An overview of changes in the characteristics, functionality and nutritional value of skim milk powder (SMP) during storage.[1]

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Summary

Skim milk powder (SMP) has low moisture and fat contents and, when stored in dry, cool conditions, has a shelf life in excess of two years. Specifically, when stored at 15°C and a relative humidity of 75%, skim milk powder has a minimum shelf life of two years, an average shelf life of three years and a maximum shelf life of four years.

Milk powders are hygroscopic: they tend to attract water readily from humid atmospheres. When moisture levels are excessive, milk powders may become sticky, caked or lumpy, and exhibit reduced flowability and solubility. These changes affect the ease of use of the product, requiring grinding for example and may affect the flavor, but do not represent a health or safety problem. If the powder's moisture content exceeds 15%, it then becomes susceptible to microbiological growth and should not be used.

Skim milk powder should have a mild flavor and aroma. After extended storage, some milk powder may develop slight off-flavors. These may be noticed in rehydrated or "recombined" milk products. However, milk powders for use as ingredients in manufactured foods and dry blends generally do not need to meet as high standards of palatability and redispersibility.

Dried skim milk products stored in optimal conditions in proper packaging show essentially no change in color, even during two years of storage at 35°C. In commercial situations, most dried milk products are susceptible to reactions that can result in small changes in the physical properties of the product, its palatability and nutritive value. These changes, however, do not significantly impact the nutritional benefits of milk powders. Vitamin and protein quality losses during storage of milk powders, when stored in good conditions, are negligible.

Skim milk powder should be stored in sanitary, cool, dry conditions, away from strong odors. Milk powders from bags that have been opened or damaged during transit or storage, or that appear spoiled; to have been contaminated or tampered with in any fashion should never be used.

[1] Prepared by the U.S. Dairy Export Council, with the collaboration of Dr. N. Farkye, California Polytechnic San Luis Obispo, Dr. K. Smith, Wisconsin Center for Dairy Research, and F. Tracy Schonrock, SchonrockConsulting. October 2001.

Influence of storage on chemical and physical properties of skim milk powders

- *Which flavor changes can be expected?*

The flavor and odor of milk powder should be sweet and clean, entirely free from rancid or other objectionable odors. Off-flavors developing in dried milk products during storage may be due to many different compositional, processing or other variables. In commercial situations, the presence of other foods or packaging materials during transport may also have an effect on the flavor of dried milk products. It is important to store milk powder away from other ingredients with a strong odor such as garlic, onions, spices and flavorings, away from other materials with strong odors such as gasoline, fuel oil, fertilizer, or chemicals, and away from moldy materials.

The occurrence of off-flavors may also be an indication of spoilage, microbial growth, or contamination. Bags of milk powders should be stored in a dry, clean area. Contact with spoiled foods, wet cardboard, wood or any other material that may be moldy or has the potential to support mold growth should be avoided. A milk powder that has developed a strong, objectionable odor should not be used.

Stale or “cardboard” flavors have also been reported in different types of dried dairy ingredients, including milk powders and maybe due to a large number of factors other than storage. Off-flavors due to the Maillard reaction are generally characterized as “caramelized” or “toasted.” At high storage temperatures, these types of flavors have been described in dried milk products. A slight caramelized taste is objectionable in products such as yogurts, ice cream and similar products. It is not a problem in other food applications such as in baked goods and some dry blends.

- *Is solubility affected by extended storage?*

Extended storage of dried milk products may result in decreased solubility of proteins. The insolubility is generally attributed to the Maillard reaction, which involves reducing sugars and proteins. Storage studies of dried milk products have shown that the products stored in a variety of conditions could exhibit slight changes of solubility. The changes are not commercially important, yet it remains preferable to store milk powders at temperatures well below 40°C for a maximum retention of solubility characteristics over a long period of time.

The term solubility is also used to describe the dispersing characteristics of milk powders when reconstituted with water or other fluids. Tests to determine the “solubility” of milk powders depend upon a number of factors such as the amount of dissolved minerals, “hardness”, in the water used, speed and duration of stirring and temperature, and other factors. The use of mechanical agitation and mild heat in sanitary conditions may be required to facilitate “wetting” and dispersion of some milk powders. For uses where the powder is blended with other dry ingredients as, for example, in baked goods, the degree of solubility of milk powder is not very critical.

- *What is the impact of browning on functionality of milk powders?*

A powder that has developed extensive browning or appears to have deteriorated should not be used. Slight browning may be associated with flavor changes, making the powder less desirable in applications such as yogurt, ice cream and other dairy products. These changes, however, are not noticeable in bakery applications. Some studies have shown, in fact, that volume of baked goods can increase with the length of storage and degree of browning of dried milk ingredients. Typically, the level of protein denaturation achieving during the processing of milk powders is a more significant indicator of performance for industrial bakers than small changes occurring during storage.

- *What is the impact of storage on the powder's acidity? (i.e. pH level)*

In some studies, the pH of milk powders stored at room temperature was shown to decrease. The pH change can also be attributed to the bonding of amino groups by lactose in the Maillard reaction. Changes in pH do not appear to be significant for a milk powder user at the commercial level.

A milk powder that has deteriorated extensively as a result of poor storage conditions, and that appears to have an unpleasant, acidic taste, should not be used.

- *What is the impact of storage of flow properties?*

Development of stickiness, caking, and lumpiness can take place during storage of dried milk ingredients. Skim milk powder is hygroscopic (attracts moisture) because of its high lactose content. If exposed to the atmosphere it can absorb sufficient moisture to induce caking or the development of lumps, resulting in a powder that flows poorly or not at all. Proper storage conditions and good packaging can reduce stickiness, caking, and lumpy problems.

- *What can be done if the product has "caked"?*

SMP that has been exposed to excessive heat and moisture may develop stickiness and "cake," and these changes do have commercial significance. Caked dried milk powder can be ground after which it will remain free flowing unless exposed to high humidity. The powder should be allowed additional time to dissolve, and may require additional stirring. In all cases, when recombining milk, clean potable water should be used and the appropriate heat treatment applied to the product after reconstitution.

If the moisture uptake is such that off-flavors have developed, the product or its packaging appears moldy or seem to have deteriorated, the milk powder should be discarded. Milk powder from any bag that has been opened prior to use or appears to have been tampered with should never be used.

- *How does browning develop in milk powders?*

Ordinarily browning is not a major type of deterioration in SMP during storage. Non-enzymatic browning can take place in SMP as in many casein-lactose systems. Non-enzymatic browning via the Maillard reaction is one mode of deterioration in milk powders, which may limit shelf life. Milk powders contain relatively high concentrations of lactose and protein high in lysine (an amino acid) content. In the presence of moisture, these components readily participate in the Maillard reaction. This interaction may result in changes in protein quality that is accompanied or followed by undesirable color changes. Non-enzymatic browning occurs during the processing of many foods, such as baked goods, and is not a safety problem.

- *Which factors contribute to color changes in milk powder?*

The most apparent visible change in SMP after storage is a light brown color. This color can develop in milk powders stored at room temperature, as well as in milk powders refrigerated for a period of three years. Browning occurs faster as the storage temperature is higher, or if bags of SMP have been opened. Some studies have shown that browning may occur faster with increased moisture content of the product itself. Typically both the temperature and humidity of storage conditions have an effect on the Maillard reaction. Uptake of moisture by milk powder is mostly attributed to the hygroscopic nature of the lactose. These changes can occur in any natural dehydrated milk product.

At every water activity level, the color index (that measures Maillard reaction browning) increases with increasing storage temperature, especially in the 20-40°C and storage time. To achieve good retention of the original attributes of milk powder during storage, temperatures should be below 20°C and the water activity below 0.2

Influence of storage on the nutritive of skim milk powders

Lysine and the sulfur-containing amino acids are principal among those that suffer some slight destruction during the high temperature treatments of milks or Maillard reaction. Protein quality losses can occur during normal storage. Studies have shown that methionine and tryptophane content do not change significantly during storage at temperatures ranging from –40 to 40°C and water activities in the 0.15 to 0.41 range. The available lysine decreases most at high water activity and at the highest temperature. However, losses of lysine after 6 months of storage at 20°C (at any water activity level) are less than 8% (typically less than 6%.) It is only during extended storage (over 6 months) at temperatures exceeding 40°C and at high water activity that the loss of lysine, and therefore the change of nutritional quality of milk proteins, becomes more significant (with losses of 15-24%). Such extreme conditions are rarely encountered in commercial situations.

- *Is the biological value of milk protein reduced during storage?*

The biological value of milk proteins is not significantly altered during the manufacture of milk powders, or during storage in good conditions for an extensive period of time. Maintaining the nutritional value of milk proteins during storage is not a problem, provided the temperature is kept below 40°C and water activity (humidity) low.

- *Is vitamin content affected by storage in milk powders?*

The amounts of thiamin (B1), riboflavin (B2), niacin, calcium pantothenate, biotin, and pyridoxine present in dried milk are quite comparable to those of market milk and are not affected by storage for 6 months at 35°C. Vitamin C content is slightly reduced during storage for 6 months.

Expected shelf-life

- *What is the expected shelf life of milk powder that has been transported or stored for three months at temperatures above 35°C?*

Storage at high temperatures can reduce shelf-life because some reactions, such as non-enzymatic browning, are temperature-dependent. It is the combination of heat and high humidity that will significantly reduce shelf-life. For example, studies have shown that storage for 3 months at 37°C and 90 percent relative humidity is equivalent to storage for 12 months at ambient temperature in temperate climates (approx. 15-25°C, 80% RH or less). Therefore, the remaining shelf-life may be reduced by a factor of 4 if the powder is stored in high heat/ high moisture conditions.

Increases in the moisture content of the milk powder will cause browning and caking first, and while SMP will be safe, it will be harder to use. Further increases in the moisture content of SMP (above 15%) may allow bacterial growth and the SMP should not be used.

If the uptake of moisture is due to packaging failure or punctures, or if it appears that the product has been tampered with in any fashion, the milk powder should not be used.

Storage and safety issues

- *Is milk powder that had been stored for a long time safe microbiologically?*

Milk powder made from good quality milk and containing low microbial counts is microbiologically safe during storage, provided the moisture content is kept low during storage. Bacteria, yeast and mold will not grow in milk powder that has been stored in good conditions.

Powder that has been exposed to water or excessive humidity during storage (so its moisture content is above 15%) can sustain microbiological growth and should not be used.

Testing quality

- *Are there quick field tests to evaluate the SMP's condition?*

Milk powders should be evaluated organoleptically, chemical-physically, and microbiologically to fully determine the quality and condition. However, an organoleptic evaluation test is the only test that can be performed with minimum equipment. The organoleptic evaluation of reconstituted skim milk powder should have a taste and smell close to that of milk. A slight cooked flavor and smell is acceptable.

Sensory Evaluation of Milk Powder (adapted from IDF Standard 99B)

Sample preparation

The required quantity is reconstituted by dissolving milk powder in water according to the following formula: 10 grams of skim milk powder in 90 grams of water
The reconstitution should be done at 25°C in colorless and tasteless water of excellent microbial quality. The skim milk powder should be mixed thoroughly in the water preferably in a glass container. Proper mixing is achieved with an electric mixer.
The reconstituted milk should be held in a covered glass container for about an hour at 20°C before evaluation. Also, intense light should be avoided.

Assessment

The reconstituted milk is examined for:

1. Appearance –

What is examined? Color, visible purity, presence of lumps, flakes, hard granules, or sediment.

Uneven color, browning, presence of lumps, hard granules, scorched particles, free fat and free protein are indications of poor quality.

2. Flavor -
What is examined? Flavor and odor of reconstituted milk.

Reconstituted milk should have a sweet, pleasing, and desirable flavor and may contain chalky, cooked, feed, or flat flavors to a slight degree. It should be free from undesirable flavors such as, burnt, oxidized, bitter, tallowy, fishy, cardboard, metallic, oily, stale, rancid, salty, foreign flavor, chemical flavor or putrid.

- *Are there advanced tests that can further evaluate the SMP's condition or quality?*

More extensive evaluations of milk powders can be made on reconstituted samples prepared as described above. Evaluation can be made of moisture content, milkfat content, pH, solubility, and titratable acidity. Microbiological tests can be performed to determine total plate count, sporeformers, coagulase-positive staphylococci, and coliform. Methods of Analysis and acceptable limits for milk powders have been published by the United States Department of Agriculture, Agricultural Marketing Service, Dairy Programs and the American Dairy Products Institute (www.americandairyproducts.com) , and are also available from the U.S. Dairy Export Council (www.usdec.org).