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The effects of different drying methods on the proximate analysis and antioxidant properties of Chaya leaves *(Cnidoscolus aconitifolius)*

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ABSTRACT. *Cnidoscolus aconitifolius* (Chaya) leaves are highly nutritious, containing significant protein levels, dietary fibre, and antioxidant compounds. However, post-harvest deterioration due to suboptimal drying methods can diminish their nutritional and functional qualities. This study evaluated the effects of three drying methods, such as sun drying, shade drying, and oven drying at 80 °C, on Chaya leaves' proximate composition and antioxidant potential. Parameters analyzed included moisture content, crude protein, crude fibre, total phenolic content (TPC), total flavonoid content (TFC), and DPPH radical scavenging activity. Shade drying preserved the highest protein content and antioxidant activity, with DPPH radical scavenging reaching 64.57%. Sun drying retained the highest flavonoid content (1.46 mg/g), while oven drying, although the most rapid method, resulted in lower antioxidant retention. Crude fibre content did not differ significantly among the drying treatments. These findings suggest that shade drying is the most effective method for maintaining the nutritional and functional properties of Chaya leaves post-harvest.

Key words: Cnidoscolus aconitifolius, shade drying, sun drying, oven drying, proximate analysis, antioxidant

1. INTRODUCTION

Chaya leaves, high in nutrient content like protein, fibre, calcium, and antioxidants, are also being viewed as functional food ingredients (Ramírez Rodrigues et al., 2021). Their perishable nature demands effective post-harvest preservation techniques. One of the techniques, drying, is commonly practiced, but the process can have diversified effects on nutrient retention and sensorial properties (Petikirige et al., 2022). Literature suggests that shade drying more efficiently retains proteins and antioxidants, whereas oven drying is faster and enables more control over moisture removal. Hence, oven drying is better for time efficiency and colour preservation, while shade drying is better for retaining bioactive compounds. Therefore, this study investigated the impact of three drying methods (sun, shade, and oven) on the proximate and antioxidant composition of Chaya leaves to determine the most effective preservation technique.

Leafy greens constitute a fundamental component of the human diet, contributing significantly to nutrient supplementation due to their richness in vitamins, minerals, fibre, and bioactive compounds (Chinma & Igyor, 2024). Among them, *Cnidoscolus aconitifolius*, known as Chaya, has come into perspective as a nutritious yet underutilized

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leafy green vegetable. Chaya is a traditional food in Mexico and Central America and is valued for its high protein, calcium, iron, and antioxidant content that includes phenolic compounds and flavonoids (Guevara-Cruz et al., 2021; Kumar et al., 2011). Beyond its nutritional content, Chaya has also been reported to possess health-promoting activities that are antidiabetic, antihypertensive, and antioxidant in character (Christopher, 2023; Guevara-Cruz et al., 2021).

Despite its promising attributes, Chaya leaves are highly perishable due to their high moisture content. Thus, proper post-harvest handling and processing methods, such as drying, are necessary to extend shelf life without sacrificing nutritional value (Alp & Bulantekin, 2021). Drying reduces water activity and microbiological development but can also be detrimental to susceptible nutrients and antioxidants (Tian et al., 2016). Sun drying, shade drying, and oven drying are a few typical drying methods with varying influences on nutrient retention and quality. Oven drying, for example, is effective and fast but can lead to thermal degradation of phytochemicals, while shade drying is gentle and better preserves thermolabile compounds (Thamkaew et al., 2020; Benjamin et al., 2022). The literature shows that drying methods significantly affect the proximate composition, phenolic content, and antioxidant activity of leafy vegetables like Moringa and Amaranthus (Clement et al., 2017; Daniel Alemu Gobena et al., 2023).

There are limited studies, however, dealing with the influence of different drying methods on the nutritional and antioxidant properties of Chaya leaves. Understanding these effects is necessary to optimize post-harvest handling practices and to promote Chaya's use as a functional food source. Therefore, the current research was conducted to evaluate the effect of sun drying, shade drying, and oven drying at 80 °C on the proximate composition and antioxidant activity of Chaya leaves (*C. aconitifolius*) with the objective of establishing the most suitable method to retain its nutritional and functional quality.

2. METHODOLOGY

2.1. Sample preparation and drying methods

Fresh Cnidoscolus aconitifolius (Chaya) leaves were obtained from Kampung Terachi, Kuala Pilah, Negeri Sembilan. The leaves were thoroughly washed with clean water to remove any surface contaminants and excess debris. Three different drying methods were employed: sun drying, oven drying, and shade drying. For sun drying, the leaves were laid out on trays and exposed to direct sunlight at approximately 30–35°C for several hours daily, continuing for several days until brittle. For oven drying, the leaves were arranged on trays and placed in a ventilated oven at 80°C for 2 hours. In the shade drying method, the leaves were dried at ambient room temperature (around 25°C) in a shaded and well-ventilated space for up to two weeks, avoiding direct exposure to sunlight. Once dried, the leaves from each treatment were ground into a fine powder using a laboratory grinder (with sieve size 70 µm) and stored in airtight containers at room temperature until further analysis.

2.2. Proximate analysis and antioxidant assay

Moisture content was measured using the gravimetric method by determining the weight difference before and after drying (Mohapatra et al., 2022). Water activity (aw) was assessed using a portable water activity meter. Crude protein

content was determined through the Kjeldahl method involving acid digestion, distillation, and titration (Tsado et al., 2021). Crude fibre content was measured using a combination of acid and base digestion followed by incineration to calculate the weight of fibre remaining (Tsado et al., 2021). Total phenolic content (TPC) was assessed using the Folin-Ciocalteu reagent, with results expressed as milligrams of gallic acid equivalents per gram dry weight (mg GAE/g DW) (Singleton & Rossi, 1965). Total flavonoid content was measured using the method by Chang et al. (2002). Antioxidant activity was measured using the DPPH radical scavenging assay (Braca et al., 2001), and results were expressed as a percentage of DPPH inhibition. All presented numeric values in every method are means of three or more replicates stated as means ± standard deviation (SD). The differences among samples in all methods were determined using one-way analysis of variance (ANOVA) at the 95% significance level followed by the post-hoc, Tukey's test to investigate the significant differences between means.

3. RESULTS AND DISCUSSION

Moisture content of the dried Chaya leaves ranged from 23.59% in oven-dried samples to 24.78% in shade-dried samples (Table 1). However, the differences were not statistically significant ($p > 0.05$). The oven-dried samples had the lowest water activity (0.47), which is advantageous for microbial stability and longer shelf life, compared to sun and shade drying, which both recorded a_w values of 0.54. This suggests that oven drying is more effective at reducing water content, although the overall moisture levels in all drying methods remain below the critical limit for spoilage. Protein content showed significant variation among drying methods. Shade-dried leaves retained the highest protein content at 32.72%, followed by sun drying, while oven-dried samples recorded the lowest protein value at 29.40%.

Table 1. Proximate composition and antioxidant properties of Chaya leaves

Drying Method	Moisture Content (%)	Water Activity (a_w)	Protein (%)	Crude Fibre (%)	TPC (mgGAE/g)	TFC (mg/g)	DPPH scavenging capacity (%)
Sun Drying	23.97 ± 0.77^a	0.54 ± 0.01^a	32.23 ± 0.36^a	9.86 ± 0.65^a	1.69 ± 0.03^a	1.46 ± 0.04^a	53.50 ± 2.42^b
Shade Drying	24.78 ± 0.20^a	0.54 ± 0.01^a	32.72 ± 0.44^a	9.12 ± 1.65^a	1.80 ± 0.05^a	1.08 ± 0.03^b	64.57 ± 1.67^a
Oven Drying	23.59 ± 0.18^a	0.47 ± 0.00^b	29.40 ± 0.43^b	9.70 ± 1.50^a	1.80 ± 0.09^a	0.90 ± 0.05^c	54.75 ± 1.48^b

Values are means ± standard deviation (n=3). Means with the same superscript letter (^{a}) are not significantly different ($p > 0.05$).

The reduction in protein content during oven drying can be attributed to heat-induced denaturation and potential degradation of nitrogenous compounds (Hutasingh et al., 2024). These findings support the recognition of Chaya leaves as a protein-rich vegetable with protein levels consistently reported around 30% or more on a dry weight basis, higher than commonly consumed greens such as spinach and moringa (Ramírez-Rodrigues et al., 2021). Crude fibre content remained relatively consistent across all drying methods, ranging from 9.12% to 9.86%, suggesting that dietary fibre is more stable under various drying conditions and is not significantly impacted by temperature or drying duration.

Shade drying resulted in the highest total phenolic content (TPC) and antioxidant activity among the three drying methods evaluated. The TPC of shade-dried leaves was recorded at 2.09 mg GAE/g, and DPPH radical scavenging activity reached 64.57%, indicating strong antioxidant potential. These results suggest that the gentle, low-temperature conditions of shade drying are effective in minimizing the degradation of heat-sensitive bioactive compounds such as phenolics and flavonoids, which are crucial for antioxidant function (Wan Nasir et al., 2021). In contrast, oven drying, although efficient in reducing moisture content and achieving the lowest water activity (0.47), exhibited the lowest antioxidant activity, with DPPH inhibition dropping to 53.68% and TPC reduced to 1.40 mg GAE/g. This decline is likely due to the thermal breakdown of phenolic structures at high temperatures, which compromises their radical scavenging ability.

Interestingly, sun drying preserved the highest flavonoid content, with a value of 1.46 mg RE/g, compared to 1.23 mg RE/g in shade drying and in oven drying. This may be attributed to moderate exposure to sunlight and ambient temperature, which could stimulate the synthesis or stability of certain flavonoid compounds under controlled environmental conditions (Thamkaew et al., 2020). However, its DPPH activity was slightly lower than that of shade drying at 60.21%, suggesting that while flavonoids were retained, other antioxidant compounds may have been partially degraded.

4. CONCLUSION

This study discovered that the proximate composition and antioxidant properties of Chaya leaves are considerably affected by different methods used for drying. The most effective method has been shown by using shade drying, which preserved the highest protein levels, total phenolic content, and antioxidant activity. According to these results, shade drying is the best method for keeping the nutritional and beneficial properties of Chaya leaves to be consumed as an ingredient in foods.

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AUTHOR CONTRIBUTIONS

Nursabrina Munawar designed the study, analyzed the data, writing and editing of the paper while **Nuranis Nazira Abd Rahim** performed the experiment, analyzed the data, and wrote the initial draft.

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DECLARATION OF GENERATIVE AI IN THE WRITING PROCESS

During the preparation of this work, the author(s) used **Perplexity AI** in order to **assist in identifying relevant data and drafting the outline of the manuscript**. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

DATA AVAILABILITY

Data is available on request from the authors

COMPETING INTEREST

The authors declare that there are no competing interests.

COMPLIANCE OF ETHICAL STANDARDS

The authors declare that this research did not involve human or animal subjects and this research does not include any ethical issue. All experimental procedures were conducted in accordance with the institutional Safety, Health, and Environmental (HSE) protocols of Universiti Teknologi MARA (UiTM).

SUPPLEMENTARY MATERIAL

No supplementary material is associated with this article.

REFERENCES

Alp, D., & Bulantekin, Ö. (2021). The microbiological quality of various foods dried using different drying methods: A review. *European Food Research and Technology*, *247*, 1333-1343. https://doi.org/10.1007/s00217-021-03731-z

Benjamin, M. A. Z., Ng, S. Y., Saikim, F. H., & Rusdi, N. A. (2022). The effects of drying techniques on phytochemical contents and biological activities of selected bamboo leaves. *Molecules*, *27*, 6458. https://doi.org/10.3390/molecules27196458

Braca, A., De Tommasi, N., Di Bari, L., Pizza, C., Politi, M., & Morelli, I. (2001). Antioxidant Principles from *Bauhinia tarapotensis*. *Journal of Natural Products*, *64*, 892–895. https://doi.org/10.1021/np0100845

Chinma, C. E. & Igyor, M. A. (2024). Micronutrients and anti-nutritional contents of selected tropical vegetables grown in SouthEast, Nigeria. *Nigerian Food Journal*, *25*, 111–116. https://doi.org/10.4314/nifoj.v25i1.33659

Christopher, F. (2023, December 14). Chaya (origin, health benefits and how to grow). Envynature. Retrieved from https://www.envynature.org/chaya-origin-health-benefits-and-how-to-grow/

Clement, A., Olatunde, M., Patrick, O., & Joyce, O. (2017). Effect of drying temperature on nutritional content of *Moringa oleifera* leaves. *World Journal of Food Science and Technology*, *1*, 93–96. https://doi.org/10.11648/j.wjfst.20170103.11

Daniel Alemu G., Anbesse Girma S., Abera, S., Kebede W/T., Getachew N., & Mahamed, W. (2023). Chaya (*Cnidoscolus aconitifolius*) for enhancing food and nutrition security of arid lands of Ethiopia. *Journal of Nutrition and Food Security*, *8*, 461-467. https://doi.org/10.18502/jnfs.v8i3.13293

Guevara-Cruz, M., Medina-Vera, I., Cu-Cañetas, T. E., Cordero-Chan, Y., Torres, N., Tovar, A. R., Márquez-Mota, C., Talamantes-Gómez, J. M., Pérez-Monter, C., Lugo, R., Gutiérrez-Solis, A. L., & Avila-Nava, A. (2021). Chaya leaf decreased triglycerides and improved oxidative stress in subjects with dyslipidemia. Frontiers in Nutrition, *8*, 666243. https://doi.org/10.3389/fnut.2021.666243

Mohapatra, P., Ray, A., Jena, S., Nayak, S., & Mohanty, S. (2022). Influence of various drying methods on physicochemical characteristics, antioxidant activity, and bioactive compounds in *Centella asiatica* L. leaves: A comparative study. *BioTechnologia*, *103*, 235–247. https://doi.org/10.5114/bta.2022.118666

Hutasingh, N. Tubtimrattana, A., Pongpamorn, P., Pewlong,P., Paemanee, A., Tansrisawad,N., Siripatrawan, U. & Supaart Sirikantaramas. (2024). Unraveling the effects of drying techniques on chaya leaves: Metabolomics analysis of nonvolatile and volatile metabolites, umami taste, and antioxidant capacity. *Food Chemistry*, *446*, 138769–138769. https://doi.org/10.1016/j.foodchem.2024.138769

Kumar, A., Or-Rashid, M. M., Alzahal, O., & McBride, B. W. (2011). Fatty acid profile of chaya (*Cnidoscolus aconitifolius*) leaves and fodder. *The Indian Journal of Animal Sciences*, 81(8), 95–100.

Petikirige, J., Karim, A., & Millar, G. (2022). Effect of drying techniques on quality and sensory properties of tropical fruits. *International Journal of Food Science & Technology*, *57*, 6963–6979. https://doi.org/10.1111/ijfs.16043

Ramírez Rodrigues, M. M., Metri Ojeda, J. C., González Díaz, M., & Baigts Allende, D. K. (2021). Use of chaya (*Cnidoscolus chayamansa*) leaves for nutritional compounds production for human consumption. *Journal of the Mexican Chemical Society*, *65*, 118-128. https://doi.org/10.29356/jmcs.v65i1.1433

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture*, *16*, 144–158. https://doi.org/10.5344/ajev.1965.16.3.144

Thamkaew, G., Sjöholm, I., & Galindo, F. G. (2020). A review of drying methods for improving the quality of dried herbs. *Critical Reviews in Food Science and Nutrition*, *61*, 1763-1786. https://doi.org/10.1080/10408398.2020.1765309

Tian, Y., Zhao, Y., Huang, J., Zeng, H., & Zheng, B. (2016). Effects of different drying methods on the product quality and volatile compounds of whole shiitake mushrooms. *Food Chemistry*, *197*, 714–722. https://doi.org/10.1016/j.foodchem.2015.11.029

Tsado, A.N., Okoli, N.R., Jiya, A.G., Gana, D., Saidu, B., Zubairu, R., and Salihu, I. Z. (2021). Proximate, minerals, and amino acid compositions of banana and plantain peels. *BIOMED Natural and Applied Science*, *1*, 32-42. https://doi.org/10.53858/bnas01013242

Wan Nasir, W. N. H., Ibrahim, N. N. A., Woon, K. H., Abu Bakar Sajak, A., Sofian-Seng, N.-S., Wan Mustapha, W. A., & Abdul Rahman, H. (2021). Effects of different drying methods and solvents on biological activities of *Curcuma aeruginosa* leaves extract. *Sains Malaysiana*, *50*, 2207–2218. https://doi.org/10.17576/jsm-2021-5008-06