Bio-Inspired Light-Redirecting Window Blinds from Banana Pseudostem for Optimised Daylighting and Energy Efficiency

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Abstract

Efficient daylighting is a critical aspect of sustainable building design, yet conventional window blinds often compromise natural light distribution. Inspired by the fibrous structure of banana (Musa spp.) pseudostems, this study proposes a bio-inspired light-redirecting window blind concept that aims to optimise indoor illumination while reducing glare and energy consumption. The proposed blind design uses extracted banana pseudostem fibres formed into thin, semi-transparent slats, leveraging the natural fibrous microstructure of the pseudostem to diffuse and redirect incoming daylight. Based on the structural and optical properties of the material, the design anticipates improved light diffusion and a projected reduction in reliance on artificial lighting, creating adaptive, energy-efficient environments in both residential and commercial buildings. This paper presents the conceptual framework and prototype design, with empirical testing recommended as the next phase of investigation.

Keywords: Biomimicry; Sustainable Architecture; Banana Plant; Light-Redirecting Blind; Daylighting; Energy Efficiency

1. Introduction

Contemporary architectural design increasingly prioritises sustainable solutions, necessitating innovative approaches to building components that enhance both environmental performance and occupant well-being (Badarnah, 2017). The integration of bio-inspired materials, such as banana pseudostems, could enhance both daylighting and energy efficiency in architectural design. The growing concern over energy consumption and its environmental impact has prompted a renewed interest in architectural design strategies that prioritise sustainability.

One way to save energy is to use natural light more and artificial light less. This can be done by making buildings that let in more sunlight. Some people are looking into using special materials, like the stems of banana plants, to make blinds for windows. These blinds can help spread sunlight around a room and reduce the need for electric lights, which can save energy.

Using banana pseudostems to make window blinds is a great idea. These stems have special properties that help redirect light, which can be really useful. Not only can they help with lighting, but they can also add to the look and feel of a building. This study wants to explore how we can use these natural materials to create better, more sustainable buildings. By combining nature-inspired ideas with modern architecture, we can create a more eco-friendly future for buildings. The goal is to find new ways to design buildings that are good for the environment and also look great. Banana pseudostems can help us do that. They can make our buildings more energy-efficient and reduce our need for artificial lighting. This is just one example of how we can use natural materials to create better buildings. By looking to nature for inspiration, we can come up with new and innovative solutions to old problems. This can help us create a more sustainable future for everyone.

2. Literature Review

The integration of biomimetic principles — drawing inspiration from natural structures and processes — has emerged as a promising avenue for developing sustainable building solutions, particularly in the realm of dynamic building envelopes and daylight management (Hosseini et al., 2021). This approach leverages nature's refined strategies for adaptability and resource efficiency, offering significant potential for advancements in responsive building systems (Abdollahi Rizi et al., 2023). Specifically, bio-inspired designs can lead to novel shading systems that dynamically interact with environmental conditions, optimising light and temperature regulation within structures.

For example, buildings can use special walls that change shape to control the amount of sunlight that comes in. These walls, called biomimetic kinetic façades, can be simple or complicated, but they all try to make the inside of the building more comfortable by adjusting to the sunlight in real-time. However, the problem is that these walls are often very expensive and hard to maintain, which means they are usually only used in very special buildings. This is why we need to find cheaper and simpler ways to control the sunlight, using ideas from nature, so that all kinds of buildings can use them. This would make it possible for more buildings to have adaptive shading without needing complicated mechanical systems.

We need to find better ways to control light and heat in buildings without using a lot of energy. Many systems that try to do this either use a lot of energy themselves or block too much natural light. This is a problem because it means we're not being as sustainable as we could be. We should look to nature for inspiration and create materials that can manage light and heat on their own, without needing a lot of energy. For example, plants are able to move and change in response to their environment, and we could create materials that do the same thing. This kind of technology could help make buildings more sustainable and reduce our reliance on energy-intensive systems. Researchers like Khosromanesh and Asefi are already working on this, and their findings from 2022 show promise for creating smarter, more responsive materials that can help us build more sustainable buildings. By studying how plants and other natural systems work, we can create new materials and structures that are better for the environment and use less energy. This is an exciting area of research that could lead to big improvements in building sustainability.

The banana plant is really interesting when it comes to finding new ideas from nature. Its pseudostem, which is like a fake trunk made from lots of tightly packed leaves, has a special layered structure that helps filter and redirect light. If you look at Figure 1, you can see how the banana plant is put together, with the pseudostem being a key part of it - this is what inspired the idea for a new kind of blind system. The way the leaves are packed together in the pseudostem is pretty unique, and it's this that gives the plant its special light-filtering abilities. By studying how the banana plant works, we can get a better understanding of how to create new systems that do similar things, like controlling the amount of light that gets through. This is a great example of how nature can inspire new ideas and solutions.

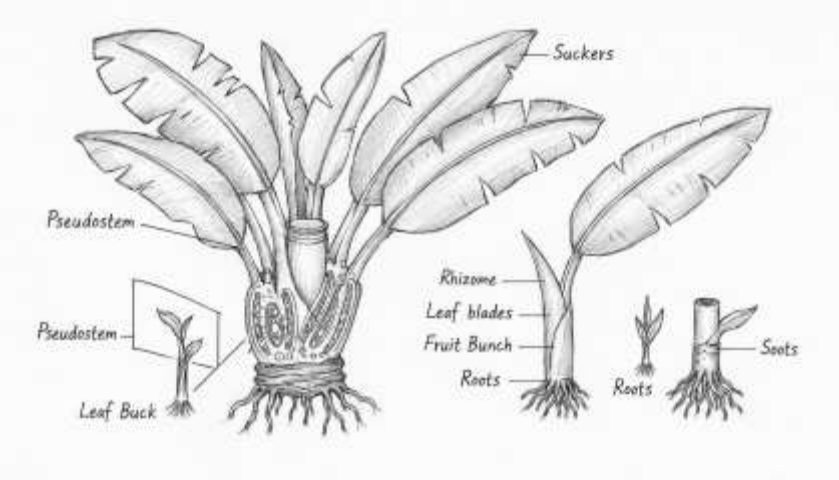

Figure 1: Annotated botanical sketch of Musa spp. (banana plant), showing the pseudostem, rhizome, leaf blades, and root system.

The integration of bio-inspired materials in architectural design has garnered significant attention as a means to enhance sustainability and energy efficiency. In particular, the use of natural resources such as banana pseudostems presents a promising avenue for optimising daylighting and reducing energy consumption in buildings. As global energy demands rise and concerns over environmental impacts intensify, architects and designers are increasingly seeking innovative solutions that prioritise natural light utilisation and minimise dependence on artificial lighting.

This research looks into using banana pseudostems in a new way - to make window blinds that can redirect light. The idea is to use the special structure of the pseudostems to make the most of natural daylight inside buildings, while also saving energy. By combining ideas from nature with modern building techniques, this study aims to help create sustainable solutions for buildings that are both functional and good for the environment. The goal is to find new ways to design buildings that work well and don't harm the planet.

Using ideas from nature, like the banana plant, can help us make buildings that are better for the environment and use less energy. This approach to design also fits with the bigger idea of sustainable architecture, which is about making sure that the way we live and build doesn't harm the natural world. By studying the structure of banana pseudostems, we can create shading systems that move and change to control how much light and heat get into a building. This can help us use energy more efficiently and make the people inside the building more comfortable. It's a way to balance our need for comfortable living spaces with the need to protect the planet.

Using natural materials like banana pseudostems in buildings can do a lot of good. It can help bring in more daylight and make the building more energy efficient. But that's not all - it can also make the people inside the building feel better. Studies have shown that being around natural light can improve your mood, help you get more work done, and even make you healthier. So, using these kinds of materials is not just a cool new idea for buildings, it's also a way to make sure the people inside are happy and healthy. The construction industry is under a lot of pressure to reduce its impact on the environment, and using renewable resources like banana pseudostems is a big step in the right direction. It's a way to build things that are good for the Earth and don't waste a lot of resources. This is especially important now, as we need to find ways to build sustainably and reduce our carbon footprint.

3. Descriptive Analysis

Making the blinds involved taking fibres from the banana pseudostem and turning them into thin, see-through pieces. These pieces kept the natural fibre structure that helps redirect light. The pieces were lined up side by side to copy the layered look of the pseudostem, which helped spread light evenly and reduce glare. This way of making the blinds made them easy to put up and kept them transparent, so lots of daylight could get through.

This research shows that blinds inspired by nature can really make a difference in how light is used, making the air inside buildings better and using less energy. When you add smart sensors, they can adjust automatically, which is what modern smart buildings are all about. If you look at Figure 2, you can see what the prototype looks like, including the special material used for the slats, how it redirects sunlight, and what it looks like when it's installed in a room. The blinds are designed to work dynamically, which means they can change how they redirect light based on the time of day and the amount of sunlight coming in. This can really help reduce energy consumption and make the inside of buildings more comfortable. By using natural materials and smart technology, these blinds are a great example of how we can use innovation to make our buildings more efficient and better for the environment.

Figure 2: Prototype concept for the Banana Fibre Light-Redirecting Window Blind — showing processed pseudostem slat material (left), sectional diagram of sunlight redirection mechanism (centre), and interior render of installed blind (right). Model and rendering by the author.

More research is needed to see how we can make this work on a big scale, how well it lasts in different weather conditions, and how we can use it with other ways to design buildings that use sunlight. One thing that's really promising is using fibres from banana plants, which are cheap and light, and can be found in many tropical places like Nigeria. This could make it possible for people to use this technology in their homes and offices without spending too much money.

4. Conclusion

Banana pseudostem-inspired window blinds provide a sustainable solution for daylight management in buildings. The bio-inspired design improves light distribution, reduces artificial

lighting needs, and aligns with eco-friendly architectural practices. Coupled with smart sensor systems, these blinds can contribute to energy-efficient and comfortable indoor environments, demonstrating the potential of biomimicry for practical, nature-inspired architectural innovations.

This research outlines a theoretical approach rather than a hands-on experiment. The expected advantages, such as better light distribution and less need for artificial lighting, are based on the known optical and structural properties of banana pseudostem fibers and match the results found in similar studies on bio-inspired passive shading. The way the pseudostem's layered fibrous structure redirects diffuse daylight is similar to how other natural systems manage light, which supports the idea of using local, renewable materials in sustainable building design. To confirm and improve the proposed design, it's recommended to do empirical testing under controlled sunlight, assess long-term durability, and create quantitative energy performance models. These steps will help validate the concept and make it more practical. By exploring the potential of natural materials like banana pseudostem fibers, we can create more sustainable and efficient architectural designs that work in harmony with the environment.

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