Supplementary Materials: Thermodynamic Balance vs. Computational Fluid Dynamics Approach for the Outlet Temperature Estimation of a Benchtop Spray Dryer

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Proof. To obtain Equation (6) it is possible to start from $\mathrm{Q_{feed}}$ (S1) and $\mathrm{Q_{loss}}$ (S2):

$$\mathrm{Q_{feed}}(T_{\mathrm{in}}, T_{\mathrm{ext}}, RH_{\mathrm{ext}}, FR, c_{\mathrm{feed}}) = (FR \cdot (1 - c_{\mathrm{feed}})) \cdot (\mathrm{H_{evap}}(T_{\mathrm{ext}}) + cp_{\mathrm{feed}}(T_{\mathrm{in}}) \cdot (\mathrm{T_{wetbulb}}(T_{\mathrm{ext}}, RH_{\mathrm{ext}}) - T_{\mathrm{ext}})) \tag{S1}$$

(see Lisboa et al. [1])

$\mathrm{Q_{loss}}$ as reported by Çengel [2] can be decomposed as:

$$\mathrm{Q_{loss}}(T_{\mathrm{in}}, T_{\mathrm{ext}}, T^{\mathrm{wall}}_{\mathrm{ext}}, T_{\mathrm{out}}, G^{\mathrm{m}}_{\mathrm{in}}) = \mathrm{Q^{R}_{loss}}(T_{\mathrm{in}}, T_{\mathrm{ext}}, T_{\mathrm{out}}, G^{\mathrm{m}}_{\mathrm{in}}) + \mathrm{Q^{rad}_{loss}}(T^{\mathrm{wall}}_{\mathrm{ext}}, T_{\mathrm{ext}}) \tag{S2}$$

where:

$$\mathrm{Q^{R}_{loss}}(T_{\mathrm{in}}, T_{\mathrm{ext}}, T_{\mathrm{out}}, G^{\mathrm{m}}_{\mathrm{in}}) = \frac{T_{\mathrm{in}} - T_{\mathrm{ext}}}{R(T_{\mathrm{in}}, T_{\mathrm{out}}, G^{\mathrm{m}}_{\mathrm{in}})} \cdot \mathrm{Tower_{length}} \tag{S3}$$

$$\mathrm{Q^{rad}_{loss}}(T^{\mathrm{wall}}_{\mathrm{ext}}, T_{\mathrm{ext}}) = K \cdot ({T^{\mathrm{wall}}_{\mathrm{ext}}}^4 - T^4_{\mathrm{ext}}) \tag{S4}$$

$$K = \mathrm{Area_{ext}} \cdot \sigma \cdot \mathrm{emissivity_{glass}} \tag{S5}$$

It is possible to obtain Equation (6) in 4 steps:

1. $\mathrm{Q_{loss}}$ can be substituted in Equation (5) with Equation (S2) getting:

$$T_{\mathrm{out}} = T_{\mathrm{in}} - \frac{\mathrm{Q_{feed}} + \mathrm{Q^{R}_{loss}} + \mathrm{Q^{rad}_{loss}}}{cp_{\mathrm{gas}} \cdot G_{\mathrm{in}}} \tag{S6}$$

2. $\mathrm{Q^{rad}_{loss}}$ can be deduced from Equation (S6)

$$\mathrm{Q^{rad}_{loss}} = (T_{\mathrm{in}} - T_{\mathrm{out}}) \cdot cp_{\mathrm{gas}} \cdot G_{\mathrm{in}} - \mathrm{Q_{feed}} - \mathrm{Q^{R}_{loss}} \tag{S7}$$

3. $\mathrm{Q^{rad}_{loss}}$ equation (S4) can be inverted to find $T^{\mathrm{wall}}_{\mathrm{ext}}$

$$T^{\mathrm{wall}}_{\mathrm{ext}} = \left(\frac{\mathrm{Q^{rad}_{loss}}}{K} + T^4_{\mathrm{ext}} \right)^{1/4} \tag{S8}$$

4. And finally it is possible to substitute $\mathrm{Q^{rad}_{loss}}$ of (S7) in (S8) getting:

$$T^{\mathrm{wall}}_{\mathrm{ext}} = \left(\frac{(T_{\mathrm{in}} - T_{\mathrm{out}}) \cdot cp_{\mathrm{gas}} \cdot G_{\mathrm{in}} - \mathrm{Q_{feed}} - \mathrm{Q^{R}_{loss}}}{K} + T^4_{\mathrm{ext}} \right)^{1/4} \tag{S9}$$

On the $T^{\mathrm{wall}}_{\mathrm{ext}}$ values can be apply the ML.

□

References

1. Lisboa, H.M.; Duarte, M.E.; Cavalcanti-Mata, M.E. Modeling of food drying processes in industrial spray dryers. *Food Bioprod. Process.* **2018**, *107*, 49–60.
2. Çengel, Y.A. Introduction to Thermodynamics and Heat Transfer; Çengel series in engineering for the thermal-fluid sciences. McGraw-Hill: New York, NY, USA, 2009.