Development of A Smart Farming Inspired Termite Nest Solving Global Boiling by Passive Air Conditioning

Haryn Kim

Received February 17, 2024
Accepted May 03, 2024
Electronic access May 15, 2024

In the 21st century, the world's average temperature is rising to levels now considered global boiling. Addressing this rapid increase in average temperature is mankind's most pressing issue. Because of global boiling human can't predict weather and average temperature rise make hard to traditional farming. In African countries, especially in Ethiopia, the rapid temperature increase has negatively impacted existing crops due to extreme floods and droughts, eroding soil depleting soil nutrients, and rising carbon dioxide. To face this problem, Africans use vertical or urban farming to harvest crops. The problem with these methods is that the structures require significant energy usage, with 38.8 kWh per kg of produce. To solve this energy consumption problem, this article discusses how to effectively maintain the energy inside the smart farm, emphasizing energy reduction in an environmentally friendly way. Termite nest unique structure can make a low temperature inside of them it's natural air conditioner. High temperature air is released at top roof, so termite nest maintains low temperature. Specifically, this article will prove that using the design of a termite nest can improve energy efficiency inside the smart farm by maintaining a constant low temperature.

Introduction

The created building mimics termite nests, which are well known for capturing wind energy through thousands of tunnels and air chambers in the side of the building[1]. The core of the termite nest maintains a constant temperature of 24$\sim$ 28^{o}C. The buildings that utilize these designs have benefited economically[2]. For example, Eastagate Centre in Zimbabwe showed a 10% reduction in energy use compared to that of a building of the same size, which resulted in rent savings of 10% compared to nearby buildings[3]. However, in this experiment, buildings for growing crops (smart farms) are created to reduce energy consumption problems by maintaining inside of smart farms temperature.

In Figure 1(a), common termite nest image effectiveness of the design air flow and cooling effect[4]. Figure 1(b) ideal smart farm model. Highly energy efficient structure. Our eco-friendly smart farm way to solving food shortage and energy problem.

Results

In figure 2 (a) hard board sample and clay sample image. (b) Meaning of Channel 1 blue line average temperature 28.5 degrees and Channel 2 green line had 30 degrees, averaging 29.25 degrees remaining in the low temperature. This two channel 1,2 are measured clay buildings. While Channel 3 yellow line had 33 degrees and Channel 4 red line 36 degrees, averaging 35 degrees staying in the high temperature. This two channel 3,4 are measured hard board buildings. The average of the channels showed that the clay building with ventilation and hardboard building with no ventilation has 6.25 degrees difference in average temperature. Energy saving point of view our bio-inspired smart farm are effective.

Furthermore, clay building proved to have stable temperature, with a minimum (27 degrees) and maximum (32 degrees) difference of 5 degrees, than that of hardboard one, with a minimum (30 degrees) and maximum (43 degrees) difference of 13 degrees.

This result means that more stable temperature are maintained in bio-inspired buildings.

Two additional experiments are performed to confirm how opened ceilings help release hot air in Figure 3. This time, hardboards are used for both buildings to use the same materials in congruent conditions and to perform the experiments precisely and efficiently. Figure 3 (a), took place on a hot summer day, while the second experiment figure 3 (b), took place on a gloomy day with low temperatures. The two experiments took place on different conditions to reduce possible variables. The background temperature remains at the same temperature as the first experiment.

The expectation was that the with ventilation building would have a lower temperature than the without ventilation building for both of the experiments.

In figure 3 (a), Ch 1 had 27.5 degrees and Ch 2 had 27 degrees, averaging 27.25 degrees, while Ch 3 had 29 degrees and Ch 4 had 32 degrees, averaging 31.5 degrees. The two channels in the first building had lower temperatures than that in the second building. This experiment resulted in the same conclusion as the previous experiment, confirming our hypothesis. Further-

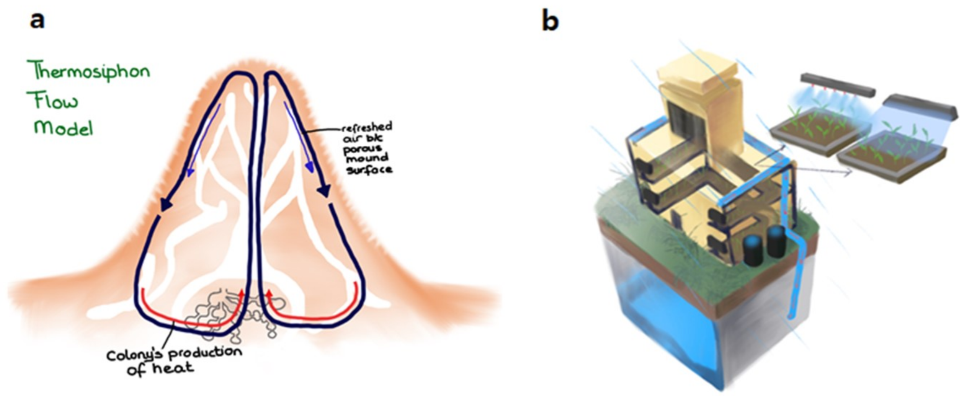

Fig. 1 (a) Ant hill's inside air circulation. (b) High energy efficiency bio-inspired smart fam design

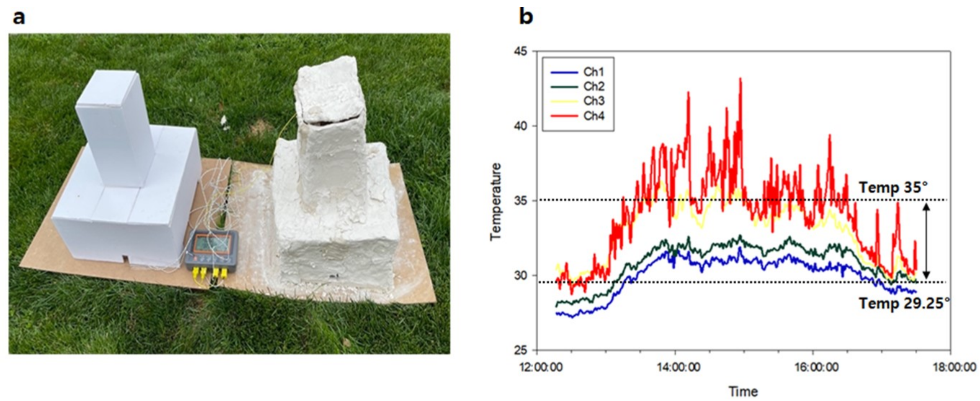

Fig. 2 (a) The right shows the first building with ventilation and the left shows the second building without ventilation. (b) Channel 1 on the thermometer is for the bottom portion of the right clay structure, Channel 2 for the top of the right building, Channel 3 for the bottom of the left building, and Channel 4 for the top of the left building. The temperature was recorded every minute.

more, this experiment confirmed the possibility and potential of applying the biomimicry design of the termite nest in buildings, reducing energy usage by lowering the inside temperature.

In figure 3 (b), Ch 1 had 25 degrees and Ch 2 had 26 degrees, averaging 25.5 degrees, while Ch 3 had 27 degrees and Ch 4 had 27.5, averaging 27.25 degrees. Both channels in the first building averaged lower temperatures than those in the second building. The average had less fluctuation in the second experiment than that of the first experiment, but had the same conclusion, reinforcing the hypothesis.

Discussion

Average temperature difference between the top and bottom of the building was Maximum 4.25 degrees to minimum 1.75 degrees. Energy saving by 1 degrees low temperature increase 5% resulting in energy saving. Our result show that 8.5% to 21.5% energy saving. Difference in average temperature in both experiments is significant, considering the previous building, Eastgate Centre in Zimbabwe, had a 10% difference in total5.

The difference energy saving lies in the similarity in structure between our smart farm and zimbabwe's Eastgate centre our smart farm more similar to termite nest.

Through the research, this bio-inspired structure was found to be suitable for energy conservation in smart farms.

And the heat dissipation effect of the roof was excellent. Top side ventilation effects figured out from figure 2 in this experiments, average temperature difference between with roof and with out roof are 6.75 degrees its 17% difference are very critical to smart farm.

Therefore, our building can be applied to address the food shortage and lack of energy problem in Africa. Thus, applying the termite nest design to vertical or urban farming is a necessary approach to the standard of good architecture, which, now more than ever, must address its energy expenditure.

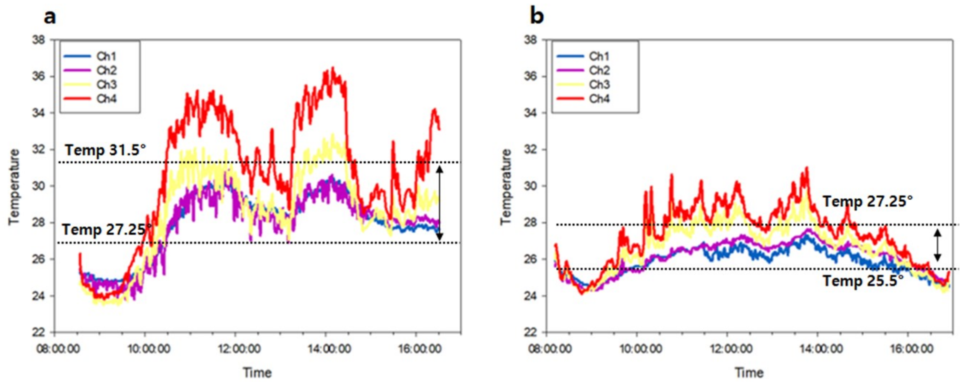

Fig. 3 (a) High temperature day and (b) low temperature day. Ch 1 on the thermometer is for the bottom portion of the open roof, Ch 2 for the top portion of the open roof, Ch 3 for the bottom of the closed roof, and Ch 4 for the top of the closed roof.

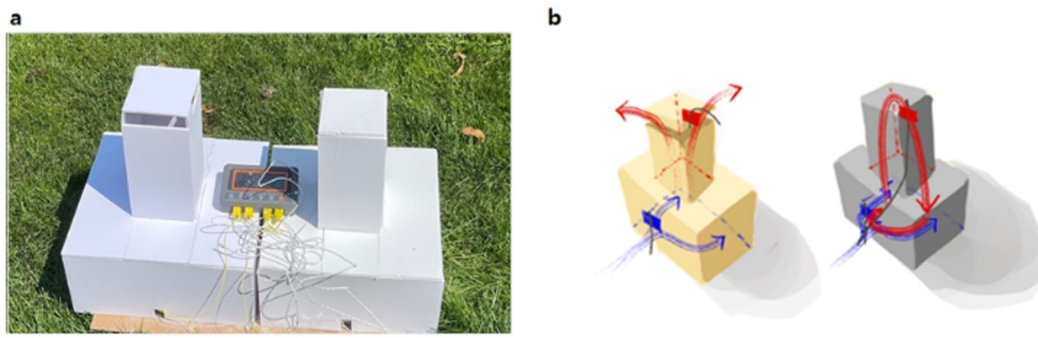

Fig. 4 (a) Smart farm structures left side one is open roof and right side is closed roof. (b) Air circulation of smart fam structure between open roof and closed roof.

Methods

In Figure 4, two thermometer channels are placed each inside the two buildings to measure the internal temperature of the upper and lower body of the building. Both buildings are placed outdoors without any shadows to test the buildings under normal conditions and minimize the possible variables.

In the experiment, clay was applied as the material since clay has the most similar heat insulation properties to concrete, one of the most widely used construction materials, while hardboard was used for a second building to confirm that warming effect of materials[5].

The expectation was that left building would have better ventilation as it is designed for better circulation of hot air and cold air through the interaction between the hole in the bottom and the space in the roof.

This illustrates the nature of the termite nests, in which the lower body stores lower temperatures and moves the higher temperature to its higher body[6].

Temperature data are collected from digital thermometer, it recording temperature at every minute. And use sigma plot programs for plotting a temperature to time graph. So we can calculate average temperature and temperature variation during experimental time.

Conclusion

In the future our work important to internet of things smart farms[7,8]. Because of IOT bases smart farm will use many energy. Energy efficiency issue should be solved. So our bio-inspired smart farm reduce internal temperature almost 6 to 7degrees and maintain stable temperature. There are two strong point of our work. First smart farm's energy efficiency related to the cost of smart farm's operation. Second stable temperature also important to low maintenance cost[9]. Global boiling is hot keyword of earth. Cost for air conditioning will be increased more and more. So passive temperature saving system by bio-inspired design will be important in near future. This research need more compact design for increase energy saving efficiency. FDTD simulation for heat efficiency will be needed, and deep learning will be useful for find a highly efficient smart farm shape or materials. More development of our work will be affect to smart farm industry.

Acknowledgements

Thanks to my dad for providing me an additional knowledge.

References

1 I. Wallies, L. Bilan, M. Smith and A. Kazi, *Industrialised, Integrated, Intelligent Sustainable Construction*.

2 J. Korb, *Naturwissenschaften*, **90**, 212–219.

3 L. Johnston and D., *Retrieved*, 80–85.

4 J. Darlington, *International Journal of Tropical Insect Science*, 149–156.

5 S. Mousavi, C. Bhojaraju and C. Ouellet-Plamondon, *A Review. Construction Materials*, 134–168.

6 E. Osilla, J. Marsidi, K. Shumway and S. Sharmas, *StatPearls*.

7 J. Doshi, *Procedia Computer Science*, **160**, 746–751.

8 C. B, *IEEE Internet of Things Magazine*, 14–19.

9 K. Chua, *Applied Energy*, **104**, 87–104.

