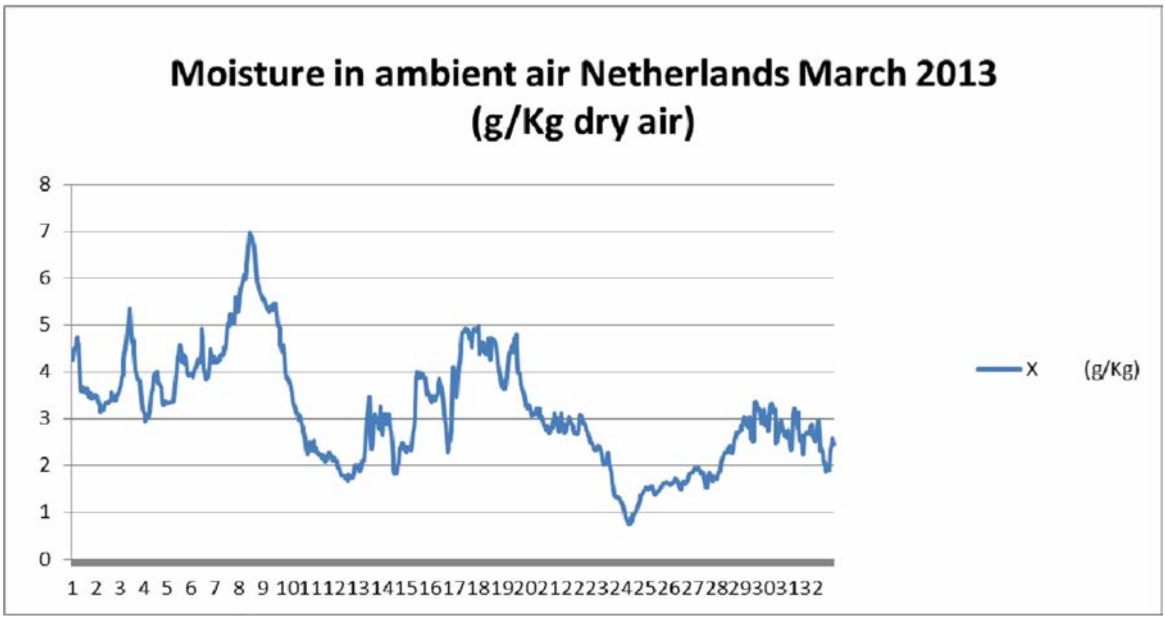
Case Study

Spray drying and variations in ambient air humidity

Report by Albert E. Steenbergen, Dairy Consultant, March 2014

This report deals with the influence of natural variations in the moisture content of ambient air on the performance of spray dryers for milk products. Research has shown that the effect is substantial. Until now, there have been limited methods by which to compensate for these variations. A proper control system can be created, however, if the moisture content of the spray dryer's outlet air is monitored continuously. Substantial economic savings are possible with such automated control systems. The recent introduction of a more accurate, laser-driven analyser – combined with a proper sampling system for handling powder-containing air streams – is a promising development.

In spray drying, it is well known that when the moisture content of ambient air increases, the moisture content of the powder will also increase. Without modifications to the dryer, this will result in the moisture content rising above specifications. The powder also tends to become sticky in this environment, and the resulting lumps of powder risk blocking the dryer.



The graph is provided by KNMI (Royal Netherlands Meteorological Institute).

To correct for these variations, one has to modify the settings of concentrate flow, and the temperature of the hot drying air.

Table 1 below gives an indication of the magnitude of the changes needed in various settings to obtain constant moisture and sticky powder properties from the drying chamber.

Air Moist In (X_{ai}=g/Kg)	Air Temp In (T_{ai}°C)	Powder Capacity (F_p=kg/h)	Powder Capacity (%)	Powder Drying Energy (E_p) KJ/Kg
2	186.0	4104	100	4581
3	183.5	3999	97.4	4643
4	181.0	3894	94.8	4705
5	178.5	3791	92.4	4766
6	176.0	3683	89.7	4828
7	173.5	3578	87.2	4890
8	171.0	3473	84.6	4952
9	168.5	3368	82.1	5014

Air moist out (Xao) = 41.0 g/Kg

Air temp out (Tao) =75.6°C

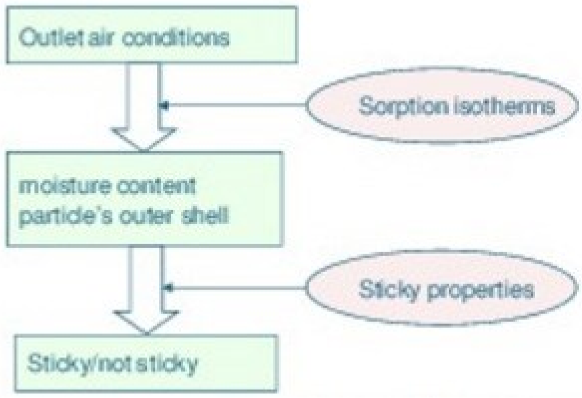
Powder moist out (Mpo) = 4.5%

Calculated for an MSD drying plant. Drying chamber 90,000 Kg/h hot air. Internal fluid bed 10,000 Kg/h hot air, Tai =75°C. Whole milk concentrate Ts = 49%, T = 75°C.

For whole milk powder: Δ Xai = +1 g/kg, then Δ Tai = -2.5°C, Δ Fp = -2.6%, Δ Ep = +1.23%.

This effect applies to the drying chamber of any spray dryer. This is because a whole milk powder will always be identical in terms of moisture content and stickiness when Tao and Xao are kept constant.

For skim milk powder, the effect is less pronounced (roughly 10% to 15%).



How can this be compensated for?

1. Generally, Tao is kept constant in spray dryers by the automatic control of the flow of concentrate. If nothing else changes, Mpo will remain the same; it does, however, have to be measured frequently. Experience will have taught the operator to change Tai in the wet month of August, or when a thunderstorm is approaching. For safety reasons, the dryer settings must accord a rather high Xai. This means that, during significant production periods, powder capacity will be prohibitively low.
2. Some plants have installed a moisture sensor to monitor Xai. Variations can now be adopted more securely, but it is still a manually-controlled system that is heavily dependent upon experience.
3. The optimal situation is an in-line measurement of both Tao and Xao. Control devices will keep Tao constant by adapting the flow of concentrate, and Xao by the adaption of Tai. In this way, both Mpo and the sticky properties will remain unaffected. Automatic measurement and control of Xao has additional advantages, including that:
    a. the effect of other variables in the production process (like the dry solids of the concentrate and the flow of hot air, after some fouling of air filters) can be corrected.
    b. the need for frequent laboratory measurements of moisture content will decrease.
    c. it is possible to operate closer to the sticky point without raising the risk for complications.

    It is clear that the integration time of the controller for Xao must be rather long.

It is obvious that the availability of a reliable in-line measurement of Xao is the missing link in modern spray dryer control. The laser-driven analyser in the Hicosys smouldering detection system measures the concentration of both CO and H2O with exceptional accuracy. Precision is listed as 0.32 g/kg, which will most likely be sufficient for spray dryer control. Reliability with respect to fouling by fine particles of the powder in the sampled air is expected to be OK, based on experience with the automatic sampling system of the former Nicosys system for the detection of smouldering milk powder.

The economic benefit of measuring Xai and Xao can only be estimated for any given situation.

Assume for the spray dryer in Table 1:

10% of production time Xai = 9 g/Kg

65% of production time Xai = 5 g/Kg
25% of production time Xai = 3 g/Kg
Average production capacity = 10% *3368 + 65% *3791 + 25 % *3999 = 3800 Kg/h
Production capacity with <u>no corrections at all</u> (at Xai = 9 g/kg) = 3368 Kg/h

The gain in production capacity in this situation is about 11%. Similar calculations on energy consumption give an extra energy benefit of 286 KJ/Kg powder = 5.8%.

It is clear that everything is dependent upon the way the spray dryer is operated. If, at this moment, corrections for Xai differences are standard procedure in the plant, the benefits will be lower. With a proper control system and skilled and attendant operators, the average benefit could be estimated at 5% to 8%.

In producing skim milk powder, the benefit will be less pronounced.

For sticky products like infant formula powder, the advantages can be even higher.

Final Comments

In-line measurement of the moisture content of the outlet air of a spray dryer creates the possibility for a more constant product quality at maximum production capacity. The energy costs may even be lower.

More accurate control of the sticky properties of the powder makes it acceptable to operate closer to the sticky curve without risking lumping and blocking of the spray dryer.

The economic benefit of such a system depends on the particular spray dryer, and the way in which it is operated. Here, it is estimated to be about 5% to 8% of the costs of spray drying.