A cost-effective evaporative cooling pad from Hyphaene Thebaica fibers as a greenhouse cooling technology

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Introduction

Evaporative coolers:
- Environmentally friendly and cost-effective cooling technologies
- Reduce Greenhouse gases and requires minimum maintenance

Principle:
- Hot air + (cellulosic material - water) medium => Fresh humid air
- Latent heat of evaporation (water) -- Sensible heat (air) => Decrease temperature (moist air).

Objective

To investigate the performance of *Hyphaene thebaica* fibers as cooling pad material for greenhouse cooling technology.

Methodology

1- Development and characterization of various pads via set-up

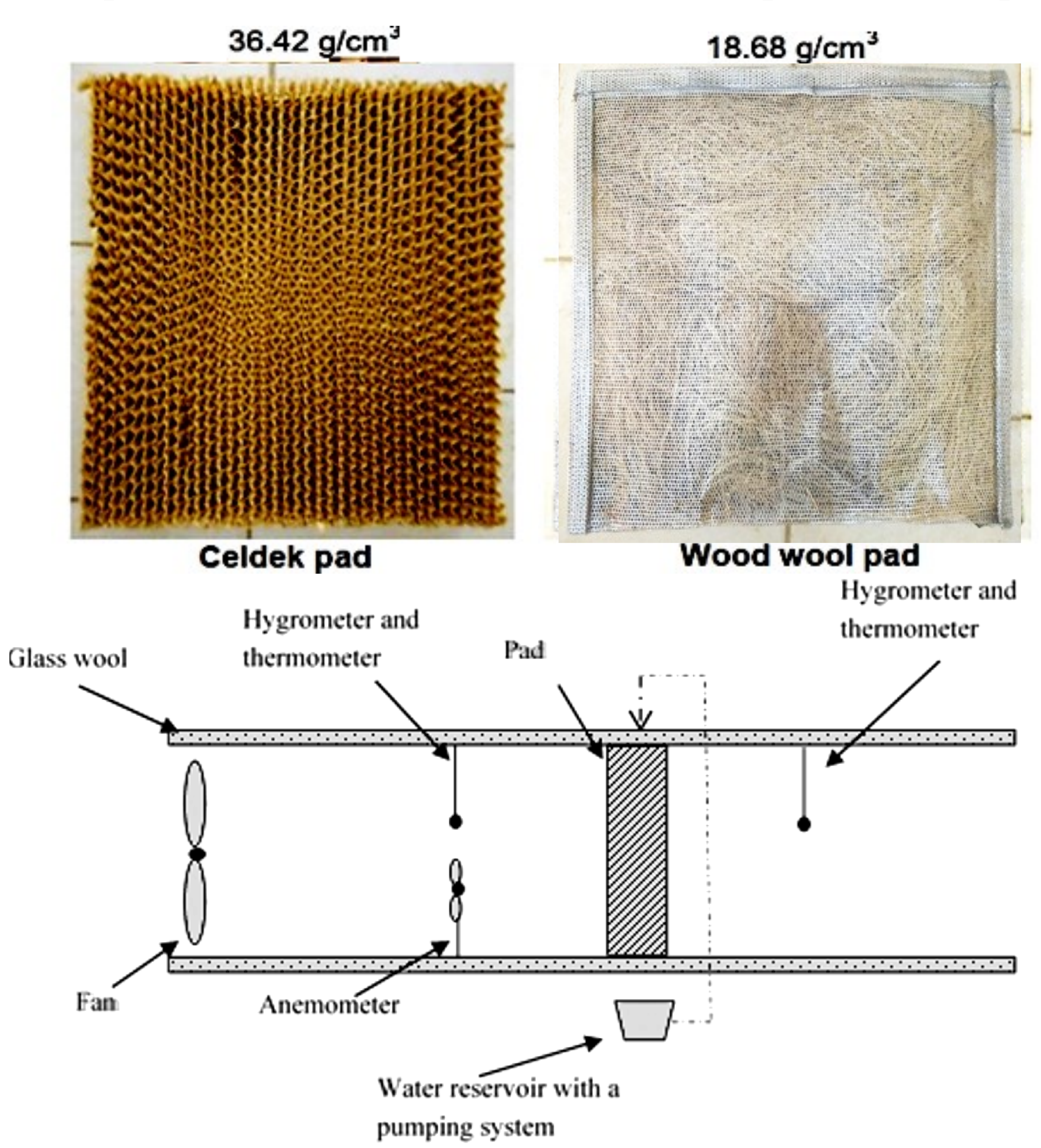

Fig. 1 Celdek pad, wood wool pad and experimental set up.[1], [2]

2- Calculations at equilibrium

- Saturation efficiency is given by: eff $= \frac{T_{db1} - T_{db2}}{T_{db1} - T_{wb}}$
- Cooling capacity is given by: Q = $m_a Cp_a (T_{db1} - T_{db2})$
- **Energy and mass balance:**

$$ma\,ha_1 + mv_1 hv_1 + mv_1 hw - ma\,ha_2 - mv_2 hv_2 - mv_2 hw - q = 0$$
$$ha_1 - ha_2 + W_1(hv_1 + hw) - W_2 (hv_2 - hw) = Cpa\,(Tdb_1 - Tdb_2)$$

- Heat loss: $q = h_H A_s \Delta T$, h_H heat transfert coefficient
- Mass transferred: $me = h_M A_s \Delta\rho_v$, h_M mass transfert coefficient
- Coefficient of performance: $COP = \frac{Q_{pad}}{P_{fan} \times P_{pump}}$

P_{pump} given by the manufacturer. $P_{fan} = \frac{ma \times \Delta Pv}{\rho a \times \eta_{fan} \times \eta_{motor}}$

- Cost-to-efficiency ratio: $CER = \frac{Cost}{eff}$

Results

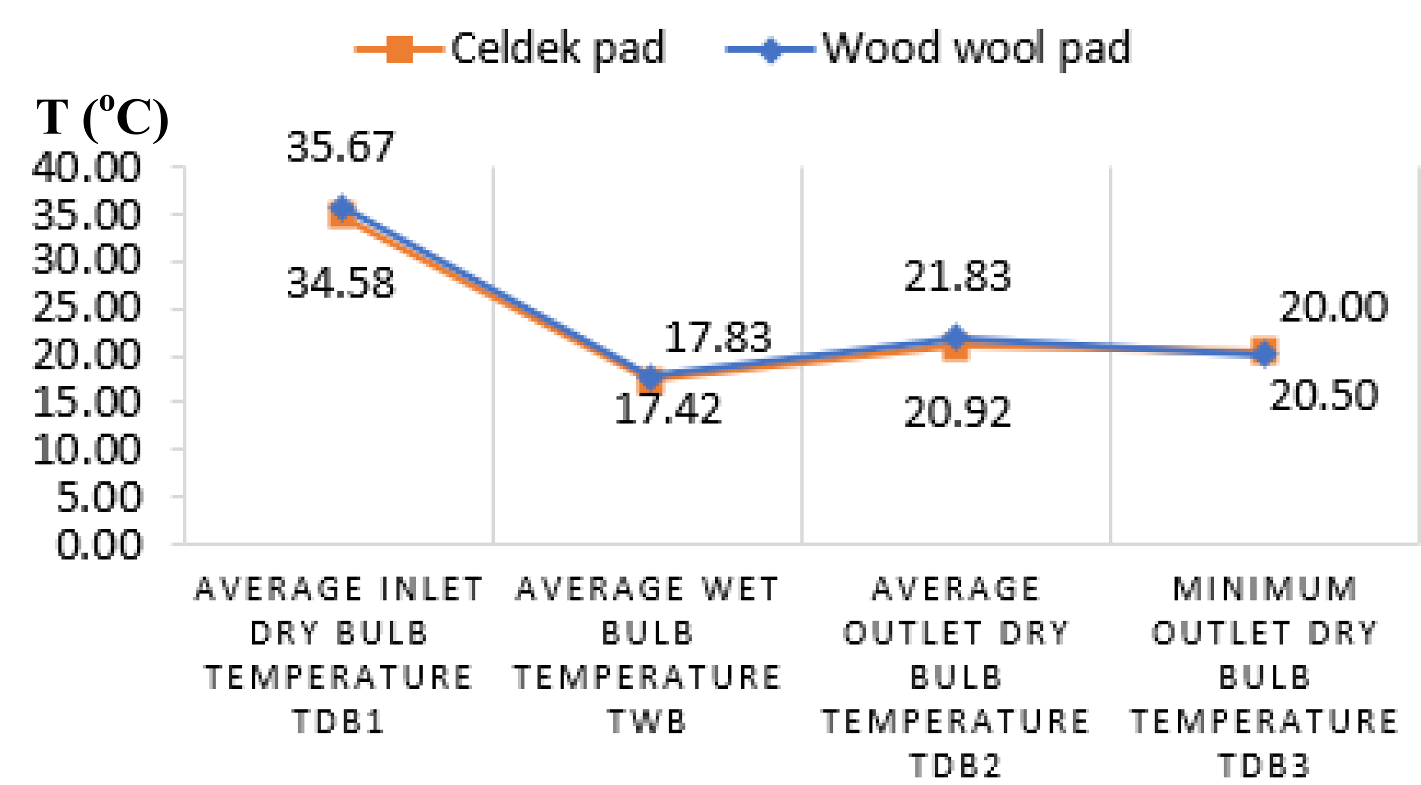

Fig. 2 Average temperature of wood wool and Celdek pad at constant frontal velocity (v = 5.522 m/s).

- Initial hot temperatures of 35.67 °C and 34.58°C were dropped to 20.50 °C (Celdek) and 20.00°C (wood wool).
- Increase in relative humidity (RH) by 270.37% (Celdek) against 140.99% (wood wool).

These values fell within the acceptable comfort zone conditions as describes in ASHRAE (RH between 19.8% and 79.5%) [3].

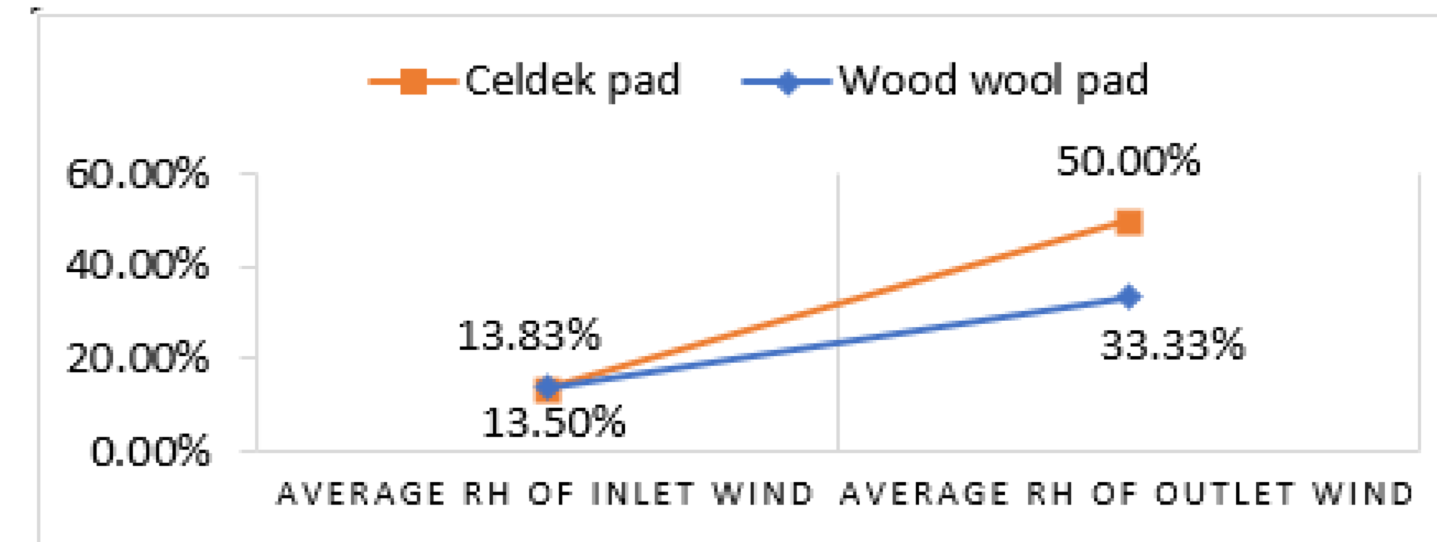

Fig. 3 Relative humidity relationship

Table 1 Average thermodynamic parameters of studied pads

	Celdek	**W. wool**
Parameters	Average values	
Efficiency	79.80%	78.80%
Mass flow rate, kg/s	0.012	0.012
Cooling capacity, kJ/s	0.170	0.172
Heat transfer coef., kW/m²°C	4.518	4.699
Mass transfer coef., kg/s	1.395	0.875
Coefficient of Performance, COP	6.557	9.036
Cost to efficiency ratio, CER (based on XOF)	12551	3219

At constant mass flow rate:
- A difference of 1% in saturation efficiency in favour of Celdek
- A difference of 0.181 kW/m^2.°C in terms of heat transfer coefficient with Celdek dominating
- Wood wool pad had better CER value of 12551 (table 1)

Conclusion

Evaporative cooling pad from the fibres of *Hyphaene thebaica* (wood wool pad) could be a better cooling pad considering the local Sahelian context

Acknowledgment

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References

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[2] A. S. M. Djibrilla, A. H. Abdoulkader, K. M. Illyassou, and Y. Aissetou, "Performance of Evaporative Cooling Pads Made from Different Plant Materials of Sub-Saharan Area (NIGER)," *LC Int. J. STEM*, vol. 2, no. 4, pp. 38–49, 2021, doi: 10.5281/zenodo.0000000.
[3] ASHRAE, "ASHRAE Handbook Fundamentals (SI)." ASHRAE, Atlanta, pp. 9.11-9.14, 2013.

ma = air mass flow rate, kg/s; mv = mass flow rate of water vapour, kg/s ; W = humidity ratio, kg of air/kg of water; ha_1, ha_2 = inlet and outlet enthalpy of air, kJ/kg of dry air; hw = enthalpy of water, kJ/kg of dry air; T_{db1}, T_{db2} = inlet and outlet dry bulb temperature, °C; T_{wb} = wet bulb temperature, °C ; Cpa specific heat capacity of air ; ρa = actual density of dry air, Kg/m^3; $\Delta\rho_v$ = log mean mass density difference of water vapour, Kg/m^3; A_s = total wetted surface area of the pad used, m^2; ΔT = log mean temperature difference, °C; P pump and P fan = fan/blower and pump power; η_{motor} = motor efficiency; ΔPv = pressure drop.