

Sensory Quality of Nonfat Dry Milk After Long-Term Storage¹

N. R. DRISCOLL,² C. P. BRENNAND, and D. G. HENDRICKS

Department of Nutrition and Food Sciences

Utah State University

UMC 87

Logan 84322

ABSTRACT

Nonfat dry milk was stored under various conditions to determine the effects of temperature, packaging, atmospheric gases, and form of milk on the sensory quality of the stored product. Nonfat dry milk was significantly affected by storage temperature during long-term storage. Nonfat dry milk held at 32°C for 6 mo began to develop off-flavors and by 24 mo was considered unacceptable when evaluated by a trained sensory panel. After 4-yr storage nonfat dry milk samples stored at 21°C were rated unacceptable by the panelists. Storage at 10°C resulted in minimal flavor changes in 52 mo. After 4-yr storage, nonfat dry milk samples stored in Polybags were statistically less acceptable than samples stored in cans. The form of milk (instant or regular) did not affect the length of time nonfat dry milk could be stored. Unacceptability of samples was due to an oxidized/stale flavor.

INTRODUCTION

The length of time that nonfat dry milk (NDM) can be stored and still maintain its sensory qualities is a concern to both consumers and industry. Groups varying from governmental to religious bodies have made food storage recommendations. The civil defense organization has recommended that people have on hand a supply of food for emergency situations. Since 1936, The Church of Jesus Christ of Latter Day Saints has en-

couraged its people to maintain a year's supply of food and other essentials necessary to maintain life and health. The Quartermaster Corps of the US Army has developed dried and special packaged foodstuffs that can be kept for long times for personnel in isolated combat situations. Nonfat dried milk is a component of these recommended programs.

In 1927, Holm et al. (3) studied the oxidative breakdown of fat in dry whole milk stored at temperatures ranging from 3° to 30°C with moisture contents between 1.5 and 3.4%. They concluded that moisture was a critical factor in the storage quality of the milk. Dry whole milk of exceedingly low moisture content stored at 3°C deteriorated at approximately half the rate of the samples stored at 25°C. No differences were noted between milk stored in a partial vacuum and milk stored in air regardless of moisture content when held at 21 to 25°C. However, dry milk stored in carbon dioxide (CO₂) developed off-flavors and odors before the dry milk stored either in air or partial vacuum (3).

Henry et al. (2) stored spray-dried NDM of high (7.3%), medium (4.9%), or low (2.9%) moisture content at 20, 28.5, and 37°C in atmospheres of nitrogen (N₂) or air for 2 yr. They concluded that moisture had the greatest effect on the storage life of dry milk. Milk stored under N₂ developed off-flavors more slowly than milk stored in an air atmosphere. They also observed an inverse relationship between storage temperature and sensory quality. Low moisture NDM stored at 20°C in N₂ atmosphere was considered palatable for over 700 d.

The effect of the atmosphere in the storage container was studied by Kliman et al. (4) using two lots of dried whole milk. The first lot was packaged in an atmosphere of N₂ with less than .1% oxygen. The second lot was held in open stainless steel trays and stirred twice each day to equalize its exposure to air. Each lot was

Received September 21, 1984.

¹Utah State University Agricultural Experiment Station Journal Paper No. 3020.

²Manchester Memorial Hospital, Manchester, CT 06040.

held at 13°C. The milk was evaluated by a trained taste panel who concluded that even in an extreme case, where less than .1% oxygen was present in the package, flavor deterioration occurred.

In 1969, the US Department of Defense recommended holding NDM no more than 60, 24, and 9 mo at 4.4, 21, and 32°C, respectively (6). Their current recommendations have been decreased to 32, 16, and 8 mo for canned NDM and 24, 12, and 3 mo for NDM in drums, bags, or cartons held at the same temperatures (7).

Mercurio and Tadjalli (5) evaluated 20-yr-old NDM for its nutritive and sensory quality. A trained panel evaluated the milk mixed in various proportions with fresh NDM. Unacceptable scores were given to reconstituted milk containing 30, 20, and 10% concentrations of the 20-yr-old milk. Stale, scorched, cooked, and old casein were characteristic off-flavors noted by the panel. Reconstituted samples containing 5% or less of the 20-yr-old milk blended with fresh NDM received acceptable ratings.

Most storage studies on dried milk were conducted prior to the use of current packaging and drying methods. The storage conditions and packaging methods necessary to maintain a high quality product during long-term storage needed to be evaluated. Effects of storage temperature, type of package, atmosphere in the container and form of milk on sensory quality are reported here.

MATERIALS AND METHODS

Samples and Experimental Design

Instant and regular NDM samples were obtained from the same batch of milk (Carnation Company, Van Nuys, CA).

The experimental design was factorial involving form of milk (instant, regular), storage containers (canned, Polybag), temperature (10, 21, 32°C) and atmosphere (air, CO₂, and N₂). All possible combinations were included with the exclusion of N₂ over NDM in Polybags, since this combination was not feasible for storing dry milk in a home situation. Samples were flushed with a stream of nitrogen gas to obtain the nitrogen-treated samples. To obtain an atmosphere of carbon dioxide, a pellet of dry ice was placed in the can and allowed to sublimate. This procedure

was repeated with a second pellet of dry ice. Air packed samples were not pretreated. All canned samples were vacuum packaged. Polybag samples used the same dry ice treatment with excess air pressed from the 3 mil Polybags. Control samples of regular NDM and instant NDM were stored in cans with an atmosphere of nitrogen at -18°C. At the end of the study (54 mo), fresh samples of both instant and regular NDM were obtained from Carnation Company and evaluated along with the stored samples.

Sample Preparation

A 10% milk solution was prepared from each of the samples at 32°C. Each solution was mixed for 90 sec in a model K5-A Kitchen-Aid mixer with a whip set on high speed. All of the milk solutions were prepared 24 h prior to panel evaluation and were held at 5°C in an odor-free environment. Immediately before tasting, samples were equilibrated to room temperature.

Sensory

An 11-member panel composed of four men and seven women was selected after 1 wk training that included taste sessions, discussions, and screening to determine those persons capable of identifying specific off-flavors in milk. Prior to each set of scheduled sensory panels, a refresher session was conducted using NDM samples containing specific off-flavors which may develop in dried milk.

Coded 30-ml portions of each milk sample were presented to panelists in a random order. Panel members were allowed to either swallow the samples or expectorate and were instructed to rinse with water between each sample. Evaluation was in individual booths in a noise-free and odor-free room.

Each panelist rated the NDM samples for the following attributes using a seven point scale: cooked flavor (7 = extreme cooked flavor and 1 = none); oxidized or stale flavor (7 = extreme and 1 = none); metallic flavor (7 = extreme and 1 = none); and mouthfeel (7 = chalky or puckery and 1 = smooth). An overall quality also was given where 7 = dislike extremely, 4 = dislike slightly, and 1 = like very much. Initially, the milk was evaluated every 3 mo. After 18 mo of storage the milk was evaluated every 6

mo for a total study of 54 mo. Each sample variable was included in the testing until the mean rating for that sample exceeded a score of 4, which meant it was unacceptable.

Statistical Analysis

Data were analyzed using a four-way analysis of variance program in the Statpac Statistical software (SAS), written by Rex Hurst at Utah State University. The independent variables were: temperature, type of package, atmosphere in the container, and the form of milk. Dependent variables were cooked flavor, oxidized/stale flavor, metallic flavor, mouthfeel of the milk, and overall acceptability of the milk. Control samples were not included in the factorial design. To avoid excessive fatigue, panel members did not evaluate replications of sample combinations. In the early stages of the study, there were 30 combinations of the four factors per time period evaluated over 1 wk. The SAS package was used for covariance analysis, which included the four main effects listed and a time factor.

RESULTS AND DISCUSSION

The decrease in overall acceptability of NDM was a direct reflection of the development of an oxidized/stale flavor. In general, panelists did not detect the presence of a cooked flavor, a metallic flavor, or a change in the mouthfeel of the NDM.

Form of Milk

No significant difference was detected between the sensory quality of instant NDM and regular NDM regardless of time or storage conditions. These results are not in agreement with the results from a preliminary study done by Bassette and Kenney (1) who found that instant NDM developed a stronger cereal-like flavor than regular milk during storage. Theoretically, an increase in porosity of instant NDM may provide a larger surface area for chemical breakdown but under the conditions used in this study the instantized NDM did not deteriorate more quickly than regular NDM.

Type of Package

The NDM samples stored in Polybags were less acceptable ($P < .01$) than samples stored in

cans (Figure 1). After 4 yr, the mean scores for the overall quality of milk samples stored in Polybags and cans were 3.80 and 2.97, respectively. The interaction of storage temperature and type of package also was statistically significant after 4 yr. The NDM stored in Polybags at 21°C were less acceptable ($P < .05$) than NDM stored in Polybags at 10°C or in cans at either 10 or 21°C. At 21°C, chemical changes occurred faster than at 10°C, and because Polybags are permeable, oxygen was present in the Polybag to react with oxidizable material and thus produce off-flavors. Consequently, even NDM packaged in bags in an atmosphere of CO₂ may be susceptible to air oxidation. Currently, the US Department of Defense recommends 32 mo for NDM if stored in cans, drums, or bags at 40°F and only 24 mo if stored in a carton (7). Thus, they do not recognize appreciable differences in the types of containers we used in our study, at least for shorter storage. It was only after 42 mo of storage that we were able to detect differences due to packaging and then only in samples stored at 21°C.

Atmosphere in the Container

Because of the permeability of the Polybags, only the data for milk samples stored in cans were used to determine the effect of atmosphere in the container on the storage of NDM. Furthermore, to observe the effect of atmosphere in the container over a long period, the data for the samples stored at 32°C were not included because these samples were dropped after 24 mo.

The sensory quality of NDM samples in atmospheres of N₂, CO₂, or air did not vary significantly over the first 36 mo of testing; however, the air-packed samples were significantly higher ($P < .05$) in off flavors after 4 yr than the N₂- and CO₂-packed samples. The canning method may have minimized the atmospheric gas treatment since vacuum canning would decrease the total oxygen present in the can.

Storage Temperature

Temperature had the greatest effect of any of the variables tested on the length of time NDM could be stored. Samples held at 32°C began to show differences from other samples

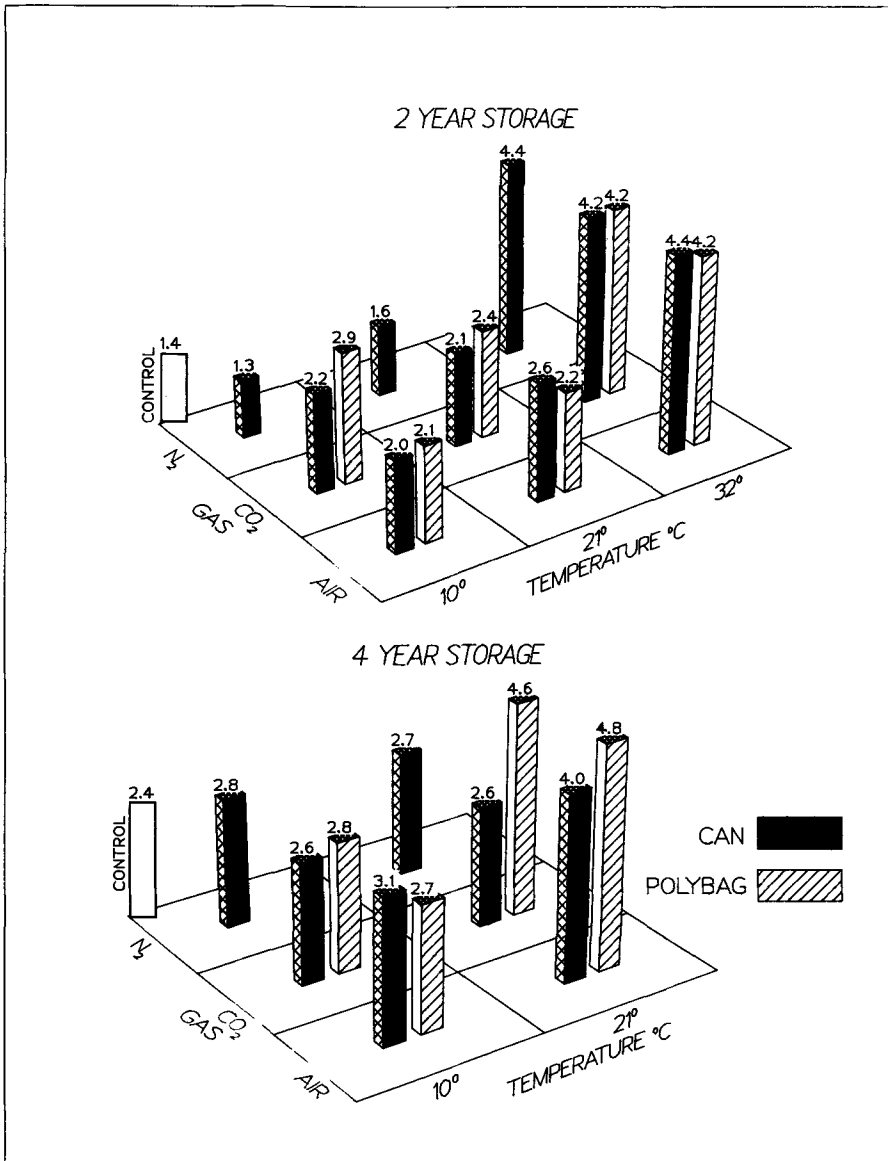


Figure 1. Effects of storage container, gas, and temperature on mean sensory scores for oxidized/stale flavors in nonfat dried milk after 2- and 4-yr storage.

very early and continued to degrade (Figure 1). By 1 yr, the samples were significantly less acceptable than those stored at 10 or 21°C (Figures 1 and 2). The 32°C samples were dropped from the study at 24 mo of age. NDM samples stored at 21°C were rated unacceptable by the panelists after 28 mo of storage ($P < .05$).

Samples stored at 10°C were acceptable after 4-yr storage. From 1969 to 1979 the US Department of Defense decreased the approximate keeping times recommended for NDM for each storage temperature. The 1969 recommendations of 60, 24, and 9 mo keeping time at 4.4, 21.1, and 32.2°C, respectively, are in

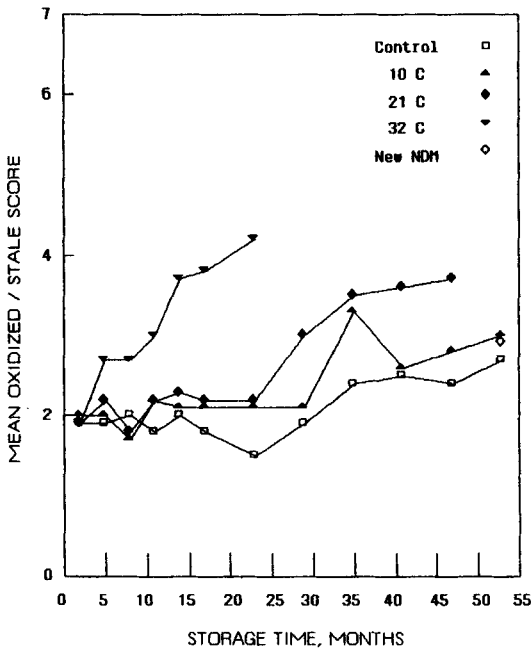


Figure 2. Effect of storage time and temperature on sensory scores for oxidized/stale flavors in nonfat dried milk.

fact in closer agreement to our data than the 32, 16, and 8 mo suggested in the 1979 manual (6,7).

Fresh and Control Samples

The mean overall acceptability scores of the control samples increased with time (Figure 2). To determine if the control samples had changed, fresh NDM was obtained from Carnation for comparison. Mean scores for the fresh and control samples were 2.83 and 2.77, respectively. Because these scores were not statistically different, it was concluded that the control samples had not changed. Considering the length of time over which the experiment was conducted, the increase in the control sample was probably a reflection of a normal bias of the taste panel members. Panelists may have assumed that because the study lasted so long, all of the samples being evaluated must have decreased in quality. Also, panelists may have simply lost interest as time progressed, resulting in less discrimination.

CONCLUSION

Nonfat dry milk cannot be stored indefinitely due to changes that result in a product with an unacceptable flavor. This flavor was identified by the trained panel as an oxidized/stale flavor and was primarily affected by high storage temperature. Nonfat dry milk held at 32°C for 6 mo began to develop an off-flavor and by 12 mo the NDM was no longer palatable, regardless of how the milk was packaged. Nonfat dry milk held at 21°C did not show a perceptible change until after 24 mo when there was a relatively rapid increase in oxidized/stale flavor. Storage temperatures of 10°C resulted in only minimal changes in 52 mo.

Packaging and gas atmosphere became important when the NDM was stored at room temperature (21°C) over long time periods. After 4-yr storage, air atmosphere canned samples and Polybag samples held at 21°C were less desirable than canned samples with N₂ or CO₂ held at the same temperature.

Form of the milk (instant or regular) did not affect the length of time NDM could be stored.

ACKNOWLEDGMENTS

The authors acknowledge Carnation Company for the donation of the nonfat dry milk used in the study. Appreciation is expressed to R. J. Brown for his contribution in the statistical analysis.

REFERENCES

- 1 Bassette, R., and M. Keeney. 1960. Identification of some volatile carbonyl compounds from nonfat dry milk. *J. Dairy Sci.* 43:1744.
- 2 Henry, K. M., S. K. Kon, C. H. Leu, and J.C.D. White. 1948. Deterioration on storage of dried skim milk. *J. Dairy Res.* 15:292.
- 3 Holm, G. E., P. A. Wright, and G. R. Greenbank. 1927. Variations in the susceptibility of the fat in dry whole milks to oxidation when stored at various temperatures and in various atmospheres. *J. Dairy Sci.* 10:33.
- 4 Kliman, P. G., A. Tamsma, and M. J. Pallansch. 1962. Peroxide value-flavor score relationships in stored foam-dried whole milk. *Org. Food Chem.* 10:496.
- 5 Mercurio, K. C., and V. A. Fadjalli. 1979. Nutritional and sensory evaluation of 20 year old nonfat dry milk. *J. Dairy Sci.* 62:633.
- 6 US Department of Defense. 1969. Storage and material handling. DSA 4145.1:55-1.
- 7 US Department of Defense. 1979. Storage and materials handling. DOD 4145.19-R-1:5-89.