MODELING AND DEVELOPMENT OF A SOLAR POWERED DATES DRYER

Part 1: Modeling and Experimental Analysis of the Solar Heat Collector

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Outline

• Dates in Oman
• Drying Dates, traditional and instrumented platforms
• Drawbacks of current drying platforms
• Solar energy potentials of Oman
• Rationale
• Geometry of prototype solar heat collector
• Experimental setup
• Modeling & simulation method
• Results
• Conclusion & future work
Sultanate of Oman

- **Geographical location:** southeastern coast of the Arabian Peninsula in Western Asia
- **Area:** 309,500 km²
- **Capital:** Muscat
- **Population:** 4,829,473
- **Weather:** very hot in summer and pleasant in winter

Figure 1. Map of Oman (Britannica.com)
Dates in Oman

• Date fruits are considered as the primary agricultural crop in Oman as it comprises 80% of all fruit crops and around 50% of the total agricultural area (Anon, 2016).

• **345,000 tons** is the annual production of dates in Oman.

• Date fruits considered one of the **most nourishing** natural foods as it consists of 70% carbohydrates (mostly sugars) and 15 to 30% water content (depend on the variety and on the maturity stage of the fruit).

• The flesh of dates contains **sugar (60 to 65 %), fiber (2.5%), protein (2%), fat, minerals, and pectin substances (each less than 2%).**

• Date fruits are good source for **calcium, iron and potassium** (Zaid & de Wet, 2002).
(Source: flicker.com)  (Source: timesofoman.com)
Drying

(Source: timesofoman.com)

(Source: flicker.com)
Figure 2. Regional distribution and percentage (from a total number of 7,795,786) of date palm trees in each region of the Sultanate of Oman.
Drying Dates: Open Sun Drying

Figure 3. Traditional sun drying using simple platforms
Open Sun Drying: Drawbacks

- Dates can get spoiled by weather conditions.
- Quality of the product can be reduced by the attack of animals, birds and insects.
- Poor dates quality (physical & nutritional).
- Poor hygiene.

Only 2.5 to 3.5% is exported to global markets*

(*Mustayen et al. 2014).
Instrumented Solar dryers

**Figure 5** solar tunnel dryer
Basunia et al., (2010),

**Figure 6** Forced convective solar dryer
Manaa et al (2013)
Oman has great potential for solar energy usages.

Oman receives a daily 5.197 kWh/m² of solar energy radiation. (1897 kWh/m²/year)

Figure 4. Global Horizontal irradiation (Source: solargis.com, 2019)
Rationale

• Greenhouse tunnel dryer (due to highest drying rate) and open sun drying (due to direct exposure to high temperature) had higher microstructural changes (Seerangurayar et al., 2019).

• Forced convective solar dryers could be improved in terms of size and technology to become more efficient and user friendly.

• Connecting remote villages and small farms in Oman to electrical grid is expensive and economically not feasible as these villages and farms are too far from the grid (Al Hatmi & Tan, 2013).

• Off-grid diesel-fueled generators are prohibitively expensive and unreliable because of the fuel high cost as well they need to be frequently maintained.
Geometry of the solar heat collector

Overall Design

- Transparent Window
- Absorptive structure with 6 air channels
- Air In
- Air Out
Geometry of the Solar Heat Collector

Dimensions: Absorptive surface
Dimensions: Transparent window
Experimental Setup

- Thermocouples in all 6 channels, transparent window, absorptive plate + inlet and outlet vents.
- Data logger.
- Weather station that measures:
  - Solar irradiance
  - Ambient air temperature
  - Relative humidity
  - Wind speed
- Photovoltaic panel to power the whole system.
- Exhaust fan with controllable speed.
CFD Numerical Modeling Method

1. Create 3D geometry of the prototype
2. Model discretization (Meshing)
3. Define the models
4. Select materials & and assign properties
5. Set the boundary conditions
6. Initialize Solution

- Material properties
- Air Properties
- Air Inlet Velocity
- Solar heat flux
- Air inlet temperature
- Convective heat transfer

ANSYS Fluent Software
Modeling & Simulation Results

Model 1: Low Velocity ($V_{in} = 0.40 \text{ m/s}$)

- Temp ($^\circ\text{C}$)
- Velocity (m/s)
- Pressure (pa)
Model 2: Medium Velocity ($V_{in} = 0.65 \text{ m/s}$)
Model 3: High Velocity ($V_{in} = 1.00 \text{ m/s}$)

Temp (°C)  Velocity (m/s)  Pressure (pa)
Experimental Vs. Simulated Temp_Outlet
Conclusion

- Air inlet velocity Vs. Temperature difference (Outlet-Inlet), as air velocity increases, the difference decreases and vice versa, true for model and experiment.

- Good conformation between values of outlet temperature measured experimentally & predicted by the simulation model.
Future Work

• Blacking of the absorptive surface.
• Addition of a solar tracking system to increase solar heat collection during the day.
• More experimental testing and modeling for better optimization.
• Develop the drying chamber, and testing drying of dates to develop the drying kinetics.
• Use of advanced electronics and microcontrollers to automate the drying process.
• Seek for commercialization potentials and distribution to local village farmers.
Thank You ....

Questions ?