive symptons of browning than non-instant nonfat dry milks. They also made clear that some of the commercial instantizing processes promoted the browning reaction. The high temperature to which milk is exposed, ranging from several seconds to several minutes, would be expected to increase the browning reaction of instant nonfat dry milks. Bassette (5) concluded that instant nonfat dry milks when reconstituted had inferior flavors when compared to non-instant remade milks, and that the instant milk powders deteriorated rapidly during storage.

QUALITY REQUIREMENTS OF DRY MILK

Sanitary and quality standards including methods of analy-

sis, of dry whole milk powders and nonfat dry milk solids were adopted by the American Dry Milk Institute in 1953, the Quartermaster Corps in 1944, and the United States Department of Agriculture in 1958. The types, classes, grades and analysis of all three agencies are in substantial agreement (2) (53) (23).

The following standards were presented in the Federal Standard Stock Catalog, Federal Specifications for Milk, Dry Powder, Whole or Skimmed and in the Federal Registrar Document for Standards for Grades of Nonfat Dry Milks (23) (22) and are reproduced here:

"Types, Classes and Grades

Type I   Dried Whole Milk
         Grades - Premium and Extra.
Type II Dried Skim Milk *
         Grades - Premium and Extra.
Class 1 - Spray Process
Class 2 - Vacuum Drum Process
Class 3 - Atmospheric Roller Process."

General Requirements

The milk used in the preparation of any product covered by these specifications should conform to regulations of the Milk Ordinance and Code (48).

Dry whole milk or nonfat dry milk should be prepared by the desiccation of whole fresh milk, or from milk with adjustment, if necessary, to establish a ratio of fat to nonfat solids, by the addition or by the abstraction of fresh cream and to which no

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*This grade has been changed to U. S. Extra and U. S. Standard according to Federal Registrar Document. 58-2627; April 9, 1958.

preservative, alkali or other chemical has been added and which has been heated in a liquid state either before or during the process of manufacture at a temperature of 143° F., for 30 minutes or its equivalent in bacterial destruction.

Whole dry milk or nonfat dry milks shall be reasonably uniform in composition, free from lumps and practically free from all brown or black specks. The color shall be white or light cream, free from any brown or yellow color typical of overheated or old stock and free from any unnatural color. The flavor and odor of the powder and of the reconstituted milk shall be sweet, clean and free from rancid, tallowy, fishy, cheesy, soapy, scorched, storage or other objectionable flavors or odors.

The manufacturer shall guarantee the keeping quality of the whole milk or skimmed milk powder in hermetically sealed containers for a period of one year from the date of delivery under ordinary conditions of storage.

All deliveries shall conform, in every respect, to the provisions of the Federal Food, Drug and Cosmetic Act and regulations or amendments promulgated thereunder (23).

Specific Requirements of Dry Whole Milk

The specific grading requirements for dry whole milk, as presented by Hunziker (37) are as follows:

"Type I - Whole Milk Powder

E-1a. The product shall be prepared by the drying of whole fresh sweet milk or standardized milk (to which no preservative, alkali, or other chemical has been added except as provided for in paragraph D-4), which has been pasteurized by heating to a temperature of not less than

143° F. and held at such temperature for not less than 30 minutes, or any other means of pasteurization which yield equivalent bacterial destruction.

E-1a. (1). Standardizing milk for the purposes of this specification shall mean milk which has been standardized by any of the following means:

(a) Milk as delivered to the plant, that has been altered by the removal of cream by plant separation or by the addition of either sweet freshly plant-separated cream or separated milk.

(b) Concentrated milk or whole milk to which has been added sweet cream or concentrated separated milk which has been prepared from milk of a quality equivalent to that required for the production of premium or extra grade powder.

(c) Concentrated milk to which has been added sweet cream which has been separated from milk in accordance with (b) above.

(d) The addition of nonfat dry milk solids conforming to all the requirements for premium or extra grade nonfat dry milk solids as defined in this specification which is identical to the grade of the whole milk powder produced.

E-1a. (2). The product shall meet the requirements of the keeping quality test. Note: Dried whole milk will be released for shipment without waiting for the outcome of the keeping quality test, provided that the product meets all the other requirements of this specification."

The specific grading requirements for dry whole milk are shown on Table 2 (23).

Table 2. Specific grading requirements of federal specifica-
tions for dry whole milk (23).

| | Spray Process | | Vacuum Drum | Atmospheric |
	Premium Grade	Extra Grade	Process Extra Grade (a)	:Roller Process Extra Grade (a)
Butterfat	26% [b]	26% [b]	26% [b]	26% [b]
Moisture	2.25%	2.5%	2.5%	3.0%
Titratable acidity	.15% [c]	.15%[c]	.15% [c]	.15% [c]
Bacterial estimates	50,000/g.	50,000/g.	50,000/g.	50,000/g.
Sediment	No. 2	No. 3	No. 3	No. 3
Solubility index	.5 cc	.5 cc	2.0 cc	15.0 cc
Flavor-odor	Normal	Normal	Normal	Normal
Color	Normal	Normal	Normal	Normal
Copper	1.5 ppm	1.5 ppm	1.5 ppm	1.5 ppm
Iron	10.0 ppm	10.0 ppm	10.0 ppm	10.0 ppm
Oxygen	3%	3%	3%	3%

a. Same requirements spray process extra grade.
b. Not less than.
c. Reconstituted basis.

Specific Grading Requirements of Nonfat Dry Milk

The specific grading requirements of nonfat dry milk solids
were changed as of July 1, 1958 and supersede the United States
standards for grades of Nonfat Dry Milk Solids, effective June,
1951 (22).

The principal changes were:

1. separation of the standard for spray and roller process

2. more detailed terminology

3. non-assignment of a U. S. Grade when the direct microscopic clump count exceeds 250 million per gram (21)

4. provision for a heat treatment classification as a supplement to the standards for spray process.

The proposed standards are based upon the experience of the Department of Agriculture in providing inspection and grading service for nonfat dry milks, numerous field conferences from coast to coast with industry representatives and users of the product, and the need for restricting the quality of the product to which U. S. grade is assigned.

Under the proposed standards, the U. S. Department of Agriculture would not assign a U. S. Grade to nonfat dry milks having a direct microscopic clump count in excess of 250 million per gram. The direct microscopic clump count test is not incorporated in the proposed standards for distinguishing between U. S. Extra and U. S. Standard Grade. This matter will be kept under review and the incorporation of the direct microscopic clump count in the standards for U. S. Extra Grade and U. S. Standard Grade will be considered at a later date.

A supplement to the proposed U. S. standards for grades of nonfat dry milk has been included to provide a classification of the spray process product according to the heat treatment of the milk prior to drying as it relates to adaptability for various uses. The heat treatment classification is applicable to the

specific grading requirements for nonfat dry milks, spray process. These requirements are shown in Table 3 (22).

Table 3. Specific grading requirements for nonfat dry milk solids - spray process (22).

	U. S. Extra Not greater than	U. S. Standard Not greater than
Butterfat	1.25%	1.50%
Moisture	4%	5%
Titratable acidity	.15%	.17%
Solubility index	1.2 ml.	2.0 ml.
Bacterial estimate	50,000/g.	100,000/g.
Scorched particles	15.00 mg.	22.5 mg.

Nonfat dry milk which fails to meet the requirements for U. S. Standard Grade and/or shows a direct microscopic clump count exceeding 250 million per gram shall not be assigned a U. S. grade (21).

The provisions for a heat treatment classification is not a U. S. Grade requirement. The heat treatment will be made available only upon a U. S. graded product.

The whey protein nitrogen test shall be used in determining the heat treatment classification as follows:

(a) U. S. High-heat. The finished product shall not exceed 1.5 mg. undenatured whey protein nitrogen per gram of nonfat dry milk.

(b) U. S. Low-heat. The finished product shall show not less than 6.0 mg. undenatured whey protein nitrogen per gram of nonfat dry milk.

(c) U. S. Medium-heat. The finished product shall show undenatured whey protein nitrogen between the levels of "high-heat" and "low-heat", (1.51 to 5.99 mg.).

The specific grading requirements for nonfat dry milks - roller process - are shown in Table 4 (22).

Table 4. Specific grading requirements for nonfat dry milk solids - roller process (22).

	U. S. Extra Not greater than	U. S. Standard Not greater than
Butterfat	1.25%	1.50%
Moisture	4%	5%
Titratable acidity	.15%	.17%
Solubility index	15.0 ml.	15.0 ml.
Bacterial estimate	50,000/g.	100,000/g.
Scorched particles	22.5 mg.	32.5 mg.

Nonfat dry milk which fails to meet the requirements for U. S. Standard Grade and/or shows a direct microscopic clump count exceeding 250 million per gram shall not be assigned a U. S. grade.

The inspection of products shall be made at point of delivery by the receiving agency, unless otherwise specified.

sampling should be done by using care to minimize any moisture absorption from air during sampling and avoid sampling on rainy days or when humidity is high. Samples should be transferred to clean, dry, sterile, airtight sample container and sealed immediately.

The testing method used should be the one contained in Methods of Laboratory Analyses for Dry Whole Milk and Nonfat Dry Milk Solids, Dry Buttermilk and Dry Whey, Agricultural Marketing Service, United States Department of Agriculture, July, 1954, (Mimeo), or the latest revision thereof. This is used to determine bacterial estimates by the standard plate count, butterfat content, moisture content, scorched particle content, solubility index, titratable acidity and flavor examination.

The method used to determine the direct microscopic clump count shall be as outlined in Standard Methods for the Examination of Dairy Products (59).

The testing method for whey protein nitrogen shall be the Modified Harland-Ashworth Method (22).

Hedrick et al. (30) discussed the importance of governmental grading of nonfat dry milk. During the past several years one-half to three-fourths billion pounds of nonfat dry milks have been graded each year by the Inspection and Grading Laboratory, Dairy Division of the Agricultural Marketing Service, U. S. Department of Agriculture. The grading is confined to chemical, bacteriological and organoleptic analysis of taste, sight and touch. Agreement between the producer of the product and the Inspection Grading Laboratory are frequent and help considera-

bly in maintaining quality. Variations occur most often with moisture tests and scorched particle tests. The use of identical techniques help to minimize these variations.

COSTS OF DRYING MILK

Interest in costs of drying milk has increased recently because of expansion of dry milk production and consumption. These changes have brought about a demand for dry milks, especially nonfat dry milks for human foods. The increased demand has been reflected in a higher price for dried milk and increased production (40).

Lately, due to a surplus of dry milks, much of the output has been purchased by the government under the price support program, resulting in a narrowing between costs and prices received for dried milk. In view of this situation, operators of milk-drying plants have shown an increased interest in processing costs and methods that may help to reduce them.

Juers and Koller (40) made a study of 18 large specialized drying plants located in Minnesota. The plants selected were those from which data had been collected from a previous study in 1947 and 1948 (6). This affords an opportunity to make comparisons of costs over a period of time to show the changes which have occurred. The costs considered in the study were restricted to those directly associated with the manufacture of dried milk. The purpose was to obtain cost comparisons which reflect efficiency as influenced by plant volume and managerial policy.

Manufacturing Costs

These costs included such items as plant and administrative labor, fuel, depreciation, manufacturing supplies, repairs and such general expenses as insurance, taxes and interest. Costs of raw materials, including receiving and separating costs, usually account for between one-half and four-fifths of all costs, including packaging and sale to the first receiver (40).

For purposes of comparisons, manufacturing costs were classified into three groups:

1. plant expenses
2. administrative expenses, and
3. general expenses.

Plant expenses included such items as plant and administrative labor, fuel, depreciation on building and equipment and rent of plant or storage space, manufacturing supplies and repairs.

Administrative expenses included office salaries, office supplies, telephone and other administrative expenses such as postage, audit book charges and depreciation of office equipment.

General expenses included insurance, interest, taxes and small expense items such as donations, subscriptions, travel expenses and many items of minor importance.

The total manufacturing cost was computed for each plant and compared with the average for all plants and with the data of a 1947 study. During the period under study, there were substantial increases in the volume of output of most of the plants

observed. The average annual output per plant was increased from 5.2 million pounds in 1947 to 7.1 million pounds in 1953. The volume of output of individual plants ranged from 2.3 million pounds to 14.5 million pounds in 1953 as compared with a range of 2.6 to 8.5 million pounds in 1947.

Labor Cost. Labor is the biggest item of expense in the manufacturing costs of dry milk. Labor costs for various plants ranged from .68 cent up to 2.03 cents for each pound of dry milk produced, with the majority of plants between 1.00 cent and 1.10 cents per pound. The average labor cost per pound of dry milk for the 18 plants in 1953 was 1.10 cents as compared with 1.6 cents in 1947. On the basis of 1953 production this amounts to an average reduction of over $4,000 per plant in spite of an increase of approximately 38 per cent in hourly wage rates between 1947 and 1953. This reduction in labor costs reflects a very substantial improvement in labor efficiency.

Much of the increased efficiency was probably due to a larger output in 1953 than in 1947. A certain amount of labor must be maintained at any level of production and this minimum amount of labor is a fixed cost of operation. As output is increased this fixed portion of labor cost is spread over more units. The resulting average cost of labor per unit of output is decreased. This study shows that the plants with larger volumes have a higher dry milk output per hour of labor than do plants with low volume.

Effect of Seasonality on Labor Costs. Of great importance in achieving low labor cost is the management of labor in accord with seasonal changes in volume. In all plants it was found that labor costs and output per hour of labor varied with seasonal variations in production. The degree of variation was considerably different in different plants. In a comparison of plants having low labor costs with those having high labor costs, it appeared that maintaining high labor productivity through the high production season is the important factor in keeping annual per unit labor cost low. Plants with high labor costs apparently hired extra labor in anticipation of higher production. On the contrary, in plants which had low labor costs, the employment policy seemed to be that of not hiring extra labor until the increase in production had taken place (42).

Plant managers indicated that it was often desirable to carry some surplus labor through the slack season to keep good men in reserve for the flush production period. There was no significant relation between dry milk output per hour of labor during the slack season and the annual labor cost. Some of the plants having the lowest average labor cost for the year had the poorest labor efficiency during the slack season. The high level of labor productivity from January through June is characteristic of all the plants with low labor costs (42).

Fuel Costs. Fuel costs were the second largest cost component in the 18 milk drying plants studied. This cost accounted for 28 per cent of the total manufacturing cost. Three

different types of fuel were used by plants included in the
study; namely, fuel oil, coal and natural gas.

Plants Using Fuel Oil. In 1953, the average fuel oil con-
sumption per pound of dry milk produced in five spray process
plants was .155 gallons. The annual volume of output of these
plants ranged from 4.3 to 7.7 million pounds of dry milk per
year. The quantity of fuel oil used per pound of dry milk pro-
duced ranged from .139 to .177 gallons in these plants and did
not show any significant relation to the volume of output of
the plants. The greatest fuel efficiency was achieved during
the heavy production months of late winter and spring but as
production declined through late fall, fuel efficiency fell
again. Some of the variations in fuel use, from month to month,
arose from errors in estimation and the time at which fuel in-
ventories were taken.

Comparison of the 1953 data with those of 1947 showed some
improvement in fuel utilization efficiency. The quantity of oil
required to produce one pound of dry milk was reduced .025 gal-
lons in 1953 for the five plants using oil. This is approxi-
mately a 14 per cent reduction in fuel requirements and quite a
significant saving (40).

As in the case of labor, there is a fixed amount of cost
involved at any level of operation. A certain amount of fuel
is required to generate steam, regardless of the amount of milk
to be dried. The greater the amount of product, the lower this
cost will be on a per unit basis.

Plants Using Coal. The 1953 data for five spray process plants using coal for fuel indicated that an average of 1.77 pounds of coal was used for each pound of dry milk produced. As in the case of plants using oil, the 1953 data reflected a considerable increase in efficiency over 1947. The average coal consumption in 1947 was 2.24 pounds per pound of dry milk produced, which indicates a 20 per cent reduction between 1947 and 1953 (40).

Cost comparisons between coal and oil could not be made because of transportation charges included in the fuel expense.

Plants Using Natural Gas. Only one plant in this study was using natural gas for fuel in 1953. Even with the highest price of natural gas since 1947, it still was the cheapest fuel for drying milk. Comparison in cost indicated that natural gas is a lower cost fuel than either coal or oil even with the cost of using standby oil for short periods (40). The fuel cost per pound of dry milk in the plant using natural gas was .59 cents as compared with a low of .84 cents for oil and .88 cents for coal. A more recent development is the use of liquified propane, which may be transported by truck or rail and can be stored in tanks. Since 1953, some plants have converted to this fuel (40). No data on costs are available on these plants.

Depreciation and Rent Expenses. All depreciation and rent expenses for the individual plants were added together and treated as one cost component. These expenses included depreciation on buildings and equipment and rent of plant or storage

space. Depreciation of trucks used for milk assembly or product
hauling was excluded. In 1953 the average depreciation and rent
expense per pound of dry milk produced was .31 cents as compared
to .55 cents in 1947. The greater part of this reduction may be
attributed to the increased volume which was processed without
any substantial addition to plant and equipment. At the 1947
level of production there was unused capacity and the increase
in production up to 1953 meant a fuller utilization of this ca-
pacity. In some plants the total rent and depreciation ex-
penses have fallen since 1947 and those may still be lower than
expected for a new plant.

Plant Maintenance Expense. Maintenance cost per pound of
milk produced rose from .19 cents in 1947 to .24 in 1953.
There are several factors which contributed to increased main-
tenance costs. The most important of these factors was the
aging of equipment and buildings. By 1947, most of the plants
were relatively new and the equipment had not begun to wear
out. By 1953 many pieces of equipment were near the replace-
ment stage. The aging plants were producing more powder which
lead to greater expenses for repair parts and services during
this period.

Administrative and General Expense. Administrative and
general expenses combined made up only 12 per cent of the cost
of manufacturing milk in the 18 plants studied. Administrative
expenses in 1953 were .10 cents and general expenses .28 cents
per pound of dry milk. The items included under administrative

and general expenses are generally of a fixed nature and the
total expense does not vary much with production. This causes
the per unit cost to vary as output changes and greater output
will cause the average per unit cost to fall. Administrative
costs per pound of dry milk produced were generally lower in
the larger plants. For all plants, administrative costs were
lowest during the heavy production months.

Packaging Costs. The costs of packaging the dried milk
were excluded from the analyses in this study because of the
diversity of the kinds of packages used and the influence of
market outlets on the choice of package. Two different types
of bulk containers were used by the plants involved, the 225
pound fiber drum and the 100 pound kraft paper bags. Most
plants used the same containers and the prices reported were
$2.78 for the fiber drums with liners and 40 to 44 cents for
the 100 pound bags including liners.

The average packaging costs for those plants using only
bulk packages ranged from 90 cents to $1.27 per hundred pounds
of dry milk. This cost was dependent on the proportion of the
amount packed in drums and bags. Fiber drums were used espe-
cially for sales to the government or where the dry milk was to
be repackaged. For sales directly to consumers, the paper bags
were used. In various plants the fiber drums were re-used to
a limited extent after the dry milk had been repackaged in
small containers.

No costs were available in two plants which were packaging

the milk in small containers. One used 3 1/2 ounce polyethylene consumer packages and the other packaged, for government use, in 4 1/2 pound polyethylene lined fiber boxes. In these cases the purchaser of the dry milk reimbursed the plants for all the expenses incurred in packaging.

Total Manufacturing Costs. The average total manufacturing cost for a pound of nonfat dry milk solids in the 18 plants studied was 3.23 cents in 1953. This is a .32 cents per pound reduction compared with 1947 when the previous study was made. The reduction in the plant expense items, labor, fuel, depreciation, since 1947 was .42 cents per pound of dry milk produced. There was a reduction of .01 cents in administrative expense and the general expense item showed an increase of .11 cents a pound. This resulted in a reduction in total manufacturing costs of .32 cents.

Of the total cost of manufacturing dry milk, 88 per cent was for plant operating expenses in 1953 as compared with 92 per cent in 1947. There was some relation between large output and lower costs in 1953. In 1953, the changes were not as apparent as they were in 1947. In general, the larger plants, five to seven million pounds, showed lower costs than small plants though some relatively small plants achieved costs lower than some of the larger ones. Any further cost reductions may be effected by managerial efforts to achieve greater labor efficiency and the adoption of improved equipment and techniques (40).

Kolmer (42) in a study of three plants in Iowa, concluded
that skimmilk equipment is not utilized most efficiently at vol-
umes of 938,000, 1,875,000 and 2,817,600 pounds of powder pro-
duced per year. He also concluded that when volume exceeds three
million pounds per year resources are used efficiently and the
lowest processing costs are obtained.

FUTURE TRENDS OF THE DRY MILK INDUSTRY

In recent years, with expanding utilization of dry milk
products, there has been emphasis not only on improving the
quality of the product, but on tailor-making products with dif-
ferent properties for different applications. As a result, a
variety of dry milk products are commercially available.

The two most common types of dry milk products are nonfat
dry milk and dry whole milk. Nonfat dry milk is further modi-
fied by the so-called "instantizing" process. The nonfat dry
milk ranks first in importance of all dry milks from the stand-
point of production and utilization and has had the greatest
increase in the last decade.

The per capita consumption statistics (19) showed 3.7
pounds per capita of nonfat dry milk powder consumed in 1950,
and 5.7 pounds in 1957. Up to 960 million pounds of nonfat
dry milk solids were used for civilian consumption in 1957 (63).

The largest single domestic market for nonfat dry milks at
present is the baking industry. Also for a good many years non-
fat dry milks have been used successfully in ice cream, cul-

tured buttermilk, chocolate drinks, cottage cheese and for mak-
ing many other manufactured dairy products requiring a uniform,
dependable year around source of high quality nonfat milk pow-
der (1).

The development of instant nonfat milk increased its ac-
ceptance and consumption as a beverage for human consumption
because of its solubility and dispersability. As long as the
quality of nonfat dry milks is maintained there will be no
problem in regard to future growth in the consumption of in-
stant milks. The only major problem with instant milk at pres-
ent is its flavor stability during storage. Research studies
are currently being conducted to solve this problem.

Dry whole milk ranks second in importance of dry milks
(19). The statistics on consumption (63) showed .28 pounds
per capita of dry whole milk were consumed in 1950; but .19
pounds were consumed per capita in 1957. The production of
dry milks has been more or less steady between the years 1951-
1957 but in 1958 it was 22 per cent less than in 1957. (See
Table 1). Nonfat dry milks may be competing for some of the
dry whole milk markets. Difficulty of re-dispersion in water,
keeping qualities and flavor are recognized as limiting fac-
tors in the use of dry whole milks.

The dairy industry is interested in the development of a
dry whole milk with solubility similar to instant nonfat dry
milk and a flavor comparable to fresh fluid milk. Yet, the
effects of a new dry whole milk product which would meet con-
sumers' wants are of tremendous importance not only to con-

sumers, but also to producers, processors and distributors in
the dairy economy. The production of such a product could make
it possible and cheaper to dry all milk and distribute it in
powder rather than to attempt to continue with our present
method of distribution. With the advent of such a product, the
era of a revolution in the dairy industry could be started.

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RECENT DEVELOPMENTS IN MANUFACTURING,
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by

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AN ABSTRACT OF
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A history of the early development of the dried milk industry with the growth of various phases of this industry is presented in this report. The rapid growth of the nonfat dry milk industry is discussed, and production figures are reported to demonstrate this growth.

Manufacturing processes are described for the production of various types of dried milk products. Preparation and selection of milk to be dried is discussed. A detailed description of the spray and roller dry processes with descriptive diagrams is included. Included in a discussion of the spray drying process is a thorough coverage of various component parts of this equipment, such as: types of nozzles, drying chambers, and recovery systems. A detailed description of the instantizing process is presented with diagrams to illustrate this method.

A chapter of this report is devoted to various phases of packaging dry milks. The requirements for packaging dried milks in order to maintain a stable product are presented. Consideration is given to the type of process in regard to the conditions necessary for packaging.

A discussion of the storage defects occurring in dried milks is included. Such defects as rancidity, oxidative rancidity, staling and browning are discussed. The effects of these deteriorations are considered from the standpoint of flavor as well as solubility of the milk powder.

Specific quality requirements are reported as they were presented in the Federal Standard Stock Catalog (January 1,

1943), Hunziker's <u>Condensed</u> <u>Milk</u> and <u>Milk</u> <u>Powder</u> and in the Federal Register Documents for dry whole milk and nonfat dry milk solids.

Data on studies of costs of drying milk in specialized milk plants are presented. These data show a reduction in manufacturing costs as the output of the plants was increased over three million pounds of powder per year.

And finally a brief discussion of the future of the non-fat dry milks and whole dry milks is presented.