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Drying kinetics of selected culinary herbs : Influence of temperature on bioactive compounds and antioxidant activity

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Topic

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Presented by:

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List of abbreviations

AA: Ascorbic acid
AAE: Ascorbic acid equivalent
Chl a: Chlorophyll a
Chl b: Chlorophyll b
DCPIP: 2,6-dichlorophenolindophenol
DM: Dry matter
DPPH: 2,2-diphenyl-1-picrylhydrazyl
DW: Dry weight
EHD: Electrohydrodynamic drying
FIR: Far-infrared
GAE: Gallic acid equivalent
HAID: Hot air impingement drying
HPLC: High liquid performance chromatography
IR: Infrared
LPSS: Low-pressure superheated steam
MIR: Mid-infrared
MR: Moisture ratio
NIR: Near-infrared
OD: Osmotic drying
R^2: Coefficient of determination
RF: Radiofrequency
RMSE: Root mean square error
SFD: Spray Freeze Drying
TCA: Trichloroacetic acid
TPC: Total phenolic contents
χ^2: chi-square

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Introduction

Introduction

Most fruits and vegetables that are not used shortly after harvesting get spoiled very quickly but some techniques of preservation are applied to help prolong their shelf life (Erdem *et al.* 2023). Culinary herbs are primarily used to enhance the flavour, aroma, and overall sensory appeal of food (Violeta *et al.* 2017). Culinary herbs are highly perishable thus a significant portion of the produce is wasted owing to poor post-harvest processing techniques (Hihat *et al.* 2017). Drying natural products being one of the oldest food preservation techniques, is most important because its impact on the quality of final products is highly significant (Ozgen 2021). By lowering the moisture content, this process inhibits microbial growth thus enhancing shelf life and reduces chemical alterations during storage (Singh *et al.* 2024; Thamkaew *et al.* 2021).

Plants are good sources of bioactive compounds, which have widely been documented to possess antioxidant, antimicrobial, anti-inflammatory, antitumor, antiviral, analgesic, and antipyretic activities, thus the desire among health practitioners and greater motivation by healthcare systems for consumption on a daily basis (Jahromi 2019).

The bioactive compounds behind the natural flavour and aroma of some culinary herbs also assist in the preservation of human health. These herbs are good dietary sources of polyphenols, which are bioactive compounds that are renowned for sharing a wide range of properties beneficial to health, including easing digestion, reducing inflammation, and exhibiting antimicrobial, antioxidant, and anticancer activities. In addition to polyphenols, culinary herbs contain other classes of phytochemicals such as chlorophylls, carotenoids, and ascorbic acid. A majority of these chemicals possess high antioxidant activity, which was discovered to be linked with reduced cancer risk and mortality in certain cancers according to findings of several epidemiological studies (Violeta *et al.* 2017).

An understanding of drying kinetics and the effects of different drying conditions on the process is vital to its designing and controlling the process so that quality is achieved. While drying, physical changes such as reduced weight and volume are initiated, which thereby decrease transportation and storage cost (Sairam *et al.* 2017)

The processing conditions significantly influence the preservation of bioactive compounds. Therefore, this study investigates the effects of drying four culinary herbs which include, laurel,

parsley, mint and coriander using a food dehydrator at 3 different temperatures, 50, 60 and 70°C.

This work is therefore divided into two main parts: the first part constitutes of a brief bibliographic review on research carried out on laurel, parsley, mint and coriander, (for each plant: its origin, description, botanic classification, traditional use as well as its world production). In another section in this part, the notion of drying and its techniques are discussed.

The second part constitutes of:

- The study of drying kinetics of the laurel, parsley, mint and coriander, and their evolution with time at different temperatures (50, 60 and 70°C).
- Mathematical modelling of drying kinetics using 4 models: Page, Midilli, Weibull, and Logarithmic.
- The study of their phytochemical quality by the determination of:
  - ✓ their content in phenolic compounds and ascorbic acid;
  - ✓ determination of their content in pigments; carotenoids and chlorophyll (a and b);
  - ✓ evaluation of their antioxidant activity: DPPH radical scavenging assay and reducing power.

Generalities

I Generalities on the plants

I.1 Laurel

Laurus nobilis L., or laurel, is an evergreen tree in the Lauraceae family. Not only is it edible but also deemed as beneficial because it has many effects on human health from its various biological properties (Anzano *et al.* 2022).

I.1.1 Description

Laurus nobilis is a multi-branched shrub or tree up to 10 meters in height. It has blackish or olive-green smooth bark. It is an evergreen with dark green, lanceolate leaves that are pointed at both tips, up to 10 cm long, and alternately arranged on the branches. In spring, the male and female flowers are on separate trees. Whitish-green flowers with four petals that are joined at the base appear in close clusters on the branch. Male flowers contain 10–12 stamens, while the female contain four staminoids, a short-stemmed ovary with one chamber, a hanging ovule, a short style, and a triangular stigma. At the end of the flowering season, deep black, ovate berries, approximately 2 cm in length, are produced on the plant (Preedy 2016).

Figure 1. *Laurus nobilis* (Pandeyey *et al.* 2022).

I.1.2 Etymology

The origin of *Laurus* is the Latin word *laureola*, a "wreath of laurel." So too has "baccalaureate" come down from the “Latin bacca lauri”, which means "bay of laurel," because laurel wreaths were antique rewards bestowed on heroes (Khaled Khodja *et al.* 2023).

I.1.3 Botanical Classification

Laurel tree, *Laurus nobilis* L., family Lauraceae is also known as bay laurel or Apollo's laurel. It belongs to the order Laurales, which consists of nine families and around 3,000

species. Calycanthaceae, Lauraceae, and Monimiaceae are some of the most noted families within the order. The Lauraceae family in general is highly diverse, with over 55 genera and 2,500 to 3,500 species. Within the *Laurus* genus, there are three species that are dominant: *Laurus azorica*, or *Laurus canariensis*, which is found in the Azorean woodlands; *Laurus nobilis*, native to the Mediterranean region; and *Laurus novocanariensis*, found in Madeira, the Canary Islands, and Morocco (Khaled Khodja *et al.* 2023). The botanical classification of *L. nobilis* was presented in Table 1.

Table 1. Botanical classification of *L. nobilis* (Chatelain *et al.* 2018).

Kingdom	Plantae
Under the reign	Vascular plants
Branch	Spermaphytes
Sub-Branch	Angiosperms
Class	Dicotyledonous
Subclass	Magnolideae
Order	Laurales
Family	Lauraceae
Genus	Laurus
Species	*Laurus nobilis* L.

I.1.4 Cultivation

Laurus nobilis is native to the Mediterranean region and is naturally found in Europe and California. It is grown widely in Europe, the Americas, and North African countries, between Libya and Morocco. The species likes sunny positions with good drainage and shelter from cold winter breeze. Seeds are the most common form of propagation but even in temperate climates germination can be a few months to one year. The most efficient and alternative technique is stem cutting, with the best rate of success if done during July or August in the Mediterranean climate. The optimum temperature of rooting medium for maximum root development would be around 20°C to 30°C. Under conditions where soil and air temperatures during winter are generally below 15°C, as is frequent in the Mediterranean climate, the medium warming up might improve rooting (Peter 2006).

I.1.5 Traditional usage

Laurel or bay leaf is a favourite herb in culinary dishes for decades. The aromatic leaves are added to many foods, including boiled chestnuts, roasted meats, codfish, sausages, chili peppers, and dried figs (Motti 2021).

Laurel has long been highly valued in conventional medicine for its diverse health benefits. Leaves and fruit of the plant are orally and externally used to cure a range of health conditions. It is commonly used to aid digestion, relieve indigestion, constipation, bloating, diarrhoea, and stomach aches. It has also been employed in kidney disease treatment, respiratory infections like common colds, cough, and sore throats, and even as a headache and light sedative treatment. In southern and central Italy, laurel leaves are a key ingredient in a traditional respiratory remedy known as Ricotto or Ricuotto, which remains in use today. The plant is also employed for analgesic, anti-rheumatic, and diaphoretic action, as well as for gynaecological indications, including menstrual colic relief and milk stimulation. Some usages even claim the use as an abortifacient. Furthermore, laurel decoctions have been used to foster cardiovascular health and to control blood pressure (Anzano *et al.* 2022).

I.1.6 Chemical composition

Laurus nobilis contains polyphenols or phenolic compounds such as flavones and flavanol which exhibit antioxidant activity. They also contain other phenolic compounds such as proanthocyanidins and structural derivatives of caffeic and coumaric acids. Alkaloids have also been isolated from laurel leaves (Khodja *et al.* 2023). It is also rich in pigments such as chlorophylls and carotenoids (Cvitković *et al.* 2021).

The composition *Laurus nobilis*'s essential oil is different, depending upon which part of the plant the oil is distilled from: flowers, leaves, or seeds. Various factors determining the yield, as well as the composition, of the oil are genetics, environmental conditions, the stage at which the plant is growing, and even by which process the extraction is achieved, e.g., steam distillation, hydro distillation, Soxhlet extraction. 1,8-cineole, α-pinene, β-pinene, sabinene, limonene, and linalool are some of the significant compounds found in *Laurus nobilis* essential oil. Other components present in bay leaf essential oil are tricyclene, γ-terpinene, eugenol, p-cymene, α-phellandrene, camphene, camphor, terpinene-4-ol, α-terpineol, α-thujene, myrcene, α-terpinene, terpineolene, sabinol, borneol, γ-cadinene, β-elemene, germacrane A, germacrane D-4-ol, α-humulene (Chahal *et al.* 2017).

I.1.7 World production

Turkey is the main producer of *Laurus nobilis*, exporting to 64 countries, nearly 97% of the global market. The annual production of the country typically varies between 7,000-7,500 tons (Paparella *et al.* 2022). Some of the other important producers of bay leaves are nations in the Mediterranean region such as Greece, Italy, and Spain, where favourable climatic conditions favour the production of the bay laurel tree. Morocco and Egypt are some of the world's contributing nations to the supply globally (Ess 2025).

I.2 Parsley

Petroselinum crispum (Mill.), a member of the Apiaceae family, is commonly known as parsley and is widely used for both culinary and medicinal purposes (Farzaei *et al.* 2013).

I.2.1 Description

Petroselinum crispum is a bright green, annual herb in the tropics and subtropics, and a biennial in temperate regions. During the first year, it forms a rosette of tripinnate leaves and a taproot to store nutrients through the winter. During the second year, it forms tall, branched stems, sparser leaves, and flat-topped umbels of small yellow-green flowers. This scented herb reaches a height of 30 to 100 cm and has hollow and grooved stems. It possesses glossy green leaves with varying shapes, from flat to curled, and the leaves are alternately arranged on the stem. The leaves on the lower part are more divided, whereas the upper leaves have fewer and more pointed lobes (Agyare *et al.* 2017).

Figure 2. *Petroselinum crispum (Ahmed et al. 2025).*

I.2.2 Etymology

The genus name *Petroselinum* is derived from the Greek word "*petra*", meaning rock or stone, and the Latin name "*selīnum*", referring to plants that inhabit rocky places. The species name crispum is derived from the Latin word "*crispus*," which means curled (Marthe 2020).

I.2.3 Botanical classification

Petroselinum crispum, as a member of the family Apiaceae, has the typical characteristics of compound leaves, umbel-type inflorescences, and an aromatic nature. Its systematic position in the plant kingdom is given in Table 2.

Table 2. Botanical classification of *Petroselinum crispum* (Marthe 2020).

Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Apiales
Family	Apiaceae
Genus	Petroselinum
Subject	*Petroselinum crispum* (Mill.)

I.2.4 Cultivation

Parsley is a mediterranean or warm temperate crop, and it prefers full sun and long days. It prefers to grow in well-drained rich soil with rich organic matter and an optimal pH of 6.5. Parsley consists of deep taproots and also has a large water requirement; therefore, it must have a good level of moisture regularly—drought as well as water stress will cripple the development and reduce yield. Germination is best when it is carried out at 20°C and the plant prefers to grow from 7 to 25°C (Sarwar *et al.* 2019).

I.2.5 Traditional uses

Parsley is commonly used to add a splash of colour and freshness to a combination of foods including soups, stews, salads, and sauces. In addition to its aesthetic use, it is also used as a flavouring agent in cooked dishes and makes valuable nutritional contributions. Parsley has also been valued for its natural diuretic action for thousands of years and has been used traditionally to relieve kidney stones. It was also employed by ancient civilizations to treat a number of ailments, including menstrual issues, gastritis, and prostatitis. Modern studies validate many of these traditional uses, showing that parsley is able to protect the liver and

kidneys, improves mental processes, and help manage metabolic disorders (E. Ahmed *et al.* 2025).

I.2.6 Chemical composition

Parsley stands out among vegetables because of its very high vitamin C content. Other than this, it is an important source of essential major minerals, volatile essential oils, natural colouring pigments such as chlorophylls and carotenoids, and a wide variety of polyphenolic compounds. These bioactive substances are attributed to its high antioxidant activity, thus its role in sustaining health and avoiding oxidative stress-related conditions (Dobričević *et al.* 2019).

The seeds, leaves, and roots of parsley contain essential oils, the principal constituents of which are myristicin and apiol. The leaves contain several different compounds like aldehydes, monoterpene alcohols, sesquiterpene hydrocarbons, alcohols, and ketones. The roots contain furanocoumarins, the seeds contain sesquiterpenes, and the stems contain phenylpropanoids. Parsley essential oil consists of numerous bioactive compounds, including α-pinene, β-pinene, sabinene, ρ-cymene, β-phellandrene, α-phellandrene, limonene, myristicin, γ-terpinene, elemicin, carotol, apiol, eugenol, and β-caryophyllene among others. It also contains some aldehydes, terpenes, and hydrocarbons responsible for its properties and aroma (Sarwar *et al.* 2019).

I.2.7 World production

Top producers of Parsley include China, United States, Italy, France and Netherlands. Other countries include; Algeria, Bosnia and Herzegovina, Brazil, Catalonia, Morocco, Serbia and Türkiye

I.3 Mint

Mint, known botanically as *Mentha*, is a member of the family Lamiaceae and subfamily Napithoidae. There are about 38 species widely distributed in all the agro-climates of the world. One of the most widespread of these is *Mentha spicata* L., or spearmint—a perennial herb grown widely for its flavouring and medicinal purposes (Boukhebti *et al.* 2011).

I.3.1 Description

Mentha spicata L., or spearmint, is a perennial herb that is typically 30 to 100 cm tall. It has an erect, square, smooth, and branched stem. The leaves are ovate to lance-shaped, measuring 2 to 7 cm long, and have serrate margins. It has dense, terminal spikes of 3 to 12 cm long and 5 to 10 mm broad with minute, stalked flowers in interrupted arrays that are generally white or pink. Spearmint is widely cultivated throughout the world in profusion for use in culinary seasoning as well as in traditional medicine (Mahendran *et al.* 2021).

Figure 3. *Mentha spicata* (Brahmi *et al.* 2017).

I.3.2 Etymology

The botanical name Mentha spicata is derived from classical Latin and reflects key morphological traits of the plant. The genus name Mentha is the Latin term for "mint," which itself originates from the Greek minthē (μίνθη). While the Greek term has mythological associations, in botanical nomenclature, Mentha is used systematically to designate a group of aromatic plants known for their volatile oils and widespread culinary and medicinal applications. The species epithet spicata comes from the Latin word spica, meaning "spike," and refers specifically to the characteristic inflorescence of the plant, where the small flowers are arranged in elongated, spike-like clusters at the tip of the stem. Thus, Mentha spicata can be understood to mean "mint with spike-like flowers," highlighting a distinctive floral feature that aids in its identification and classification within the diverse Lamiaceae family (Silva 2020).

I.3.3 Botanical classification

Mentha spicata L. is a member of the Lamiaceae family—commonly known as the mint family. The Lamiaceae is a diverse plant family with approximately 260 genera and some 7,000

species, many of which can thrive under a broad variety of agroclimatic conditions (Mahendran *et al.* 2021). The Botanical classification of *M. spicata* was presented in Table 3.

Table 3. Botanical classification of *Mentha spicata* L.

Domain	Eukaryota
Kingdom	Plantae
Phylum	Spermatophyta
Subphylum	Angiospermae
Class	Dicotyledonae
Order	Lamiales
Family	Lamiaceae
Genus	Mentha
Species	*Mentha spicata* L.

I.3.4 Cultivation

Spearmint thrives in tropical and subtropical regions and can be cultivated in a wide range of soils, so it is not rare even in domestic gardens. It needs regular showers and lots of sunshine during the growing season to develop properly and yield well. Like most mints, spearmint needs plenty of water, especially when it is in its most active growing stage. However, water availability must be tightly managed—both water stress and waterlogging of soil can damage plant growth and reduce herb and essential oil yields. Water requirements are also a function of local conditions such as soil type, fertility, and climate (Kassahun *et al.* 2014).

I.3.5 Traditional uses

Mentha spicata is cultivated all over the globe for its culinary, medicinal, and aromatic properties. Its fresh and dried leaves are used in tea and as a flavouring. Spearmint has long been traditionally used in the treatment of gastrointestinal and respiratory ailments, bad breath, and as an antispasmodic, carminative, diuretic, and mild sedative. The leaves are used in traditional Iranian medicine in the form of decoctions, tinctures, and tablets to alleviate flatulence and facilitate digestion, with the leaves reported to make the stomach strong and alleviate dyspepsia. Spearmint oil is today widely used as a flavouring agent in chewing gum, toothpaste, and cosmetics (Mahendran *et al.* 2021).

I.3.6 Chemical composition

Polar extracts of *Mentha spicata* leaves have been found to include phenolic compounds such as rosmarinic acid and luteolin and apigenin derivatives, which have been proven to possess antioxidant activity, thus qualifying the plant as a natural source of antioxidants (Cirlini

et al. 2016). The principal pigments in *Mentha spicata* are chlorophylls and carotenoids (Rocha *et al.* 1993).

Phytochemical analysis also shows that spearmint is rich in volatile oils such as menthol and menthone. These phytochemicals are responsible for spearmint's therapeutic effects like its antioxidant, anti-inflammatory, antimicrobial, antifungal, and muscle-relaxant activities. The chemical constitution of *Mentha spicata* essential oil varies with climate, region, and method of extraction. However, carvone is always the major one, making up 50–80% of the oil, which is known for its antioxidant, anti-inflammatory, and antimicrobial activities. Other significant constituents include limonene, β-caryophyllene, α-pinene, β-pinene, 1,8-cineole (eucalyptol), and linalool (Boukhebti *et al.* 2011).

I.3.7 World production

According to Food and Agriculture Organization, the global production of mint (including Mentha spicata and other Mentha species) reached 145,182 metric tons. However, the data does not separately specify production for spearmint (*Mentha spicata*) alone, as it is aggregated with other mint varieties. The leading producers typically include India, China, the United States, and Egypt (FAOSTA 2022).

I.4 Coriander

Coriander (*Coriandrum sativum* L.) is an annual herb belonging to Apiaceae (Umbelliferae) family and is extensively used in the food, pharmaceutical, and cosmetics industries (Mhemdi *et al.* 2011).

I.4.1 Description

Coriandrum sativum is a small, branching herb with oval young leaves changing to elongated on maturity, white flowers with a purple colour tinge, round fruits in two parts, and seeds that develop along with flowers by late winter (Momin *et al.* 2012).

Figure 4. *Coriandrum sativum* L (Asgarpanah and Kazemivash 2012).

I.4.2 Etymology

The term "coriander" comes from the Greek name *korannon*, a combination of *koris* (meaning "bug") and *annon* (an aromatic plant closely akin to anise), which was originally applied to the plant's ripe seeds. The Roman naturalist Pliny the Elder afterwards applied the name *Coriandrum* to the genus, taking a cue from *koris* to name the fresh herb and young fruits' pungent, bug-like odour.

I.4.3 Botanical classification

From a taxonomic perspective, Coriandrum sativum has a well-established position. The Table 4 provides the elaborate taxonomic hierarchy of *Coriandrum sativum* L.

Table 4. Botanical Classification of *Coriandrum savitum* L. (Rajeshwari and Andallu 2011).

Family	Umbelliferae
Division	Angiospermae
Class	Dicotyledonae
KSub-class	Calyciflorae
Order	Umbellales
Genus	Apiaceae
Species	Umbellifera

I.4.4 Cultivation

Coriander performs well in tropical regions, where it prefers a frost-free, cool, dry environment, especially for flowering and seed formation for highest quality and production and with temperatures between 20–25°C for optimal germination and early growth (Rajeshwari and Andallu 2011).

I.4.5 Traditional uses

While every part of the plant is edible, green leaves and dehydrated seeds are most commonly utilized as a spice in culinary processes. Coriander is of great value in Indian traditional medicine for its stimulating, carminative, diaphoretic, and diuretic properties and employed for the treatment of urinary, respiratory, and digestive disorders. Similarly, in Iranian traditional medicine, coriander is employed for the treatment of a number of disorders of the body, including anorexia, dyspepsia, convulsions, and insomnia (Momin *et al.* 2012).

I.4.6 Chemical composition

Fresh coriander leaves contain moisture (87.9%), protein (3.3%), and carbohydrates (6.5%). They also provide minerals, including calcium (0.14%), phosphorus (0.06%), and iron (0.01%). Additionally, they are rich in vitamins, offering 60 mg of vitamin B2, 0.8 mg of niacin, 135 mg of vitamin C, and a high dose of vitamin A (10,460 IU) per 100 grams. Coriander seeds, however, are denser in nutrients and have around 11% starch, 20% fat, 11% protein, and almost 30% crude fibres in every 100 grams (Shahwar *et al.* 2012).

Although the coriander leaves have been less extensively studied than the fruits, they also contain essential oils, flavonoids, phenolic acids, and polyphenols (Sahib *et al.* 2013). The polyphenolic profile of coriander leaves shows the presence of vanillic, ferulic and p-coumaric acids and flavonoids such as quercetin, kaempferol and acacetin (Scandar *et al.* 2023).

I.4.7 World production

India is the top producer of coriander globally. Other countries that are high producers of coriander include; Türkiye, Mexico, Syria, Iran, China, Russia Egypt and Morocco in descending order.

II. Generalities of drying techniques

Drying, or dehydration, is the process of removing water by evaporation from a liquid or solid food material with the ultimate goal of obtaining a solid product with considerably lower moisture content (Singh *et al.* 2024).

There are two primary mechanisms of moisture movement during drying; the movement of moisture from the interior of the material to the surface and the movement of moisture from the surface to the surrounding air, where it evaporates as water vapor (Belessiotis and Delyannis 2011).

Drying method methods can be divided into two broad groups: natural and artificial methods. Natural drying makes use of solar energy for the evaporation of moisture from food products. However, this process is extremely weather-dependent and therefore not always dependable and a bit unpredictable. Artificial drying, however, is more prevalent since it has greater drying rates, increased efficiency, and is able to remove higher levels of moisture. Artificial drying also leads to improved product quality as it allows for greater control of temperature, air flow, and drying time. A very significant advantage of artificial drying is the ability to optimize the drying process through the use of mechanical or electrical equipment, i.e., fans or dehumidifiers, to enhance air circulation and control. This helps maintain consistent drying conditions, thereby yielding more uniform results (Adeyeye *et al.* 2022).

Furthermore, artificial drying methods are generally preferred in industrial practice because they are more predictable and scalable, and therefore can be employed for large-scale production of dried products.

Additionally, emerging advances in artificial drying, such as the application of microwave or dielectric heating, can further reduce energy consumption while improving drying efficiency, making the technologies increasingly popular for food quality preservation.

II.1 Natural drying methods

II.1.1 Solar drying

Solar drying is the method of using sunlight to dry substances, such as foods, to maintain shelf life and prevent spoilage. Solar drying involves two overall steps: first, solar radiation transfers thermal energy from the sun to the material to be dried (heat transfer), and second, water is evaporated from the material and transferred to the surrounding environment as vapor (mass transfer) (Rahman *et al.* 2025).

Solar drying is a low-technology, environmentally friendly process, particularly useful where sunshine is plentiful. It is widely used for drying food items like fruits, vegetables, and cereals and offers a sustainable way of preserving produce and reducing wastage in areas where other forms of preservation are not easily available. Sun drying may be of two kinds: Direct sun drying – Where products are exposed to the sun directly and indirect (convective) solar drying – Where solar-heated air is used to dry the products by evaporating the moisture without exposing the products to direct sunlight (Belessiotis and Delyannis 2011).

II.2 Artificial dry methods

II.2.1 Convective drying

Over 85 percent of the industrial dryers are convective type using hot air or direct firing gases as the drying agent(Mujumdar and Devahastin 2000). Convective drying consists in the supply of heat by hot air or gas flow that moves over the surface of the material. The heat for evaporation is conducted from the heat energy to the air-exposed surface of the substance by convection, and the water evaporated is taken away by the drying medium. Air, inert gases (e.g., nitrogen, especially when drying wet solids in contact with organic solvents), combustion gases, or superheated steam are typical drying media. In some cases, solvent vapours may also be used, depending on the drying operation (Mujumdar and Devahastin 2000).

This is a process that is largely employed in processes in which proper evaporation of water is necessary, e.g., the food industry, the production of drugs, and chemical manufacturing. There are parameters that influence the efficiency of convective drying, e.g., the temperature, velocity, and humidity of air, and the material's surface area to be dried.

II.2.2 Drying by radiation

Radiation drying offers an alternative to hot air drying, which creates loss of heat-labile food components through dehydration for prolonged periods and high temperatures (Adeyeye *et al.* 2022). Radiation drying utilizes the electromagnetic waves to dehydrate food and other products (An *et al.* 2025).

Infrared drying operates by transferring infrared energy directly to the food surface, which then radiates into the product. This energy stimulates water molecules to vibrate and produce localized heat. The moisture evaporation from the surface is boosted by the resulting heat, leading to successful drying. The penetration depth of infrared energy varies with its wavelength; shorter wavelengths penetrate more into the material to allow for internal moisture removal, while longer wavelengths are most ideal for surface heating (Sabbaghi and Nhu 2025)

Infrared radiation lies between the wavelength of 0.75 and 1000µm and is divided into three broad categories: near-infrared (NIR) from 0.75–2µm, mid-infrared (MIR) from 2–4µm, and far-infrared (FIR) from 4–1000µm (Huang *et al.* 2021).

Infrared energy is produced with the assistance of electrically heated or gas-fired heaters. In electric radiators, the energy is produced when an electric current flows through a heating element. Gas-fired heaters consist of a perforated metal or refractory plate, which is warmed by gas flames on one side. As the temperature of the plate increases, it emits infrared energy (Sakare *et al.* 2020).

Microwave energy in the form of electromagnetic waves penetrates food based on frequency and food properties. Operating between 300 and 300 GHz, the most common heating frequencies are 0.915 and 2.45 GHz. These fall within industrial, scientific, and medical radio bands and have good penetration. While lower frequencies penetrate deeper, the efficacy of heating is based on material properties. Correspondingly, 2.45 GHz is used widely in home microwaves, while 0.915 GHz is used industrially (Olaniyi 2016).

Radiofrequency (RF) processing, a form of radiation drying, but distinct from infrared (IR) drying and microwave drying, differs in the way it generates heat. With the frequency of 3 kHz to 300 MHz, offers deep penetration, fast heating, and chemical-free treatment. Its effectiveness depends on the dielectric characteristics of the product, and it is an ideal choice for heating, drying, sanitizing, and cleaning bioproducts. RF enhances quality, flavour, and safety by generating heat through molecular friction caused by oscillating molecules and ions in an alternating electric field (Hegde *et al.* 2025).

II.2.3 Freeze drying

Freeze-drying, also called lyophilization, is a dehydration process where food is first frozen, then dried under low pressure, allowing water to be removed through sublimation. Freeze-drying stores food for a very extended period of time without any quality loss (Pragti *et al.* 2025).

Freeze-drying is the most reliable method for preservation of heat-sensitive foods, outperforming conventional drying methods. It operates under low temperature and high vacuum and is therefore highly suitable for foods containing thermally sensitive or oxidation-prone ingredients. Consumers enjoy freeze-dried foods due to the convenience they offer, as they retain their natural shape, texture, and colour and are easy and quick to prepare (Yusoff *et al.* 2024).

Vacuum freeze-drying is the most appropriate method for producing high-quality dehydrated food with minimal change in texture, flavour, nutrients, and chemical composition. It maintains the inner structure of the food particles by combining vacuum and freeze-drying, and speeds up the sublimation rate (Sajjad *et al.* 2024).

Atmospheric freeze drying is the circulation of cold, dry air at -6 to -10°C over a frozen product to speed up heat and mass transfer near atmospheric pressure. The principle is to maintain the water vapor pressure below the triple point of water so that the elimination of moisture is through sublimation only. The need is to maintain the partial pressure of water vapor in the drying medium low in order to enhance the transfer of moisture from the frozen sample. The temperature must be low enough to maintain the product structure frozen and its vapor pressure at a maximum (Rahman and Mujumdar 2012).

Spray-freeze-drying (SFD) is a three-step process whereby a liquid or solution is atomized into droplets, rapidly frozen by a cold fluid, and then freeze-dried under low temperature and pressure. Combining spray drying and freeze drying, SFD enhances drying efficiency by particle size reduction and enhanced surface mass transfer. Since freezing and freeze-drying times are scaled with the square of sample thickness, minimizing the material dimensions significantly accelerates the process (Ishwarya *et al.* 2015).

II.2.4 Ultrasound drying

Operating above the human hearing range, it uses transducers to change electrical energy into sound vibrations. It is classified based on frequency as power ultrasound (20–100 kHz), high-frequency ultrasound (100 kHz–1 MHz), and diagnostic ultrasound (1–500 MHz). An ultrasonic system consists of a generator, a transducer, and an application system, where the generator produces energy that is converted by the transducer into ultrasonic waves, which are used in processing operations for drying a wide range of products (Samarasinghe *et al.* 2024).

II.2.5 Osmotic drying

Osmotic dehydration (OD) partially dehydrates plant tissues by immersing them in hypertonic salt or sugar solutions. The process enhances nutritional and functional value and preserves food integrity. OD increases drying efficiency, reduces processing time, and minimizes heat exposure, leading to better quality and energy conservation. It also allows for the incorporation of healthy solutes like isomaltulose, which is a low-glycemic, prebiotic carbohydrate that is non-cariogenic (Abrahão *et al.* 2024).

II.2.6 Electro-hydrodynamic drying

Electrohydrodynamic drying (EHD) is an innovative, nonthermal technology utilizing cold plasma in a high electric field for the efficient drying of heat-sensitive foods without compromising quality, with energy conservation, environmental benefits, and low capital cost (Paul and Martynenko 2021).

II.2.7 Hot air impingement drying (HAID)

Using high-speed hot air from annular nozzles to agitate thermal boundary layers, it significantly enhances heat transfer—up to five times as effective as cross-circulation drying (Zheng *et al.* 2023).

II.2.8 Fluidized-bed drying

Fluidization is widely used in drying, combustion, and synthesis operations primarily for non-viscous and fine particles. During fluidized bed drying, air is drawn at rate to suspend particles of solids and create a boiling-like effect termed fluidization. Using hot air enhances drying capacity by enhancing the evaporation of moisture (Senapati *et al.* 2024).

II.2.9 Low-pressure superheated steam (LPSS) drying

It uses low-pressure superheated steam to dry wet goods at relatively low temperatures. This oxidation-free process minimizes oxidation and heat decomposition, maintaining nutrients, appearance, and overall product quality (Li *et al.* 2022).

Experimental part

I. Materials and methods

I. Materials and methods

I.1 Collection of samples

The plants used in the present study include the aerial parts of parsley (*Petroselinum crispum*) and coriander (*Coriandrum sativum*), as well as the leaves of laurel (*Laurus nobilis*) and mint (*Mentha spicata*), selected based on their common culinary use. These species are widely cultivated in Algeria and are available year-round. All plant materials were purchased fresh from a local market in the wilaya of Béjaia on the same day of their harvest.

I.2 Drying process and samples preparation

The culinary herbs were dried using a domestic food dehydrator (Proficook Food Dehydrator PC-DR 1116, Kempen, Germany). The food dehydrator is equipped with an electronically adjustable temperature control ranging from 40 to 70°C, allowing precise regulation of drying conditions for various food types. It includes four large, transparent, and stackable trays that provide ample drying space and allow visual monitoring of the process. The compact design, with dimensions of 34 × 26 × 26 cm (length × width × height), makes it suitable for use in domestic kitchens. The device operates on a standard 230 V, 50 Hz power supply.

Drying was carried out at three different temperatures: 50, 60, and 70°C. The plant samples (30g) were evenly spread on trays, and their mass was recorded at regular, fixed time intervals. The drying process was monitored continuously, and measurements were taken until a constant mass was reached, indicating the end of the drying period.

The dried samples were ground using an electric analytical grinder (IKA A10, IKA Labortechnik, Staufen, Germany) to obtain fine powders with particle sizes below 250 µm. The resulting powders were stored in sealed flasks under appropriate conditions until further use.

I.3 Determination moisture content of plants and plant powders

The water content was determined using a moisture balance (Radwag MA 50.R, Poland) equipped with an infrared (IR) lamp. Approximately 2 g of each sample were placed in the drying chamber and heated at 120 ± 1 °C. The moisture content, expressed as a percentage, was automatically recorded by the device once a stable mass was achieved.

I.4 Mathematical modelling of drying

For the mathematical modelling of plant drying, the kinetics were presented as MR (Moisture Ratio) as a function of time. The moisture ratio was calculated using the formula $MR = (M_t - M_e) / (M_0 - M_e)$, where M_t is the moisture content at time t, M_0 is the initial moisture content, and M_e is the equilibrium moisture content.

This study investigates the drying kinetics of four aromatic plants (mint, coriander, parsley, and laurel) at three temperatures (50, 60, and 70°C) using nonlinear models. The aim is to characterize the impact of temperature on the drying dynamics and identify each plant's specific behaviour.

The most commonly used models in drying research were applied to verify the reliability of the experimental data fitting. The four mathematical models chosen were: the Page model, expressed as $MR(t) = \exp(-k \cdot t^n)$, the Midilli model is given by $MR(t) = a \cdot \exp(-k \cdot t^n) + b \cdot t$, the Weibull model is expressed as $MR(t) = \exp[-(k \cdot t)^n]$, and the logarithmic model is written as $MR(t) = a - b \cdot \ln(t)$.

In these equations, *MR(t)* represents the moisture ratio at time t. The parameter k denotes the drying rate constant, while n adjusts the shape of the decay curve (notably in the Page, Midilli, and Weibull models). The parameters a and b are empirical constants specific to each model. The term t refers to drying time (in minutes).

To assess the accuracy and goodness of fit of the developed models, the coefficient of determination (R^2), root mean square error (RMSE), and chi-square test (χ^2) were used.

I.5 Assessment of the quality of dried powders

I.5.1. Total phenolic contents

Polyphenols were extracted by adding 20 mL of methanol/water (80:20, v/v) to 0.25 g of each sample. The mixtures were stirred on a magnetic stirrer for 1 hour, followed by centrifugation at 5000 rpm for 5 minutes. The resulting supernatants were then collected and transferred to clean tubes for further analysis.

Total polyphenol content was determined according to the procedure reported Fatiha *et al.* (2024). Briefly, 750 µL of Folin–Ciocalteu reagent (diluted 1:10 with distilled water) was added to 200 µL of each extract. After 5 minutes, 400 µL of sodium carbonate solution (7.5%) was added. The mixtures were incubated at room temperature for 1 hour. Absorbance was then measured at 760 nm using a spectrophotometer (UviLine 9400, Secomam, Ales, France). The total polyphenol content was quantified using a calibration curve prepared with gallic acid

(*Figure I, Appendices*), and results were expressed as milligrams of gallic acid equivalents per gram of dry weight (mg GAE/g DW).

I.5.2 Ascorbic acid

Ascorbic acid was extracted by adding 10 mL of oxalic acid solution (1%) to 0.1 g of dried sample powder. The mixture was stirred on a magnetic stirrer for 20 minutes and then centrifuged at 5000 rpm for 5 minutes. For the determination of ascorbic acid content, 1 mL of 2,6-dichlorophenolindophenol (DCPIP) solution was placed in a cuvette, followed by the addition of 0.3 mL of the extract. Absorbance was recorded at 515 nm after 15 seconds (Bachir-Bey *et al.* 2024). Quantification was carried out using a calibration curve prepared with standard solutions of ascorbic acid (*Figure II, Appendices*). Results were expressed as milligrams of ascorbic acid per gram of dry weight (mg AA/g DW).

I.5.3 Determination of chlorophylls and carotenoids

Chlorophyll and carotenoid contents were quantified spectrophotometrically using the methanolic extract of the samples. Briefly, 0.5 mL of the extract was mixed with 2 mL of methanol, and the mixture was transferred into a quartz cuvette. Absorbance was measured at 663 nm (chlorophyll a), 645 nm (chlorophyll b), and 470 nm (total carotenoids) using a UV–visible spectrophotometer. Concentrations were calculated using the following equations (Faizi *et al.* 2023):

Chlorophyll a (µg/mL) = 15.65 × A663 – 7.34 × A645

Chlorophyll b (µg/mL) = 27.05 × A645 – 11.21 × A663

Total carotenoids (µg/mL) = (1000 × A470 – 2.86 × Chl a – 129.2 × Chl b) / 245

The pigment concentrations (µg/mL) were then converted to µg/g dry weight (DW) of sample using the extract dilution volume and the initial sample mass.

I.5.4 Antioxidant activity

I.5.4.1 DPPH radical scavenging activity assay

The antioxidant activity of the plant methanolic extracts was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay (Djaoudene *et al.* 2024). In this assay, 1.9 mL of a 0.1 mM DPPH solution (prepared in methanol) was mixed with 100 µL of the extract at an appropriate dilution. The mixture was incubated in the dark at room temperature for 30 minutes. The decrease in absorbance was measured at 517 nm using a spectrophotometer. A control was prepared by replacing the extract with 100 µL of methanol. The radical scavenging activity was calculated using the following formula:

Scavenging percentage = (1 - (sample absorbance / control absorbance)) × 100

A calibration curve was established using standard solutions of ascorbic acid (*Figure III, Appendices*). Results were expressed as milligrams of ascorbic acid equivalents per gram of dry weight (mg AAE/g DW).

I.5.4.2 Reducing power assay

The reducing power of the extracts was assessed according to the method reported by Nugraha *et al.* (2022). Briefly, 0.5 mL of the extract was mixed with 0.5 mL of methanol (80%), followed by the addition of 1 mL of phosphate buffer (0.2 M, pH 6.6) and 1 mL of potassium ferrocyanide (1%). The mixture was shaken and incubated at 50 °C for 20 minutes. After incubation, 1 mL of trichloroacetic acid (TCA, 10%) was added. Next, 1 mL of the resulting solution was mixed with 1 mL of distilled water and 500 µL of ferric chloride (0.1%). The absorbance was measured at 700 nm using a spectrophotometer. A calibration curve was established using standard solutions of ascorbic acid (*Figure IV, Appendices*). Results were expressed as milligrams of ascorbic acid equivalents per gram of dry weight (mg AAE/g DW).

I.6 Statistical analysis

All analyses were performed in triplicate. Mathematical modelling and statistical analyses were conducted using STATISTICA software version 10.0. Drying kinetics were analysed through nonlinear regression, generating key fitting parameters such as the Root Mean Square Error (RMSE), coefficient of determination (R^2), and chi-square (χ^2). Statistical significance was evaluated using one-way ANOVA, followed by the LSD post-hoc test, with a significance threshold set at $P < 0.05$.

II. Results and discussion

II. Results and discussion

II.1. Drying kinetics

Drying is a fundamental post-harvest process employed to extend the shelf life of plants by reducing their moisture content, thereby inhibiting microbial growth and enzymatic activity. The efficiency of the drying process is influenced by several factors, including the drying method, temperature, and the intrinsic properties of the plant material. Understanding the drying kinetics of specific herbs is crucial for optimizing drying protocols that preserve quality attributes such as colour, aroma, and bioactive compounds.

In the present study, the drying kinetics of mint (*Mentha spicata*), coriander (*Coriandrum sativum*), parsley (*Petroselinum crispum*), and laurel (*Laurus nobilis*) were investigated at drying temperatures of 50, 60, and 70 °C. As shown in Figure 5, the moisture of each herb decreased progressively over time, with higher temperatures accelerating the drying process. All plants exhibited the fastest drying rates at 70 °C (100–195 min), followed by 60 °C (150–264min), and the slowest at 50 °C (216–300 min). Mint and coriander displayed intermediate drying rates, with mint drying slightly faster than coriander at lower temperatures.

The drying times of the aromatic herbs, averaged over the three temperatures tested (50, 60, and 70 °C), showed noticeable differences among species. Mint had the shortest average drying time at 155 minutes, followed by laurel at 172 minutes. Coriander required an average of 229 minutes to dry, while parsley exhibited the longest average drying time at 248 minutes.

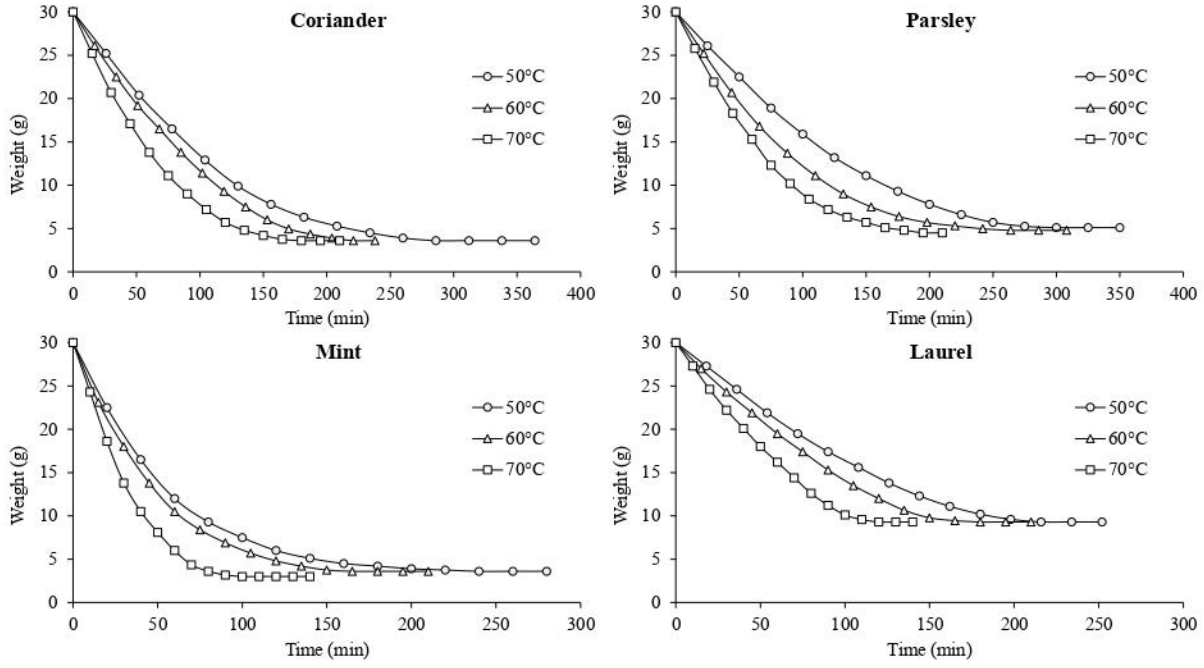

Figure 5. Drying kinetics of studied herbs at three different temperatures (50, 60, and 70°C).

These differences in drying behaviour can be attributed to the specific plant parts used, as well as the morphological and anatomical characteristics of the samples. For instance, the plant part selected often reflects common culinary practices: in the case of laurel and mint, only the leaves are dried, whereas for parsley and coriander, the entire aerial parts are dehydrated. The relatively thinner leaves of laurel and mint may partially explain their faster drying rates compared to the slower drying observed for parsley and coriander. Additionally, factors such as initial moisture content, exposed surface area, physical properties, and chemical composition of the plant material can significantly influence drying behaviour.

The observed drying patterns align with findings reported in previous studies. For example, Massarioli *et al.* (2023) demonstrated that higher drying temperatures significantly reduced drying time for herbs such as mint, parsley, and oregano. Their results showed that drying at 50 °C completed in 300 minutes for mint under forced-air conditions, consistent with our observations. Similarly, Taha *et al.* (2015) found that oven drying of mint at 50 °C led preserving aroma and physical integrity more efficiently compared to solar drying and microwave. During the drying of coriander, increasing the temperature led to a reduction in drying time. However, the lowest temperature evaluated (45 °C) resulted in the highest retention of chlorophylls Ahmed *et al.* (2001).This highlights the importance of carefully selecting the drying temperature to balance processing efficiency and the preservation of product quality. In the case of laurel leaves, the drying duration using an oven markedly decreased with increasing temperature. The time required to dryness was approximately 80, 48, 32, and 25 minutes at 60, 80, 100, and 120°C, respectively Khodja *et al*. (2020).

II.2. Mathematical modelling of drying kinetics

II.2.1. Evaluation of drying models

The results of fitting the experimental drying data of mint, coriander, parsley, and laurel to four commonly used thin-layer models (Page, Midilli, Weibull, and Logarithmic) at 50 °C, 60 °C, and 70 °C are summarized in Table 5. The table presents the estimated model parameters alongside statistical indicators (R^2, RMSE, and χ^2), providing a comprehensive evaluation of model performance across different herbs and drying temperatures.

The drying kinetics of mint, coriander, parsley, and bay laurel samples were modelled using four common mathematical models: Page, Midilli, Weibull, and Logarithmic. Across all herbs and temperatures (50, 60, and 70 °C), the Midilli model consistently demonstrated the best fit, as evidenced by its very high coefficients of determination ($R^2 > 0.9995$), and the lowest values

of root mean square error (RMSE ≤ 0.0035) and reduced chi-square ($\chi^2 \leq 3.61 \times 10^{-4}$). These results confirm the robustness and flexibility of the Midilli model in capturing the drying behaviour of different plant materials under varying thermal conditions.

The Page model also showed good performance, particularly at lower temperatures, although its fit was slightly less precise than that of the Midilli model. The Weibull model achieved satisfactory results with acceptable R^2 values and moderate error indicators, making it a viable alternative. In contrast, the Logarithmic model consistently underperformed, exhibiting the highest RMSE (0.0045–0.0115) and χ^2 ($2.29–39.7 \times 10^{-4}$) values and the lowest R^2 (0.9957–0.9989), indicating a poor agreement with the experimental data.

Based on statistical performance indicators across all plant species and drying temperatures, the Midilli model proved to be the most accurate and reliable for describing drying kinetics. It consistently exhibited the highest coefficients of determination (R^2) and the lowest values of root mean square error (RMSE) and reduced chi-square (χ^2), regardless of temperature conditions. The superior performance of the Midilli model is attributed to its mathematical flexibility, combining both exponential and linear terms, which enables it to effectively capture the complex moisture removal mechanisms in plant materials, including simultaneous internal diffusion and surface evaporation. Its consistent accuracy and robustness make it particularly valuable for the design, optimization, and scale-up of drying processes for aromatic and medicinal plants.

Several previous studies support the current findings regarding the superior performance of the Midilli model. For instance, Karaaslan *et al.* (2021), reported that the Midilli model best described the drying behaviour of zucchini slices in a solar tunnel dryer, showing the highest R^2 values and the lowest RMSE among the tested models, including the Page and Logarithmic models. Similarly, Arslan *et al.* (2021), in their investigation of the infrared drying kinetics of conventional sweet red peppers, highlighted the Midilli model's excellent fit to experimental data, emphasizing its ability to accurately describe the drying curve due to its flexible structure.

II.2.2. Effect of temperature on drying behaviour

Temperature exerted a pronounced influence on the drying kinetics of all the studied herbs. As anticipated, increasing the drying temperature significantly enhanced the drying rate, as evidenced by the rise in the drying constant (k) across all applied models. For example, within the Midilli model, the drying constant for parsley increased from approximately 0.0141 at 50 °C to around 0.0291 at 70 °C, indicating more than a twofold acceleration in drying kinetics.

Comparable trends were observed for mint, coriander, and laurel, confirming the strong temperature dependence of the drying process.

The improvement in drying efficiency at elevated temperatures was also reflected in the substantial reduction in total drying time. At 70 °C, all herbs reached the desired moisture content much faster compared to drying at 50 °C, underscoring the positive correlation between drying temperature and drying rate. However, it is important to note that excessively high temperatures can adversely affect the quality of thermolabile bioactive compounds, potentially leading to degradation or loss of functional properties. Therefore, this trade-off between drying speed and the preservation of phytochemicals warrants careful consideration, ideally supported by complementary physicochemical and phytochemical analyses.

Several studies corroborate these findings. For example, Doymaz (2012)demonstrated that increasing the drying temperature from 50 to 70 °C significantly reduced the drying time of persimmon slices (*Diospyros kaki* L.) while simultaneously increasing the drying rate constants. Similarly, Kıpçak (2024) and Ahmed *et al.* (2001)observed that elevated drying temperatures enhanced the drying kinetics of blueberries and coriander leaves, respectively, resulting in shorter drying times and higher drying rate constants.

II.2.3. Comparison of plant species

Herb morphology played a critical role in determining drying performance. Among the four studied herbs, mint exhibited the fastest drying behaviour, with a total drying time ranging from 90 to 240 minutes, followed by laurel (120–216 minutes), coriander (180–286 minutes), and parsley (180–300 minutes), which demonstrated the slowest drying kinetics.

A key morphological distinction lies in the plant parts used: only the leaves were used for mint and laurel, whereas for parsley and coriander, the entire aerial parts, including leaves, stems, and petioles, were included. These additional structural components tend to retain more water due to their higher initial moisture content, thicker cell walls, and denser tissue organization, all of which reduce the rate of internal moisture diffusion and prolong the drying process.

In contrast, the leaf-only samples of mint and laurel, characterized by thin, delicate, and porous structures, enabled more efficient moisture migration and evaporation. These anatomical traits promote faster heat and mass transfer, contributing to their shorter drying durations. This finding underscores the importance of considering plant morphology when evaluating or optimizing drying protocols for aromatic and medicinal herbs.

According to the findings of Massarioli *et al.* (2023), the drying times required to reach equilibrium moisture content varied notably among the studied herbs when dried in a forced-air oven. Common fennel and mint exhibited the fastest drying behaviour, each requiring approximately 150 minutes. In contrast, lemon grass and basil dried significantly more slowly, with drying durations extending up to 320 minutes. These differences were primarily attributed to morphological characteristics such as tissue density, leaf structure, and moisture distribution, all of which influence the rate and efficiency of moisture removal during thermal drying.

Table 5. Comparison of drying kinetics models and fitting parameters for the four herbs at three drying temperatures (50, 60, and 70°C).

Herb	Temperature	Model	Parameters	R^2	RMSE	χ^2 ($\times 10^{-4}$)
Mint	50°C	Page	k = 0.0231	0.9989	0.0062	3.82
			n = 1.14			
	50°C	Midilli	a = 0.981	0.9995	0.0035	1.21
			k = 0.0245			
			n = 1.09			
			b = -0.00018			
	50°C	Weibull	a = 72.4	0.9986	0.0068	4.59
			b = 0.87			
	50°C	Logarithmic	a = 1.012	0.9978	0.0081	6.51
			k = 0.0187			
			c = -0.012			
			k = 0.0234			
			n = 1.12			
			b = -0.021			
			c = 0.15			
	60°C	Page	k = 0.0342	0.9992	0.0048	2.29
			n = 1.23			
	60°C	Midilli	a = 0.992	0.9997	0.0028	0.78
			k = 0.0361			
			n = 1.18			
			b = -0.00021			
	60°C	Weibull	a = 52.7	0.9988	0.0056	3.11
			b = 0.82			
	60°C	Logarithmic	a = 1.025	0.9971	0.0089	7.87
			k = 0.0284			
			c = -0.025			

			k = 0.0346			
			n = 1.24			
			b = -0.015			
			c = 0.12			
	70°C	Page	k = 0.0673	0.9988	0.0059	3.45
			n = 1.38			
	70°C	Midilli	a = 1.003	0.9998	0.0019	0.36
			k = 0.0715			
			n = 1.34			
			b = -0.00031			
	70°C	Weibull	a = 26.8	0.9982	0.0072	5.15
			b = 0.73			
	70°C	Logarithmic	a = 1.052	0.9957	0.0115	13.1
			k = 0.0546			
			c = -0.052			
			k = 0.0482			
			n = 1.32			
			b = -0.012			
			c = 0.1			
Coriander	50°C	Page	k = 0.0158	0.9993	0.0038	1.43
			n = 1.17			
	50°C	Midilli	a = 0.984	0.9997	0.0026	0.67
			k = 0.0164			
			n = 1.14			
			b = -0.00015			
	50°C	Weibull	a = 95.2	0.9989	0.0045	2.01
			b = 0.89			
	50°C	Logarithmic	a = 1.008	0.9982	0.0062	3.82
			k = 0.0132			
			c = -0.008			
			k = 0.0152			
			n = 1.18			
			b = -0.018			
			c = 0.11			
	60°C	Page	k = 0.0219	0.9994	0.0032	1.01
			n = 1.21			
	60°C	Midilli	a = 0.989	0.9998	0.0018	0.32
			k = 0.0226			
			n = 1.18			
			b = -0.00019			

	60°C	Weibull	a = 68.3	0.9991	0.0038	1.43
			b = 0.85			
	60°C	Logarithmic	a = 1.018	0.9985	0.0053	2.79
			k = 0.0178			
			c = -0.018			
			k = 0.0201			
			n = 1.15			
			b = -0.016			
			c = 0.13			
	70°C	Page	k = 0.0279	0.9995	0.0029	0.83
			n = 1.24			
	70°C	Midilli	a = 0.993	0.9999	0.0015	0.22
			k = 0.0286			
			n = 1.21			
			b = -0.00022			
	70°C	Weibull	a = 55.1	0.9992	0.0035	1.21
			b = 0.83			
	70°C	Logarithmic	a = 1.022	0.9988	0.0048	2.29
			k = 0.0223			
			c = -0.022			
			k = 0.0278			
			n = 1.21			
			b = -0.014			
			c = 0.12			
Parsley	50°C	Page	k = 0.0136	0.9996	0.0027	7.21
			n = 1.15			
	50°C	Midilli	a = 0.981	0.9998	0.0018	3.24
			k = 0.0141			
			n = 1.12			
			b = -0.00012			
	50°C	Weibull	a = 104.6	0.9993	0.0033	10.7
			b = 0.91			
	50°C	Logarithmic	a = 1.005	0.9989	0.0046	20.8
			k = 0.0114			
			c = -0.005			
			k = 0.0168			
			n = 1.14			
			b = -0.017			
			c = 0.1			
	60°C	Page	k = 0.0182	0.9995	0.003	8.91

			n = 1.19			
	60°C	Midilli	a = 0.987	0.9998	0.0019	3.61
			k = 0.0188			
			n = 1.16			
			b = -0.00014			
	60°C	Weibull	a = 79.3	0.9992	0.0036	12.8
			b = 0.87			
	60°C	Logarithmic	a = 1.011	0.9987	0.0051	25.9
			k = 0.0153			
			c = -0.011			
			k = 0.0195			
			n = 1.16			
			b = -0.019			
			c = 0.14			
	70°C	Page	k = 0.0283	0.9996	0.0026	6.72
			n = 1.22			
	70°C	Midilli	a = 0.995	0.9999	0.0014	1.96
			k = 0.0291			
			n = 1.19			
			b = -0.00020			
	70°C	Weibull	a = 53.8	0.9993	0.0032	10.1
			b = 0.84			
	70°C	Logarithmic	a = 1.024	0.9989	0.0045	20.1
			k = 0.0231			
			c = -0.024			
			k = 0.0293			
			n = 1.19			
			b = -0.013			
			c = 0.11			
Laurel	50°C	Page	k = 0.0241	0.9997	0.0022	4.81
			n = 1.25			
	50°C	Midilli	a = 0.997	0.9999	0.0013	1.68
			k = 0.0248			
			n = 1.22			
			b = -0.00017			
	50°C	Weibull	a = 63.4	0.9994	0.0029	8.35
			b = 0.86			
	50°C	Logarithmic	a = 1.019	0.9988	0.0048	22.8
			k = 0.0202			
			c = -0.019			

			k = 0.0251			
			n = 1.22			
			b = -0.011			
			c = 0.09			
	60°C	Page	k = 0.0307	0.9996	0.0025	6.25
			n = 1.28			
	60°C	Midilli	a = 0.998	0.9999	0.0014	1.96
			k = 0.0315			
			n = 1.25			
			b = -0.00023			
	60°C	Weibull	a = 49.7	0.9993	0.0033	10.7
			b = 0.82			
	60°C	Logarithmic	a = 1.028	0.9987	0.0052	26.8
			k = 0.0256			
			c = -0.028			
			k = 0.0317			
			n = 1.25			
			b = -0.01			
			c = 0.08			
	70°C	Page	k = 0.0429	0.9994	0.0031	9.61
			n = 1.33			
	70°C	Midilli	a = 1.002	0.9998	0.0019	3.61
			k = 0.0441			
			n = 1.30			
			b = -0.00028			
	70°C	Weibull	a = 34.2	0.9989	0.0042	17.6
			b = 0.79			
	70°C	Logarithmic	a = 1.042	0.9978	0.0063	39.7
			k = 0.0364			
			c = -0.042			
			k = 0.0428			
			n = 1.31			
			b = -0.008			
			c = 0.07			

II.3. Phytochemical contents

II.3.1. Total phenolic contents

The total phenolic content of the four culinary herbs (coriander, parsley, mint, and laurel) dried at 50, 60, and 70°C using a food dehydrator revealed a strong influence of both plant species and drying temperature on the preservation of phenolic compounds (Figure 5).

Among analysed herbs, mint dried at 50°C showed the highest TPC, reaching 18.18 mg GAE/g DM, which was nearly four times higher than parsley at the same temperature (4.68 mg GAE/g DM). Laurel at 50°C also displayed a high phenolic content (17.10 mg GAE/g DM), comparable to mint, and clearly superior to coriander and parsley. These values illustrate the strong interspecies variability in phenolic content, with mint and laurel standing out as the richest sources.

The impact of drying temperature on TPC had also a significant impact on plant species. In coriander, TPC increased by 19% from 50 to 60°C, before insignificant slight decreasing at 70°C. In parsley, TPC remained relatively stable across all temperatures, fluctuating slightly between 4.44 and 4.90 mg GAE/g DM, indicating a thermal resistance of its phenolic profile. However, its TPC values were the lowest among all tested herbs, regardless of temperature.

For mint, the TPC decreased from 18.18 mg GAE/g DM at 50°C to 16.39 mg GAE/g DM at 60°C, then remained relatively stable at 70°C. Although the drop from 50°C is moderate (approximately 10%), these results confirm that 50°C is the most favourable drying temperature for preserving phenolic content in mint. In laurel, TPC showed a more pronounced decline, decreasing by approximately 11% from 50°C to 60°C, and by an additional 15% from 60°C to 70°C, resulting in a total reduction of about 26% across the temperature range. This pattern highlights the high thermal sensitivity of laurel phenolics, with 50°C emerging as the most efficient temperature for their preservation.

Overall, the preservation of phenolic compounds during drying depends strongly on both the plant species and the temperature applied. Optimal retention was achieved at 50°C for most herbs, particularly mint and laurel, while 60°C proved most suitable for coriander. These results highlight the importance of choosing the appropriate drying temperature for each herb to maintain its phenolic content.

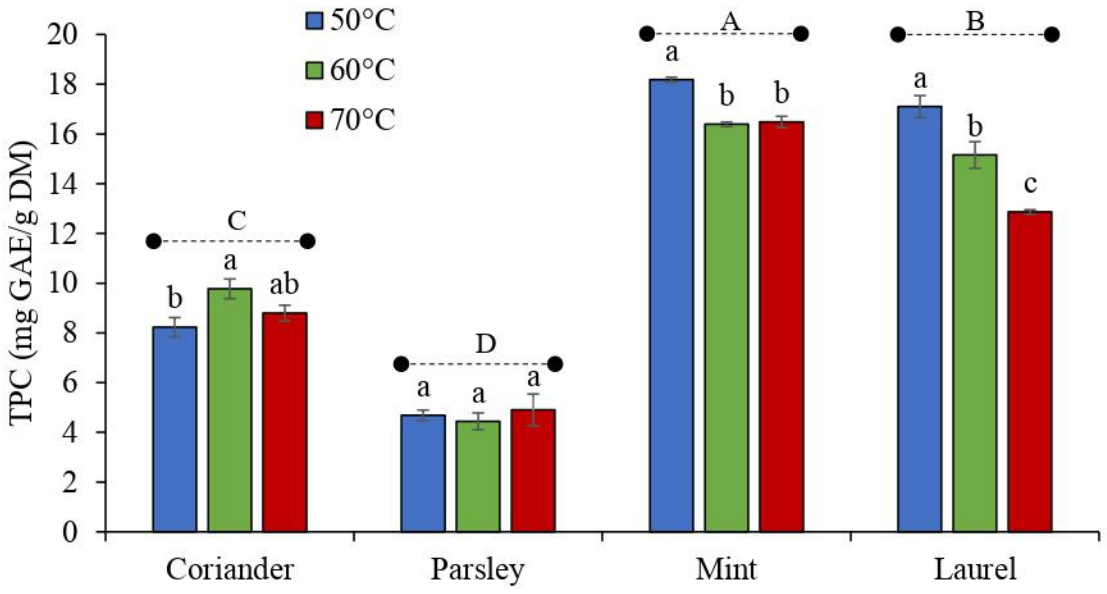

Figure 6. Total phenolic content of culinary herbs dried at different temperatures.

Values for each herb at a given temperature marked with different lowercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $a > b > c$). For each pigment parameter, herbs labeled with different uppercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $A > B > C > D$).

II.3.2. Ascorbic acid content

The ascorbic acid content of coriander, parsley, mint, and laurel, dried at different temperatures, showed considerable variation depending on both plant species and drying temperature (Figure 6). Coriander exhibited the highest levels of ascorbic acid across all herbs. Its content increased significantly from 9.24 mg/g DM at 50°C to a peak of 16.05 mg/g DM at 60°C, followed by a significant slight decline at 70°C. This trend suggests that 60°C is the optimal temperature for retaining or possibly releasing more ascorbic acid in coriander.

Parsley also showed a clear temperature-related increase in ascorbic acid content: starting at 9.17 mg/g DM at 50°C, the value increased by approximately 27% at 60°C and by further 11% at 70°C. In contrast, mint exhibited the lowest ascorbic acid levels among all tested herbs, with only moderate variation across temperatures (ranging from 0.54 to 1.04 mg/g DM). Laurel showed a more pronounced response to temperature changes, with its ascorbic acid content nearly doubling with each 10°C increase in drying temperature.

The rise in ascorbic acid content observed with increasing drying temperatures, particularly in parsley and laurel, can be attributed to several factors. Higher temperatures may induce

structural changes in the plant matrix, improving the release and extractability of ascorbic acid. Additionally, elevated temperatures reduce drying time, thus minimizing exposure to oxygen and light, which are known to degrade vitamin C. Thermal inactivation of ascorbic acid oxidase, the enzyme responsible for its degradation, may also contribute to better retention. This combination of enhanced extractability, reduced oxidative losses, and enzyme inactivation can explain the increased ascorbic acid content observed at moderate to high drying temperatures.

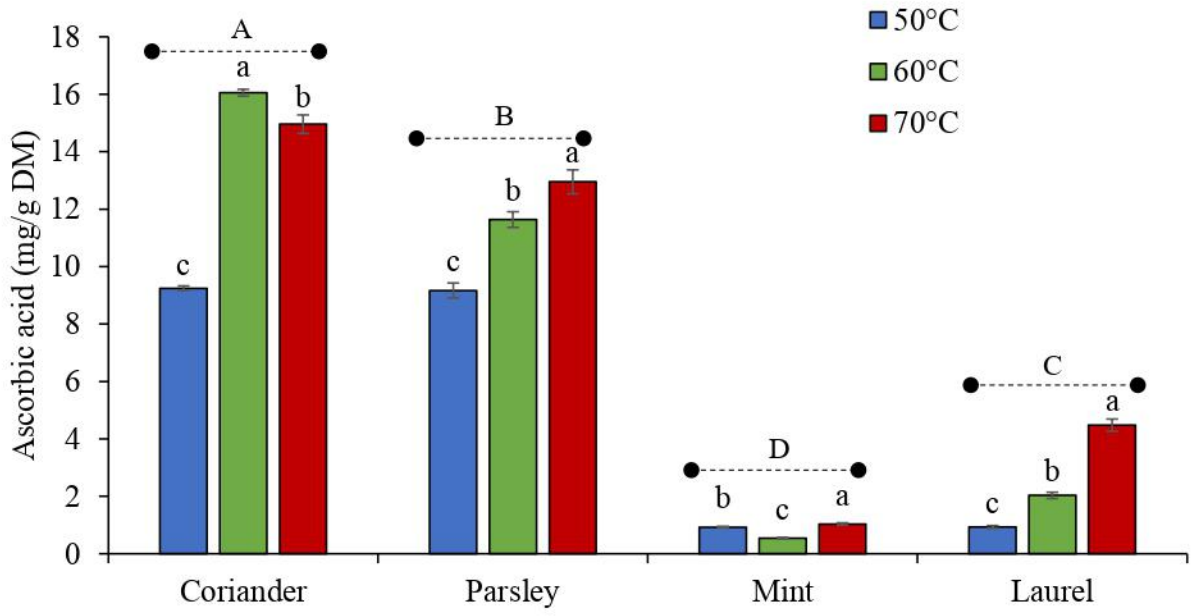

Figure 7. Ascorbic acid content of culinary herbs dried at different temperatures.

Values for each herb at a given temperature marked with different lowercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $a > b > c$). For each pigment parameter, herbs labeled with different uppercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $A > B > C > D$).

II.3.3. Carotenoids and chlorophylls contents

The results of carotenoids and chlorophylls content obtained, for the powders of the selected culinary herbs dried using a food dehydrator, are illustrated in Figures 8, 9, and 10.

The carotenoid content varied significantly among the four herbs but was relatively stable across drying temperatures for each species (Figure 8). No significant differences were observed between temperatures within each herb, indicating that drying temperature had minimal influence on carotenoid content. Coriander consistently exhibited the highest

carotenoid levels (ranging from 781.65 to 838.14 µg/g DM), followed by parsley and mint, while laurel showed the lowest concentrations (around 400–421 µg/g DM).

In contrast, chlorophyll a content was more influenced by drying temperature. In both coriander and parsley, chlorophyll a content decreased significantly with increasing temperature, dropping by approximately 35% in coriander (from 4567.08 to 2969.90 µg/g) and by about 33% in parsley (from 1598.67 to around 1080–1067 µg/g), indicating clear thermal degradation (Figure 9). Interestingly, mint and laurel demonstrated an opposite pattern. In mint, chlorophyll a content increased by approximately 29% from 1009.17 µg/g at 50°C to 1302.47 µg/g at 70°C, suggesting enhanced extractability or retention at higher temperatures. A similar trend was observed in laurel, with chlorophyll a rising by about 58% from 1080.3 µg/g to 1707.4 µg/g.

Chlorophyll b followed broadly similar trends to chlorophyll a. Coriander and parsley showed decreases of approximately 21 and 18%, respectively, with rising temperatures, indicating degradation. In contrast, mint's chlorophyll b content remained stable across temperatures, showing no significant variation, while laurel exhibited a significant increase of around 36% (Figure 10).

The contrasting trends in chlorophyll a and b content between the herbs can likely be explained by the different plant parts used for drying. Coriander and parsley samples consisted of aerial parts, including stems, which are more prone to pigment degradation due to their structural composition. Conversely, mint and laurel samples were composed of leaves, which have a denser cellular structure and better protect chlorophyll pigments. Additionally, the breakdown of leaf cell walls at higher temperatures may enhance chlorophyll extractability, resulting in stable or even increased pigment levels. Thus, the nature of the plant tissue appears to play a key role in the observed differences in chlorophyll stability and response to drying temperature.

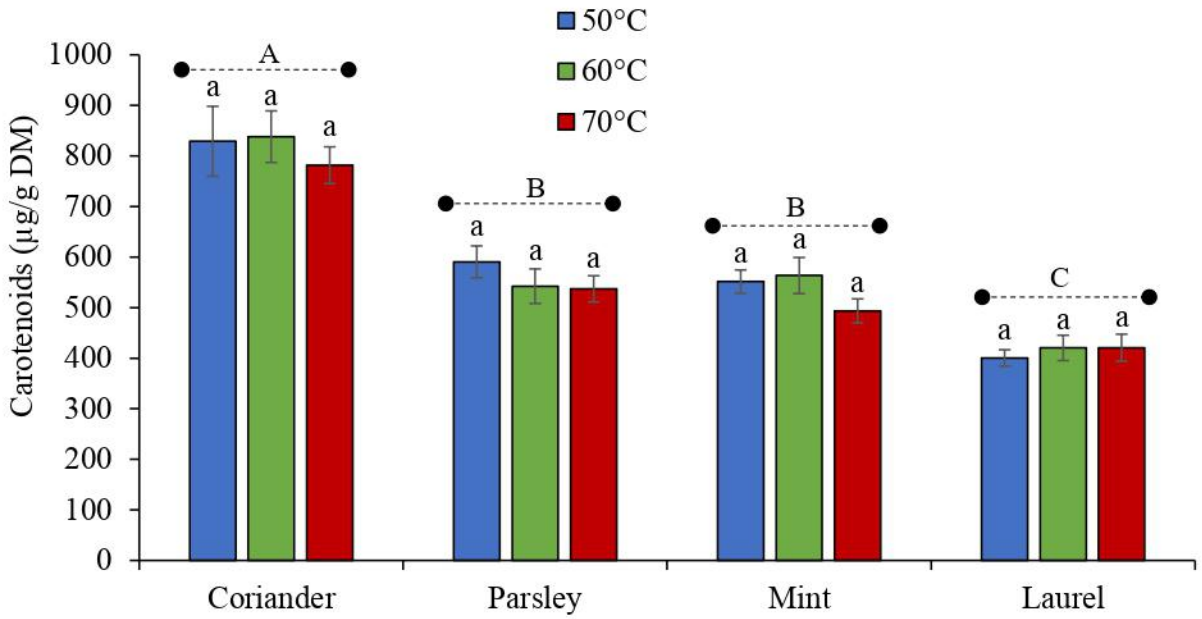

Figure 8. Carotenoids content of culinary herbs dried at different temperatures.

Values for each herb at a given temperature marked with the same lowercase letters are significantly similar (ANOVA, LSD-test, $p<0.05$). For each pigment parameter, herbs labeled with different uppercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $A > B > C$).

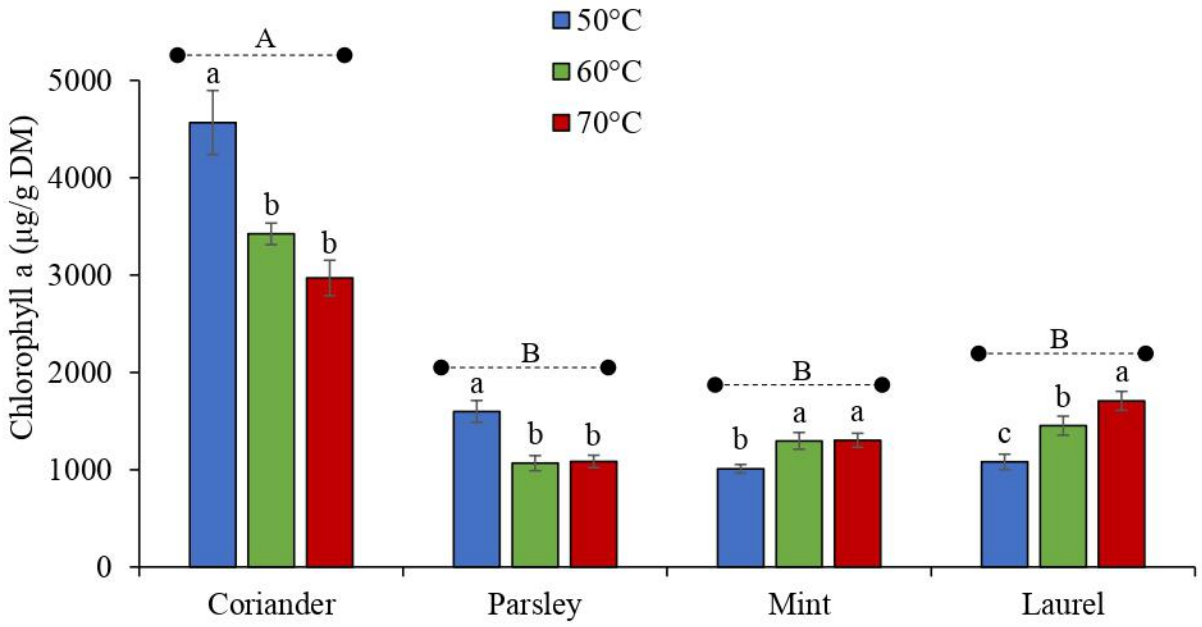

Figure 9. Chlorophyll a content of culinary herbs dried at different temperatures.

Values for each herb at a given temperature marked with different lowercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $a > b > c$). For each pigment parameter, herbs labeled with different uppercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $A > B$).

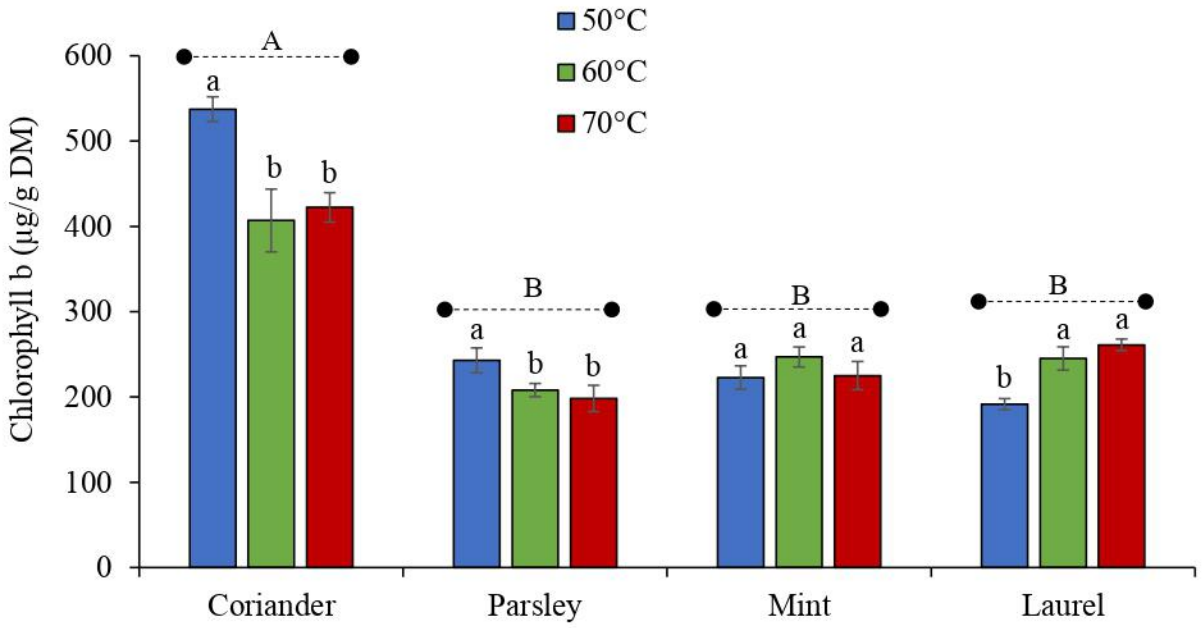

Figure 10. Chlorophyll b content of culinary herbs dried at different temperatures.

Values for each herb at a given temperature marked with different lowercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $a > b$). For each pigment parameter, herbs labeled with different uppercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $A > B$).

II.4. Antioxidant activity

II.4.1. DPPH free radical scavenging activity

The DPPH radical scavenging activity of the four culinary herbs is presented in Figure 11. Statistical analysis revealed significant differences in antioxidant activity among the herbs and drying conditions. Coriander exhibited the highest activity at 50°C (45.72 mg GAE/g DM), with a slight decrease at higher temperatures. Parsley showed the lowest values, ranging from approximately 25 to 27 mg GAE/g DM across all temperatures. Both mint and laurel demonstrated increased antioxidant activity with rising temperature, reaching their highest levels at 70°C, with values of 46.06 and 26.62 mg GAE/g DM, respectively. Overall, 50°C was the optimum drying temperature for preserving antioxidant activity in coriander and parsley, while for mint and laurel, 70°C proved to be the most favorable.

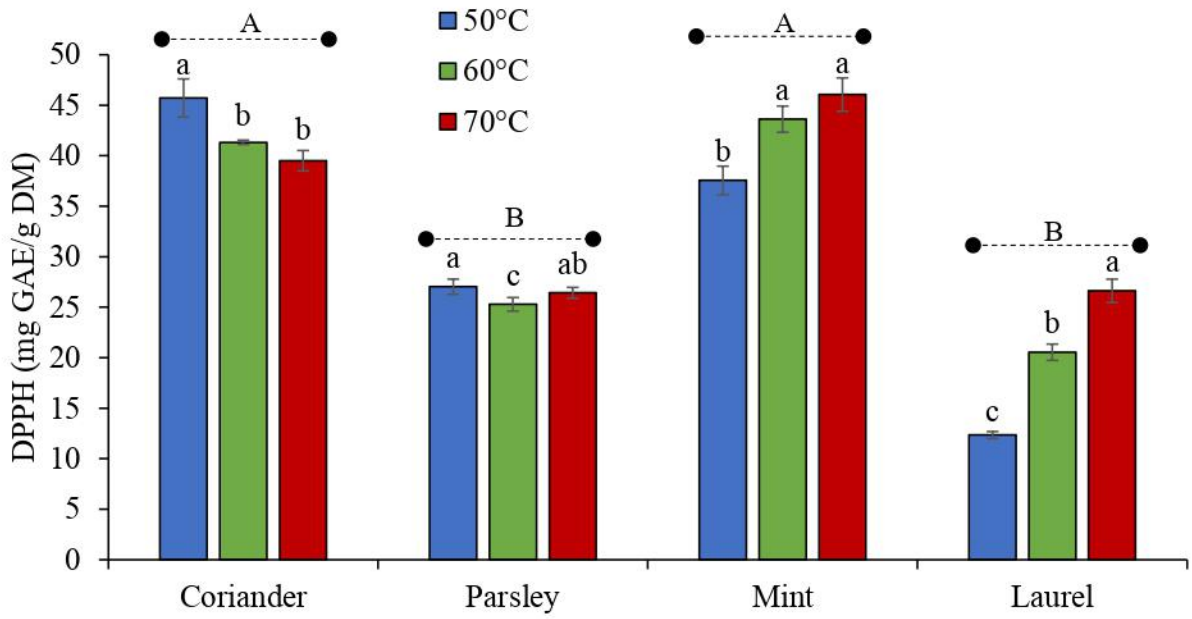

Figure 11. DPPH scavenging activity of culinary herbs dried at different temperatures.

Values for each herb at a given temperature marked with different lowercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $a > b > c$). For each pigment parameter, herbs labeled with different uppercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $A > B$).

II.4.2. Reducing power

The reducing power of the four culinary herbs dried at different temperatures showed a clear dependence on both plant species and drying temperature (Figure 12). Among the tested herbs, mint dried at 50°C exhibited the highest antioxidant capacity (14.72 mg GAE/g DM), nearly 10 times greater than parsley at the same temperature (1.54 mg GAE/g DM). Laurel also showed high reducing power at 50°C (12.77 mg GAE/g DM), clearly exceeding that of coriander and parsley. These results highlight the marked interspecies differences in antioxidant activity among the studied herbs, with mint and laurel standing out as the richest sources of antioxidants.

The influence of temperature varied depending on the plant species. For coriander, reducing power increased by 17% from 50 to 60°C, but then declined by 24% at 70°C, suggesting that 60°C may be the most favorable temperature for preserving its antioxidant potential. In parsley, values gradually rose from 1.54 to 1.97 between 50 and 70°C, representing a 28% increase. However, despite this improvement, parsley consistently showed the lowest antioxidant capacity among all tested herbs.

In the case of mint, a 15% decrease in reducing power was observed between 50 and 60°C, followed by a further significant drop at 70°C. This trend confirms that 50°C is the optimal drying condition for preserving the antioxidant properties of mint. In laurel, the decline was even more pronounced: reducing power dropped by 26% between 50 and 60°C, and by an additional 16% at 70°C, resulting in a total reduction of 42%, highlighting the high thermal sensitivity of its antioxidant compounds.

Therefore, both plant species and drying temperature significantly influenced the reducing power of the herb extracts. The highest antioxidant activity was observed in mint and laurel at 50°C, whereas parsley consistently exhibited the weakest activity, although it showed a moderate improvement with increasing temperature. These findings underscore the importance of selecting suitable drying conditions to effectively preserve the antioxidant properties of aromatic herbs.

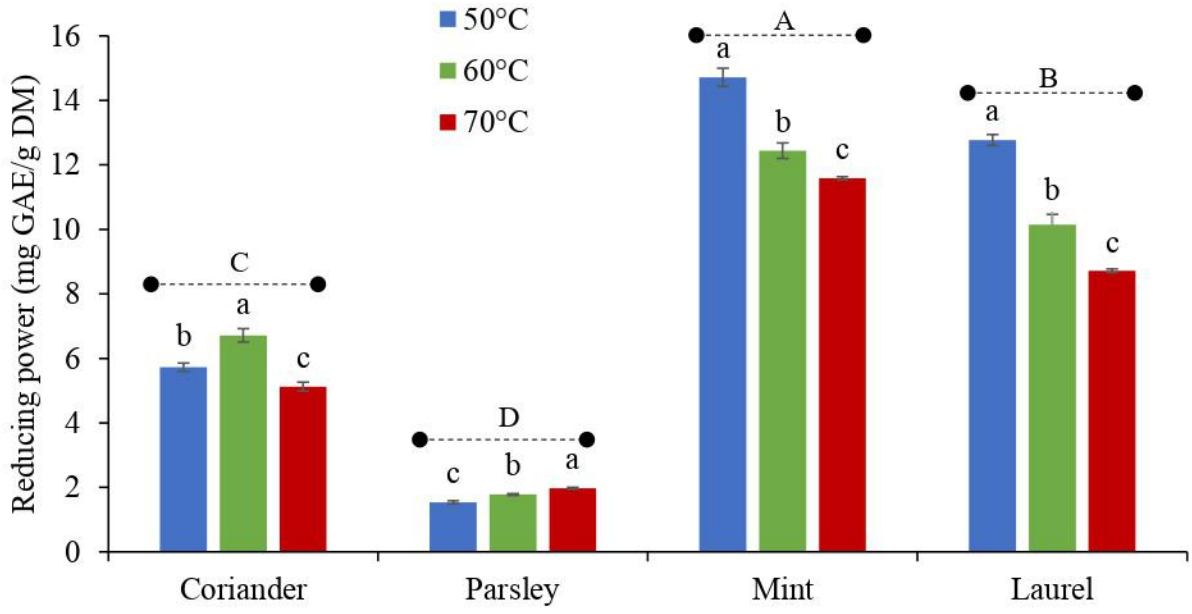

Figure 12. Reducing power activity of culinary herbs dried at different temperatures.

Values for each herb at a given temperature marked with different lowercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $a > b > c$). For each pigment parameter, herbs labeled with different uppercase letters are significantly different (ANOVA, LSD-test, $p<0.05$, $A > B > C > D$).

Conclusion

Conclusion

In this study, the drying kinetics of selected culinary plants (coriander, parsley, mint and laurel) were followed using a food dehydrator at 50, 60 and 70°C and were compared on the basis of the kinetic results obtained, with time and speed being the main factor. The powders obtained after drying were compared on the basis of the evaluation of their phytochemical quality; total phenolic, ascorbic acid, carotenoids and chlorophyll contents and antioxidant activity whereby DPPH radical free scavenging activity and reducing power were determined.

From the kinetic results, mint and laurel displayed short average drying time compared to coriander and parsley. These differences in drying behaviour can be partially explained by the specific plant parts used, as well as the morphological and anatomical characteristics of the samples, whereby the relatively thinner leaves of mint and laurel were dried while for parsley and coriander, the entire aerial parts were dried.

Mathematical modelling of experimental data obtained shows that among the four models studied, the Midilli model perfectly represents the behaviour of these four culinary herbs as it consistently exhibited the highest coefficients of determination (R^2) and the lowest values of root mean square error (RMSE) and reduced chi-square (χ^2), regardless of temperature conditions.

Concerning the results of the phytochemical analysis, the total phenolic contents showed strong interspecies variability in phenolic content, with mint and laurel standing out as the richest sources. The preservation of phenolic compounds during drying showed high dependency on both the plant species and the temperature applied. Optimal retention was achieved at 50°C for mint and laurel, at 60°C for coriander while it remained stable at the three temperatures in parsley. Despite the stability of TPC in parsley, these results highlight the importance of choosing the appropriate drying temperature for each herb to maintain its phenolic content.

The ascorbic acid content showed considerable variation depending on both plant species and drying temperature with coriander, highest retention at 60°C, and parsley being the richest. The rise in ascorbic acid content observed with increasing drying temperatures, particularly in parsley and laurel which showed the highest ascorbic acid retention at 70°C, can be attributed to three factors: enhanced release and extractability of ascorbic acid due to higher temperatures that may induce structural changes in the plant matrix, minimized exposure to oxygen and light which are known to degrade vitamin C due to reduced drying time at higher temperatures and thermal inactivation of ascorbic acid oxidase, the enzyme responsible for its degradation.

Regarding carotenoid content, significant variation was observed among the four herbs with coriander having the highest and laurel having the lowest. It was however relatively stable

across drying temperatures for each species as drying temperature had minimal influence on carotenoid content.

Chlorophyll a content was more influenced by drying temperature. A significant decrease was observed in coriander (35%) and parsley (33%) with increasing temperature indicating clear thermal degradation. However, an opposite pattern was observed whereby chlorophyll a content increased with increase in temperature in mint (29%) and laurel (58%) suggesting enhanced extractability or retention at higher temperatures.

Chlorophyll b followed broadly similar trends to chlorophyll a with coriander (21%) and parsley (18%) showing a decrease with rising temperatures indicating degradation. In contrast, mint's chlorophyll b content remained stable across temperatures, showing no significant variation, while laurel exhibited a significant increase (36%). The contrasting trends in chlorophyll a and b content between the herbs can likely be explained by the different plant parts used for drying.

The antioxidant activity with regards to DPPH free radical scavenging activity, significant differences in antioxidant activity are observed among the herbs and drying temperatures. Coriander exhibited the highest activity at 50°C, this the optimum temperature, with a slight decrease at higher temperatures while parsley showed the lowest values. Both mint and laurel demonstrated increased antioxidant activity with rising temperature, reaching their highest levels at 70°C thus the optimum temperature for the two herbs.

Concerning reducing power, there is a clear dependence on both plant species and drying temperature. Mint and laurel dried at 50°C exhibited high antioxidant capacity. For coriander, 60°C may be the most favorable temperature for preserving its antioxidant potential. High thermal sensitivity of antioxidant compounds is highlighted in laurel as the decrease is more pronounced with increase in temperature.

Drying temperature has a distinct and complex influence on the preservation of phytochemicals, and this influence is highly species-specific. While moderate temperatures (50–60°C) generally favour the retention of most bioactive compounds, optimal conditions must be tailored to each herb to balance the retention of phenolics, vitamins, pigments, and antioxidant potential. This highlights the necessity of customized drying protocols in the processing of culinary herbs to maximize their nutritional and functional quality.

To strengthen this study, it would be useful to include additional analyses such as color evaluation of the powders, total flavonoid content, and the HPLC-based characterization of polyphenols and carotenoids. Moreover, calculating the energy consumed during drying and determining the essential oil content and composition would offer a more complete view of the process and its impact on product quality.

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Appendices

Appendices

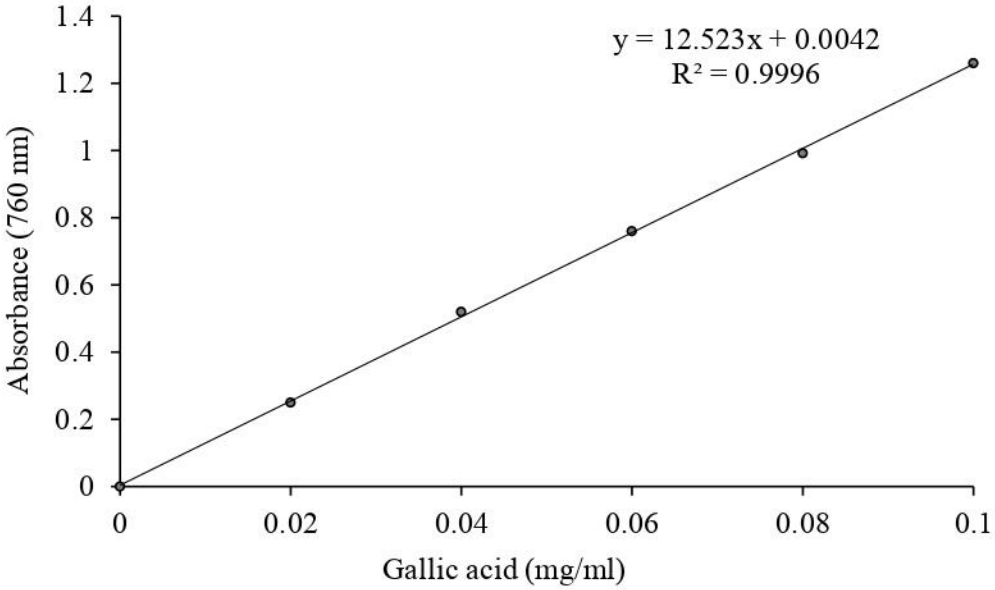

Figure I. Calibration curve of TPC

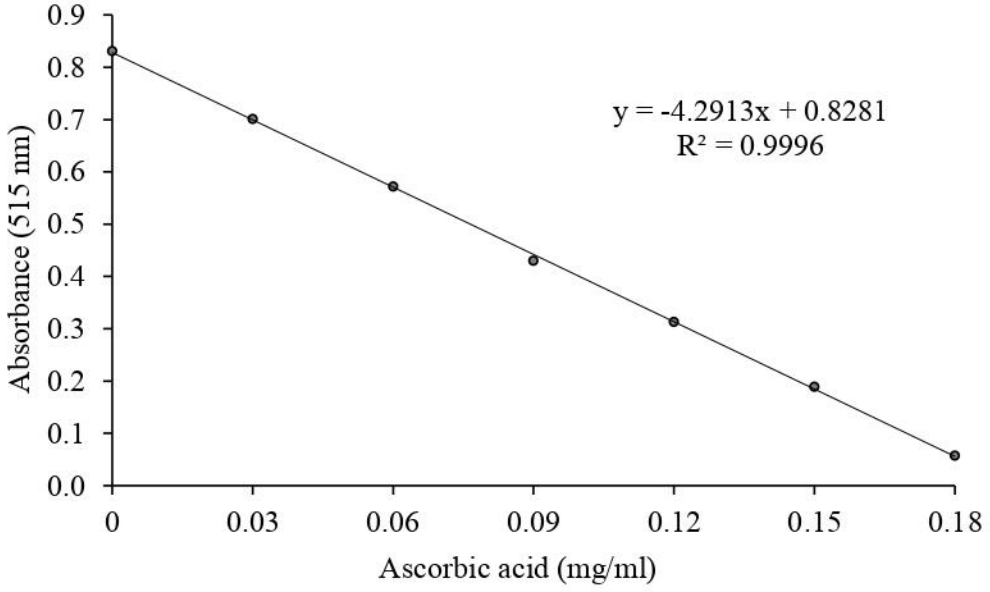

Figure II. Calibration curve of ascorbic acid

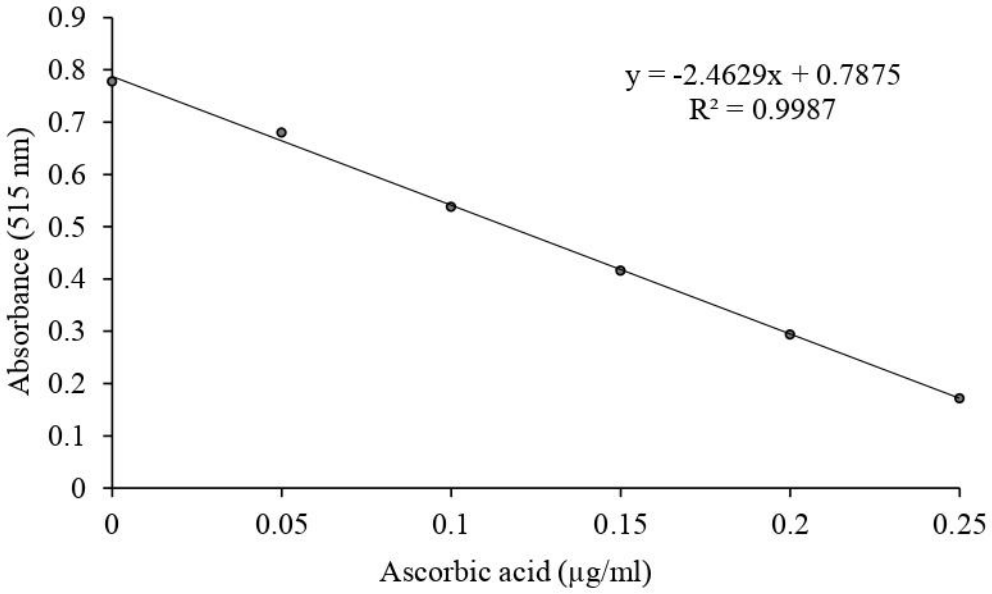

Figure III. Calibration curve of DPPH free radical scavenging activity

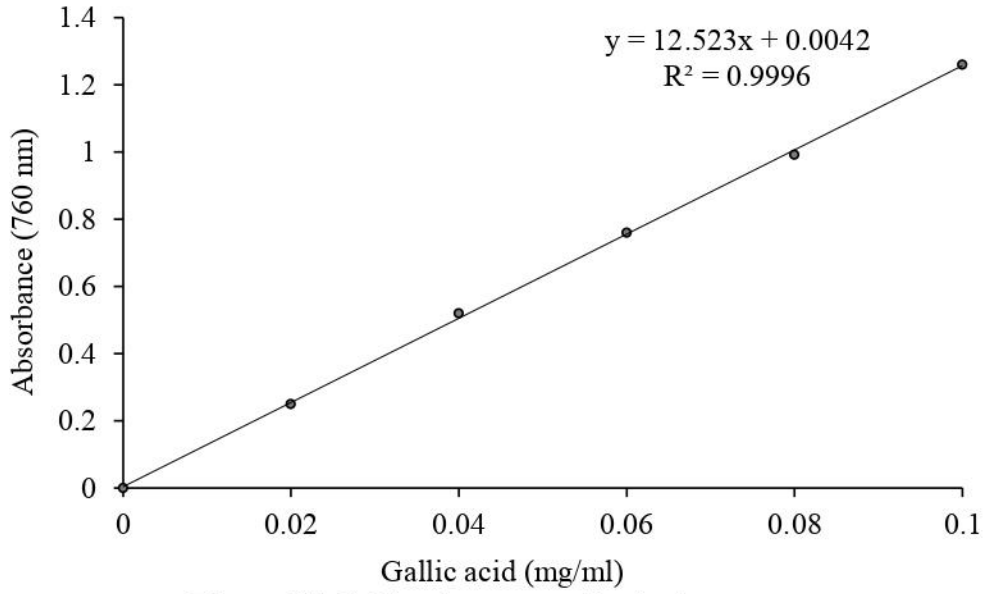

Figure IV. Calibration curve of reducing power

Abstract

Culinary herbs, though highly perishable when fresh, are valued worldwide for their flavour, aroma, and medicinal benefits as they encompass diverse bioactive compounds. In this study, four culinary herbs (coriander, parsley, mint and laurel) were subjected to drying using a food dehydrator at three different temperatures (50, 60 and 70°C) and the effects of the process on the drying kinetics, mathematical modelling and phytochemical quality were studied. Aeriel parts of coriander and parsley and leaves of mint and laurel were dried. Analysis on total phenolic contents, ascorbic acid content, carotenoids, chlorophylls (a and b) and antioxidant activity (DPPH and reducing power) was conducted. The results revealed that the moisture of each herb decreased progressively over time, with higher temperatures, with mint and laurel displaying a short average time. The experimental drying data of the herbs was fitted to four commonly used thin-layer models, Page, Midilli, Weibull, and Logarithmic and Midilli model perfectly represented their behaviour. In all phytochemical qualities analysed, there is considerable variation depending on both plant species and drying temperature observed apart from carotenoids content where a significant variation was only observed among the herbs. Drying temperature has a distinct and complex influence on the preservation of phytochemicals, and this influence is highly species-specific and while moderate temperatures (50–60°C) generally favour the retention of most bioactive compounds, optimal conditions must be tailored to each herb to balance the retention of phenolics, vitamins, pigments, and antioxidant potential.

Keywords: Culinary herbs, drying kinetics, mathematical modelling, temperature, bioactive compounds.

الملخص:

تُعدّ الأعشاب الطهوية، رغم قابليتها السريعة للتلف عند كونها طازجة، ذات قيمة كبيرة في جميع أنحاء العالم لما تضفيه من نكهة ورائحة وفوائد طبية، إذ تحتوي على مركّبات نشطة بيولوجيًا متنوعة. في هذه الدراسة، تم تجفيف أربع أعشاب طهوية (الكزبرة، والبقدونس، والنعناع، وورق الغار) باستخدام مجفف غذائي عند ثلاث درجات حرارة مختلفة (50، 60 و70 درجة مئوية)، وتمت دراسة تأثير عملية التجفيف على حركيات التجفيف، النمذجة الرياضية، وجودة المركبات الفيتوكيميائية. تم تجفيف الأجزاء الهوائية من الكزبرة والبقدونس، وأوراق النعناع وورق الغار. وأُجريت تحاليل لقياس المركبات الفينولية الكلية، محتوى حمض الأسكوربيك، الكاروتينات، الكلوروفيلات (أ و ب)، والنشاط المضاد للأكسدة(باستخدام اختبار DPPHوقدرة الاختزال). أظهرت النتائج أن محتوى الرطوبة في كل عشبة انخفض تدريجيًا بمرور الوقت، مع انخفاض أكبر عند درجات الحرارة المرتفعة، حيث أظهر النعناع وورق الغار وقت تجفيف متوسط أقصر. تم تطبيق بيانات التجفيف التجريبية على أربعة نماذج رياضية شائعة للطبقات الرقيقة: نموذجPage ، Midilli، Weibull، وLogarithmic، وقد مثّل نموذج Midilli سلوك الأعشاب بشكل مثالي. في جميع الخصائص الفيتوكيميائية التي تم تحليلها، لوحظ تفاوت كبير حسب نوع النبات ودرجة حرارة التجفيف، باستثناء محتوى الكاروتينات حيث لوحظ اختلاف معنوي فقط بين الأعشاب المختلفة. تؤثر درجة حرارة التجفيف تأثيرًا واضحًا ومعقدًا على الحفاظ على المركبات الفيتوكيميائية، ويعتمد هذا التأثير بشكل كبير على نوع النبات. وبشكل عام، تفضّل درجات الحرارة المتوسطة (50–60°C) الحفاظ على معظم المركبات النشطة بيولوجيًا، إلا أن اختيار الشروط المثلى يجب أن يكون مخصصًا لكل عشبة لتحقيق توازن بين الحفاظ على الفينولات والفيتامينات والأصباغ والقدرة المضادة للأكسدة .

الكلمات المفتاحية: الأعشاب الطهوية، حركيات التجفيف، النمذجة الرياضية، درجة الحرارة، المركبات النشطة بيولوجيًا.