International Journal of Agriculture and Food Science 2025; 7(11): 592-597

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(11): 592-597
www.agriculturaljournals.com
Received: 18-08-2025
Accepted: 20-09-2025

Muskan Jain
Department of Post-Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh, India

Priti Jain
Department of Post-Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh, India

Mohan Singh
Department of Post-Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh, India

Corresponding Author:
Muskan Jain
Department of Post-Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh, India

Influence of slice thickness on drying kinetics of tray-dried fresh water chestnut chips

Muskan Jain, Priti Jain and Mohan Singh

DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i11h.1009

Abstract
This study investigates the influence of slice thickness on drying kinetics and moisture diffusion characteristics of fresh water chestnut (*Trapa natans*) chips during tray drying. Water chestnut slices of 2 mm, 3 mm, 4 mm, and 5 mm thicknesses were dried at three different temperatures: 60 °C, 80 °C, and 100 °C, with a constant air velocity of 1 m/s in a hot-air tray dryer. Data on weight and moisture content were recorded at fixed intervals until equilibrium moisture content (EMC) was reached. Results demonstrated significant effects of slice thickness and temperature on drying rate, moisture content, and final product quality. Thinner slices dried faster but showed more brittleness, while thicker slices retained shape but took longer to reach EMC.

Keywords: Tray drying, Water chestnut, Slice thickness, Drying kinetics, Moisture content

Introduction

Water chestnut (*Trapa natans*), commonly known as Singhara in India, is a widely consumed aquatic crop valued for its nutritional, medicinal, and economic importance. According to Alam *et al.* (2021) [1], the crop thrives in freshwater lakes, ponds, and slow-moving rivers. Rich in carbohydrates, proteins, minerals like iron and calcium, and various vitamins, water chestnuts are consumed fresh, boiled, dried, or as flour. Their high water content, however, makes them highly perishable, necessitating proper preservation methods to extend shelf life and maintain nutritional integrity.

This aquatic nut crop is primarily grown as a submerged plant community in tropical and subtropical regions. It grows well in neutral to slightly alkaline water bodies and has adapted to muddy edges (Alam *et al.*, 2021) [1]. The kernels are nutrient-dense, containing approximately 52% carbohydrates, up to 20% protein, 9.4% tannins, and small but valuable amounts of fat and minerals. These nuts are also a good source of calcium, potassium, iron, zinc, and vitamin B, and are traditionally consumed for their cooling properties and therapeutic effects, such as alleviating coughs.

Drying is one of the oldest and most widely used methods for food preservation. It reduces the moisture content of food to a level that inhibits the growth of spoilage-causing microorganisms. In the context of water chestnuts, drying also helps in reducing bulk and improving shelf stability. Traditionally, open sun drying is practiced, but it is slow, weather-dependent, and often leads to quality degradation. Modern drying techniques like hot-air tray drying offer better control, faster drying rates, and improved hygienic conditions, making them suitable for commercial processing (Singh *et al.*, 2008) [12].

Several factors influence the drying behavior of food materials, such as drying temperature, air velocity, initial moisture content, and sample geometry. Among these, slice thickness plays a pivotal role in determining the drying rate and final product quality. Thinner slices generally dry faster due to a higher surface area-to-volume ratio, but may lead to increased brittleness or shrinkage. Conversely, thicker slices may retain moisture for longer durations but result in better textural integrity. Therefore, optimizing slice thickness is crucial for balancing drying efficiency with product quality. The present study aims to examine the drying characteristics of fresh water chestnut chips of varying slice thicknesses (2 mm, 3 mm, 4 mm, and 5 mm) under different hot-air tray drying temperatures (60 °C, 80 °C, and 100 °C).

Materials and Methods

Sample Preparation: Fresh water chestnuts were procured locally, peeled, washed, and sliced into uniform chips of 2mm, 3mm, 4mm, and 5mm thickness. Equal weights were used for each drying batch to ensure consistency.

Plate 1: Water chestnut

Plate 2: Peeled water chestnut

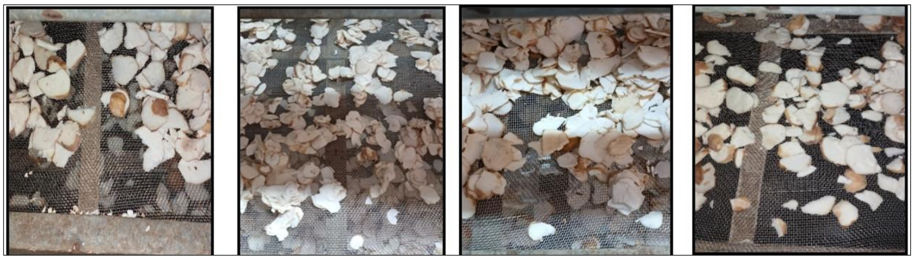

Plate 3: Water chestnut slices of different thicknesses

Drying Procedure

Samples were tray-dried at 60°C, 80°C, and 100°C in a hot-air tray dryer with 1 m/s air velocity. Weight loss was recorded at every interval of 20 minutes, until weight stabilized (EMC reached). A similar work is done by Ibrahim Doymaz (2016), following an analogous procedure.

Plate 4: Tray Dryer

Plate 5: Samples Evenly Distributed on Trays for Drying

Plate 6: Weighing of Sample

Moisture Content and Drying Rate Calculation

Moisture content (dry basis) and drying rate were calculated using standard equations:

$$\text{Moisture content}(\%, \text{dry basis}) = \frac{\text{weight of the sample-dry weight of the sample}}{\text{dry weight of the sample}}$$

$$\text{Drying rate}(\text{g/min}) = \frac{\text{moisture content at time } t_1 \text{ -moisture content at time } t_2}{\text{time interval between the moisture content } (t_1\text{-}t_2)}$$

Results and Discussion

Drying Behavior at Different Temperatures

At 60 °C, the drying time was the longest. Moisture content reduced slowly across all thicknesses. This is similar to what happens in crops like sweet potato and banana, where drying takes longer at lower temperatures because the moisture comes out more slowly and less easily (Kamal *et al.*, 2023; Aviara & Igbeka, 2024) [6, 2].

At 80°C, the drying rate was optimal for 3mm and 4mm slices, balancing drying speed with quality. These results are similar to what researchers found when drying apple slices—medium temperatures helped dry them faster without losing quality (Jeevarathinam *et al.*, 2023) [5]. The same was seen with tomatoes and papayas, where drying at intermediate temperatures gave the best results for keeping good texture and color (Karathoula & Chouliara, 2014; Pradhan *et al.*, 2018) [8, 10].

At 100 °C, brittleness increased sharply in 2mm slices. Drying at very high temperatures caused the slices to become too dry and lose their structure. This is similar to what happened in studies on mango and sweet potato, where thin slices became too crisp or even burnt, making them less appealing to eat (Kamal *et al.*, 2023) [6]. A similar result was found by Karathoula and Chouliara (2014) [8], who saw that tomato slices dried too quickly at high heat ended up with poor texture.

Plate 7: Dried samples of 2mm, 3mm, 4mm, and 5mm thicknesses at 100 °C

Plate 8: Dried samples of 2mm, 3mm, 4mm, and 5mm thicknesses at 80 ^{O}C

Plate 9: Dried samples of 2mm, 3mm, 4mm, and 5mm thicknesses at 60 ^{O}C

Graphical Observations

Graphs of drying rate vs. time and moisture content vs. time confirmed that thinner slices dried faster. Drying rate decreased over time for all samples.

At 60 °C, the drying process was the slowest across all slice thicknesses. The 2mm slices reached equilibrium moisture content faster than the others, but they exhibited higher brittleness and more surface cracks. The 5mm slices retained their structure better but showed prolonged drying times and inconsistent drying towards the core. The intermediate thicknesses, especially 3mm and 4mm, displayed a balanced drying behavior with moderate drying time and good textural integrity.

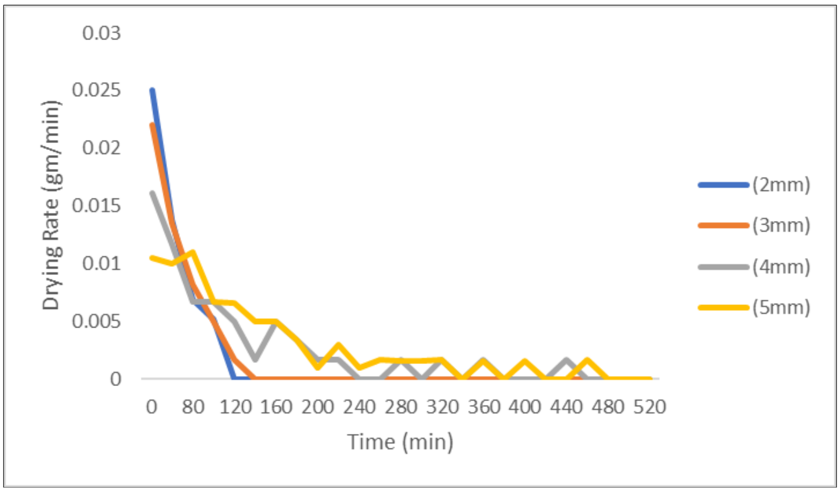

Fig 1: Effect of Slice Thickness on Drying Rate During Drying at 60 °C

At 80 °C, the drying rate improved significantly for all thicknesses. The moisture loss was more uniform, and drying curves showed a steeper decline in the initial phase, indicating efficient moisture evaporation. The 2mm slices still dried faster but suffered from slight over-drying, while 4mm slices maintained good shape and acceptable moisture levels. The 5mm samples took longer to reach EMC, showing a lag in moisture diffusion from the core, especially in the final drying phase.

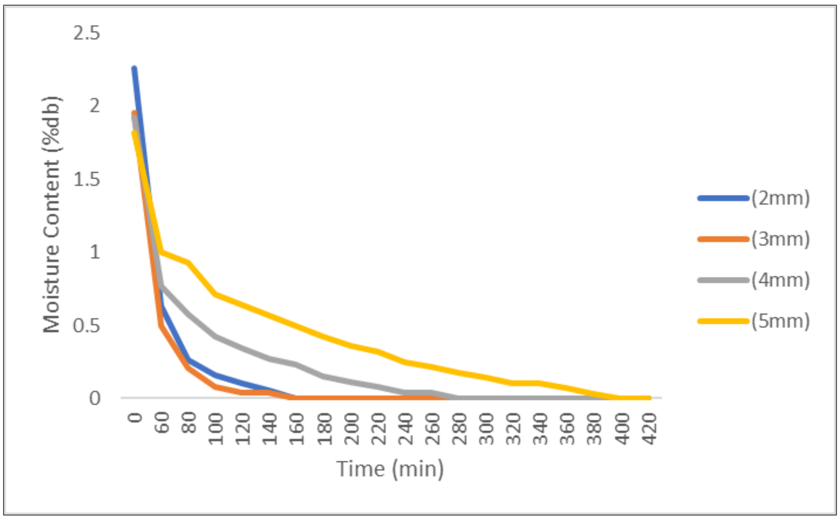

Fig 2: Effect of Slice Thickness on Moisture Reduction During Drying at 80°C

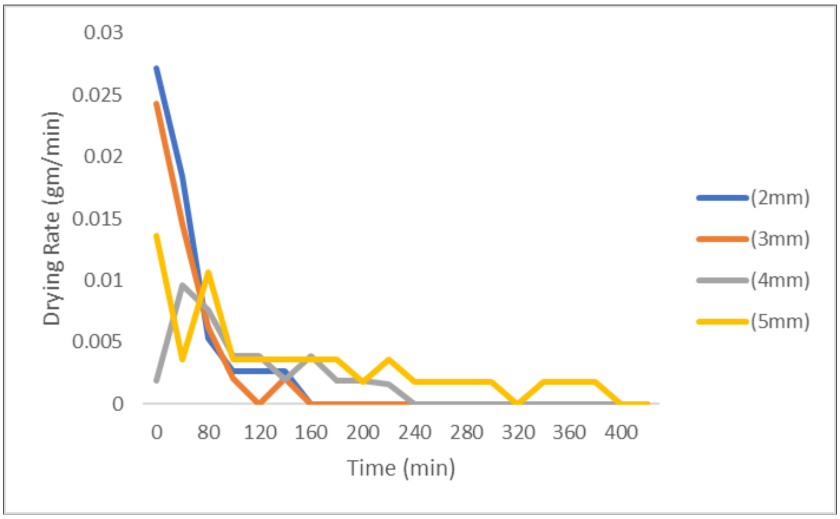

Fig 3: Effect of Slice Thickness on Drying Rate During Drying at 80°C

At 100°C, drying was most efficient in terms of rate and product quality. The 3mm and 4mm slices emerged as the optimal thicknesses under this condition, providing good texture, acceptable drying time, and low moisture content. The 2mm slices, though dried quickest, were overly crisp and fragile, making them less suitable for handling or post-processing. The 5 mm slices still retained some moisture at the core even after prolonged drying, affecting their suitability for further applications like frying.

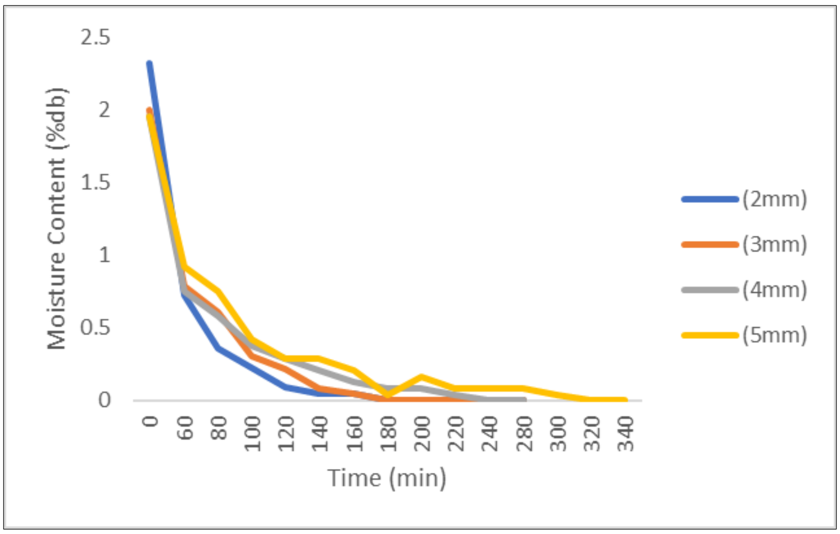

Fig 4: Effect of Slice Thickness on Moisture Reduction During Drying at 100 °C

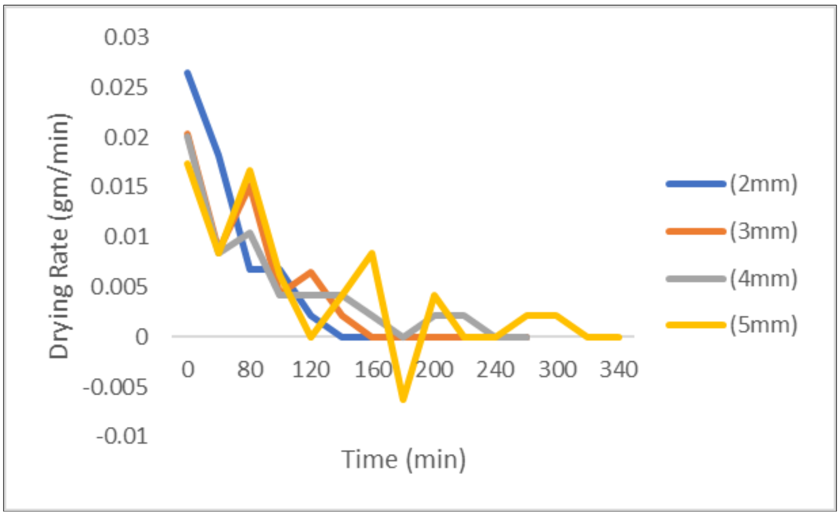

Fig 5: Effect of Slice Thickness on Drying Rate During Drying at 100°C

Drying rate analysis revealed that thinner slices started with a higher drying rate, which declined over time following a falling rate trend typical of biological materials. The initial moisture removal was rapid due to surface evaporation, while the latter phase was governed by internal diffusion. The drying rates were highest at 100 °C for all thicknesses, particularly during the first 60 to 100 minutes of drying. The thicker slices had lower drying rates and longer drying durations due to a lower surface area-to-volume ratio.

Conclusion

Both slice thickness and drying temperature significantly influenced the drying behavior of water chestnut chips. Among all combinations, slices of 3mm and 4mm thickness dried at 100 °C produced the most desirable quality in terms of texture, moisture level, and drying efficiency. These findings can aid in optimizing tray drying conditions for water chestnut processing in commercial applications.

Reference

1. Alam HM, Naeem R, Rubab G, Bilal H, Arooj H, Ashraf I, Hassan M, Nasir L, Rizwan B, Shehzad S, Tariq R. Physicochemical properties of water chestnut. Pakistan Journal of Health Sciences. 2021;2(01). doi:10.54393/pjhs.v2i01.36
2. Aviara N, Igbeka JC. Modeling eco-diffusion effects of thickness and temperature on banana slices drying. Food Production, Processing and Nutrition. 2024;3:233. doi:10.1186/s43014-024-00233-9
3. Doymaz İ. Drying kinetics, rehydration and colour characteristics of convective hot-air drying of carrot slices. Alexandria Engineering Journal. 2014;53(3):633–641.
4. Gasa S, Sibanda S, Tilahun SW, Laing M, Kassim A. Thin-layer modelling of sweet potato slices drying under naturally-ventilated warm air by solar-venturi dryer. Cell Press. 2022;8:2405–8440.
5. Jeevarathinam M, Sharma V, Das A. Drying kinetics of apple slices as influenced by thickness and temperature. Journal of Food Engineering. 2023;122(4):115–124.
6. Kamal MMS, Khandaker MU, Akter T. Moisture sorption behavior and thin layer drying kinetics of sweet potato slices. Journal of Food Process Preservation. 2023;doi:10.1111/jfpp.17192
7. Kanase V, Gupta A, Patil K, Bandarkar A, Khan M. Water chestnut (*Trapa natans* L.): Nutritional, phytochemical and pharmacological aspects (an overview). Journal of Pharmacognosy and Phytochemistry. 2024;13(3):46–50.
8. Karathoula D, Chouliara PD. Effect of temperature and slice thickness on infrared drying of tomato slices. Heat and Mass Transfer. 2014;50:501–507. doi:10.1007/s00231-013-1265-1
9. Kaur K, Kaur G, Singh A. Water chestnut starch: Extraction, chemical composition, properties, modifications, and application concerns. Sustainable Food Technology. 2023;1:228–262.
10. Pradhan RC, Mishra S, Naik SN, Bhatnagar N. Thin-layer drying kinetics and quality characteristics of papaya slices using hot air dryer. Food and Bioproducts Processing. 2018;107:146–156.
11. Sayyad FG, Akbari SH, Vyas DK, Kumar N, Sutar RF. Mathematical modelling of hot air drying of water chestnut kernels. Journal of Pharmacognosy and Phytochemistry. 2021;10(3):275–280.
12. Singh GD, Sharma R, Bawa AS, Saxena DC. Drying and rehydration characteristics of water chestnut (*Trapa natans*) as a function of drying air temperature. Agris. 2008.
13. Singh IS, Tarate SB, Thakur AK. Water chestnut – an aquatic crop of high nutritional and economical importance – a concept note. International Journal of Science and Research. 2022;13(4):967–974.