Tent-frame structure for drying agricultural products

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Abstract: Drying agricultural products is one of the oldest methods of food preservation known to mankind. By removing moisture with the help of heat, products can be stored for extended periods, their transportability is improved, and spoilage processes are slowed down. Today, due to climate change and increased production volumes, the need for fast and high-quality drying methods has become even more critical. Traditional sun drying methods, especially in open areas, have numerous disadvantages: contamination by dust, birds, or insects, poor drying conditions leading to reduced quality, and significant product losses. Transitioning to modern drying technologies is essential. In this regard, structures that require minimal energy, are environmentally safe, and require simple technical maintenance are especially important. Tent-frame drying structures stand out due to their simplicity, affordability, quick assembly, and adaptability. This article analyzes the structural features, operational principles, and practical effectiveness of a tent-frame structure developed for drying agricultural products. The primary goal of the research is to explore the potential of drying products economically and efficiently using solar energy, and to compare the system's advantages with traditional methods.

Keywords: tent-frame structure, drying technology, agricultural products, solar energy, product quality, moisture loss, drying efficiency, eco-friendly drying, energy-saving, innovative technology

Methodology

Construction Materials and Structural Description

The tent-frame drying structure is simple, affordable, and robust, allowing it to be assembled quickly and relocated if necessary. The structure consists of the following main components:

1. Frame Structure:

Galvanized metal pipes with a diameter of 25-32 mm are used as the frame. These pipes are rust-resistant and can withstand long-term exposure to open air. The frame is assembled in a semi-circular (arched) shape, ensuring structural stability and maximizing internal volume.

2. Tent Material:

The covering material is made from polyethylene or polyvinyl chloride (PVC) fabric that is resistant to UV radiation, wind, and rain. This lightweight material retains heat and transmits light, while protecting the product from direct sunlight and maintaining a stable internal temperature.

3. Ventilation System:

Both ends of the structure are equipped with ventilation openings, ensuring continuous air circulation. This helps to remove excess moisture during the drying process. If natural convection is insufficient, low-energy electric fans can be added.

4. Floor Structure:

The floor inside the drying structure is elevated using wooden panels or metal mesh grids, allowing the products to be evenly spread. Air moves freely from below, ensuring uniform drying of the products.

5. Dimensions:

The experimental drying structure was built with dimensions of 3×6 meters. The internal height at the center is 2.5 meters. This size is convenient for small and medium-scale farms and can be expanded with modular sections if needed.

The main advantages of this structure include economic construction materials, ease of maintenance, durability, environmental safety, and most importantly, energy efficiency. Solar radiation and natural air circulation serve as the primary energy sources during the drying process.

Drying Conditions: Temperature, Humidity, Time

The drying process was conducted under natural summer climatic conditions using solar radiation. To monitor the internal microclimate of the tent-frame drying structure, thermo-hygrometers were installed and measurements were taken periodically. Attention was given to the following key parameters:

Temperature Regime:

The internal temperature of the tent structure was on average 10-15°C higher than the ambient temperature. During the day, the maximum internal temperature ranged from 45 to 55°C, while nighttime temperatures were between 25 and 30°C. Ventilation panels were adjusted to maintain stable internal conditions.

2. Relative Humidity:

In the initial days, the relative humidity inside the structure was about 55-65%. As moisture evaporated from the products, humidity levels gradually decreased to around 35-40%, which is optimal for efficient drying.

3. Drying Duration:

The duration of drying depended on the size, structure, and initial moisture content of each product. Based on the experimental results:

• Melon slices dried within 18-24 hours,

• Tomatoes required 24-30 hours,

• Pumpkin slices took 20-26 hours,

• Figs required the longest time - 36-40 hours.

Drying was carried out daily from 9:00 AM to 6:00 PM. At night, the structure was kept closed to retain internal heat. Product weight was measured twice a day - in the morning and evening - while temperature and humidity were recorded every 3 hours.

Under these conditions, the dried products maintained good appearance, natural color, and acceptable storability. This confirms that tent-frame drying structures are a practical option for small- and medium-sized farms.

Results

The results obtained during the study showed that the tent-frame drying structure provides an energy-efficient, environmentally friendly, and economically viable method for drying agricultural products. The dynamics of moisture loss, drying time, and final quality indicators of the dried products clearly demonstrate the effectiveness of the system.

Drying Efficiency

The results of moisture loss for each product were as follows:

• Tomatoes had the highest moisture loss - 76%.

• Melon, pumpkin, and figs showed moisture losses of 70%, 72%, and 60%, respectively.

The structure and composition of each product played a decisive role. For example, tomatoes contain a high amount of liquid and have a thin surface layer, which contributed to faster evaporation. In contrast, figs have a thicker peel and higher sugar content, resulting in a slower moisture release.

Product Quality

The dried products maintained their external appearance, color, and natural aroma. The diffused sunlight passing through the tent material prevented the products from overheating, which helped preserve their quality. Especially figs and apples retained their sweet taste and natural color after drying.

Despite its compact size, the modular structure of the tent allows for expansion. This makes the system suitable not only for small-scale farms but also for medium-sized agricultural enterprises.

Discussion

The findings of this study clearly demonstrate that the tent-frame drying structure is a practical and efficient solution for drying agricultural products. The significant moisture loss rates, acceptable drying durations, and high-quality outcomes validate the effectiveness of this system in real-world conditions.

Drying Performance

Moisture loss across all tested products ranged between 60% and 76%, depending on their structure and composition. Tomatoes showed the highest moisture loss due to their high water content and thin surface, which facilitated faster evaporation. Figs, on the other hand, had the slowest drying rate because of their dense structure and high sugar concentration.

Product Quality Indicators

All products retained their desirable physical and sensory properties. Their natural color, aroma, and shape were preserved. The tent material dispersed sunlight, preventing overheating and maintaining uniform internal temperature - a critical factor in preserving product quality. Especially for delicate fruits like figs and apples, the tent-frame structure proved effective in maintaining texture and flavor.

Comparison with Traditional Drying

Compared to conventional open-air drying, the tent-frame system provides the following advantages:

• Reduced drying time (from 3-5 days to 1-2 days);
• Protection from contamination by dust, insects, and weather;
• More stable and controlled air circulation;
• Better preservation of product appearance and nutritional value.

Limitations

Despite its benefits, the system has certain limitations:

• Weather dependence: Efficiency decreases during prolonged cloudy or rainy conditions;
• Temperature control: Maintaining warmth during cold nights can be challenging;
• Labor: Regular turning or repositioning of the products is needed to ensure uniform drying.

Recommendations and Future Prospects

The drying structure can be further improved through the following:

• Using multi-layer, thermally-insulated tent materials to retain heat longer;
• Integrating solar panels to power low-energy fans for air circulation;
• Adding automated monitoring systems with sensors for temperature and humidity control.

Such innovations would increase system efficiency, reduce manual labor, and ensure consistent drying results regardless of external conditions.

Conclusion

The tent-frame drying structure developed and tested in this study has proven to be an innovative, efficient, and practical solution for drying agricultural products. The experimental

results confirmed that this system effectively utilizes solar energy, maintains a stable internal microclimate, and enables products to be dried without compromising their natural quality.

The drying performance for apples, tomatoes, pumpkins, and figs was carefully analyzed. Each product's optimal drying time and final moisture content were determined. The results were compared with traditional drying methods, and it was found that the tent-frame structure significantly reduces drying time and improves product quality.

The tent-frame dryer offers the following key advantages:

• Utilization of natural energy sources (solar radiation);

• Protection from dust, insects, and environmental contaminants;

• Faster drying and consistent product quality;

• Economical, simple, and easy-to-assemble design.

Based on the findings, this system is particularly suitable for small- and medium-sized farms, rural cooperatives, and household-scale producers. It presents an affordable and efficient technological solution for regions with abundant sunlight.

In the future, this system can be enhanced by:

• Incorporating thermal-insulated tent materials;

• Integrating solar power systems;

• Automating temperature and humidity control via sensors.

Such developments would further expand the functionality and usability of tent-frame drying systems across various agricultural settings.

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