WAGENINGEN UNIVERSITY
WAGENINGEN UR

Reducing Energy Consumption in Food Drying: Opportunities in Desiccant Adsorption & Other Dehumidification Strategies

J.C. Atuonwu (james.atuonwu@wur.nl), X. Jin., G. van Straten., H.C. van Deventer and A.J.B van Boxtel.

INTRODUCTION & METHOD

Drying is important in food processing but is energy intensive. Energy efficiency of convective dryers can be increased by raising the dryer inlet temperature or by lowering the outlet temperature. Raising the dryer inlet temperatures can result in product quality degradation. By dehumidifying the drying air, the dryer outlet air temperature is implicitly reduced and can meet the requirements for keeping quality and gain energy efficiency. Dehumidification methods include desiccant adsorption, heat pump and drying air condensation. Although dehumidification increases drying capacity (as shown in Fig. 1), energy is still needed for regeneration of adsorbents or for compression in heat pump systems. Optimizing the interaction between improved drying capacity and extra energy spent therefore, holds the key to utilizing the benefits of dehumidification.

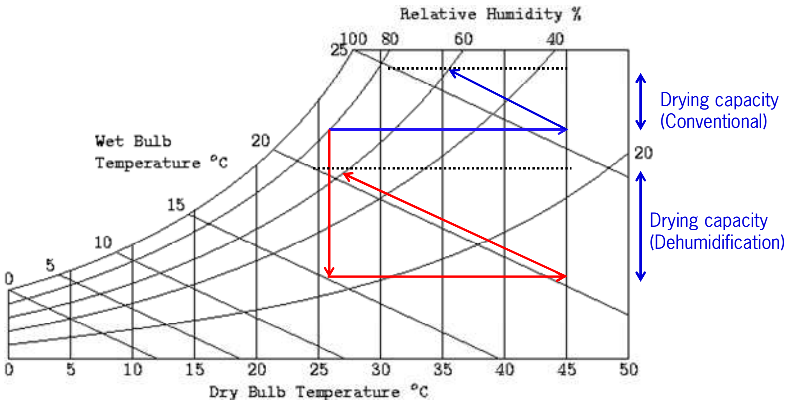

Fig. 1. Psychrometric chart: improved drying capacity by dehumidification

Energy balances for adsorption, heat-pump and condensation dryers (Figs. 2, 3 & 4) are formulated and calculation results are compared with that of a conventional dryer (Fig. 5). The results show the critical variables in each of the dryers and also how the energy efficiency can be optimized. Vitamin C as an indicator for quality is calculated for an adsorption dryer in which pumpkin is being dried. Results are compared with a conventional dryer operating at the same level of energy efficiency.

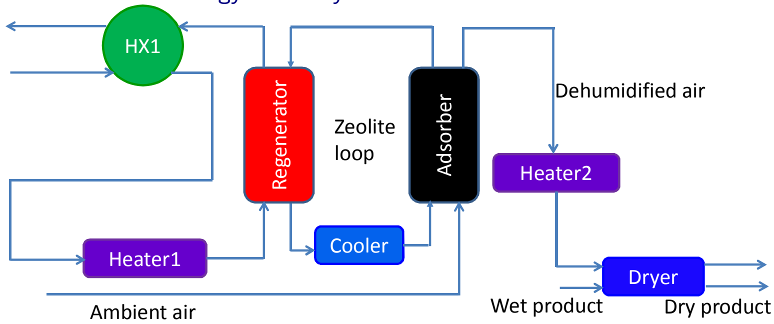

Fig. 2. Adsorption dryer, with regenerator exhaust heat recovery by exchanger HX1

Fig. 3. Condensation dryer

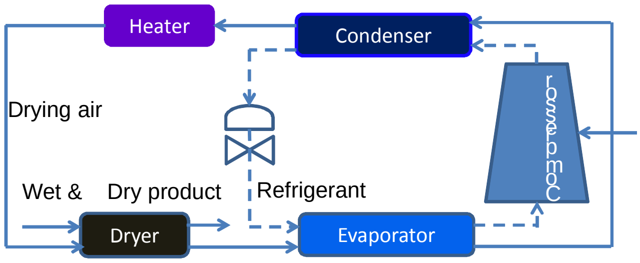

Fig. 4. Heat pump dryer: exhaust air cooled below dew-point and reheated; gained sensible and latent heat "pumped" by compressor

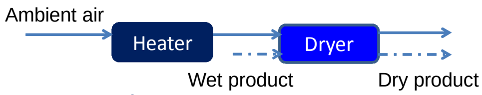

Fig. 5. Conventional dryer: ambient air heated

RESULTS & DISCUSSION

The energy efficiency of a dryer is the ratio of the latent heat of evaporation of the moisture removed to the drying air heat input:

η=latent heat of evaporation/energy need of the total system

For all the dryers the energy efficiencies are calculated, while considering terms for each specific dryer. For the adsorption dryer, adsorption heat release, regeneration energy and heat recovery is included. For the heat pump dryer and condensation dryers, sensible heat loss terms for cooling below dew point are included; so also is the compression energy term for the heat-pump dryer.
The energy efficiencies of the various dehumidification dryers are shown in Fig. 6(a), compared with the conventional dryer. For the same energy efficiency, the conventional dryer must operate at higher temperature. This increases product quality degradation as seen in Fig. 6(b) for the same energy consumption and evaporative load.

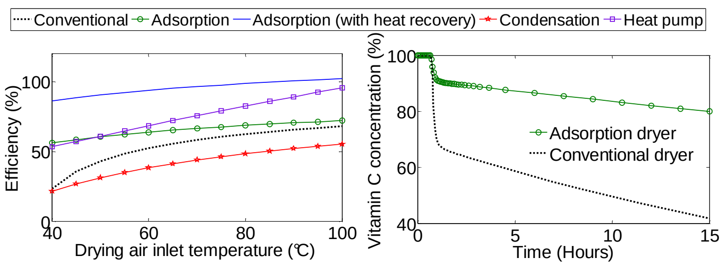

Fig. 6.(a). Energy efficiency of conventional dryer compared with dryers with 50% drying air dehumidification (b). Normalized vitamin C degradation for adsorption & conventional dryer operating at equal energy efficiencies

CONCLUSION

Dehumidification dryers are capable of improved energy efficiency in low temperature drying. Optimizing these dryers holds the key to utilizing the benefits of dehumidification. To achieve desired quality levels, such optimization should include product quality models.

Wageningen University, Agrotechnology and Food Sciences, Systems and Control Group
Postbus 17 Wageningen 6700AA
Tel: 0317 – 483 364 - Fax: 0317 – 484 957
E-mail: james.atuonwu@wur.nl