The aim of this document is a communication on the conditions dry milk products experience when shipped in dry shipping containers and how this impacts the quality of these goods.

Dry dairy product transport

Low moisture dairy products are defined as those goods that result from water removal in milk processing that are able to be stored and transported under ambient environmental conditions. This includes milk powder, lactose, casein, whey powder, infant formula powder, growing up and follow up formula powders, milk protein concentrate powder, whey protein concentrate powder, dairy powder blends, and anhydrous milk fat.

All organisations involved in the production, sale, transport, and secondary processing of dairy products share a responsibility to ensure all finished goods received by the final consumer are safe and of a consistently high quality, and that this quality is maintained throughout the supply chain. The use of dry shipping containers to carry dry milk products worldwide began in the 1970’s. Dry shipping containers have proven to be a fast, effective, and economical way of moving goods with little impact on food quality, and without the added equipment, fuel and space required for refrigeration.

Mechanisms affecting the heating of dry milk products in dry shipping containers

Dry dairy products shipped in dry shipping containers are exposed to largest variations in temperature and humidity during transport and shipping. Direct solar radiation is the main cause of temperature variations inside dry shipping containers (1). Daytime exposure to sunlight causes that the headspace to be the hottest location inside the container. Substantial cooling, however, occurs at night. The resulting temperature profile is cyclical with the daytime headspace temperatures reaching as high as 55°C and cooling to 30°C or below at night. The extent of temperature variation within the product, however, is significantly lower due to:

- air to product interaction being limited as a result of tight product stacking patterns, packaging and wrapping materials, and air movement within the headspace being limited to natural convection only;
- the high specific heat capacity of dry dairy product (1.8 – 2.3 kJ/kg°C ) (2) means that a lot of heat must be supplied to cause a temperature increase in the product;
- the low thermal conductivity of dry dairy products (0.14 – 0.27 W/m°C) (2) means that heat energy movement within the product is slow

Temperature profile of milk powder in dry shipping containers

The result is that only the product closest to the headspace will experience temperatures above 30°C but not above 38°C or 40°C. This is illustrated in figure 1 using recorded headspace temperature data and mathematical modelling. New Zealand
data was used for this modelling to enable evaluation of shipping times of up to 60 days.

**Heat induced changes in dry milk products during shipping are minimal**

**Microbiological spoilage**: Increased microbiological spoilage is not a risk because the water activity of dry dairy products is substantially below the limit where bacteria, yeasts, or molds are able to grow (3). Subsequently there is no significant food safety or other microbial risk associated with dry containerised shipments.

**Sensory characteristics**: Dry dairy products manufactured and packaged using modern practices have a relatively long expiration period, typically 12 or 24 months. The duration of exposure to temperatures above 30°C is relatively short and not of sufficient intensity to change product sensory characteristics significantly.

**Nutritional impact**: Nutritional impacts of short periods of time at high product temperature have been assessed and are not significant. Fat, protein, and minerals are not known to be affected by the temperatures experienced. Of the vitamins present in milk all are considered to be present in relatively low concentration except for Riboflavin and Vitamin B12. Riboflavin has been shown to be stable during storage (4). Though Vitamin B12 levels are known to reduce naturally in dry dairy products (5), the rate of decrease during dry container shipment is unknown. Milk powders stored under adequate conditions (no light, minimal oxygen, low moisture) will likely incur smaller losses overall.

**Caking and browning**: Powder caking occurs in dairy powders that have relatively high levels of amorphous lactose (principally milk powder). However, this generally occurs when these products exceed 40°C for a period of seven days or more. Maillard browning does not take place in milk powder with a moisture content below 4% w/w when stored below 40°C (6). Maillard browning is only considered a risk when dry dairy products exceed 45°C or 50°C for more than 5 to 10 days. Observed occurrences of powder caking and Maillard browning defects from dry container shipments are extremely low.

**Impact of humidity during shipment in dry shipping containers**

The moisture barrier properties of modern packaging dictates that air borne moisture in the headspace is very slow to migrate through to the product. The relatively short shipment duration, typically 2-6 weeks, means that moisture absorption and subsequent product damage is not a significant concern. The placement of water absorbing desiccant in the container headspace is a useful optional practice to mitigate ‘container rain’ when environmental conditions present a risk of condensation inside the container.

**Ambient transport of dry dairy products is sufficient to maintain product quality**

The technical information provided in this fact sheet demonstrates that measures such as temperature controls are not technically justified to ensure high quality standards are maintained. Furthermore, introduction of temperature control requirements would add costs and increase the environmental impact of shipping. Temperature controls such as refrigerated container shipments are only appropriate to be applied where there is proven and justified product quality benefit. For the majority of dry dairy products, ambient transportation alone is sufficient to ensure that product arrives at the intended destination without any deterioration.

References