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Enhancing energy efficiency in medicinal and aromatic plants (MAP) drying through optimised recirculation of exhaust air

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I. INTRODUCTION

Drying is a critical post-harvest step for preserving the quality of medicinal and aromatic plants (MAP), but highly energy-intensive. This study investigates the potential for enhancing the energy efficiency of conventional flatbed dryers through recirculation of exhaust air.

Figure 1. Outside (left) and inside (right) view of the flatbed dryer used for experimental tests

II. METHODS

Experiments were conducted in a flatbed dryer (6.5 × 4.7 × 3.0 m) located in Mrzović, Croatia, using chamomile (*Matricaria recutita*) for drying. The dryer was retrofitted with an automated air recirculation system, enabling programmable flap control of fresh and recirculation air during drying process (Figure 2).

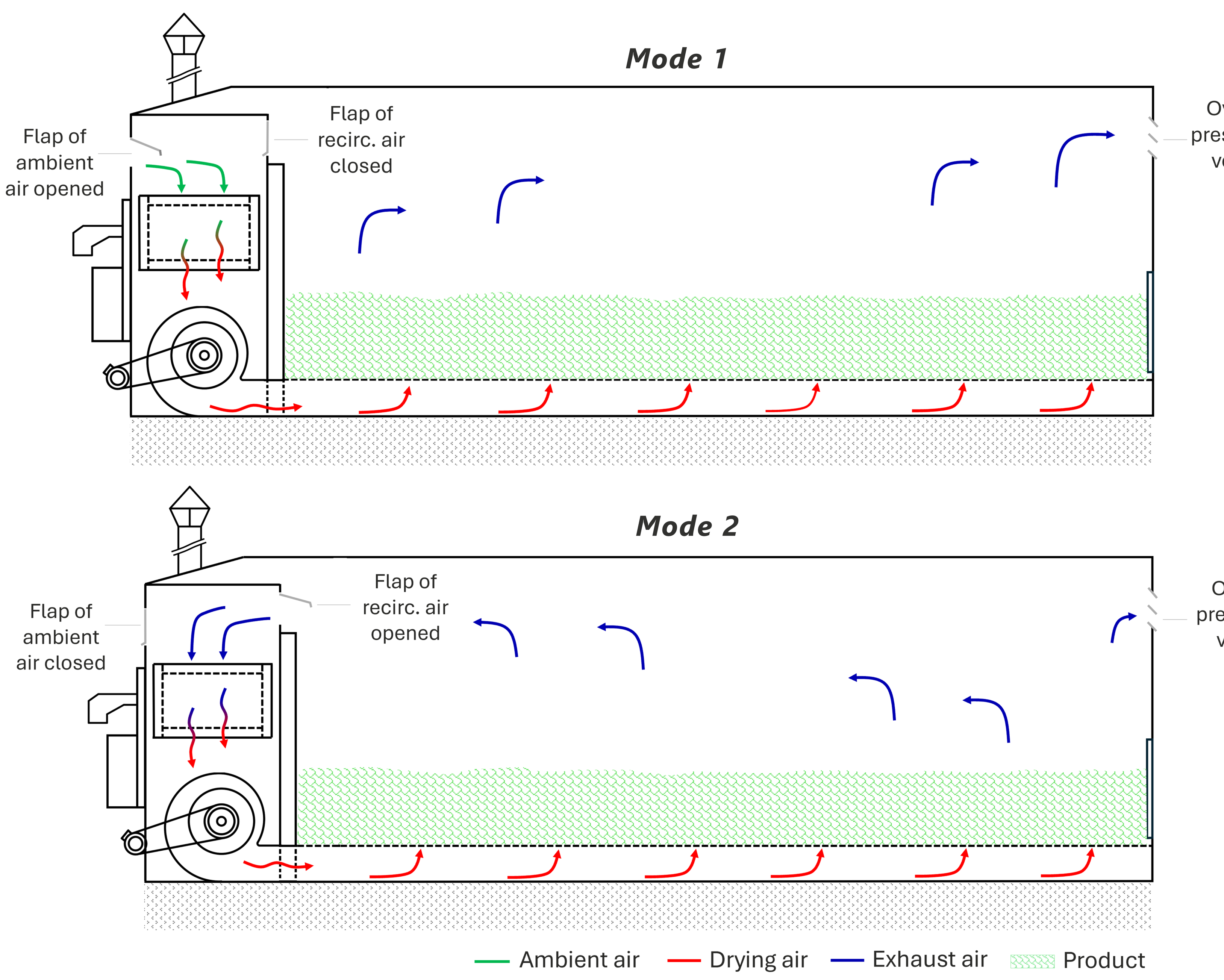

Figure 2. Dryer showing flaps in mode 1 with fresh air (*top*) and in mode 2 with full recirculation of exhaust air (*bottom*).

The experimental plan included four comparative strategies. Fresh air operation was compared with three strategies where the dryer switched to full recirculation at different relative humidity levels. Their impact on energy consumption was evaluated (Table 1).

Table 1: Experimental strategies

Set temperature	Strategy	Switching point to recirculation mode	Code
50°C	Fresh air	–	FA
50°C	Recirculation	Rh_{out}=40 %	R40-out
50°C	Recirculation	Rh_{out}=60 %	R60-out
50°C	Recirculation	Rh_{in}=40 %	R40-in

III. RESULTS AND DISCUSSION

Results of temperature and relative humidity variations during operation under the different strategies are presented in Figure 3.

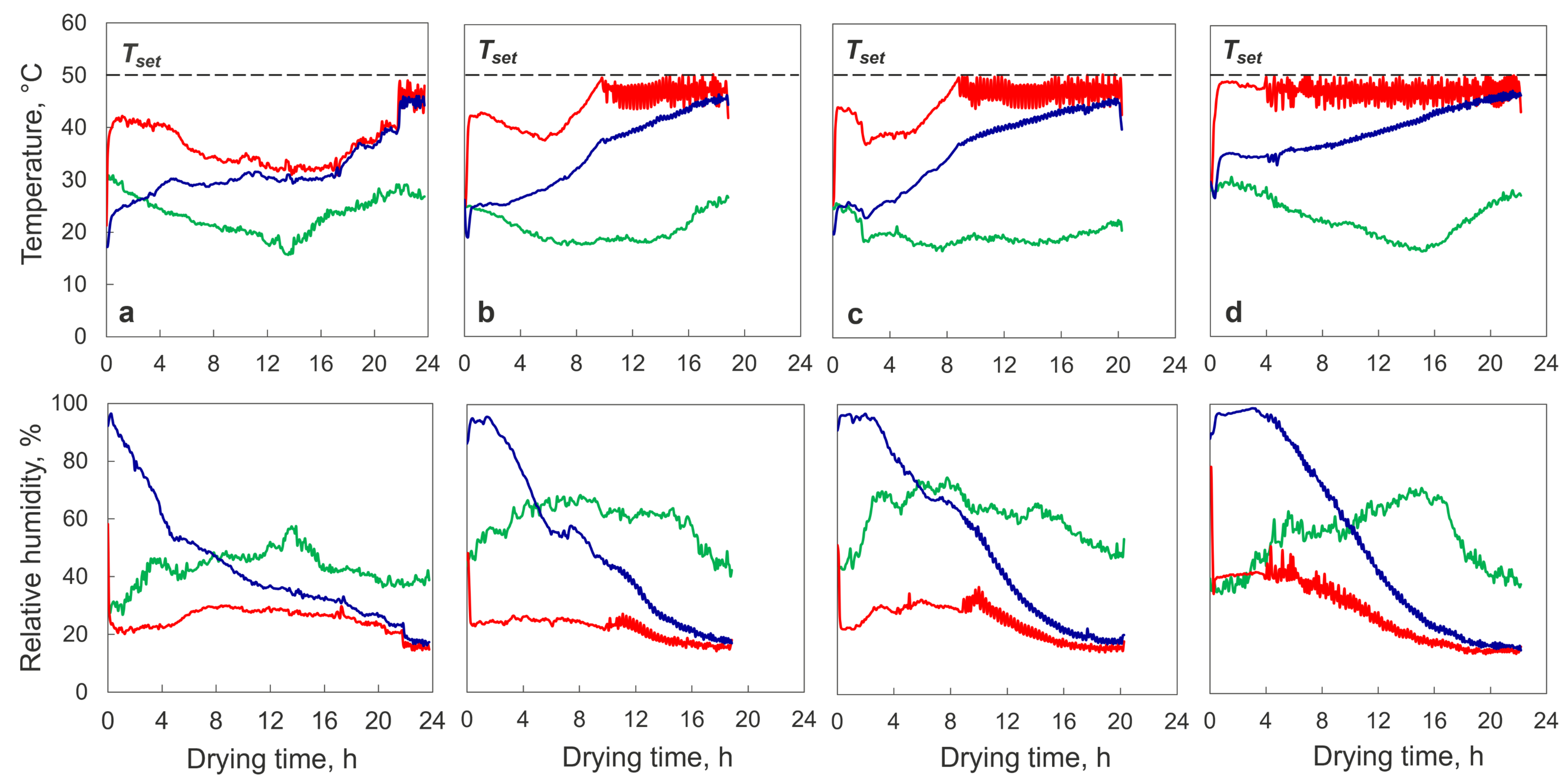

Figure 3. Temperature and relative humidity data for — Ambient air, — Drying air, and — Exhaust air for (a) FA, (b) R40-out, (c) R60-out, and (d) R40-in

Table 2: Drying conditions and performance parameters

Strategy	T_{drying}, °C	t, h	MC_{in}, % $_{w.b.}$	MC_{fin}, % $_{w.b}$	m_{in}, kg	m_{out}, kg
FA	38.2±1.9	22.4±3.3	77.5±8.3	8.9±1.5	1699±74	410±81
R40-out	42.8±1.7	19.8±1.4	76.9±7.1	7.0±0.2	1868±144	447±50
R60-out	44.2±0.5	19.9±0.5	79.3±6.9	6.9±0.8	1935±295	417±65
R40-in	47.4±0.9	22.2±1.4	77.6±6.3	6.3±0.4	1731±56	411±17

The R40-in strategy resulted in a higher average drying temperature compared to the other strategies, due to the earlier transition to full recirculation. A marginal increase in drying time was observed due to higher humidity in the drying air.

It emerged as the most energy-efficient strategy. R40-in reduced fuel consumption by 41.9% compared to FA and yielded the lowest specific fuel consumption (7.6 ± 0.8 kg·h^{-1}) as well as the lowest specific energy utilisation (5.5 ± 0.3 MJ·kg^{-1} H_2O).

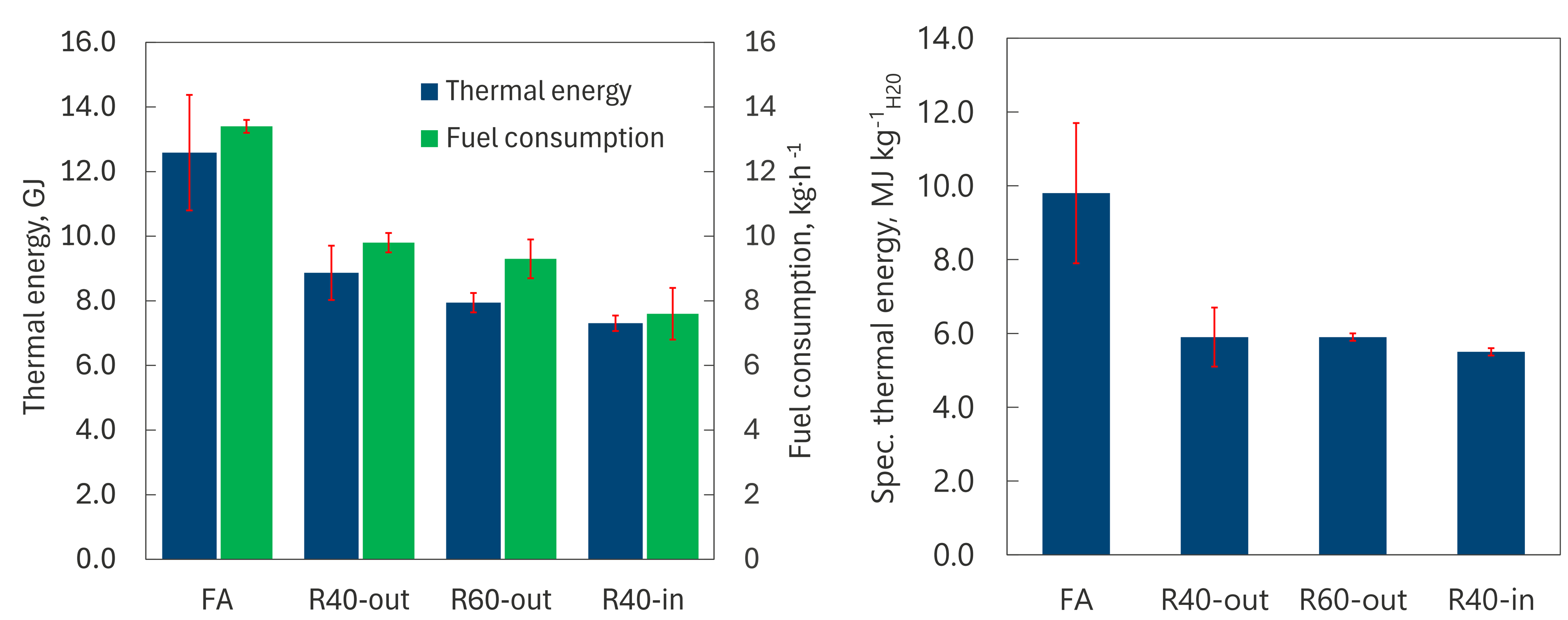

Figure 4. Comparison of drying strategies in terms of thermal energy supplied by the burner and fuel consumption (*left*), and specific energy requirement (*right*)

IV. CONCLUSION

Drying results indicated that operating the dryer in controlled mode with 40% inlet relative humidity was the most energy-efficient strategy for reducing thermal energy demand. These findings demonstrate the effectiveness of controlled exhaust air recirculation in flatbed dryers as a practical and scalable solution for enhancing energy efficiency in MAP drying systems.

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