Journal of Sustainable Agricultural and Environmental Sciences
https://jsaes.journals.ekb.eg/
JSAES, 2022,1(1): 161 - 168

ISSN-Print: 2735-4377
ISSN-Online: 2785-9878

A Techno-Economic Assessment for the Possibility of Luffa as a Pad Cooling Material

Elsergany, N.[1*]; Darwish, M.[1]; Salah Sh.[1] and Ghoname, M.S.[1]

[1] Department of Agricultural Engineering, Faculty of Agriculture, Tanta University, Egypt.

*Corresponding Author: Nessrien Elsergany (nessreen854@gmail.com)

J.Sust.Agri.Env.Sci. (JSAES)

Keywords:
Evaporative cooling; Passive cooling; Cooling effectiveness; Cooling pads.

ABSTRACT

The possibility of using luffa as a pad cooling material was experimentally assessed. The basis of this study depends upon the comparison between a luffa and commercial cellulose pads. Their costly analysis was evaluated to indicate that considering luffa as pad cooling material is economically feasible. The experiments were conducted in the summer of 2021. The obtained results showed that the cooling efficiency calculated for luffa ranged from $57.9 \leq \eta f \geq 94.1$. Meanwhile, the efficiency of the cellulose pad ranged from $60.6 \leq \eta c \geq 92$.

1. INTRODUCTION

Mushroom is one of good cash crops; they are rather easy to grow and are brimming with protein, B vitamins, and minerals. Also, they even have medicinal properties that humans needed it. Therefore, mushrooms can improve food security by increasing diversity. **Rosmiza *et al.* (2016)** reported the economic importance of mushrooms because it has a short growing time, require limited land, and have low investment as the growing medium is widely available. Mushroom is a type of fungus and they do not contain chlorophyll, thus can be cultivated in a greenhouse or production house. **Tesfaw *et al.* (2015)** mentioned that relative humidity, aeration, temperature, and contaminations are the most important factors during mushroom cultivation using locally available substrates, materials and technologies. The heat stress is a big problem that faces the agricultural structures, which caused many harmful effects on biological systems production growing inside farm buildings, **Abouzaher *et al.* (2020)**. Therefore, using an evaporative cooling system keep the atmospheric conditions around mushrooms in desirable temperature and relative humidity requirements. Pad fan evaporative cooling system is widely spread in mushroom cultivation structures to reduce temperature and increase relative humidity. But the use of this system needed a commercial pad that high expensive and increased the production costs. Consequently, the costs of primary establishment reflect on profit.

Therefore, it is necessary to use alternative pad material that cheap or less than the costs of the commercial pad. Present study aimed to compare the commercial pad and the luffa as an alternative pad considering their cost and economic values.

2. MATERIALS AND METHODS

The experimental work was carried out from August to September 2021 in the agricultural engineering laboratory on the roof of the agriculture faculty, Tanta University, Egypt (latitude angle of 30.49ºN, longitude angle of 30.59ºE.

2.1 Materials

The following sections describe the materials that functioned in the present experimental work. These materials such as: mushroom house, mushroom crop and evaporative cooling systems.

2.1.1Mushroom

12 kg of straw are soaked in 200 L of dissolved water in which 2.5 kg of slaked lime is for 24 h, then dried for 48 h, then half a kilo of seeds is planted, and mushrooms are placed in plastic bags of size 40 x 60 cm on 6 kg of straw, empty the bags from the air, close well and incubate them for about two weeks at room temperature or about 25°C. Then the bags are punctured and waiting for the fruits to come out, in an atmosphere of humidity ranging from 80 to 90% and temperature ranging from 20 to 30°C.

2.1.2 House of mushroom

Two identical mushroom units functioned during the experimental work. The first unit operated the cellulose cooling pads as commercial pads and another employed the luffa as alternative pad material. The two unite orientated in the N-S direction. The geometric dimensions of each house were as follows, 2.6 m in length, 1.5 m in width, and 1.5 m in height, and had a floor surface area of 3.9 m^2 and a volume of 5.85 m^3. The houses were made of wooden plates and internally insulated with 2 cm fiberglass as insulation material as illustrated in Fig. 1.

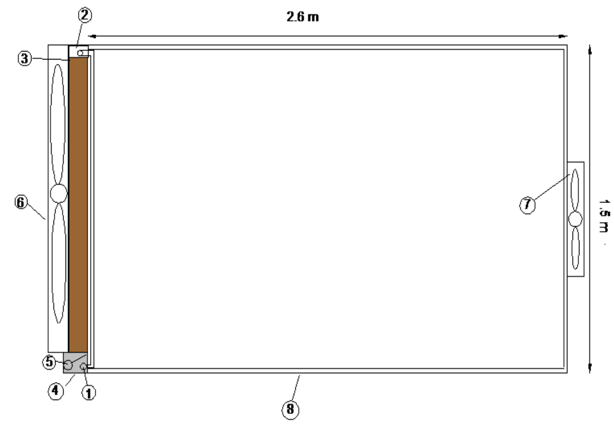

Fig. 1: Schematic diagram of the mushroom room with an evaporative cooling system

2.2 Evaporative cooling system

The outdoor air was forced using one axial-flow, direct-driven suction fan with an internal diameter of 126 cm, single phases, and 15000 $m^3\ h^{-1}$ discharge through 2.25 m^2 face area of 10cm thick cooling pads situated on the North side wall of the northern vertical wall of the house (side toward the prevailing winds) as shown in Fig. 1. Luffa and corrugated cellulose pads, each having gross dimensions of 1.5 m wide and 1.5 m height. A sump (gutter) was mounted under the pads to collect the water and return it to the water tank (200 L capacity) from which it can be recycled to the pads by the water pump. A small extracting fan located on the opposite sidewall (southern wall) generated an airflow rate of about 2500 $m^3\ h^{-1}$. The extraction fan faces a wall of the pad to draw the moist air outside the air chamber. The evaporative cooling system was continuously operated when the indoor air temperature of the house reached 30°C. The air temperature inside the house, at a height of about 0.5 m above floor level (monitor), was controlled by an on-off controller (differential thermostat) to initiate house temperature below 30ºC. The specifications of pad cooling system are indicated in Table 1.

Table 1: The specifications of pad cooling system

No	1	2	3	4
Part	Pump	Perforated pipe	Pad	Sump
No	5	6	7	8
Part	Mechanical float	Fan 1	Fan 2	Mushroom room

2.3 Methods

The experimental work was carried out to determine the efficiency and economic utility of two different pad materials during the cooling process. The efficiency of the evaporative cooling system is namely associated with the cooling effect, wet-bulb depression, rate of heat transfer from air to water, and water consumption in the evaporation process.

Table 2 indicated the cooling efficiency for cellulose and luffa as pad materials. The cooling efficiency can be computed in terms of the cooling effect (denominator) and the wet-bulb depression (numerator).

Table 2: Cooling efficiency for cellulose and luffa as pad materials

Pad material	Saturation efficiency
Cellulose	57.9≤S.E≤94.1
Luffa	60.6≤S.E≤92

2.4 Calculation

2.4.1 Performance of cooling system

Temperature reduction describes the cooling effect inside the mushroom house and is an easy criterion to evaluate the effectiveness of the cooling system and it can be calculated according to the following equation:

$$\Delta T = (T_{db,o} - T_p) \quad [1]$$

Where:

$T_{db,o}$ is the outside air dry bulb temperature, T_{ab}; is the dry bulb temperature of the air entering the cooling system (°C); $T_{p;}$ is the dry bulb temperature of air exiting the cooling system (°C) and ΔT is temperature reduction (cooling potential), °C.

2.4.2 Saturation efficiency

Saturation efficiency (S.E) is defined as the ratio between the actual dry-bulb temperature reduction (i.e., cooling effect) and the theoretical maximum at 100% saturation **(ASHARE, 2005)**. It is calculated as a percentage from the following equation:

$$S.E = \frac{(T_{db,o} - T_p)}{(T_{db,o} - T_{wb,o})} \quad [2]$$

Where:

The saturation efficiency is decimal, $T_{wb,o}$ is wet bulb temperature of outside air (°C) and ($T_{ab,o}$ - $T_{wb,o}$) is wet-bulb depression (°C).

2.4.3 Cost analysis

Economic viability is a determinant factor for the widespread implementation of any evaporative pad cooling units to produce a mushroom. It is imperative that such a cost analysis for any apparatus utilized in agricultural applications be carried out, taking into consideration both the inputs and outputs of the proposed system.

Cost analysis commonly tests the fixed costs of the cooling system and mushroom units (initial costs), costs of the production process (variable costs), and payback (return profit on capital). Initial costs of evaporative pad cooling system and mushroom units comprise its construction and what parts it utilizes (i.e., pipes and valves of the system, water pump, fans, mushroom unit, pad, and electric control unit in the present study).

The variable costs (operating costs) are those that change primarily with the processing practices as used. These costs include the price of mushroom, the electrical energy consumed as well as the costs of labor, taxes, overhead, and maintenance. Accordingly, total costs of the production process and cooling process include the variable and fixed costs, the latter inclusive of depreciation of materials (capital), interest, insurance and taxes.

3. RESULTS AND DISCUSSION

3.1 Saturation efficiency

The packing material is the key element in the heat and mass transfer process, as it fulfills two important functions: it provides a large contact surface for the mixing of the water and air flows, while at the same time ensuring that the transfer process takes as the average saturation efficiency values were varied according to different treatments for cellulose and luffa pad materials.

The saturation efficiency of the cellulose cooler was typically between 57.9% and 94.1%. Meanwhile, in luffa system ranged between 60.6% and 92%. The previous results agreed with **Franco *et al.* (2014)** and **Warke and Deshmukh (2017)** when used cellulose as a pad material. Meanwhile, in this present study the luffa was employed as number units of little time as possible. As a result, the amount of water evaporated increases and the temperature of the non-saturated air decreases.

3.2 Cost analysis

Cost analysis is a fundamentally important step for gauging the potential success of an Initial costs for the system field-tested in our study are listed in Tables 3 and 4. The total initial costs of both the mushroom unit and cooling system reached about $528.22 (USD) in case of using a cellulose pad as pad materiel. Whereas the initial cost per operation (based on 12 operations) was just $44.018 and the salvage value per year of the initial costs per operation was about $11.0054 (USD). While the total initial costs of both the mushroom unit and cooling system reached about $507.95 in the case of using luffa as pad materiel. Whereas the initial cost per operation (based on 12 operations) was just $42.33 and the salvage value per year of the initial costs per operation was about $10.58.

Table 3: Initial costs for the cellulose pad material with a depreciation rate of 25%

No.	Item	Cost (USA, $)	Salvage (Years)	Depreciation
1	Structural frame:	367.6		
	- Cooling unit room and insulation materials	81.08	10	8.108
	- PVC pipes elbow joints ball	45.94	10	4.594
	- Pushing fan with steel frame (1.1 kW)	216.26	10	21.626
	- Suction fan	24.32	10	2.432
2	Cooling pad materials 2.25 m^2 (Cellulous)	33.78	10	3.378
3	Pump	27.02	5	5.04
4	Plastic tank, 0.2 m^3	24.32	10	2.432
5	Floating valves (mechanical)	5.4	5	1.08
6	Electric control box, electric cables and variable speed regulator	70.1	5	14.02
7	Total initial costs (USA, $)	528.22	--	132.055
8	Cost/operation (USA, $)	44.018	--	11.0054

Table 4: Initial costs for the luffa pad material with a depreciation rate of 25%

No.	Item	Cost (USA, $)	Salvage (Years)	Depreciation
1	Structural frame:	367.6		
	- Cooling unit room and insulation materials	81.08	10	8.108
	- PVC pipes elbow joints ball	45.94	10	4.594
	- Pushing fan with steel frame (1.1 kW)	216.26	10	21.626
	- Suction fan	24.32	10	2.432
2	Cooling pad materials 2.25 m^2 (luffa)	13.51	10	1.351
3	Pump	27.02	5	5.04
4	Plastic tank, 0.2 m^3	24.32	10	2.432
5	Floating valves (mechanical)	5.4	5	1.08
6	Electric control box, electric cables and variable speed regulator	70.1	5	14.02
7	Total initial costs (USA,$)	507.95	--	126.9875
8	Cost/operation (USA, $)	42.33	--	10.58

Tables 5 and 6 present the variable costs, for the cellulose pad, which totaled $36.92 per operation; hence, the total annual costs for each operation inclusive of two different items construction plus operating costs, was $47.92. While using the luffa pad totaled $25.1 per operation; hence, the total annual costs for each operation inclusive of two different items (construction plus operating costs) was $35.68. The system used in this study was designed and built to provide the suit temperature and relative humidity for mushroom production.

The net income when using cellulose as a pad material for the cooling system, according to the current market rates from selling mushroom production, was $214.83 for one month. Consequently, the estimated return profit was $166.91, which represents 77.7% of the total income per operation. While using the luffa as a pad material, the net income, according to the current market rates from selling mushroom production, was $384.9 for one month. Consequently, the estimated return profit was $346.22, which represents 89.95% of the total income per

operation. Using luffa as a pad material increases the return of a profit by 107.42%. However, if the cellulose is employed as pad material, the operational costs will increase. From the results mentioned above, using luffa as pad material in the cooling system reduces the consumption of electrical energy by 16.66%. This stark reduction is very important in cases of energy reduction costs. From an economic point of view, the production of mushrooms is promising for supplying the anticipated demand for them. Table 7 listed the hourly cost of the cellulose pad compared with the luffa pad. The hourly cost of the cellulose pad was 0.157762 $/h while the hourly cost of using the luffa pad was 0.149822 $/h.

Table 5: Variable costs of the mushroom unit using evaporative pad cooling (cellulose pad material)

No.	Item	Costs

		(USA, $)
1	Mushroom	8.13
2	Electrical energy consumed (48 kWh)	1.764324324
4	Labors	27.027
5	Total variable cost	36.92

Table 6: Variable costs of the mushroom unit using evaporative pad cooling (luffa pad material)

Cooling system	Capital investment, $	Yearly operating hours, h	Life expectancy, year	Investment rate, %	Taxes and overhead, %	Repair and maintenance, %	Electrical energy, kWh/day	Price of electricity,$/kWh	Hourly cost, $/h
Cellulose pad	528.22	1440	10	18	10	10	0.4	0.0367	0.157762
Luffa pad	507.95	1440	10	18	10	10	0.333	0.0367	0.149822

Table 7: The hourly cost of the cellulose pad material vs. luffa pad

No.	Item	Costs, USD, $
1	Mushroom	8.13
2	Electrical energy consumed (40 kWh)	1.47
4	Labors	15.5
5	Total variable cost	25.1

Fig. 2 shows the operating and criterion cost of the cellulose pad compared with the luffa pad. Data showed that, the operating cost of a luffa pad was 2.2864 $/kg. Meanwhile, in case of cellulose pad the operating cost was 1.4138 $/kg. The criterion cost of the luffa pad was 2.9885 $/kg, while it was 1.6479 $/kg in case of the cellulose pad. The previous results can be attributed to lower electrical energy consumption and mushroom losses cost. From an economical point of view, the luffa pad is the best for being a pad material for the evaporated cooling system in mushroom production unit.

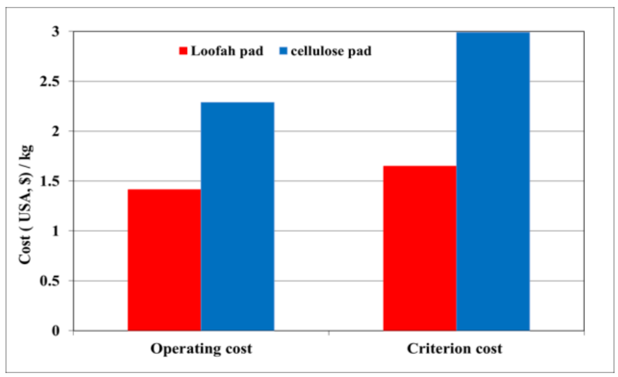

Fig. 2: Operating and criterion costs of the cellulose pad material vs. the luffa pad

4. CONCLUSION

This study set out to determine the cooling efficiency and the economics used it with compared by industrial commercial pad material such as cellulose. From viewpoint of the economic indicators, using luffa as pad material had high values vs. cellulose pad.

5. REFERENCES

Abouzaher, S. E.; M. R. Darwesh and M. S. Ghoname (2020). Reduce energy and heat stress in closed rabbit housing under

Egyptian Delta zone conditions. Misr J., Ag. Eng., 37(4):373-392.

ASHARE, (2005). Handbook of fundamentals. American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA, p.30329.

Franco, A.; D. L. Valera and A. Pena (2014). Energy efficiency in greenhouse evaporative cooling techniques: cooling boxes versus cellulose pads, Energies 7: 1427-1447.

Rosmiza, M. Z.; W. P. Davies; C. R. Kosniza Aznie and M. J. Jabil (2016). Prospects for increasing commercial Mushroom production in Malaysia: Challenges and opportunities. Mediterranean J. of Social Sciences, MCSER Publishing, Rome-Italy, 7(1):406-415.

Tesfaw, A.; A. Tadesse and G. Kiros (2015). Optimization of oyster (*Pleurotus ostreatus*) mushroom cultivation using locally available substrates and materials in Debre Berhan, Ethiopia. J. of Applied Biology and Biotechnology, 3(1):15-20.

Warke, D. A. and S. J. Deshmukh (2017). Experimental Analysis of Cellulose Cooling Pads Used in Evaporative Coolers. International Journal of Energy Science and Engineering, 3(4):37-43.

Journal of Sustainable Agricultural and Environmental Sciences
https://jsaes.journals.ekb.eg/
JSAES, 1(1): 00 - 00

ISSN-Print: 2735-4377
ISSN-Online: 2785-9878

تقييم تقني اقتصادي لإمكانية استخدام اللوف كمادة تبريد الوسادة

نسرين السرجانى[1]، محمد رمضان درويش[1]، شيماء السيد صلاح[1]، محمد سعيد غنيم[1]

[1] قسم الهندسة الزراعية – كلية الزراعة – جامعة طنطا – مصر.

مجلة العلوم الزراعية والبيئية المستدامة

الملخص

نظرا لأهمية الرطوبة النسبية في انتاج فطر عيش الغراب فقد تم عمل دراسة تجريبية في صيف ٢٠٢١م لتقييم امكانية استخدام اللوف كأحد وسائل التبريد في نظام التبريد بالتبخير، واعتمدت هذه الدراسة على المقارنة بين وسائد اللوف ووسائد السليلوز التجارية من الناحية الاقتصادية.
وجد أن استخدام اللوف كوسائد تبريد مقارنة بوسائد السليلوز مجدية اقتصاديًا. وأظهرت النتائج المتحصل عليها أن كفاءة التبريد المحسوبة لوسائد اللوف تراوحت بين ٥٧،٩ $\geq \eta f \geq$ ٩٤،١ %. وفي الوقت نفسه، تراوحت كفاءة وسادة السليلوز بين ٩٢ $\geq \eta_c \leq$ ٦٠،٦.