Economics of drying microalgae Chlorella in a conveyor belt dryer with recycled heat

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Abstract: The objective of this research is to estimate the cost of drying microalgae chlorella in a conveyor belt dryer using wasted heat from an industrial source. The recycling system consists of a run around thermal fluid between two finned tube heat exchangers. The dryer was mathematically modeled and the mass transport coefficient was obtained from empirical thin-layer kinetic data. The dryer and heat recovery system are designed for production of 1000 kg/h dried microalgae at moisture content of 10% (wet basis). The input moisture content can range from 35 to 75% (wet basis). Depending upon the applied Hand factor, the total cost to dry microalgae can change significantly. The results show that integrating waste heat recovery with conveyor belt dryer decreases the drying costs of chlorella drying in comparison to spray drying and conveyor belt dryer using natural gas.

Rationale and Objectives

Why Drying?

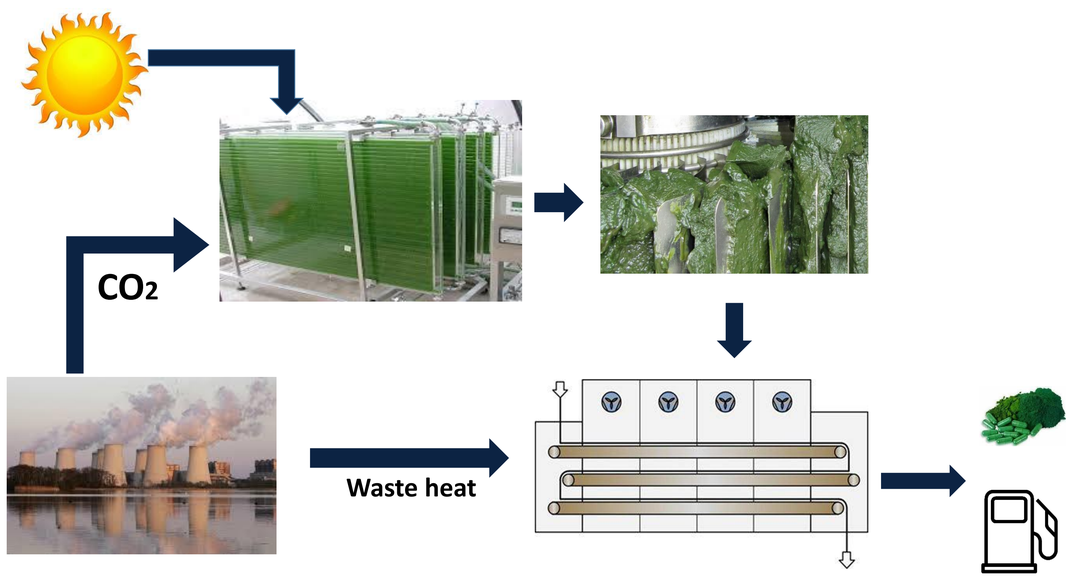
- Easier handling and transportation of dried microalgae; Microalgae paste becomes non-Newtonian at 7%
- Easier storage of dried microalgae; Target moisture content for safe storage is 10%
- Higher conversion efficiency of dried microalgae to biodiesel via transesterification process

Why Conveyor belt dryer?

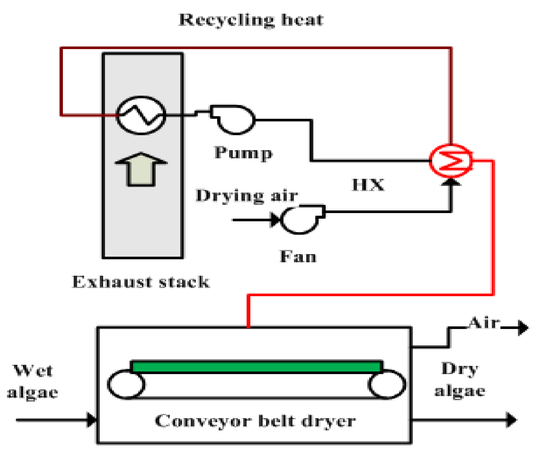
- Less turbulent airflow than spray/flash dryer, so no need for cyclones
- Operation at low temperatures (<100◦ C), so less risk of fire and volatile organic carbon (VOC) emissions
- Possible to apply waste heat

Why waste heat recovery?

- Lower the energy and cost, more sustainable
- Co-location with industrial plants to use CO_2 for microalgae cultivation and waste heat to dry biomass



Hypothesis and Objectives



Hypothesis: Using Conveyor belt dryer coupled with waste heat recovery system could reduce microalgae drying costs in comparison to spray dryer and conveyor belt dryer utilizing natural gas.

Objective: Cost analysis of drying microalgae chlorella to produce 1000 kg/h biomass at 10% moisture content (wet basis, w.b.) from initial moisture content of 55% (w.b.) on a conveyor belt dryer by recycling the waste heat in exhaust flue gas of an industrial plant

Figure 1. Schematic diagram of the conveyor belt dryer with the heat exchanger

Approach

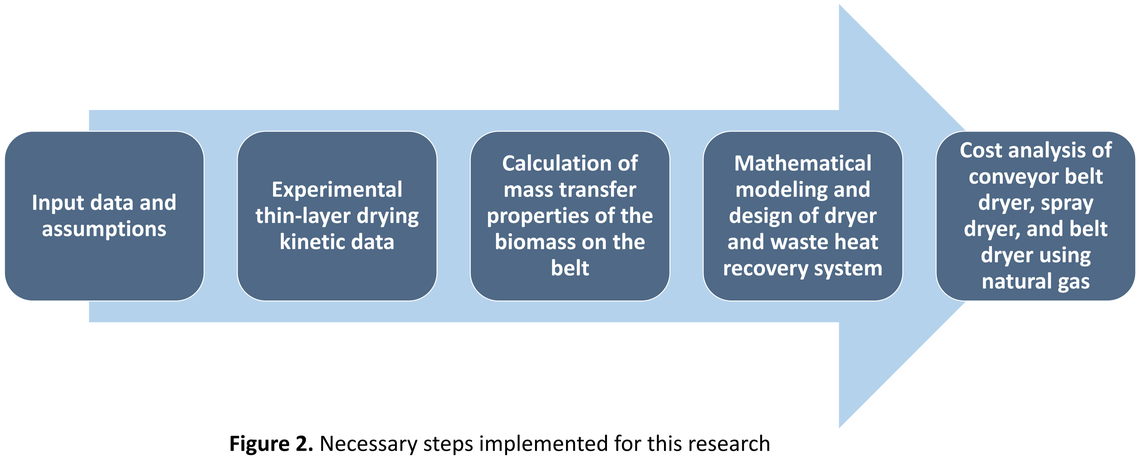


Figure 2. Necessary steps implemented for this research

Assumptions

- Single-pass conveyor belt dryer with counter-current air flow
- Run-around heat exchanger with thermal liquid (water-ethylene glycol solution)
- Range of inlet moisture content: 35-75% w.b.

Table 1. List of process assumptions and input data for dryer and heat recovery system design

Parameter	Value
Microalgae final moisture content (% w.b.)	10
Ambient air temperature (˚C)	25
Ambient air humidity (kg/kg d.b.)	0.0063
Drying temperature (˚C)	80
Material depth on conveyor belt (m)	0.05
Belt width (m)	3
Dryer duct height (m)	1
Flue gas temperature exhausting from stack (˚C)	260
Distance between heat exchangers (m)	200
Heat transfer coefficient of heat exchangers (W/m^2.K)	100

Results

Table 2. Design parameters of dryer system at different initial moisture contents

Initial moisture content (% w.b.)	35	45	55	65	75
Wet feed flowrate (kg/h)	1385	1636	2000	2571	3600
Dry product flowrate (kg/h)	1000	1000	1000	1000	1000
Evaporation rate (kg/h)	384.6	636.6	1000	1571	2600
Residence time (min)	165.7	194.3	217.2	242.2	263.1
Bed length (m)	20.7	24.3	27.2	30.3	32.9
Air flowrate (kg/s)	6.7	10.9	17.5	25.6	45.4
Thermal oil flowrate (kg/s)	7	11	18	26	47
Heat exchanger area (m2)	310	499	804	1177	2086

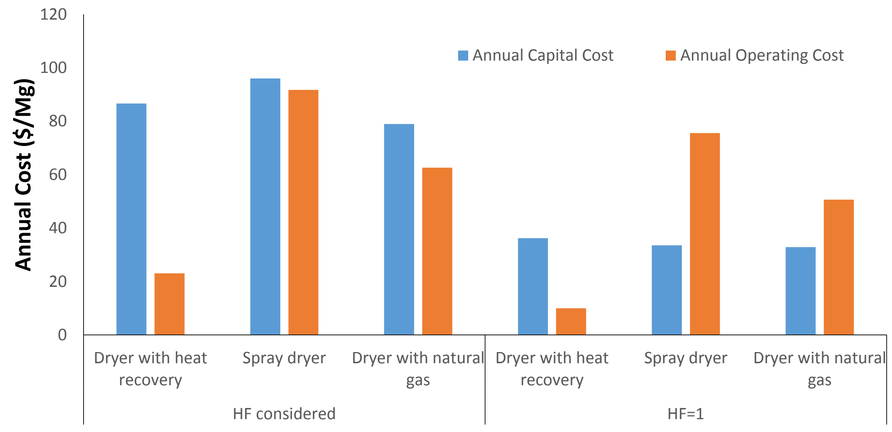


Figure 3. Annual cost per ton of dried product for different drying systems by considering different Hand factors (input moisture content 55% w.b.)

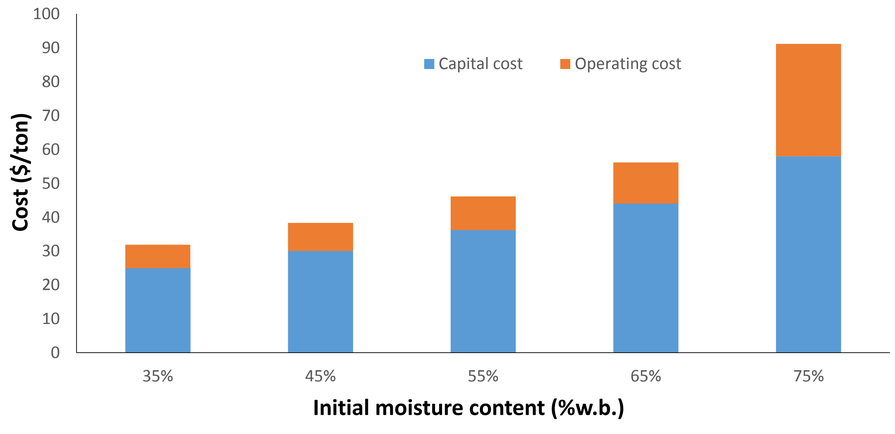


Figure 4. Sensitivity of drying cost to input moisture content for the belt dryer with recycled heat (HF=1)

Conclusion and future research

Conclusion:

- The total annual drying cost from initial moisture content of 55% in conveyor belt dryer with recycled heat ranges from $46.13 to $109.64/ton dried product (by changing the Hand factor(Installed cost/ purchase cost of equipment)).
- The drying costs in spray dryer is 1.7 times higher than the recycled system at $187.67/ton.
- The drying costs in belt dryer using natural gas is 1.3 times higher than the recycled system at $141.5/ton.
- By increasing the inlet moisture content from 35 to 75% the drying costs rises from $31.88 to $91.13/ton.

Future research:

- Lab and pilot scale tests of microalgae drying in conveyor belt dryer is required.