Technews

National Dairy Development Board

For Efficient Dairy Plant Operation

May-June 2005 No.56

DIFFERENT HEAT CLASS MILK POWDERS

This bulletin includes technical information based on latest developments on products, systems, techniques etc. reported in journals, companies' leaflets and books and based on studies and experience. The technical information in different issues is on different areas of plant operation. It is hoped that the information contained herein will be useful to readers.

The theme of information in this issue is **Different Heat Class Milk Powders**. It may be understood that the information given here is by no means complete.

In this issue:

1. INTRODUCTION

Milk powders are an important class of milk products and are one of the most used dairy commodities in dairy as well as non-dairy foods such as dairy whiteners, sterilized evaporated milks, cheeses, ice creams, fermented milk products, bread, biscuits, etc. These different applications ideally require different kinds of milk powders. For example, milk powder should be able to withstand high temperatures without 'feathering' (formation of visible particles throughout the surface or beverage, or as sediment at the bottom) for use in dairy whitener and should be thermostable for use in sterilized evaporated milk. On the other hand, retention of original natural properties, such as flavour, colour and protein quality of milk in the milk powder are important for production of another array of products such as recombined milk, cheeses and standardized milk.

Currently the dairy industry in our country is mostly manufacturing milk powders without above considerations. Milk powders with specific functional properties may fetch a premium price for the milk powder manufacturers, provide a better ingredient to product manufacturers utilizing milk powders as one of the ingredients in their products and help present an improved quality product to the consumer of milk powder based products.

Milk powders with different heat classes have different functional properties and, therefore, can be utilized for different applications more efficiently. Though used in many countries for long, the heat classification of milk powders has received little attention by the industry in our country. This issue of *Technews* provides information on various aspects of heat classification of milk powders including the parameters for production and post manufacturing verification of milk powders of specific heat classes.

2. WHAT IS HEAT CLASSIFICATION OF MILK POWDERS ?

Heat classification refers to assigning the milk powders to different heat classes depending upon the extent of heat treatment applied during powder manufacturing and generally reflects the severity of the treatment during pre-heating before evaporation[1].

The preheating of milk induces certain changes in milk constituents, particularly proteins, and thereby affects the functional properties of resultant milk powders. The whey proteins in milk are particularly sensitive to heat and can be easily denatured at temperatures above 65°C. Skimmed milk, as well as whole milk, is given controlled heat treatment in the pre-heat section of the evaporator, to achieve desired levels of whey protein denaturation and other reactions like whey protein-whey protein interactions, whey protein-casein interaction, Maillard reaction etc. The degree of these changes influence the functional properties, like heat stability, sensory properties, solubility, emulsifying, foaming and water binding abilities, etc., of the resultant powder. These properties determine the suitability of milk powder for use in particular applications [1,2]. Therefore, heat class of a milk powder is an indirect indicator of its functional properties.

The American Dry Milk Institute (ADMI) specifies 3 principal categories for skimmed milk powder (SMP): high, medium and low heat skimmed milk powders based on the content of undenatured whey proteins per grams of powder in terms of an index called Whey Protein Nitrogen Index (WPNI)[2]. However, SMP of 6 heat categories, with additional categories of extra-low heat, medium-high heat and high-high heat class, are also manufactured [1,2,3]. The vast majority of SMP produced is of the medium-heat class[1]. Apart from WPNI, other approaches like Heat Number and Cysteine Number have also been used for heat classification of milk powders.

These are discussed in Section 6. Table 1 provides the heat classification of milk powders based on these approaches.

Table 1: Criteria used for heat classification of milk powders [1,3,4,5]

Heat Class	WPNI, mg/g	Casein / Heat No., %	Cysteine No., %
Extra-low heat	-	-	24-31
Low heat	≥ 6.00	< 80.0	32-38
Medium heat	5.99-4.50	80.1-83.0	39-48
Medium-high heat	4.49-1.50	83.1-88.0	49-62
High heat	< 1.50	>88.1	> 62
High-high heat	<1.50	-	-

Although the heat classification was developed for skimmed milk powder, the principle can also be applied to whole milk powder, as it is non-fat portion of the powders that is affected by heat treatment [2]. However, whole milk powder is generally not heat classified but the milk for its production is heated at 85-95°C to ensure inactivation of lipase and to expose antioxidant sulfhydryl groups[1].

3. USES OF MILK POWDERS OF DIFFERENT HEAT CLASSES

Skimmed milk powder is a unique ingredient providing a range of usage in a variety of application. Skimmed milk powders of different heat classes find different applications making heat classification a useful tool in identifying the correct milk powder for intended end use. Table 2 provides information on food applications of different heat classes of milk powders along with the functional characteristics associated with the heat class of milk powder.

Table 2: Functional properties and food applications of skimmed milk powders of major heat classes [1,2,5,6]

Heat Class	Functional properties	Food applications
Extra low heat/ low heat	Solubility, freedom from cooked flavour	Recombined milk and cream, milk standardization, cheese making, cheese starters
Medium heat / medium high heat	Emulsification, foaming, water absorption, viscosity, whitening, colour, milky flavour	Ice cream, milk chocolate, confectionery, desserts, soups, sauces, hot and cold beverages, recombined dairy products like liquid, evaporated and sweetened condensed milks, cheese and butter
High heat	Heat stability, gelation, water absorption	Recombined evaporated milk, fermented milk products
High-high heat	Flavour, water binding, colour	Bakery, recombined evaporated milk

4. PRODUCTION OF MILK POWDER OF A SPECIFIC HEAT CLASS

The heat treatment applied to milk during preheating, prior to concentration and drying, determines the heat class of resultant milk powder. Therefore, the heat class of a milk powder is decided outside the evaporator and spray drier, depending upon the levels and types of protein denaturation achieved by preheating of milk prior to evaporation[3].

Heat treatments that can be applied to milk for manufacture of specific heat class milk powder are provided in Table 3 along with the major heat induced changes in proteins. Figure 1 provides time-temperature treatments needed to achieve any desired Whey Protein Nitrogen Index (WPNI) for guidance only[4]. Variations in the concentration of whey proteins in raw milk, due to seasons and genetic polymorphism of β-lactoglobulin, influence the heat class and related properties of resultant milk powders. Under actual conditions the whey protein levels may be monitored by powder manufacturers to allow more accurate control of properties of milk powders and assigning it to appropriate heat class[1].

Table 3: Heat treatments and major changes in proteins of skimmed milk powders of major heat classes [1,2,5]

Heat class	Typical heat treatments	Major heat induced changes in protein
Extra low heat/ low heat	70–72°C for 15s 72°C for 15s to 60s	Little protein denaturation or aggregation
Medium heat / medium high heat	82°C for 2-15 min. 85°C for 1min. 90°C for 30s 105°C for 30s	Some protein denaturation & aggregation; mainly whey protein-whey protein interactions
High heat	82°C for 30 min. 90°C for 5 min. 120°C for 1 min. 135°C for 30s	High levels of protein denaturation & aggregation; mainly whey protein-casein interactions
High-high heat	> 120°C for > 40 min.	High levels of protein denaturation & aggregation; mainly whey protein-casein interactions, Maillard reaction (carbohydrate-protein interaction)

5. HEAT STABILITY OF MILK POWDERS

The heat stability, also called thermostability (ability of reconstituted milk powder to withstand high temperatures), is pertinent in the production of many products such as coffee whiteners (coffee stability: absence of ‘feathering’, i.e. formation of visible particles throughout the surface or beverage, or as sediment at the bottom), dessert products, bakery products and, most importantly, sterilized reconstituted whole milk [1].

The low-heat and medium-heat SMPs exhibit poor heat stability when reconstituted and subjected to severe heat treatments, such as those used in sterilization or UHT processes. Some high-heat SMPs can also exhibit poor heat stability under such conditions, particularly if the preheating achieved sufficient whey protein denaturation as per the heat class but insufficient whey-protein-casein interactions to prevent heat induced gelation[2]. High-heat heat stable skim milk powders are required for manufacturing of recombined evaporated milk. Powders with WPNI $\leq$ 3 mg/g exhibit best coffee stability.

Milk powder from late lactation milk is inherently unstable due to changes in ionic calcium content and protein concentration. Milk powder produced from milk with high somatic cell count (SCC) may also exhibit low heat stability due to high proteolytic activity in mastitic milk [1]. Heat stability of milk powder may decrease slightly after storage for 90 days and the reduction is more pronounced at higher storage temperatures (about 37°C).

The means available for controlling the heat stability of milk powders are [1, 2, 4]:

- **High heat treatment of raw milk:** Higher temperatures as indicated in Table 3 for production of high heat and high-high heat milk powders can be used to enhance the heat stability of milk powders.

- **Method of heating**: With direct heating systems, the rise in temperature of milk is instantaneous and protein interactions are mainly protein-casein which improve heat stability of resultant milk powder. With indirect heating systems, the rise in temperatures is slower and whey protein-whey protein interactions predominate and resultant milk powder has comparatively lower heat stability.

- **Method used to concentrate milk:** It has been reported that the heat stability of concentrated milk prepared by ultrafiltration was markedly higher than that of evaporated milk. Altering the protein profile or mineral content by diafiltration can increase heat stability of concentrates.

- **Use of additives**: Heat stability of whole milk powder (WMP) is enhanced by addition of lecithin or buttermilk prior to evaporation and drying. Addition of stabilizers and pH regulators is also possible for regulation of heat stability of milk powders.

The tests for thermostability is similar to that for solubility index, i.e. by measuring the volume of sediment created when milk powders are dissolved in a defined hot coffee solution (coffee test) or hot water (hot water test)(4). An objective test involves subjecting a 20% aqueous solution of skim milk powder to heat treatment of 120°C for 40 minutes. The solution should not show signs of heat-induced gelation(2). A more objective heat stability test that also takes into consideration the destabilizing effect of fat on product stability, and provides results in terms of viscosity, that are directly comparable with results of commercial processing, is also available(7).

6. POST MANUFACTURING VERIFICATION OF HEAT CLASS OF MILK POWDER

Different methods have been used to verify the heat classes of milk powder. These are defined and briefly discussed below:

i) **Whey Protein Nitrogen Index (WPNI):** It is the amount of undenatured whey protein nitrogen present in a gram of powder. This is the most commonly applied criterion for heat classification of milk powders.

In this method, published by the American Dry Milk Institute (ADMI), casein and denatured whey proteins are precipitated by addition of sodium chloride and removed by filtration. The filtrate containing undenatured whey proteins is treated with hydrochloric acid which causes them to denature and produce a turbidity. The degree of turbidity depends on the concentration of undenatured whey protein and can be measured spectrophotometrically at 420 nm. By reference to a calibration graph, the WPNI can be determined[2, 8].

The above method is suitable for differentiating between low heat, medium heat/ medium high heat and high heat milk powders but is not sensitive enough to achieve a proper differentiation between the low heat and extra low heat powders[9].

ii) **Heat Number (also called Casein Number):** It is the casein plus heat denatured whey protein nitrogen content in acid precipitate (pH~4.8), expressed as the percentage of total nitrogen content in equal volume of reconstituted milk powder[4].

In this method, developed by the International Dairy Federation (IDF), the milk powder is reconstituted and the pH of the mixture is adjusted to 4.8, which causes the casein plus heat denatured whey protein to precipitate. The nitrogen content of the precipitate is determined, as is the nitrogen content of an equal volume of the reconstituted milk powder. The nitrogen content of the precipitate is expressed as a percentage of the nitrogen content of the reconstituted milk powder. This can be used to assign the powder to one of the four heat classes – low, medium, medium-high and high-heat classes [10].

iii) Cysteine Number: It is the percentage of cysteine plus cystine in acid precipitated (pH 4.6) casein plus denatured whey protein fraction multiplied by 100. It determines the thermal history of milk powders by quantifying the free sulfhydryl content [1] and is based on the difference in cystine plus cysteine content of casein and whey proteins respectively. It is useful in differentiating between low heat and extra low heat milk powders[9].

iv) HPLC method: A High Performance Liquid Chromatography (HPLC) based IDF method is available for quantifying the undenatured whey protein content in the milk powder. It takes into consideration the undenatured immunoglobulin as well as bovine serum albumin in the test sample *vis-a-vis* a reference extra low heat milk powder and can be used for differentiating between low heat and extra low heat milk powders[11].

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