

Automatic Thermal-Controlled Dryer Machine Integrated with Uninterruptible Power Supply for Commercial Carrot Snack Production

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Abstract: In response to the growing demand for efficient local food preservation technologies, an automatic thermal-controlled drying machine integrated with an Uninterruptible Power Supply (UPS) was developed to improve the production quality of commercial dried carrot snacks in Cavite City. This study focuses on the development of a prototype that automates flavor application, regulates drying temperature, stabilizes moisture removal, and sustains operation during power interruptions. Utilizing a qualitative development research design, the study involved iterative prototyping, observational assessments, and expert evaluation to refine the machine's features and determine its practical applicability in small-scale food processing. A qualitative development research design to develop and assess a thermal-controlled drying system for the nutrient preservation of carrot snack chips. The effectiveness of the system will be assessed using observational data as well as semi-structured interviews with a few specific users which are vegetable sellers and consumers in Cavite City, Cavite. Initial data was collected through interviews conducted by the researchers in Cavite City where vegetable vendors and consumers routinely buy and/or sell fresh carrots. In order to assess current issues in postharvest carrot handling, a preliminary interview took place with 28 respondents, consisting of vendors/consumers in Cavite City. The findings revealed that the prototype effectively minimized spoilage, with an average rate of 7.1%, and maintained moisture content at 13.6%, which is within the acceptable standard ($\leq 15\%$). The drying process preserved such as color, texture, flavor, and aroma, indicating good nutrient retention. Additionally, the integrated UPS ensured continuous and stable operation during power interruptions, improving overall efficiency and reliability. These results confirm that the prototype enhances shelf life, reduces losses, and demonstrates strong potential for practical and commercial application. In response to the increasing demand for efficient agricultural processing technologies in the Philippines, several challenges continue to affect the quality, consistency, and shelf life of dried food products such as baby carrot snacks. Findings from this research indicate that incorporating temperature control with uninterruptible power sources increases drying reliability, particularly in regions with fluctuating power. Automating various aspects of the production process supports improved efficiency and decreased reliance on human input, improving the consistency of produced goods.

Keywords: Drying Machine, Moisture Reduction, UPS Integration, Thermal Control, Conveyor System, Flavoring Automation, Carrot Snack Prototype.

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I. INTRODUCTION

Agriculture is a vital role of the Philippine economy, yet it constantly holds significant postharvest losses, particularly in perishable matter like baby carrots. These losses, often attributed to inadequate storage, inefficient process, and impoverished market access, severely impact food security, economic losses, and the livelihoods of smallholder farmers nationwide [1]. In Cavite—a highly urbanized province with rapidly decreasing agricultural land—these postharvest losses

are amplified by the conversion of farmlands into residential and commercial areas, especially impacting cities such as Cavite City where agricultural lands have largely reduced or decreased [2]. Cavite City with a total land area of roughly 1,183 hectares, currently has no designated agricultural land, thereby limiting traditional or conventional farming activities and preservation practices [2]. This scenario necessitates innovative approaches to preserve and add value to the agricultural produce sourced from nearby municipalities,

especially to support urban and rural farming communities and local markets.

Globally, literature has explored various processing techniques to develop value-added carrot snacks. For example, extrusion technology incorporating carrot pomace has been optimized to produce fiber-rich puffed snacks with appealing sensor properties. Other methods like infrared blanching, hot air drying, and frying have been utilized to create crispy, nutritious carrot chips, aligning with consumer preferences for texture and health benefits [3]. Additionally, vacuum frying has emerged as a promising technique for producing low-moisture, nutrient-preserving carrot chips with enhanced crispness and consumer appeal [4]. Microwave drying methods have been explored to produce carrot chips with efficient nutrient retention and texture suitability for snack consumption [5]. In addition to processing advances, digital transformation in carrot processing enables automation and real-time quality monitoring, optimizing throughput and reducing failures [6]. The growing consumer focus on health has pushed technological advancements to optimize carrot snack processing, aiming to retain nutrients, improve sensory qualities, and extend shelf life [7].

These studies emphasize that despite the ecological appeal of solar energy, DC systems provide more superior control, efficiency, and product quality in the processing of carrot snacks, making them a more effective choice for reliable commercial operations. This study aims to design, develop, and evaluate an automated controlled thermal dryer system using DC power supply with uninterruptible power supply (UPS) optimized for Cavite City local conditions, providing backup power and ensuring continuous operation. The study will assess drying efficiency, nutrient holding, and sensory qualities of direct current-dried baby carrot snacks and explore this system's commercialization potential to benefit local farmers, vendors and consumers. Additionally, it attempts to contribute to sustainable food preservation solutions responsible for Cavite City's unique agricultural land and economic environment.

This study is significant as it introduces a sustainable and practical innovation through the development of an automated system with controlled thermal drying specifically designed for carrot snack production in Cavite City. By providing a backup power and ensuring continuous operation during power interruptions, the technology aims to reduce postharvest losses and improve the quality of carrot products, contributing to environmental sustainability and economic empowerment.

- Agriculture extension workers. This can be used in results and technology from this study as part of their training modules, field demonstrations, and educational services. This will help them more effectively disseminate sustainable postharvest methods to rural communities and support farmers in adopting modern, environmentally friendly practices.
- Small-scale farmers. The use of the automated thermal-controlled drying system will help small-scale farmers reduce postharvest losses by allowing them to preserve

their carrot harvest efficiently. This enables farmers to extend the prolonging shelf life of their produce, increase the amount of salable snacks, and increase their income.

- Food vendors. This will assist vendors from this technology by being able to offer safer and longer-lasting carrot snacks to their customers. The improved product quality and extended shelf life may help vendors avoid losses from spoilage and meet consumer demands for improved health, and value-added snacks.
- Consumers. This will provide nourishing, safe, and locally produced dried carrot snacks through DC power supply. The technology helps ensure the snacks retain essential nourishment and remain safe for consumption over a longer period.
- Future Researchers. The output of this study will serve as a useful reference and guide for future researchers who wish to develop or enhance drying food preservation systems. The documented methods and results can aid further studies on renewable energy in agriculture and food technology.

This study focuses on the development and evaluation of an automatic thermal-controlled drying system integrated with uninterruptible power supply for carrot snack production in Cavite City. The research fills the design, fabrication, and testing of the thermal-controlled dryer, specifically examining its efficiency, drying rate, and ability to preserve the quality and food value of carrot slices. The study also considers the practical application of the thermal-controlled dryer for small-scale farmers, food vendors, and consumers within the local perspective. Data collection includes the measurement of moisture reduction, power interruption and sensory evaluation (taste, color, and texture) of the dried product. The implementation setting is within selected agricultural communities of Cavite City, with an emphasis on providing backup power and sustainable postharvest methods.

The study limits carrot slices as the primary agricultural product for drying and does not cover other root crops. The thermal-controlled drying system is designed for small to medium scale processing and may not be immediately applicable for large-scale and full-scale commercial operations. The UPS capacity is limited to short-term power backup; prolonged outages beyond the UPS capacity. Economic feasibility and long-term durability of the prototype are assessed under controlled testing conditions and may differ in actual widespread use. This study does not include distribution logistics, or in-depth financial analysis beyond initial design and test phases.

II. METHODOLOGY

➤ Research Design

This study uses a qualitative development research design to develop and assess a thermal-controlled drying system for the nutrient preservation of carrot snack chips. The effectiveness of the system will be assessed using observational data as well as semi-structured interviews with a few specific users which are vegetable sellers and consumers in Cavite City, Cavite. The performance of the system will be evaluated with regard to drying effectiveness, consistency and

ease of use. The target testing conditions are a drying temperature of 50-70°C which is good for the long-term storage of dried vegetable products. The performance parameters for the system will be the accuracy of the system which will be determined by how well the system can maintain uniform internal drying conditions whereas effectiveness will be determined by the sensory qualities and uniformity of the dried carrot chips as determined by the consumers. These will provide the basis for further optimization of the prototype as well as indicate its practical suitability.

➤ *Sampling Technique*

This study applied primary and secondary data to support the creation and experimentation of the Automatic Thermal-Controlled Dryer Machine with an Uninterruptible Power Supply (UPS) for commercial carrot snack production. The primary data were obtained through semi-structured interviews from interviewed sampled carrot farmers, vegetable vendors, and small-scale food processors in Cavite City. These respondents were chosen based on their first-hand experience of postharvest handling, drying operations, and processing of carrot products. Interviews were instrumental in revealing practical realities of current storage issues, average losses during spoilage, and inefficiencies of traditional drying processes. Consumers were also interviewed to identify preferred attributes such as taste, texture, and color, which are crucial factors in the commercial success of carrot-based snacks. In addition to the interviews, there were also observations that were captured when the prototype being developed was implemented. Observations were on quantifiable items like drying time, consistency of temperature control, color and texture formation, moisture content elimination, retention of nutrients, and quality of the final product. The secondary data were obtained from credible sources like journals of academics, technical handbooks, institution reports, and publications of institutions like the Food and Agriculture Organization (FAO), Philippine Center for Postharvest Development and Mechanization (PHILMech), and Department of Agriculture (DA). Performance outcomes of how the UPS functioned, such as efficiency during periods of power outages and impact on uninterrupted drying operations, were also documented. The sources mentioned provided background information on postharvest losses, thermal drying technology, power reliability issues in food processing, and standards of dried foods. Through the integration of primary and secondary data, the research provided complete understanding of carrot postharvest problems in processing, technical efficiency of the constructed dryer, and its use to provide higher reliability and commercial feasibility of carrot snack making.

➤ *Research Instrument*

This study applied technical equipment and interview equipment to evaluate the efficiency of the Automatic Thermal-Controlled Dryer Machine with an Uninterruptible Power Supply (UPS) for handling carrot spoilage, drying efficiency, sensory attributes, and operational reliability. Initial visits to vegetable vendors, small-scale processors, and carrot growers in Cavite City. The instrument consists of close-ended questionnaire such as multiple choice,

dichotomous, and checkboxes given to respondents to evaluate specific criteria such as thermal control efficiency, drying consistency, ease of use, sensory attributes, and reliability of the Uninterruptible Power Supply (UPS) during operation. Additional open-ended questionnaire items were included to measure user satisfaction and overall system effectiveness.

Furthermore, Real-Time Clock (RTC) module were utilized to gather quantitative data including moisture reduction, temperature accuracy, and drying time. The UPS performance was also assessed through simulated power interruption tests to evaluate system continuity

➤ *Data Gathering*

Initial data was collected through interviews conducted by the researchers in Cavite City where vegetable vendors and consumers routinely buy and/or sell fresh carrots. The location was chosen based on the goals of the study and Statement of the Problem (i.e., postharvest carrot wasting, lack of preservation options available to urban and peri-urban communities, etc.) that directs the study, and service. The interviews helped identify key preservation criteria for the study, including anticipated shelf life, market acceptability for dried forms of snack, providing backup power and sensory quality attributes important to users.

Although the prototype will be finished before its final assembling, another round of data collection will include the applicable performance testing of the system (i.e., non-fresh to snacking carrot transformation), and a follow-up interview with vegetable vendors and consumers in Cavite City. The output snacks were assessed using measurable criteria: 1) consistency of drying temperature 2) drying time (using RTC), 3) compliance with the blanching process (using a thermometer), and 4) shelf life. 5) providing backup power and ensuring a continuous process using UPS (Uninterruptible Power Supply). Effectiveness will be defined and assessed in both references to published benchmark values, and its sensory performance with participating users. This approach helps guarantee that the preserved performance of the system is evaluated both technically and from a user perspective in two-stages of data collection.

➤ *Data Analysis*

The data gathered in this study were analyzed using descriptive statistics. It was analyzed using the mean (average) to summarize and interpret the results based on the performance. The average was used to determine the overall performance of the developed system in terms of drying efficiency, moisture reduction, sensory quality and UPS reliability. The responses obtained from the close-ended questionnaire and technical measurements were computed using the mean to represent the general evaluation of the respondents and the system's performance.

For each variable, the computed averages were then used to identify whether the system met the desired criteria, such as achieving moisture content below 15%, maintaining consistent drying temperature, and ensuring continuous operation during power interruptions.

The use of the mean (average) is appropriate in this study because it provides a clear and simplified representation of multiple responses and measurements, allowing for easier comparison and interpretation of results. It helps in determining the overall trend and effectiveness of the system rather than focusing on individual variations, making it suitable for evaluating the general acceptability and performance of the prototype.

III. RESULTS AND DISCUSSION

This section of the study outlines the outcomes and results after the development and testing of the prototype, providing an answer to the statement of the problem.

Table 1 Spoilage Rate of the Dryer Machine

Trial	Start Weight (g)	Spoiled Weight (g)	Spoilage Rate (%)
1	455	28	6.1%
2	495	32	6.5%
3	480	38	7.9%
4	510	36	7.1%
5	500	40	8.0%
AVERAGE			7.1%

Sources: Primary Data, 2025

The table illustrate that carrots kept in regular storage were spoiled at rates greater than 16-22% (average 19%), however, carrots which were processed using the drying machine had a low spoilage rate of 6-8% (average 7%). This is an approximately 63% decrease in spoilage and supports the use of a drying machine as an effective way to slow down microbe growth and moisture-related damage to crops. Because both sets had similar initial weight at the beginning of the experiment, it is a valid comparison, demonstrating that the use of drying will greatly improve shelf-life and ultimately decrease loss over time as well as provide other advantages regarding how you handle product after you have harvested it.

➤ Moisture Content

The percentage of moisture content was determined according to the AOAC standard wet-basis calculation, a method that has been used for many years in food sciences and in the field of postharvest engineering as a means of evaluating the effectiveness of drying systems. It represents the amount of moisture removed from a sample as a percentage of the original weight of the sample, thereby providing a straightforward way to assess the efficacy of any fruit or vegetable drying system.

Table 2 Moisture Content of the Dryer Machine

Trial	Initial Moisture (%)	Final Moisture (%)	Drying Time (hrs)
1	450 g	385 g	14.4%
2	500 g	430 g	14.0%
3	490 g	425 g	13.3%
4	505 g	440 g	12.9%
5	515 g	445 g	13.6%
AVERAGE			75 g

Sources: Primary Data, 2025

The Automatic Thermal-Controlled Dryer reduced the moisture content of carrots from 13.0% to 14.4% on average, indicating that the dryer is effective in providing consistent drying that is within the acceptable range of moisture content ($\leq 15\%$). Because of the reduction in moisture content of the carrot products, their shelf life was greatly improved from 100% to 120% longer than that of fresh carrots (with ambient

conditions lasting for 5–7) to prototype-dried carrots (which lasted for 12–16). These findings indicate that this dryer is capable of greatly reducing the amount of moisture present within carrot products and effectively preventing spoilage of carrots, thereby providing a very reliable means of preserving the freshness of carrots.

Table 3 Nutrient Retention of the Dryer Machine (before and after)

Nutrient	Observation Before Drying	Observation After Drying	Retention
Color (β -carotene)	Bright oranges	Bright orange, uniform	Maintained
Texture (Fiber)	Firm, crips	Slightly form, no mushiness	Maintained
Flavor (Vitamins)	Fresh, sweet	Fresh, mild sweetness preserved	Maintained
Aroma	Characteristic carrot smell	Aroma preserved, no burnt door	Maintained
Moisture Level	High, prone to spoilage	Reduced $\leq 15\%$, state	Improved

Sources: Primary Data, 2025

During the dehydration and storage of these snacks, bright orange colour, firm texture and characteristic carrot flavour were maintained which indicates that the products have retained their nutrients through these processes while achieving a significant reduction in moisture content. Therefore, since the successful achievement of an effective

nutritional retention and an effective drying process demonstrates that this system can produce a commercially viable and healthy snack product even when laboratory analysis has not been performed on the nutrient composition of carrots.

Table 4 UPS Reliability Test Results

Trial	Condition	UPS Runtime (min)	System Status
1	Sudden Power Cut	10	Fully Operational
2	Voltage Flunctation	12	No System Interruptions
3	Brownout Simulation	8	Control System Stable
AVERAGE	10.3 minute		Stable

Testing on the UPS have shown that the unit performed optimally and provided continuous drying of the prototype unit when providing power during test interruptions, such as power outage, voltage fluctuations and periods of limited electrical supply. The UPS performed with a mean run time of 10.3 minutes, providing the drying system with a continued operational time and maintaining a stable control system for the duration of the test trials performed. The drying time was 5.3 hours with an energy consumption of 1.6 kWh; therefore, the efficiency of 113% was 13% greater. These results indicate that the UPS, when interfaced with the drying system, allows for continuous and uninterrupted drying processes during electrical interruptions, and provides quicker and more energy efficient drying of materials and results in improved performance and overall productivity of the drying machine.

IV. SUMMARY

In response to the increasing demand for efficient agricultural processing technologies in the Philippines, several challenges continue to affect the quality, consistency, and shelf life of dried food products such as baby carrot snacks. These challenges include irregular heating, inconsistent drying times, and interruptions caused by unstable electrical supply. To address these issues, the researchers created the automatic dryer machine with UPS. Through Combining mechanical fabrication and programming, the automatic dryer machine can time the boiling, coordinate motor actions of conveyor and the cutting through consistent timing, while maintaining stable performance even in fluctuation in the power supply. With these innovations, not only will it improve the product quality, but also improve the efficiency in making the dried carrot snacks.

Equipped with an automated flavoring mechanism for salt and cheese variants, dual conveyor transport, and a controlled heating chamber, the machine ensures uniform moisture reduction and consistent product output. The UPS integration prevents sudden shutdowns during power outages, allowing the system to maintain workflow and protect the product from under-drying or contamination. Through qualitative development methods, expert evaluation, and repeated testing, the prototype demonstrated its capability to produce dried carrot snacks with reduced spoilage rate, improved texture consistency, and stable processing conditions. Observations gathered during trials indicate that the automated system performs more reliably than traditional

manual drying, particularly in maintaining temperature and reducing human error.

Feedback collected from engineers and food processing practitioners showed strong acceptance of the prototype's functionality, usability, and reliability, indicating its potential for adoption in small business settings. The integration of automation significantly reduced labor-intensive tasks, while the controlled heating system enhanced product uniformity. The flavoring mechanism also provided an efficient method for applying seasonings, improving the overall market appeal of the final product.

In conclusion, findings from this research indicate that incorporating temperature control with uninterruptible power sources increases drying reliability, particularly in regions with fluctuating power. Automating various aspects of the production process supports improved efficiency and decreased reliance on human input, improving the consistency of produced goods. There is still room for enhancement on some components of the design, but current performance indicates that the prototype can be developed into a practical and productive option for carrot snack producers at the commercial level. This project serves as a starting point for developing future technologies related to local food processing.

RECOMMENDATION

After conducting the study, the researchers provide several recommendations to further improve the development and performance of the prototype.

- *Expand the Capacity of Drying Station:* At its current capacity, the prototype can handle only a limited volume of carrot slices per batch. Increasing the size of the conveyors, extending the drying bed, or adding multi-layer trays would significantly improve productivity. A larger capacity would make the machine more suitable for commercial-scale production, allowing more efficient processing of bigger batches.
- *Develop Mobile Application Interface:* To enhance the ease of use and ability to observe from afar, mobile application developers in the future can develop that connects the machine through WiFi or Bluetooth. Allowing users to see their drying on the phone while

adjusting settings remotely, and receiving information on when processes are complete and machine errors. Making it possible for technology to lessen the amount of time workers need to be on-site to oversee processes.

- *Optimize the UPS Management System:* To improve the overall efficiency of the power system, the UPS is the key component ensuring that it provides a backup power source during outages. The use of UPS is to maximize the machine's operational time while running on a low power mode that includes the implementation of the essential components over the non-critical components.
- *Enhance the System's Thermal Performance:* To Improving thermal performance further is also recommended for the dryer through the implementation of new technologies for temperature measurements and controls. More advanced temperature measurement techniques such as thermocouples or digital probes can be integrated with an improved PID-style control system, enabling continuous temperature control during the entire steam drying process and ensuring that all carrot chips dry uniformly every time. By implementing this upgrade, the dryer will become more reliable for commercial use and have less variability in product quality between batches.
- *Optimize Conveyor and Motor Performance:* To enhance the overall drying workflow, future developers may refine the conveyor speed control, upgrade motors, or integrate adjustable-speed drivers. Improving the mechanical performance would reduce processing delays, improve slice movement, minimize jams, and ensure smoother operation throughout the drying cycle.

REFERENCES

- [1]. Srivastava, P. K., & Sit, N. (2024). A review on fruit and vegetable processing using traditional and novel methods. *Future Postharvest and Food*, 2(1), 4–26. <https://doi.org/10.1002/fpf2.12046>
- [2]. Cavite Provincial Government (2020). Comprehensive Economic Profile of Cavite (2020 Data). <https://cavite.gov.ph/home/wp-content/uploads/2020/01/cep2018-C4.pdf>
- [3]. Ding, H., & Liu, M. (2024). From root to seed: unearthing the potential of carrot processing and comprehensive utilization. *Food Science & Nutrition*, 12(11), 8762–8778. <https://doi.org/10.1002/fsn3.4542>
- [4]. Chen, J., Venkatasamy, C., Shen, Q., McHugh, T. H., Zhang, R., & Pan, Z. (2020). Development of healthy crispy carrot snacks using sequential infrared blanching and hot air drying method. *LWT*, 97, 469–475. <https://doi.org/10.1016/j.lwt.2018.07.026>
- [5]. De Mendonça, K. S., Corrêa, J. L. G., De Jesus Junqueira, J. R., De Carvalho, E. E. N., Silveira, P. G., & Uemura, J. H. S. (2023). Peruvian carrot chips obtained by microwave and microwave-vacuum drying. *LWT*, 187, 115346. <https://doi.org/10.1016/j.lwt.2023.115346>

- [6]. 360iResearch. (2025). Carrot Processing Market Size & Share 2025-2030. <https://www.360iresearch.com/library/intelligence/carrot-processing>
- [7]. Motegaonkar, S., Shankar, A., Tazeen, H., Gunjal, M., & Payyanad, S. (2024b). A comprehensive review on carrot (*Daucus carota* L.): the effect of different drying methods on nutritional properties and its processing as value-added foods. *Sustainable Food Technology*, 2(3), 667–688. <https://doi.org/10.1039/d3fb00162h>