Impact of drying methods on antioxidant activity, phenolic and flavonoid compounds in *Stevia rebaudiana* Bertoni leaves

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ABSTRACT

An experiment was conducted at the Faculty of Agricultural Engineering Sciences, Baghdad University (Iraq) during the spring season of 2023 to assess the impact of eight drying techniques and drying time on antioxidant substances (Phenolics and Flavonoids) and antioxidant activity, in Stevia leaves. The study included shade drying, oven drying at 40, 50 and 60 °C, and microwave drying for 1, 2 and 3 minutes. The treatments were arranged using a randomized complete blocks design (RCBD) with three replications. The results showed that the contents of phenolic and flavonoid compounds differed significantly according to the drying technique, drying time and conditions. In general, microwave drying gave the best results, where the highest phenolic content was observed after 3 minutes of microwave drying, while the highest flavonoid content was recorded after 2 minutes. In contrast, a reduction in some compounds was observed during shade drying at 40 °C. These results indicate that the preservation of antioxidant compounds was mainly influenced by the interaction between drying temperature and drying time. Under oven drying at 40 °C, the moisture content decreased from 76.28% in fresh stevia leaves to 11.57% after 7 hours of drying, after which the moisture content remained constant and the leaves reached a stable weight. Higher antioxidant activity was observed ~~on~~ when the moisture content was approximately 70%. The highest total phenolic content was recorded in fresh stevia leaves, whereas the lowest values were observed at the 3 h, 5 h and 6 h drying intervals.

***Keywords*:** Antioxidant activity, drying temperature, phenolic and flavonoid compounds preservation, stevia

INTRODUCTION

Stevia (*Stevia rebaudiana* Bertoni) is a globally cultivated crop valued as a medicinal plant and a natural non-caloric sweetener due to its high content of steviol glycosides mainly stevioside and rebaudioside A, in addition to various natural antioxidants (Khshan and Al-Taweel, 2024). Beyond its use~~,~~ sweetening properties, stevia leaves are recognized as a rich reservoir of bioactive phytochemicals, including phenolic acids and flavonoids which contribute to antioxidant capacity and

associated health benefits (Covarrubias-Cárdenas *et al.,* 2018; Periche *et al.,* 2015).The therapeutic potential of medicinal plants is credited to their complex chemical composition, which includes a wide range of bioactive compounds such as phenolics, terpenoids, and flavonoids.(Shafi *et.al.,* 2025). However, the sensitivity of these compounds to processing conditions indicates that treatment and drying methods can significantly influence the final phytochemical composition and antioxidant potential of dried stevia leaf products (Periche *et al.,* 2015; Agüero *et al.,* 2019).

Drying markedly affects total Phenolic content (TPC), Total Flavonoids content (TFC), and antioxidant capacity, as heat, oxygen exposure, and drying time can either degrade antioxidants compounds or increase their extractability by disrupting cellular structures. Phenols and flavonoids are among the most prevalent antioxidants and play crucial roles in human health. Existing evidence indicates that different drying techniques (e.g., air drying, shade drying, microwave-assisted drying, and vacuum freeze-drying) may result in substantial variations in the retention of glycoside content, total phenolics, flavonoids and antioxidant activity (Huang, 2021).

Nevertheless, the reported findings remain inconsistent due to variations in cultivar, leaf maturity, drying parameters and analytical techniques (Periche *et al.,* 2015; Agüero and Pasten, 2019). Recent studies emphasize the importance of tuning drying parameters to preserve Stevia bioactive components while ensuring secure moisture elimination and product durability (Roohinejad *et al.,* 2025). Addressing this knowledge gap is essential for improving evidence-based postharvest handling protocols for stevia as a functional crop and for enhancing the quality of stevia leaf products for medicinal and nutraceutical applications (Kalsi *et al.,* 2023).

The findings enhance comprehension of drying behavior and demonstrate that the thermophysical properties and energy characteristics of dried stevia leaves are influenced by drying procedures (Lemus-Mondaca *et al.,* 2021). Huang, et al. (2020) examines the efficiency of various drying techniques in maintaining antioxidant levels in stevia leaves and identifies optimal processing parameters that maximize the retention of bioactive compounds while preserving overall product quality. Accordingly, the current investigation analyzes the effectiveness of selected drying methods in conserving bioactive content in Stevia leaves and determines processing conditions that enhance bioactive compound preservation without compromising product quality. The lack of advanced production technologies and the presence of an unregulated market represent major challenges that must be addressed to overcome existing constraints and to develop appropriate and sustainable strategies within the sector (Rathore, R. 2024). One of the key outcomes of this research is to support the development of optimized postharvest handling procedures for stevia leaves and to promote their utilization in food and medicinal applications.

MATERIALS AND METHODS

The Stevia plant cultivar Spanti, obtained from Fito Co. (Spain), was planted in March 2023 at the Station B of the Faculty of Agriculture, Baghdad University. The experiment was arranged in a randomized complete block design (RCBD with three replications, and ten plants were sampled from each plot. Stevia plants were harvested at a physiological maturity stage and cleaned to eliminate dust and dirt. Field samples were collected during the first season and first cut. Fresh leaf samples, from each treatment were randomly assigned to eight different drying methods for evaluation, resulting in a total of 24 experimental units. To investigate the impact of drying time on antioxidant

compounds, a controlled drying treatment at 40 °C for 7 h. was included in this experiment.

The primary drying method involved open-sun drying of stevia leaves under direct sunlight at temperatures ranging from 44 to 46 °C for 72 h. In this method, leaves were detached from the stems and evenly spread in a single layer without overlap on drying surfaces. If drying was incomplete by sunset, the samples were transferred indoors and the process was repeated daily until complete drying was achieved. The second method consisted of shade air-drying at an average temperature of 33°C for 72 h.

The third method employed Microwave drying using a microwave oven (Samsung, ME721K,) operating at 2550 MHz and 850 W, with drying times of 1, 2, and 3 min. The fourth method utilized a fan-assisted oven (Binder model) at temperatures of 40, 50 and 60°C for 24 h.

Drying was continued until predetermined safe moisture content was reached to ensure product stability within leaves handling, processing and storage, as indicated in stevia drying studies (Agüero *et al.,* 2019). After drying, the samples where ground using a high-speed blender (1,400 rpm) and stored in sealed bags at 4–5 °C for subsequent analyses.

Determination of the concentration of phenols

The levels of phenols in dried and ground leaves were measured using the extraction and High-Performance Liquid Chromatography (HPLC) technic (Al Taweel *et. al,,* 2022). Compounds such as Pyrogallol, P-OH-benzoic, Benzoic Acid, Gallic Acid, Protocatch Acid, Caffeic Acid and Salicylic Acid were identified by blending powdered leaf samples with hot water at 65°C in a 1:25 w/v ratio, for 3 hours (Galal, 2002). The HPLC parameters and retention times varied depending on the compound. A separation column of C18 (4.5 x 250 mm) was used. The Mobil phase (MeOH: acetonitrile: dichloromethane (18: 2: 80), flow was 1 ml. min^{-1}, measurement at wavelengths 280 nm and at 35 ° C. The phenolic compounds were quantified through comparing the peak area of the sample compound to that of the standard. The process was repeated on all the samples under the same separation conditions. The concentration of the samples was calculated according for the Calibration model.

Determination of the concentration of flavonoids

Flavonoid concentration was determined using HPLC (Mattila *et al.,* 2000) which covered: Quercetin, Naringenin, Luteolin 7 glucoside, Apigenin-7glucoside Apigenin7-O-neohesperidoside Kamp-3-7-diham and Apigenin-7-rha. This followed the phenol estimation method. The HPLC conditions varied and the retention time depended on the compound type.

The C18 separation column (4.5 x 250 mm) was utilized; the mobile phase consisted of H_3PO_4: Acetonitrile (80:14) with a flow of 1 $ml.min^{-1}$ and wavelength of 330 nm and a temperature of 35 °C. Flavonoid compounds were quantified by comparing the peak area of the sample compound to the standard. This procedure was replicated for all samples, under separation conditions. The sample concentrations were determined based on the calibration model.

Drying time

This experiment was conducted separately from the other eight treatments. A drying temperature of 40 °C was selected for a drying duration of 7 h in order to investigate the relationship between drying time with moisture content, total phenolic compounds and antioxidant capacity.

Stevia leaves were chosen by evaluating color and freshness through inspection to create a uniform batch. The process was conducted at 40^0 C with airflow oven until a constant weight was attained, which required 7 hours. Samples were collected hourly and preserved in a desiccator to inhibit moisture

absorption until subsequent analysis. The moisture content was quantified in stevia leaves and in samples obtained during the drying process utilizing a thermo-balance (Ohaus MB-45-2A, Greifensee, Switzerland) (Tellez *et al.,* 2018).

Determination of Total phenolic content (TPC):

The extraction procedure will be carried out employing a food-safe solvent system maintaining a regulated solvent, to sample ratio, extraction duration and temperature. Solvent extraction is extensively applied to retrieve stevia phenolics and assess capacity (Agüero *et al.,* 2019). The overall phenolic content was quantified using the Folin-Ciocalteau method. The (TPC) was quantified as mg of g/Gallic acid equivalent per gram of dry weight of sample, according to the calibration.

Determination of antioxidant activity

The DPPH radical scavenging activity was measured using the formula established by (Kokilananthan *et al.* 2021). DPPH Radical Scavenging (%) = A control - A sample / A control x 100; Where A control and A sample denote the absorbance of the control and the sample, respectively.

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) to determine significant differences among drying techniques. When significant effects were detected, mean comparisons were performed using the least significant difference (LSD) test at $p \leq 0.05$. This statistical approach is appropriate for evaluating treatment means in postharvest studies (Agüero *et. al.,* 2019).\

RESULTS AND DISCUSSION

Effect of drying in phenols content

Table 1 revealed that the solar drying method resulted in the highest Caffeic acid content (20.67 µg. g^{-1}) followed by microwave drying for 2, 3 and 1 min., which attained 16.42, 14.22 and 14.05 µg. g^{-1} respectively, with no significant differences among these treatments. In contrast, them compared to the lowest caffeic acid content was observed in oven drying at 40°C (8.45 µg. g^{-1}).

Regarding salicylic acid, has been observed that the drying microwave for 2 and 3 minutes recorded highest concentrations (637 and 561 µg. g^{-1} respectively) followed by microwave drying for 1 min (435 µg. g^{-1}). The lowest salicylic acid content was recorded in samples dried in the oven at 50 °C (210 µg. g^{-1}). Typically microwave drying for 2 min resulted in the highest Benzoic acid content (2188.33 µg g^{-1}). (Figure 1).

Myint *et al.* (2023) stated that polyphenols constitute approximately 2–4% of dried Stevia leaves and are primarily composed of various chlorogenic acids and their derivatives. These compounds make stevia a plentiful and renewable biomaterial with promise as a source of phenolic antioxidant and antibacterial agent possessing anti-inflammatory properties. Comparative research have shown that drying methods significantly affects the phenolic content, flavonoid levels and antioxidant activity assessments (such, as DPPH, FRAP) in stevia leaves (Agüero *et. al.,* 2019; Halim *et. al.,* 2019). In addition, detailed phenolic analysis reveals that drying parameters can modify phenolic substances and overall, antioxidant capacity, indicating chemical alterations that depend on the selected drying technique (Covarrubias-Cárdenas *et. al.,* 2018)

Effect of drying on flavonoid content

Analysis of flavonoid compounds (Table 2) revealed significant variations in their concentrations depending on the drying technique and processing parameters, particularly the drying temperature and duration. The microwave drying for 2 minutes recorded the highest percentage of Quercetin (52.0 µg.g^{-1}) with significantly increasing compared with others treatments while lowest

percentage was recorded at microwave drying for 1 minute (10.8 μg.g^{-1}).

Typically microwave drying for 2 min resulted in the highest Luteo-7-glucose content (2287.03 μg g^{-1}) (Figure 2), which was significantly greater than that of all other treatments. In contrast, the lowest quercetin concentration was observed following microwave drying for 1 min (10.8 μg.g^{-1}). Regarding naringin content, the highest values were recorded with microwave drying for 2 min. followed by microwave drying for 2, 3 min. and oven 60°C (12.18, 10.95 and 10.92 μg.g^{-1} respectively). These values did not differ significantly from those obtained with shade and solar drying (9.68 and 9.05 μg.g^{-1}. respectively). The lowest naringin concentrations were observed in samples dried by microwave for 1 min and oven drying at 50 °C (5.10 and 5.62 μg.g^{-1}).

The results presented in Table 2 reveal that microwave drying for 2 minutes and shade drying resulted in higher amounts of Kamp-3-7-diham (145.5 and 140.2 μg.g^{-1} respectively) surpassing the other treatments whereas the lowest level was recorded at oven drying at 40 °C (47 μg.g^{-1}). Regarding the Apigenin-7-glucose compound the maximum concentration seemed to be noted after microwave drying for 12 minutes with the highest amount observed after microwave drying for 2 min (120.0 and 81.7 μg.g^{-1} respectively) whereas the smallest concentration was showed with oven drying at 50 and 40°C (48.7 and 52.5 μg.g^{-1} respectively).

These results were consistent with Roohinejad *et al.* (2025) who reported that microwave drying provided preservation of antioxidant activity and enhanced particle morphology. From the results obtained by Haider *et al.,* (2020), It was confirmed that drying conditions, specifically temperature and air flow, result in alterations to stevia that may lead to quality deterioration. Also, the overall content of chlorophyll, phenolics and flavonoids, decreased with the increase in air-airflow and air-drying temperature.

In the Apigenin-6-raha compound the greatest concentration was found with microwave drying for 2 minutes (747 μg.g^{-1}) whereas the smallest amounts were observed with microwave drying for 1 minute and oven drying at 50 °C (180 and 209 μg. g^{-1}). The data in Table 2 showed an advantage for microwave drying for 2 minutes and solar drying over other methods, in terms of Lutea-7-glucose concentration (2287 and 1954 μg.g^{-1} respectively) while the lowest level (351 μg.g^{-1}) was recorded with oven drying at 50 °C. The findings indicated that the greatest concentration of Apigenin-7-oheo (373 μg.g^{-1}) occurred after microwave drying for 2 minutes with subsequent levels observed in microwave drying for 3 minutes shade drying and solar drying (283.2, 256.6 and 237 μg.g^{-1}.

The lowest levels were found at 50 °C (162.6 μg.g^{-1}). Based on the outcomes of the evaluation of phenolic compounds and flavonoids subjected to various drying techniques it was demonstrated that the compound concentration varied depending on the drying method. Nonetheless it is typically seen that two primary factors exert the influence: the duration of drying and the drying temperature. Accordingly, microwave drying for 3 minutes was notably the best, at preserving the amount of most phenolic compounds while flavonoids were most retained during microwave drying for 2 minutes.

The detected differences in phenolic and flavonoid amounts indicate that both the drying temperature and drying time are factors influencing antioxidant preservation in stevia leaves. Microwave drying typically resulted in phenolic and flavonoid content probably due to its shorter drying period and fast moisture removal, which reduces enzymatic oxidation and curtails the duration, for thermal or oxidative damage.

The higher phenolic preservation at microwave 3 min implies that the quicker

moisture extraction and reduced processing duration compensated for thermal harm in this scenario while the optimum flavonoid outcome at microwave 2 min suggests that flavonoids could be more vulnerable, to extended microwave treatment. Elevated temperatures combined with drying durations like oven drying at 50 and 60 °C can result in a reduction in the proportion of compounds due to the temperature's impact on cell composition and the enzymes involved causing the breakdown of these compounds (phenolics and flavonoids) as well, as a significant decline and destruction of a large amount of them (Zainol *et al.,*2009; Periche*, et al.,* 2015).

Conversely it was noted that numerous of these substances diminished during in an oven at 40 °C and in shade despite the temperature. This could be attributed to the drying duration (72) hours for shade and 24 hours for oven at 40 °C) which resulted in ongoing enzymatic alteration and modification in the composition and proportion of the compounds, over a longer period compared to drying using microwave for 2 and 3 minutes (Kumar *et. al.,*2025).

The drying by microwave was characterized in high temperature during the drying, but the drying time was short (2 and 3 minutes). These conditions were appropriate in maintaining the largest amount for antioxidants of most compounds by stopping enzymatic activity responsible for the degradation of compounds, which led to record better results compared with other drying methods of study.

Inadequate drying may accelerate browning and oxidative damage whereas prolonged contact with heat and oxygen can diminish thermolabile phytochemicals resulting in lowered bioactivity and a decreased shelf life (Wang *et al.,*2025). Therefore, selecting a drying method is vital, for maintaining phenolic compounds, flavonoids, pigments and other antioxidant elements that uphold the functional properties of plant-based products (Myint *et al.,* 2023).

On the hand decreases in various compounds during shade drying and oven drying at 40 °C can be attributed to prolonged drying times and ongoing exposure to oxygen, which may increase oxidative processes and enzyme activity prior, to complete drying. Even though 40 °C is a low temperature the lengthy period needed to attain safe moisture content might result in more significant overall losses compared to a brief high-intensity method. These findings emphasize that temperature, by itself does not forecast retention; instead, the joint influence of temperature × time dictates compound durability and ultimate antioxidant efficacy.

Moisture content

Figure 3 indicates the reduction of moisture content from 76.28% in new stevia leaves to 11.57% after 7 hours of drying, after which the moisture stabilized and attained a fixed weight. Castillo-Tellez *et al.,* (2018) concurred that optimal period for harvesting and storing stevia leaves is when they become brittle, exhibiting a moisture content of 10–12%. Previous research indicated an increase in total phenolic content (TPC) following air drying, peaking at 40 °C with a measurement of 55.04 ± 2.27 mg GAE/100 g dry weight, as documented by Lemus-Mondaca *et al.* (2015). According to Castillo-Téllez *et al.* (2023), the optimal drying rate was achieved at 65 °C with an air velocity of 4 m/s, resulting in 0.05 kg of water evaporated per kilogram of dry matter per minute. A comprehensive understanding of the drying processes will facilitate optimal extraction of secondary chemicals from stevia leaves.

Total phenolic compounds (TPC)

Figure 3 illustrates the impact of drying duration on the (TPC)extracted from Stevia leaves. The findings obtained range from 26.39 ± 0.02 mg GAE/gm dw to 97.89 ± 0.13 mg GAE/gm dw. The maximum total phenolic

content (TPC) was recorded in fresh leaves post-drying, reaching 98.99 mg GAE/gm dry weight, whereas the minimum concentrations were identified at the 3-hour, 5-hour, and 6-hour drying intervals. Periche *et al.* (2015) reported that fresh stevia leaves showed a higher phenolic content (44.4 ± 1.04 mg GAE/g) compared to dried leaves (31.5 mg equivalent) when analyzed at 100 ◦C. A significant difference was observed in stevia leaves between drying periods of 6 and 7, with values of 33.149 ± 0.06 and 44.18 ± 0.08 mg GAE/gm dw, respectively.

DPPH radical scavenging efficacy

Antioxidant activity was assessed using DPPH as per Lemus-Mondaca (2016), revealing the peak value at 40 °C. The antioxidant activity results associated with the drying techniques was ranged from 775.99 ± 19.13 to 935.69 ± 4.56 µmol TE/gm dw (Figure 3). Increased antioxidant activity was noted when the moisture content approached 70%. This investigation demonstrated elevated levels of antioxidant activity.

The maximum phenol level in the leaves occurred at 7 hours after drying; however this did not correlate with activity. The peak antioxidant activity was recorded after 6 hours of drying, whereas the minimal antioxidant activity was noted at 4 hours, establishing it as the most effective drying method. Previous research indicates that the glycosides and phenolic compounds in stevia possess several hydroxyl groups that enhance their antioxidant properties.

CONCLUSION

The results indicated that microwave drying for 2 and 3 minutes produced the highest retention levels of most phenolic and flavonoids compounds, in the stevia plant leaves examined.

Accordingly, the adoption of novel drying techniques is essential to preserve stevia's physicochemical, sensory, medicinal, and functional food properties of stevia. Further research is necessary to assess the effects of alternative drying methods, such as vacuum oven drying, infrared drying, freeze drying, and spray drying, on the bioactive secondary compounds of stevia leaves.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES:

Agüero, M. V., and Pasten, A.2019. Antioxidant, antimicrobial and anti-inflammatory potential of Stevia rebaudiana leaves dehydrated by seven different methods. *Journal of Applied Research on Medicinal and Aromatic Plants*, **11**(3): 37–46.

Al-Taweel, S. K., Al-Anbari, I.H.A. A. and Al-Hamdani, H. M. 2022.Antioxidant identification, antimicrobial activity of stevia rebaudiana bertoni leaves extract on flavored milk. *Int. J. Agricult. Stat. Sci.,* **18** (2): 344-352.

Castillo, M., Pilatowsky, I., Castillo, B., López-Vidaña. E.C. and Anabel L.O. 2018. Solar drying of Stevia (*Rebaudiana Bertoni*) leaves using direct and indirect technologies. *Solar Energy*, **159** (4): 898–907. https://doi.org/10.1016/j.solener.2017.11.031

Castillo-Téllez, B., Téllez, M. C., López-Vidaña, E.C., Niño, A.D., Mejía-Pérez, G.A., and Carlos Jesahel Vega-Gómez.

2023. Temperature air velocity association and modeling study for drying of stevia leaves. *Energy Exploration &Exploitation,* **41**(5): 1802–1818.https://doi.org/10.1177/01445987231

Covarrubias-Cárdenas, A. G., Martínez-Castillo, J. I., Medina-Torres, N., Ayora-Talavera, T., Espinosa-Andrews, H., García-Cruz, N. U. and Pacheco, N. 2018. Antioxidant capacity and UPLC-PDA ESI-MS phenolic profile of *Stevia rebaudiana* dry powder extracts obtained by ultrasound assisted extraction. *Agronomy*, **8**(9):

Galal, W. K. 2002. Natural stevioside sweetener, production, and utilization in food. Ph. D. Thesis, Food Technology, Faculty of Agriculture, Cairo University.

Halim, A. A., Zain, Z. M., Mubarak, A. and Ahmad, F. T. 2019. Effect of different drying methods on antioxidant properties, stevioside and rebaudioside A contents of stevia (*Stevia rebaudiana* bertoni) leaves. *Asian Journal of Agriculture and Biology*, **7**(1):61-68

Hidar, N, Ouhammou,M, Mghazli, S, Idlimam, A, Hajjaj, A, Bouchdoug, M, Jaouad and A. Mahrouz, M. 2020. The impact of solar convective drying on kinetics, bioactive compounds and quality of stevia leaves. *Renewable Energy*. **161:** 1176-1183.

Huang, X. Li, W., Wang, Y., Wan, F.2020. Drying characteristics and quality of Stevia rebaudiana leaves by far-infrared drying. *Journal of Food Engineering*, **140**(10):110638. doi: 10.1016/j.lwt.2020.110638.

Kalsi, B. S., Singh, S., Alam, M. S. and Sidhu, G. K. 2023. Comparison of ANN and ANFIS modeling for predicting drying kinetics of *Stevia rebaudiana* leaves in a hot-air dryer and characterization of dried powder. *International Journal of Food Properties*, **26**(2): 3356–3375. https://doi.org/10.1080/10942912.2023.2283380.

Khshan, N.S. and. Al-Taweel, S.K. 2024. IOP Conf. Series: Earth and Environmental Science 1371 (2024) 052070, DOI 10.1088/1755-1315/1371/5/052070.

Kokilananthan, S., Bulugahapitiya, V.P., Gangabadage, C.S. and H. Manawadu. 2021. Comparative accounts on proximate and phytochemical compositions and antioxidant properties of *Garcinia quaesita* and *Garcinia zeylanica. International Journal of Minor Fruits, Medicinal and Aromatic Plants,* **7** (2): 59-67.

Kumar, P., Rani, P. and Tripathy, P.P. 2025. Indirect mode solar drying of stevia (*Stevia rebaudiana*) leaves: experimental and numerical investigation of fluid flow pattern, moisture, and temperature distribution profile. *Biomass Conv. Bioref.,* **15**: 7523–7542.https://doi.org/10.1007/s13399-024-05725-9.

Lemus-Mondaca R, Ah-Hen, K., Vega-Gálvez, A., Honores, C. and Moraga, N. 2016. *Stevia rebaudiana* leaves: Effect of drying process temperature on bioactive components, antioxidant capacity and natural sweeteners. *Plant Foods Hum Nutr*., **71**(1):49-56. doi: 10.1007/s11130-015-0524-3.

Lemus-Mondaca, R., Liliana Zura-Bravo, Kong Ah-Hen, Karina Di Scala. 2021. Effect of drying methods on drying kinetics, energy features, thermophysical and microstructural properties of *Stevia rebaudiana* leaves. *Journal of the Science of Food and Agriculture*, **101 (**15): 6484-6495.

Lemus-Mondaca, R., Vega-Gálvez, A., Moraga, N. O. and Astudillo, S. 2015. Dehydration of *Stevia rebaudiana* Bertoni leaves: kinetics, modeling and energy features. *Journal of Food Processing and Preservation*, **39**(5*)*:

508–520. https://doi.org/10.1111/jfpp.12256.

Mattila, P., Astola, J. and Kumpulainen, J. 2000. Determination of flavonoids in plant material by HPLC with diode-array and electro-array detections. *Journal of Agricultural and Food Chemistry*, **48**(12): 5834–5841.

Myint, K.Z.; Zhou, Z.; Shi, Q.; Chen, J.; Dong, X.,and Xia, Y. 2023. Stevia Polyphenols, Their Antimicrobial and Anti-Inflammatory Properties, and Inhibitory Effect on Digestive Enzymes. *Molecules*, **28,** https://doi.org/10.3390/molecules28227572.

Periche, A., Castelló, M. L Heredia, Ana and EscricheI. 2015. Effect of different drying methods on the phenolic, flavonoid and volatile compounds of *Stevia rebaudiana* leaves. *Flavour and Fragrance Journal,* **31**(2): 205-215. DOI: 10.1002/ffj.3298.

Periche, A., Koutsidis, G., Escriche, I. and Lemus-Mondaca, R. 2015. *Stevia rebaudiana* leaves: Effect of drying process temperature on bioactive components, antioxidant capacity and natural sweeteners. *Plant Foods for Human Nutrition,* **70**(2): 49–56. https://doi.org/10.1007/s11130-015-0524-3.

Rathore, R. 2024. Production and marketing of medicinal and aromatic plants: prospects and constraints-A review. *International Journal of Minor Fruits, Medicinal and Aromatic Plants,* **10** (1):13-22.

Roohinejad, S.; Koubaa, M. and Gharibzahedi, S.M.T. 2025. Drying technologies for *Stevia rebaudiana* Bertoni: Advances, challenges, and Impacts on bioactivity for food applications, A Review. *Foods*, **14.** https://doi.org/10.3390/foods14162801.

Téllez, M.C.; Figueroa, I.P.; Téllez, B.C.; Vidaña, E.C.L. and Ortiz, A.L. 2018. Solar drying of stevia (*Rebaudiana bertoni)* leaves using direct and indirect technologies. *Sol. Energy*, **159***:* 898–907.

Wang, L., Chang, T., Zhu, T., Hu, W., Wang, X., Dong, C., Sun, Y., Zhang, T., Jiang, Y., Zhao, C., Cui, Y., Guo, J., & Liao, X. 2025. Stevia *rebaudiana* Bertoni as a sweet herbal medicine: traditional uses, potential applications, and future development. *Frontiers in Pharmacology,* **16**: 1638147

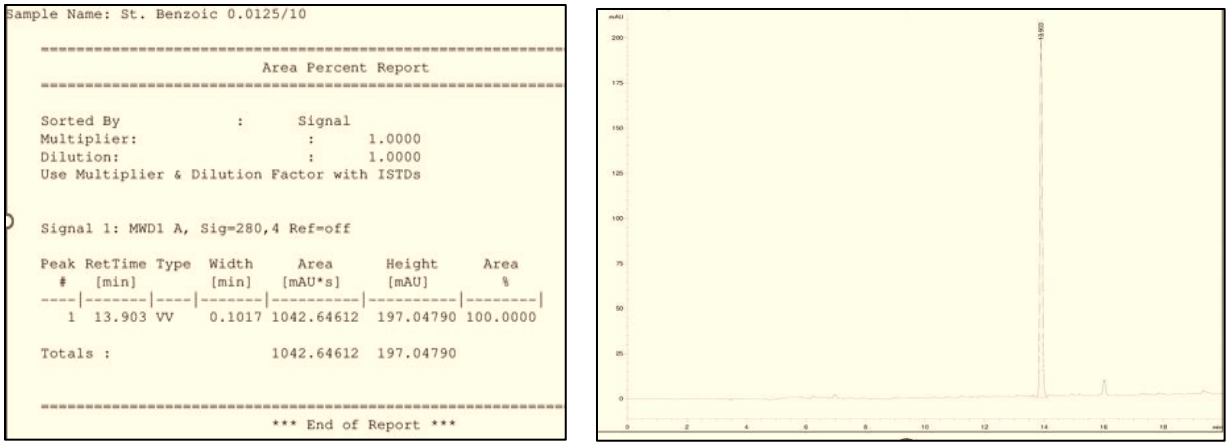
Zainol, M., Khairi, M., Abdul Hamid, A., Abu Bakar, F., & PakDek, M. S. 2009. Effect of different drying methods on the degradation of selected flavonoids in Centella asiatica. *International Food Research Journal***, 16**(4): 531–53.

Table 1: Effect of drying in phenol content (µg. g^{-1}) for Stevia plant leaves

Compound	Oven 60°C	Oven 50°C	Oven 40°C	Microwave 3 min	Microwave 2 min	Microwave 1 min	Shade	Solar	LSD
Pyrogallol	177.23	323.67	503	248.44	129.45	95.67	317.78	410	109.81
Gallic acid	15.11	15.71	11.6	32.66	12.42	15.78	9.22	9.7	8.88
Protocatechuic acid	20.60	21.63	27.1	52.12	19.11	29.23	34.32	20.2	14.56
p-OH benzoic acid	40.22	36.33	37.1	69.60	58.40	60.31	29.40	50.4	18.06
Benzoic acid	2127	1557.10	1161	2122.50	2188.33	1839.70	1424.21	1886	561.11
Caffeic acid	9.85	10.09	8.45	14.22	16.42	14.05	9.81	20.67	4.28
Salicylic acid	386.45	210.22	382	561.33	637.56	435.09	358.78	303	163.80

Table 2: Influence of drying method on flavonoid content percentage (µg.g^{-1}) in Stevia plant leaves

Type of compound	Oven 60°C	Oven 50°C	Oven 40°C	Microwave 3 min	Microwave 2 min	Microwave 1 min	Shade	Solar	L.S. D
Quercetin	32.9	22.80	14.10	12.66	52.01	10.80	22.50	13.38	15.83
Naringin	10.91	5.62	9.34	10.95	12.18	5.10	9.68	9.04	4.05
Kamp-3-7-diham	99.22	129.31	47.25	136.03	145.40	123.72	140.27	101.76	49.21
Apigenin-7-glucose	68.71	48.73	52.54	67.64	81.71	120.02	65.08	65.54	18.39
Apigenin-6-rha	209.02	235.05	263.08	378.06	747.02	180.02	382.06	228.04	151.05
Luteo-7-glucose	444.04	351.05	1115.01	1318.0	2287.03	1585.02	425.0	1954.0	383.51
Apigenin-7-oheo	207.33	162.65	184.97	283.2	373.02	227.23	256.6	237.1	83.58



Sample Name: St. Benzoic 0.0125/10

Area Percent Report

Sorted By : Signal
Multiplier: : 1.0000
Dilution: : 1.0000
Use Multiplier & Dilution Factor with ISTDs

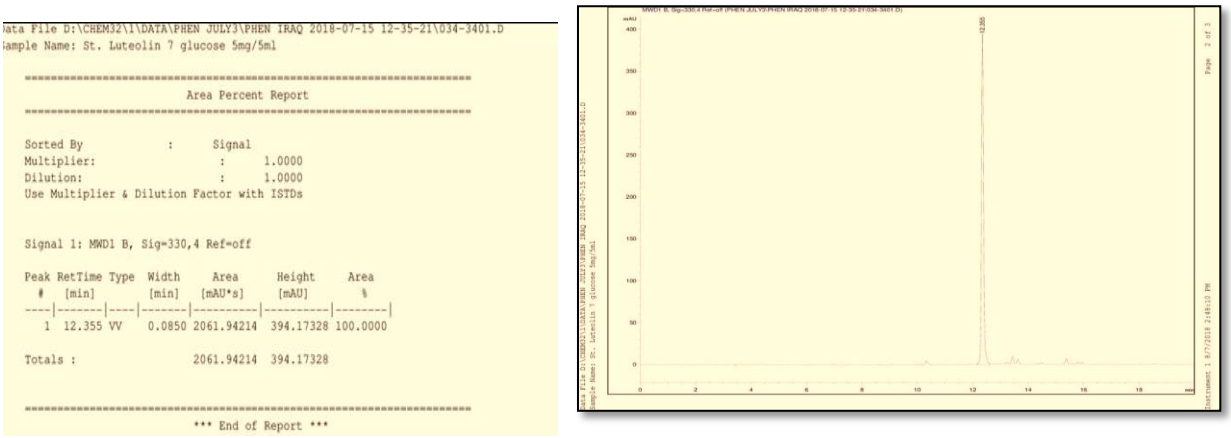
Signal 1: MWD1 A, Sig=280,4 Ref=off

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.903	VV	0.1017	1042.64612	197.04790	100.0000

Totals : 1042.64612 197.04790

*** End of Report ***

Fig. 1 Standard curve, retention time, peak area, and concentration of Benzoic acid compound by Microwave 2 min.



Data File D:\CHEM32\1\DATA\PHEN JULY3\PHEN IRAQ 2018-07-15 12-35-21\034-3401.D
Sample Name: St. Luteolin 7 glucose 5mg/5ml

Area Percent Report

Sorted By : Signal
Multiplier: : 1.0000
Dilution: : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: MWD1 B, Sig=330,4 Ref=off

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.355	VV	0.0850	2061.94214	394.17328	100.0000

Totals : 2061.94214 394.17328

*** End of Report ***

Fig. 2 Standard curve, retention time, peak area, and concentration of Luteolin7 glucoside compound by Microwave 2 min.

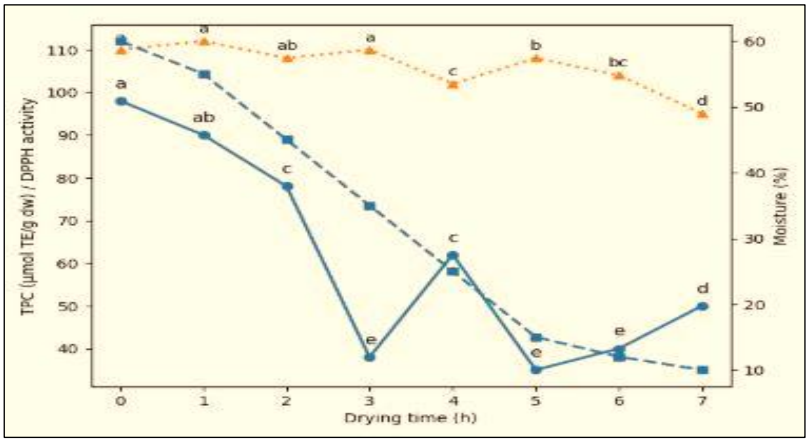


Figure 3: Changes in TPC, DPPH radical scavenging activity, and moisture percentage of plant material during different drying times. Different letters above the data points indicate significant differences among drying times for each parameter at $p \leq 0.05$.