Quantifying Product Variation in Milk Powder Production Using a Monte Carlo Analysis

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INTRODUCTION

Milk powder is often deliberately fortified during processing by the addition of vitamins and minerals in carefully controlled quantities. However the concentration of one ingredient showed a troubling variation especially on the lower specification limit.

The overall aim of this work was to systematically assess the sources of variation in the ingredient dosing system, and to evaluate if operational changes could be made to reduce this variability.

MONTE CARLO STRATEGY

A Monte Carlo uncertainty analysis was used to quantify the variation in concentration of the ingredient in question due to processing. It develops an estimate of the statistical distribution of the output probability density function (PDF) by evaluating a model many times given a representative sample of the inputs, (Fig. 1).

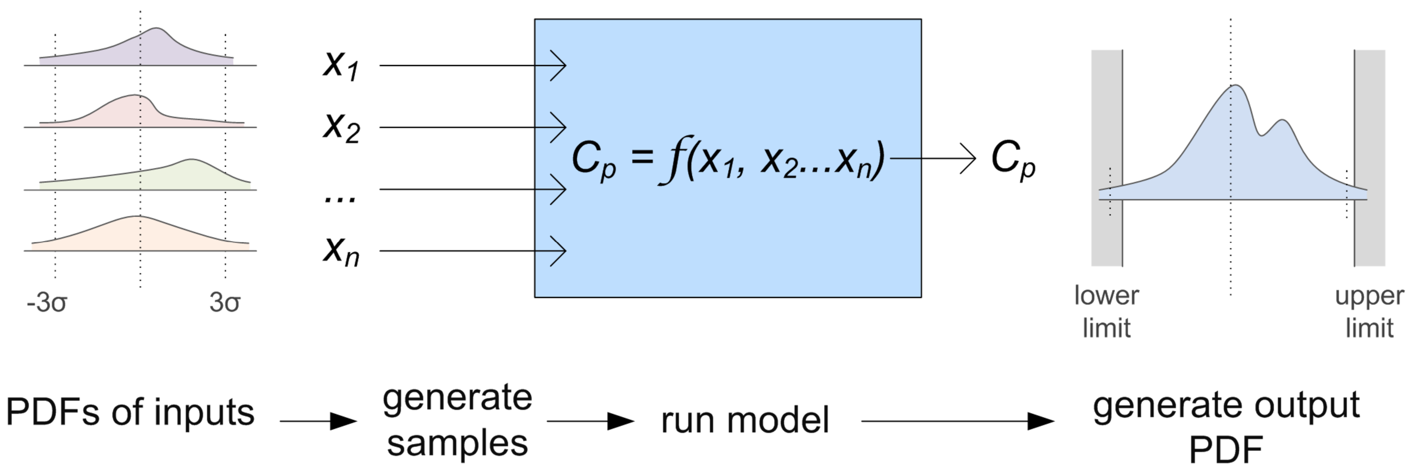

Fig. 1: Diagram of the Monte Carlo method.

A simple mass balance was used to model the output concentration of the ingredient in the final milk powder,

$$C = \frac{F_D P[100 - M]}{V F_E S}[1 - L/100]$$

where C is the concentration of the ingredient in the powder, F_D is the dosing flow rate, P is the mass of ingredient powder dissolved in volume, V, L is the processing losses, M is the moisture content of the milk powder, F_E is the flow rate and S is the total solids content of the milk.

The PDFs were based on data extracted from the plant historian and previous work carried out on the plant.

RESULTS & DISCUSSION

Comparing the simulated and measured ingredient concentration distributions in Fig. 2 shows that the both distributions lie skewed towards the upper specification limit. The measured concentration distribution is even wider than that simulated, likely due to other variations in the dosing process not accounted for.

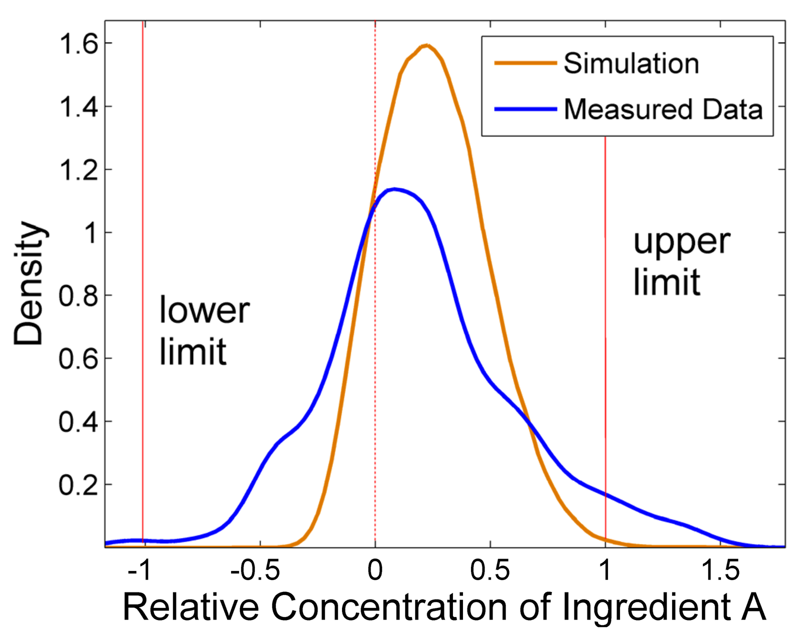

Fig. 2: Comparison of the simulated and measured output distributions.

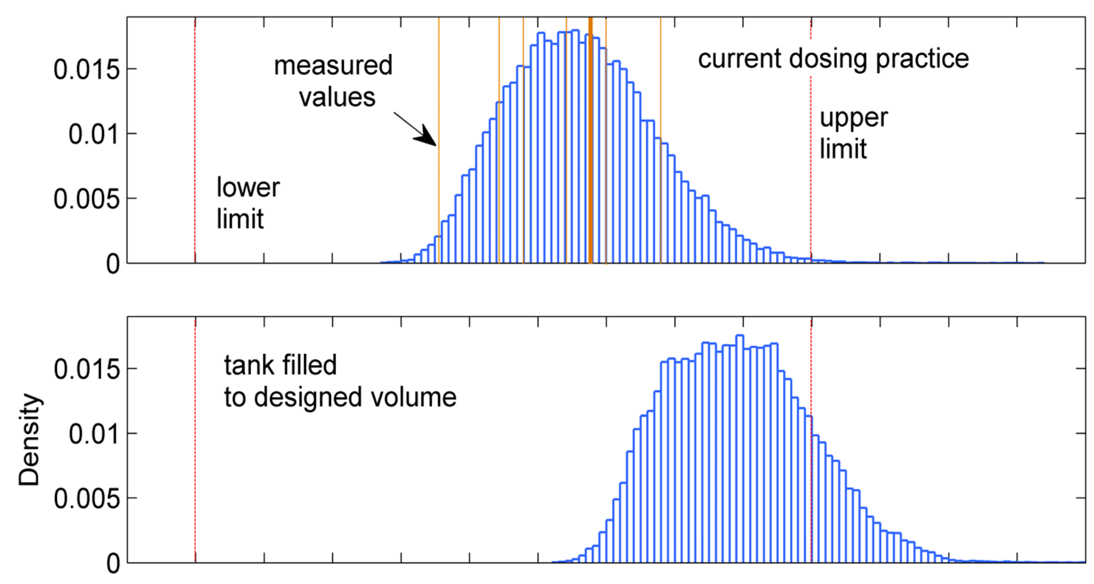

Fig. 3: Comparison of current output concentration distribution and the distribution if the dosing tank was filled to designed volume.

It was found that 50% of the time the dosing tank was overfilled by 10% or more and 95% of the time the tank was overfilled by at least 6%. If the tank volume was filled as designed in dosing calculations a significant portion of the powder, ~16%, would be out of specification over the high limit (Fig. 3). This implies that some plant processing losses may be due to over-dilution.

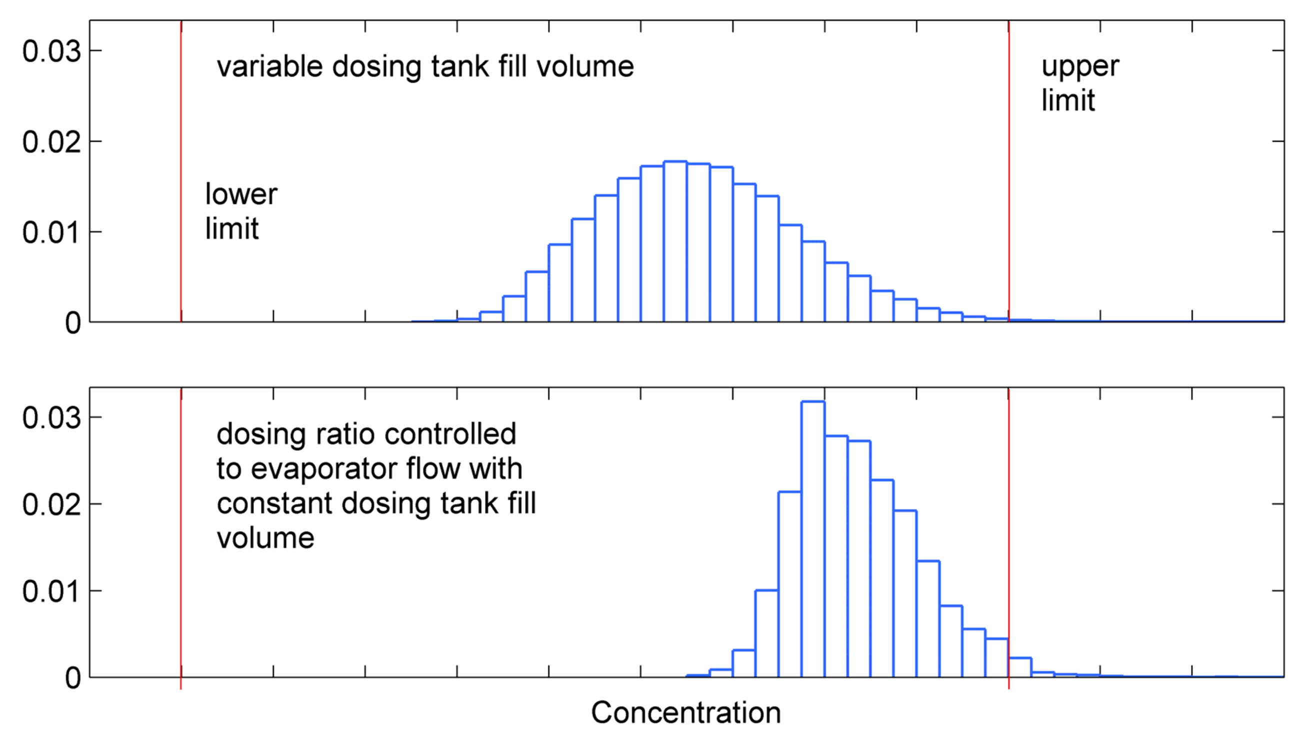

Fig. 4: Comparison of current output concentration distribution and distribution if the dosing was ratio controlled.

Fig. 4 shows the predicted improvement when controlling the ingredient dosing rate in ratio to the milk solids flow rate. This works whether the dosing tank is filled to a consistent level or not, and also causes a shift in the mean towards the maximum concentration limit.

Implementation of ratio control and accounting for variation in tank fill volume would significantly decrease the variation of the process, and allow the plant to run closer to the upper limit without dosing over specification. This would make it possible to compensate for losses that occur downstream or in storage for better overall product consistency and prevention of downgrades and wastage due to dosing inaccuracy.

CONCLUSIONS

- Product out of specification over the upper limit is likely caused by normal process variation; however this is unlikely for milk powder out of specification below the lower limit.
- A reduction in the variability of the concentration of the ingredient in the milk powder could make it possible to run closer to the upper allowable limit and thus provide a greater buffer for any unpredictable losses during processing, storage and handling, improve product quality and reduce product downgrades.
- Ratio control of the dosing flow rate has since been implemented by the plant as a result of this work. Improvement of the dosing flow rate calculation using the actual fill volume of the dosing tank, could also be implemented to reduce the variation further.

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