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Experimental Determination of Guava Leaf Drying Technology

Nguyen Thanh Phong and Le Anh Duc*

Faculty of Engineering and Technology, Nong Lam University Ho Chi Minh City, Ho Chi Minh City, Vietnam

***Corresponding Author:** Le Anh Duc, Faculty of Engineering and Technology, Nong Lam University Ho Chi Minh City, Ho Chi Minh City, Vietnam.

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Abstract

Psidium guajava L., commonly known as guava, belongs to the Myrtle family and is cultivated in tropical and subtropical climates. Guava leaves have been used for medicinal purposes due to their numerous health benefits in several countries. This study presents the results of determining the drying methods and drying conditions for guava leaves through various techniques: the sun drying, shade, the hot air drying, the heat pump drying, and the vacuum drying. The drying methods were conducted at three temperature levels: 45°C, 50°C, and 55°C. Moisture reduction rate, tannin content, and sensory evaluation of the color and flavor of the dried guava leaves were the basis for selecting the appropriate drying method and conditions. The results identified heat pump drying at 45°C for 210 minutes as the most suitable method, producing dried guava leaves with a standard moisture content of 11 ± 0.5%. The dried guava leaves had a tannin content of 7.75%, with the characteristic color and aroma of guava leaves, making them suitable for processing into medicinal products such as guava leaf powder or tea. The equation predicting the moisture content of guava leaves over drying time during the drying process has been established.

Keywords: Guava leaves; heat pump dryer; Tannin; hot air drying; sun drying

Introduction

Research on the preservation of plants and plant parts for long-term food storage is currently receiving significant attention, as plants contain high medicinal value and offer numerous other benefits in daily life. Guava leaves, scientifically known as *Psidium guajava* L., belong to the evergreen Myrtle family [1]. Guava leaves emitted a pleasant aroma when crushed and originate from tropical and subtropical climates [2].

Guava leaves are also known as a traditional remedy with the ability to treat diarrhea, gastrointestinal diseases, cardiovascular conditions, and lower blood sugar levels in people with diabetes. Research officially recorded in the Dutch pharmacopoeia [3] indicates their use in treating diarrhea and viral-induced intestinal inflammation (rotaviral enteritis). Another study also demonstrated that extracts from guava leaves possess activity against Simian Rotavirus, which causes diarrhea. The inhibitory effect of guava leaf extract on the enzyme protein tyrosine phosphatase 1B (PTP1B) indicates its potential for treating type 2 diabetes [4]. According to Brazilian research, guava leaf extracts exhibit various activities on the cardiovascular system and are effective in treating arrhythmia [5].

For the purpose of long-term preservation and use in the pharmaceutical industry, drying guava leaves is a critical step in the overall preservation process, directly affecting the quality of the product. This process is also highly time-consuming and energy-intensive, making it essential to select an appropriate drying method that maintains high medicinal content, reduces energy costs during drying, and ensures effective product storage. Research to determine the optimal temperature and the most suitable drying method for each type of product is a crucial need in the drying and preservation of agricultural products, especially for those used as medicinal materials [6, 7].

Currently, guava leaves are dried using various methods available on the market, including natural sun drying, hot air drying, heat pump drying, heat pump combined with infrared drying, and vacuum drying. Each method has its own advantages and disadvantages; however, finding the most suitable method for producing dried guava leaves for medicinal use requires thorough research. Therefore, to enhance the quality of dried guava leaf products, increase the value and content of beneficial compounds, and reduce production costs, it is necessary to conduct research to determine the appropriate drying technology for guava leaves.

Materials and methodology

Materials

Freshly harvested guava leaves were cleaned and drained of water. The leaves were spread on drying trays with a material thickness of 35-40 mm. The initial relative moisture content of the guava leaves used in the experiments is 60.4 ± 1%, with the required moisture content after drying being 11 ± 0.5%. The moisture content of material is the wet basis.

Testing Equipment

The device name, origin, measurement range, and error of the measuring equipment during the experiment show in Table 1.

No.	***Name of equipment***	***Code***	***The name of country manufacture***	***Measuring range***	***Measurement error***
1.	Wet and dry bulb thermometer	74900-002-ca	France	0 ÷ 100°C	± 1°C
2.	S2202 BEL Engineering	AC015	Italy	0 ÷ 2200 g	± 0.01 g
3.	Digital Anemometer	MASTECH MS6252A	China	0.4 ÷ 30.0 m/s	± 3%
4.	Sample drying cabinet – WTC Binder	E28	Germany	60°C ÷ 230°C	± 3°C

Table 1: Technical data of the measuring equipment used in the test.

Drying experiments

Implemented five different drying methods: the vacuum drying (CK), the heat pump drying (BN), the forced convection hot air drying (KKN), the sun drying (PN) and shade (BR), used to dehumidify guava leaves at drying temperatures of 45, 50 and 55°C. The drying air velocity in the drying experiments was 0.57 m/s [8]. Vacuum pressure during drying is 25 mmHg. All dryers were designed and manufactured at the Faculty of Mechanical Engineering and Technology, Nong Lam University Ho Chi Minh. Samples were determined for moisture content each 30 minutes during drying process for the heat pump and the hot air convection, while samples were determined for moisture content each one and two hours during drying process in sun exposure and shade due to a much longer drying time. There is no sampling during the vacuum drying.

The drying time, the temperature of the drying agent and the moisture content of the dried samples are always monitored and measured throughout the drying process. The drying modes in each method were performed 3 times and averaged for the measured parameters.

To determine the appropriate drying technology, drying rate and product quality after drying are the basis for analysis and evaluation [9].

The experimental data were statistically processed according to the method of Least Significant Difference (LSD) [10].

Quality analyses
Moisture content

Loss of mass of drying samples during drying process was measured using an electronic balance. Moisture content was determined as percentage of moisture removal on weight basis [11].

Coloration and sensory testing

Green color, aroma and taste of dried *Guava leaves* were evaluated by sensory panelists.

Tannin content

The tannin content in the dried guava leaves was determined according to Vietnamese standard the AOAC 955.35 TCVN at Research Institute of Biotechnology and Environment (RIBE, Nong Lam University Ho Chi Minh City, Vietnam).

Results and discussion
Forced-hot air convection drying (KKN)

The moisture reduction process of the guava leaves during forced-hot air convection drying (KKN) at temperatures of 45°C, 50°C, and 55°C is illustrated in Figure 1. The results showed that the drying time ranges from 2.5 to 5 hours, depending on the drying temperature. The average moisture reduction rates and drying times for guava leaves at temperatures of 45°C, 50°C, and 55°C are 10.07%, 14.28%, and 20.06% per hour, and 5, 3.5, and 2.5 hours, respectively, as shown in Figure 2. The color of the guava leaves dried using KKN at the three different temperatures is depicted in Figure 3. Among the three drying temperatures, the leaves dried at 45°C have a visually appealing green color, slight warping, a crispy dryness, and better retained the characteristic aroma of guava leaves compared to those dried at the other two temperatures.

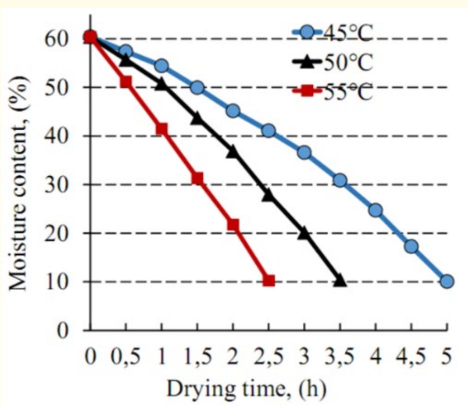

Figure 1: Effect of drying temperatures in forced-hot air convection drying on moisture content removal of the guava leaves.

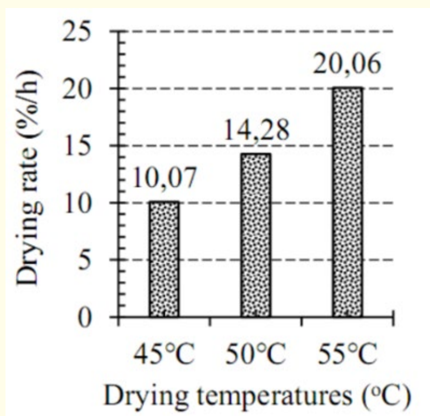

Figure 2: Moisture reduction chart of the guava leaves when dried using forced-hot air convection drying (KKN) at three different temperatures.

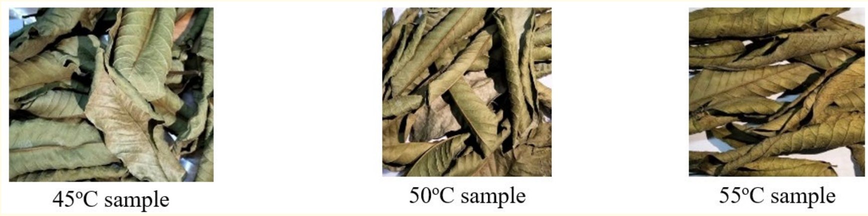

Figure 3: Color of the guava leaves after forced-hot air convection drying (KKN).

The heat pump drying (BN)

The moisture reduction process of guava leaves during BN drying at temperatures of 45°C, 50°C, and 55°C is shown in Figure 4. The results indicate that the drying time ranges from 1.7 to 3.5 hours, depending on the drying temperature. The average moisture reduction rates and drying times for guava leaves at temperatures of 45°C, 50°C, and 55°C are 14.33%, 18.41%, and 29.37% per hour, and 3.5, 2.7, and 1.7 hours, respectively, as illustrated in Figure 5. The color of the guava leaves dried using BN at the three different temperatures is displayed in Figure 7. Guava leaves dried using BN at these three temperatures exhibit more distinctive color and aroma compared to those dried using KKN.

According to sensory evaluation, among the three drying temperatures, guava leaves dried at 45°C maintain a deep green color, similar to their initial appearance, with moderate warping, crispy dryness, and retain the characteristic aroma of guava. However, sensory assessment indicates that the differences in color and flavor quality of the dried product at temperatures of 45°C, 50°C, and 55°C are not significant.

As shown in Figure 6, the guava leaves dried at 45°C have the highest tannin content at 7.75%, which is higher compared to the guava leaves dried at 50°C and 55°C, with tannin contents of 7.24% and 5.82%, respectively. This indicates that the 45°C sample has the highest tannin content among the three samples. It is observed that when the drying temperature exceeds 50°C, the tannin content of the dried product decreases significantly, which is consistent with the findings of Paula Jylhä [12].

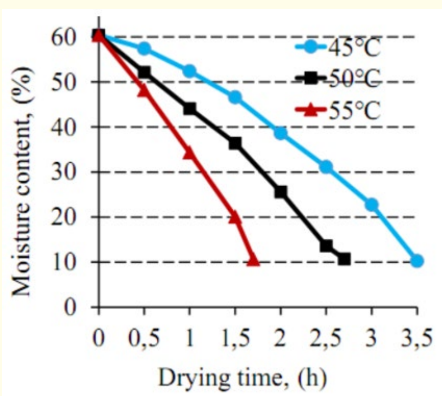

Figure 4: Effect of heat pump drying (BN) temperature on the moisture reduction process of the guava leaves.

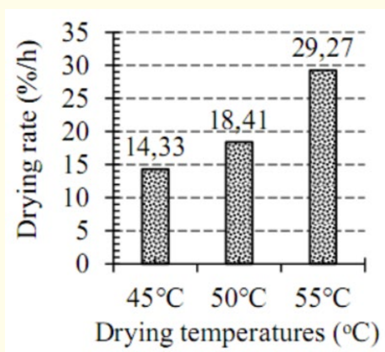

Figure 5: Moisture reduction chart of the guava leaves when dried using heat pump drying (BN) at four different temperatures.

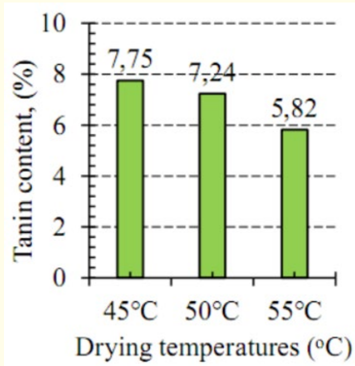

Figure 6: Tannin Content of Dried Guava Leaves at Three Different Drying Temperatures.

Figure 7: Color of the guava leaves after heat pump drying (BN).

The vacuum drying (CK), the sun drying (PN) and shade (BR)

The moisture reduction process of guava leaves during vacuum drying (CK) at 35°C, direct sun drying (PN), and shade (BR) is illustrated in Figure 8. The results show that the average moisture reduction rates and drying times for guava leaves using CK, PN, and BR methods are 50.59%, 12.38%, and 2.08% per hour, and 1, 4, and 24 hours, respectively, as shown in Figure 9. The quality of guava leaves dried by CK at 35°C matches that of fresh guava leaves in terms of color and aroma. However, the drying process is complex, requiring the operator to have technical expertise, and consumes a significant amount of energy for each drying batch. Therefore, this method is nearly ineffective for drying guava leaves due to the much higher cost per unit compared to other drying methods.

The sun drying method (PN), although requiring only 4 hours, is highly dependent on weather conditions. The product often accumulates dust, experiences significant color changes due to direct sunlight exposure, and the flavor is considerably diminished compared to fresh guava leaves.

The shade method (BR) has a very long drying time of about 24 hours and is also highly dependent on weather conditions. However, the quality of the dried guava leaves is better preserved compared to the sun drying method (PN) in terms of flavor and color. Nevertheless, the quality of products from both PN and BR methods cannot be compared with the quality achieved using the CK, BN, and KKN drying methods. The data from drying with PN and BR in this study demonstrate that these methods are less suitable as scientific and technological advancements continue to evolve.

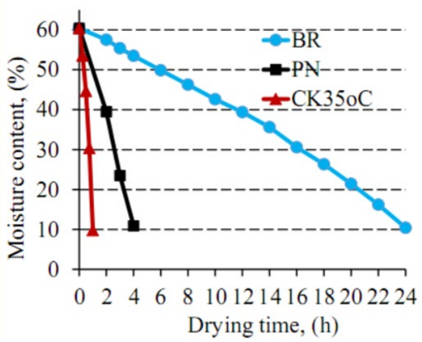

Figure 8: Effect of drying temperature on the moisture reduction process of guava leaves during vacuum drying (CK), sun drying (PN) and shade (BR).

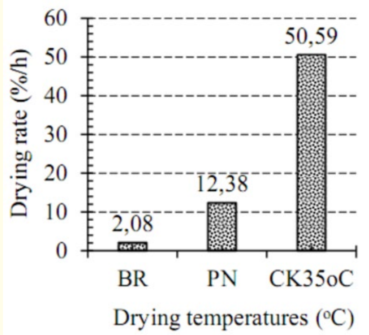

Figure 9: Moisture Reduction Chart of Guava Leaves during Vacuum Drying (CK), Sun Drying (PN), and Shade (BR).

Figure 10: Color of guava leaves after drying.

Evaluation of the suitable drying method

Based on the analysis of the results from each drying method mentioned above, it is observed that guava leaves dried under direct sunlight have lower quality and a relatively long drying time (5 hours). Shade drying (BR) improves the quality but requires a very long moisture reduction time to meet the required moisture content (24 hours). Among the other drying technologies, guava leaves dried show better quality in terms of color, aroma, and even tannin content in the dried product. Therefore, to determine the most suitable drying technology for guava leaves, the study selected a drying temperature of 45°C, as this temperature yields the best quality for each drying method. The appropriate drying technology was determined based on drying time, moisture reduction rate, color, and flavor of the guava leaves after drying. The moisture reduction process and rate of moisture reduction of guava leaves with the three different drying technologies are illustrated in Figures 11 and 12.

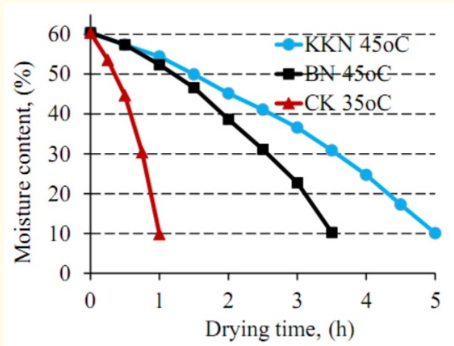

Figure 11: Moisture Reduction Chart for Guava Leaves Using Three Drying Technologies.

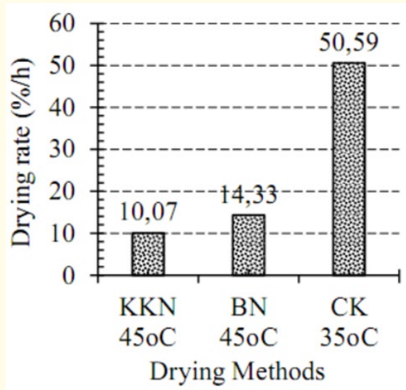

Figure 12: Comparison of Moisture Reduction Rates for Different Drying Technologies.

The drying times and moisture reduction rates for the KKN, BN, and CK drying technologies are 5 hours / 10.07% per hour, 3.5 hours / 14.33% per hour, and 1 hour / 50.59% per hour, respectively. Among these, the CK drying technology has the shortest drying time and the highest moisture reduction rate. The quality of the dried product is closest to the quality of fresh guava leaves based on sensory evaluation. However, CK drying requires operators with specialized skills, a complex operating process, and consumes significantly more energy per unit of dried product compared to the BN and KKN methods. Therefore, CK drying technology is not suitable for drying guava leaves for medicinal purposes.

With the KKN drying technology, the color and flavor of the guava leaves after drying show a noticeable shift towards yellowing compared to the BN drying technology, which results in a significant reduction in tannin content. Therefore, when comparing the KKN and BN drying technologies at the same drying conditions, it can be concluded that BN drying preserves the tannin content of the dried guava leaves better, and the color and flavor remain more robust compared to KKN drying.

Thus, based on the experimental results, analysis, and evaluation, the BN drying technology at 45°C is suitable for drying guava leaves. This technology offers a rapid moisture reduction rate, a short drying time, and results in dried guava leaves with high tannin content, good color, and characteristic flavor. It meets the requirements for use as a material for producing and formulating medicinal products.

To describe the drying process with the heat pump drying method at drying temperature 45oC as defined above, a mathematical equation was built to describe the process of moisture loss of materials versus drying time as follow:

$$M = 62{,}761 - 1{,}6337*t - 0{,}607*t^2; \ (R^2 = 0.99)$$

Where: M is moisture content of the guava leaves (%, wb.); t is drying time (hour).

Conclusions

Based on the characteristics and quality standards of guava leaves, the study conducted experiments with five drying technologies—sun drying (PN), shade (BR), hot air drying (KKN), heat pump drying (BN), and vacuum drying (CK)—at drying temperatures of 45°C, 50°C, and 55°C to determine the most suitable drying technology for guava leaves. The evaluation of the drying technology was based on criteria such as drying time, moisture reduction rate, and the quality of the guava leaves after drying.

The research results identified that the heat pump drying (BN) technology is suitable for drying guava leaves at a temperature of 45°C, with a drying time of 3.5 hours and a moisture reduction rate of 14.33% per hour. The dried guava leaves have a tannin content of 7.75%, and exhibit good color and flavor, meeting the requirements for use as a raw material and for medicinal formulation.

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