

## Introduction

- Upwards of **75% of the energy** needed to produce dairy powder can be consumed by evaporation and spray drying (process dependent). Of that, spray drying may consume **up to 50%** of the total energy required for water removal.
- Therefore, in order to increase the sustainability of dairy processing, attention must be paid to this highly energy intensive process.
- Identification of critical process parameters (like air flow and temperature) and understanding their influence on the water evaporation rate and energy usage of spray dryer is essential in order to maximise the throughput and limit the energy consumption.
- Viscosity of concentrates is a key parameter** during water removal. Excessive viscosity is often the limiting factor during evaporation and also is critical in determining subsequent atomisation properties and dehydration rates.



Fig. 1 Pilot scale three stage spray dryer pilot upgraded with robust data capturing system

## Objectives

The current study characterised the effect of temperatures on capacity (kg water evaporated/h) and specific energy (SE kJ/kg water evaporated) usage in a pilot multi-stage spray dryer.

The **main objectives** of the study are:

- To demonstrate the influence of temperatures on spray dryer capacity and energy consumption
- To determine the effect of standardisation media and heat classification on skim milk concentrate viscosity and spray dryer energy usage

## Methodology

### 1. Characterisation of three stage spray dryer

- A **multi-stage spray dryer** was characterised by conducting experiments with water as the feed material and varying:
  - Inlet temperature
  - Outlet temperature

### 2. Spray drying of skim milk

Trial	Standardising solution	Heat treatment	Abbreviation
1	Lactose	Low (72° C x 15s)	LH-Lactose std.
2	Lactose	High (120° C x 30s)	HH-Lactose std.
3	Permeate	High (120° C x 30s)	HH-Permeate std.

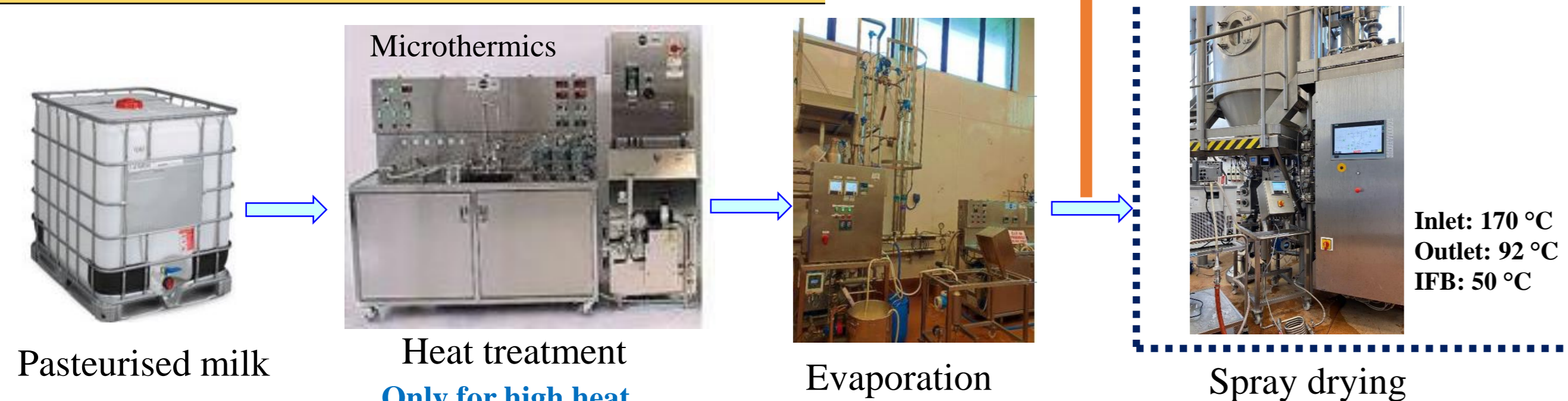


Fig. 2 Schematic representation of different parts of a three-stage spray dryer

Concentrates were produced with varying dry matter contents and standardised viscosity

Fig. 3 Simplified process flow diagram for skim milk production trials

## Results and Discussion

### ❖ Energy consumption mapping of spray dryer

- Newly installed energy meter infrastructure provided total energy consumption of each heater and fan of pilot scale spray dryer (Fig. 4).
- The **primary air heater** was responsible for the majority of energy use (>85%) with the **primary air fan** being the second biggest consumer (<10%).

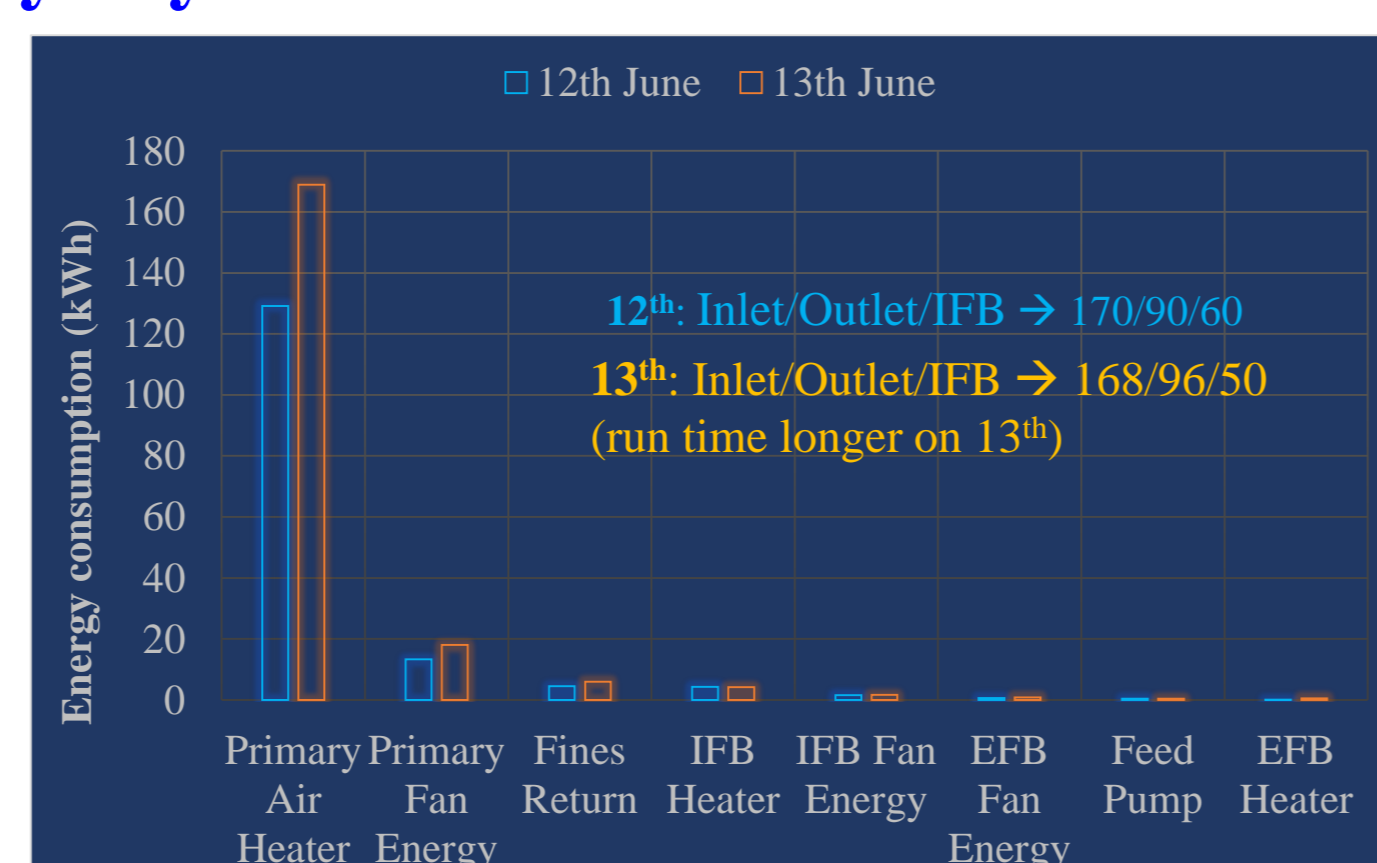


Fig. 4 Distribution of energy consumption in the spray dryer

### ❖ Effect of process parameters on dryer capacity

- The capacity of spray dryer is defined in terms of water evaporation rate. Typical capacity of spray dryer is **25 kg/h**.
- Range is **10-30 kg/h**.
- Increasing inlet air temperature ( $T_i$ ) and reducing outlet temperature ( $T_o$ ) increased the water evaporation rate capacity (as expected)
- Useful for:
  - Trial planning
  - Determining the effect of process parameters on capacity (to be applied with caution, all dryers/trials are different).

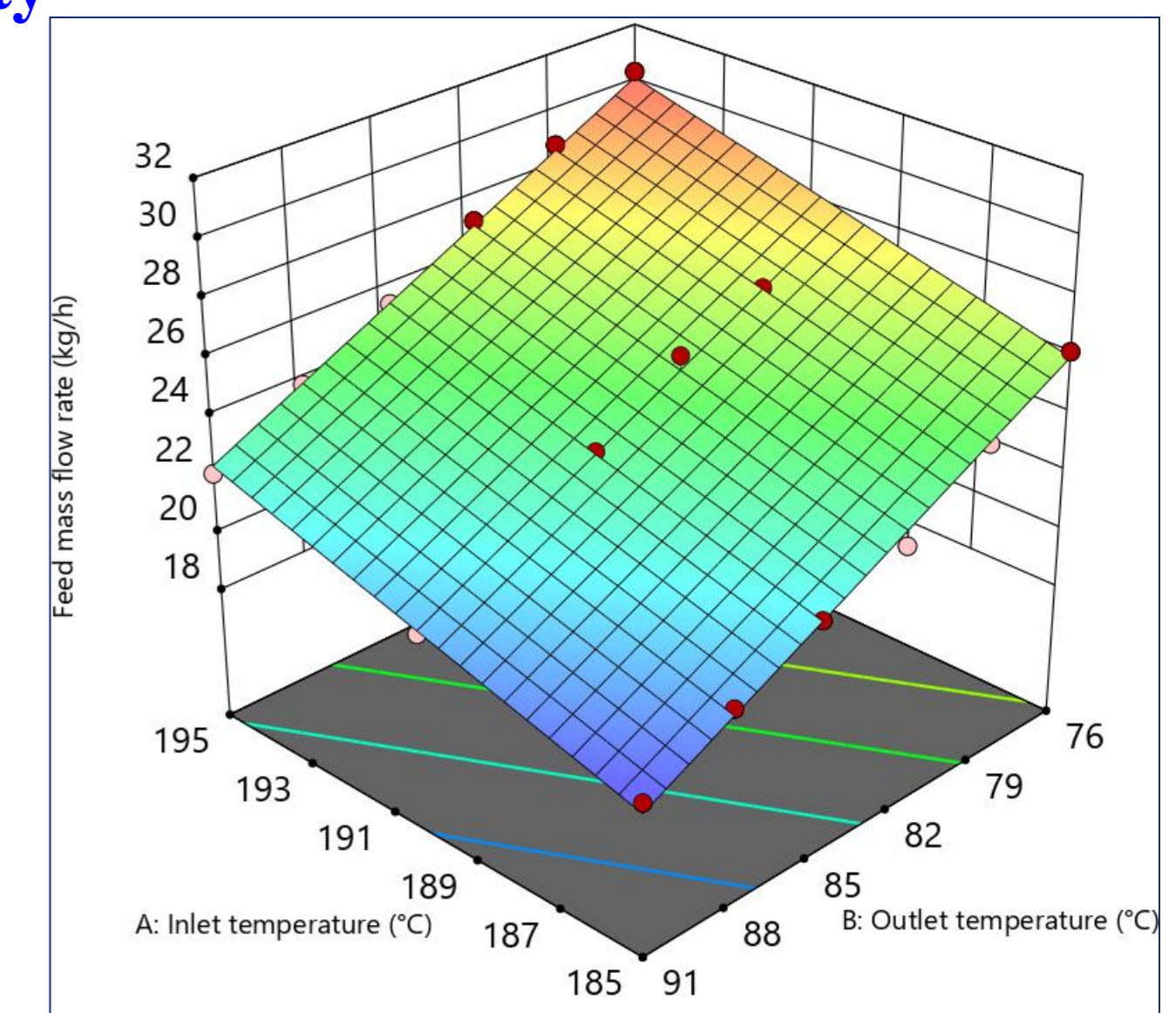


Fig. 5 Effect of temperatures on feed mass flow rate

### ❖ Effect of process parameters on energy use

- Specific energy consumption:** energy consumption per kg of water evaporation.
- The highest specific energy consumption (7075 kJ/kg) was observed at  $T_i=185^\circ\text{C}$ ,  $T_o=91^\circ\text{C}$ , while the lowest was (4936 kJ/kg) water recorded at  $T_i=195^\circ\text{C}$ ,  $T_o=76^\circ\text{C}$ .
- Higher thermal efficiency achieved at high inlet air temperature.

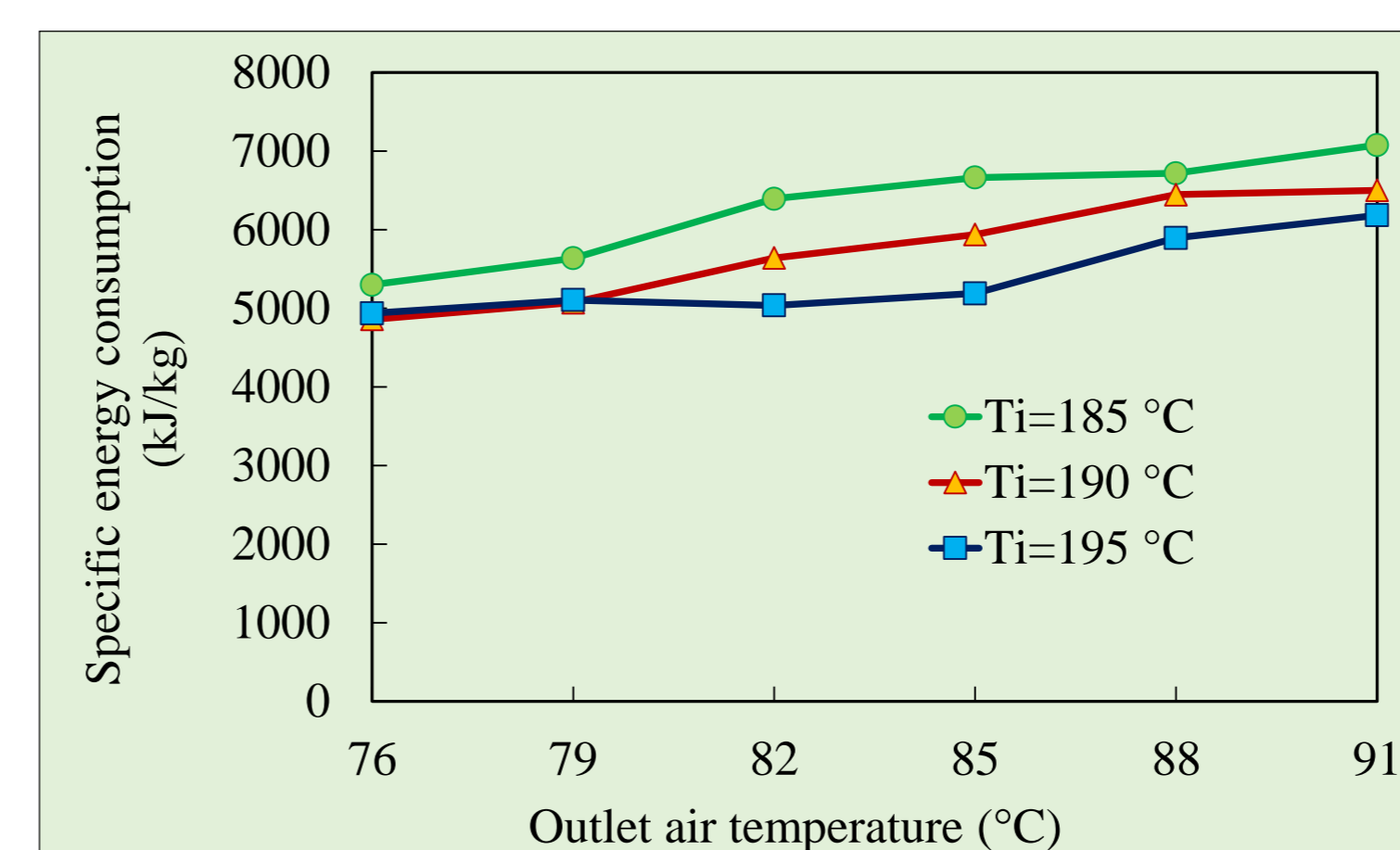


Fig. 6 Effect of temperatures on specific energy consumption

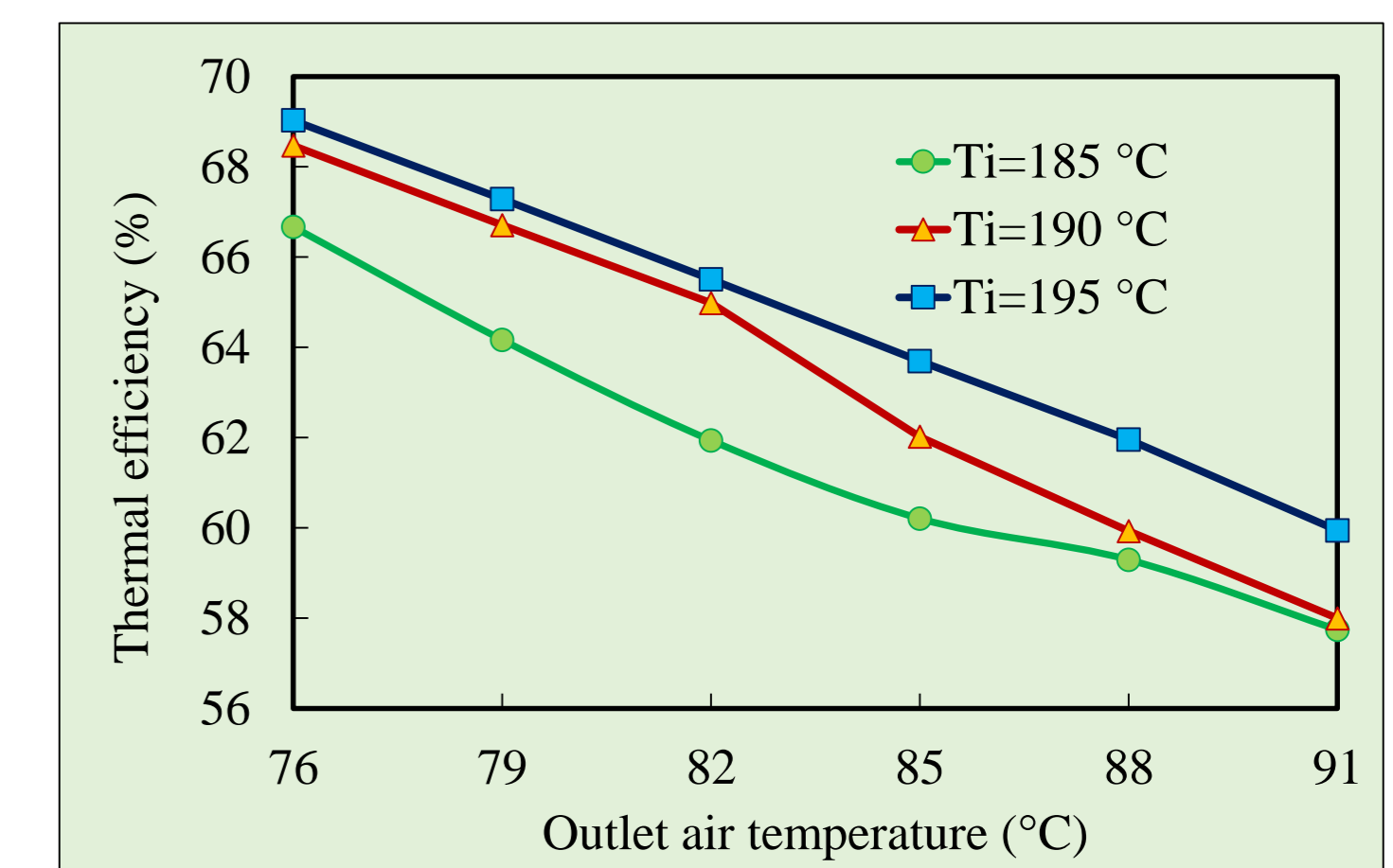


Fig. 7 Effect of temperatures on thermal efficiency

### ❖ Spray drying of skim milk concentrate

Preliminary work:

- Holding skim milk at  $> 40^\circ\text{C}$  for extended times resulted in extreme age thickening which reduced solubility of resultant skim milk powder (Fig. 8).
- Illustrates the benefit of viscosity monitoring.

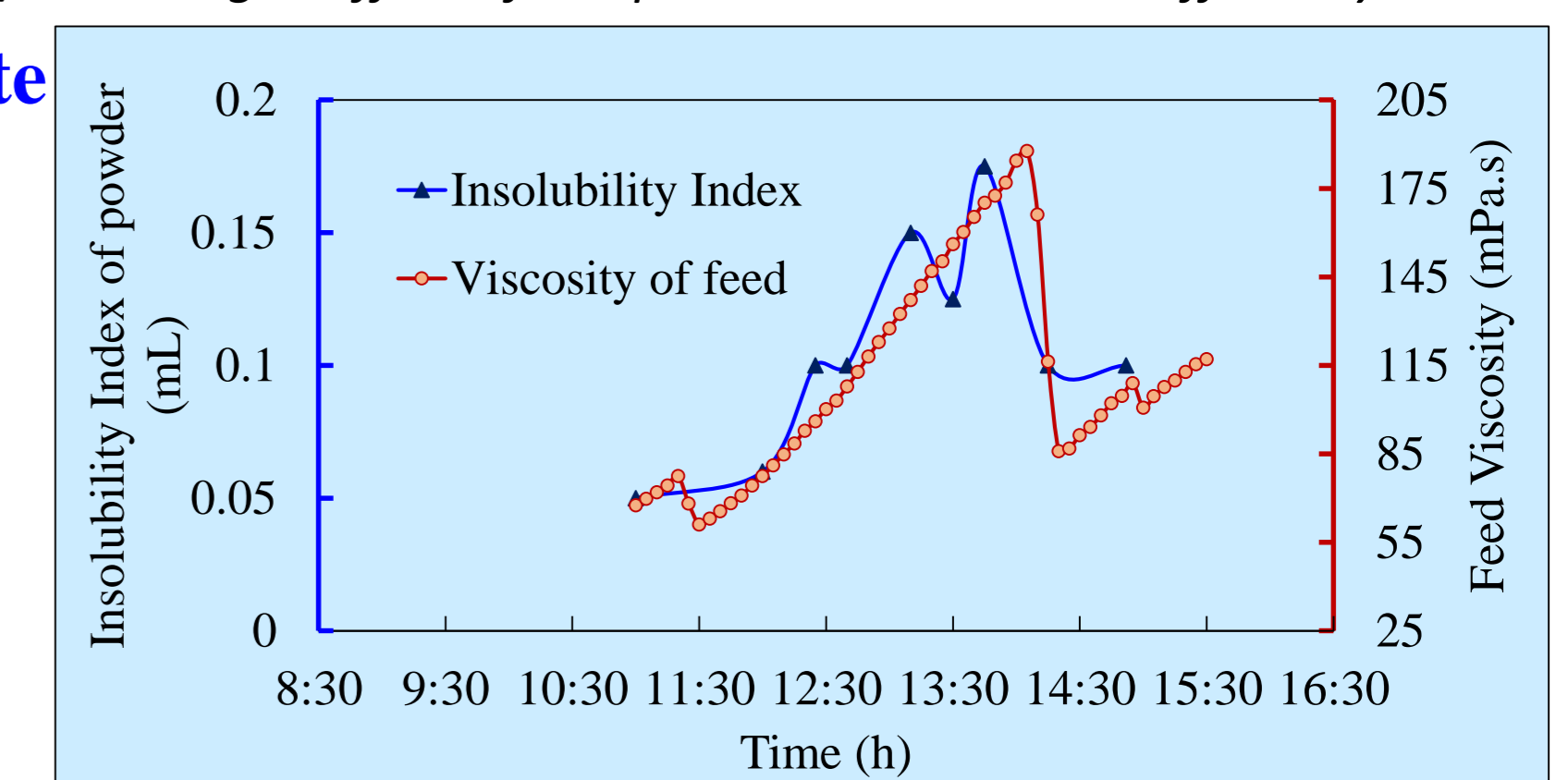


Fig. 8 Impact of age gelation on powder solubility

- Feed was heated to  $> 40^\circ\text{C}$  using a continuous heat exchanger for subsequent trials.
- The target viscosity (19-22 mPa.s) was set based on the viscosity of LH-lactose at ~50% w/w.
- To achieve similar viscosity the dry matter of HH-lactose and HH permeate were ~45% and 42%, respectively.
- As a result, the effect of heat treatment and standardising media on energy consumption was huge, indicating lower energy consumption per kg product in LH-Lactose std. milk.

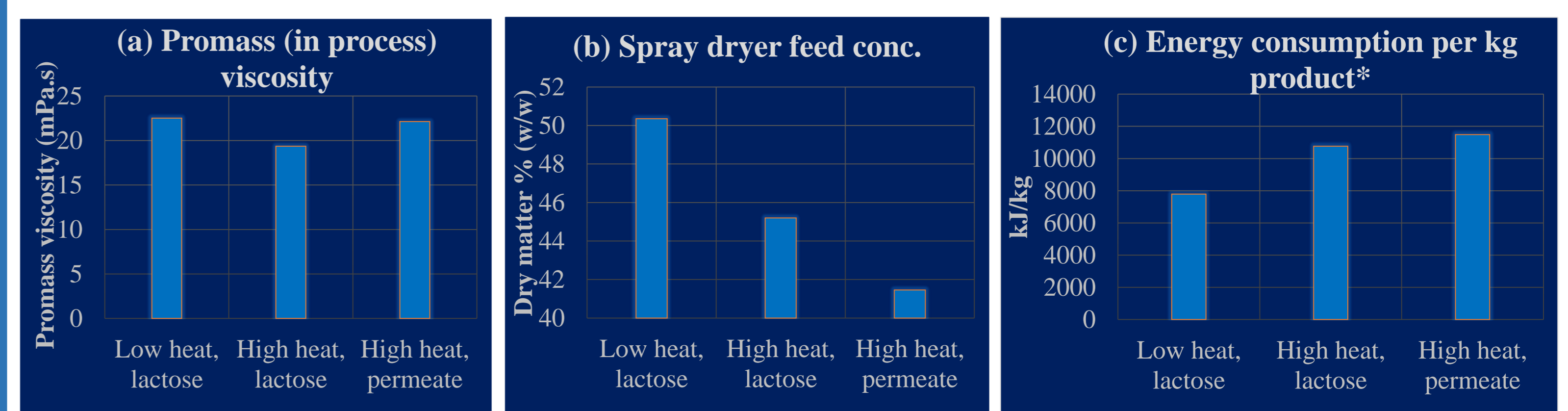


Fig. 9 (a) Viscosity (b) Dry matter (c) Spray dryer energy consumption of skim milk concentrate (\*estimated)

## Conclusions

- Recently installed flow, energy and humidity meters were successfully used in conjunction with a data capturing system to supply real time information on water evaporation and energy use.
- The **primary air heater** was identified as the most energy consuming component of spray dryer, **→ focus for optimization**.
- In addition to monitoring the process and energy parameters listed above, **in-line viscosity** monitoring may be key to optimising energy use and product quality in milk powder manufacture.
- Drying energy required for low heat, lactose standardised skim was **~28% and 33% lower** when compared to high heat, lactose and high heat, permeate.
- Current study was carried out at relatively low viscosities and dry matters. Further work will **push viscosity** to determine **operational limits** and **associated energy consumption**

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