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Abstract

State-space thermodynamic modeling of vanilla ethanolic extracts spray drying with heat pump and N_2 was developed. Thermodynamic modeling considers activity coefficients for Raoult law deviations of ethanol vapor pressure, water vapor pressure, ethanol evaporation latent heat and water evaporation latent heat in a N_2-ethanol-water-vanilla solids system. State space considers 12 ordinary differential equations (ODEs) for ethanol and water concentrations in solid, N_2 and condensed liquid; temperatures and condensed liquid rate. The model was validated with 32 treatments of vanilla ethanolic extract experimentally spray dried with heat pump and N_2. The mathematical model reproduced the experimental gas outlet temperature with 4% of averaged error. An additional two parameters fit reached 11.4% of averaged error with respect to product outlet moisture and gas outlet temperature simultaneously. Proposed model demonstrated that heat pump spray drying can reach a 58% of thermal efficiency and a conventional spray drying can reach only 30%.

Key words: Ethanolic vanilla extracts; spray drying; heat pump; mathematical modeling; thermal analysis.

Nomenclature

a	Specific surface	$\mathrm{m}^2 \cdot \mathrm{m}^{-3}$
a	Thermodynamic activity	…
A	Surface area	m^2
Cp	Constant pressure specific heat	$\mathrm{J} \cdot \mathrm{kg}^{-1} \cdot \mathrm{K}^{-1}$
$\mathbf{D}$	Jacobean matrix	…
E	Total energy requirement	$\mathrm{J} \cdot \mathrm{kg}^{-1}$
$F_{1-\alpha(1,n-3)}$	F cdf with 1 and $n-3$ degrees of freedom	…