AROMATIC HERBS IN FOOD
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Herbs drying

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5.1 Introduction

Preserve or perish of herbs. But how to preserve herbs? What are the barriers to retain the bioactive compounds of herbs in functional food and the key factors necessary to promote effective drying? Considering a different approach to investigate the retention of bioactive compounds, we believe that smart drying technology and the identification of specific compounds are the keys to retaining the product quality in this century. This chapter introduces the techniques and issues of the selected herbs drying, reviews the existing drying techniques and their impact on the bioactive compounds, and at last, introduces several smart drying technologies.

Thus far, it has been tacitly assumed that freeze drying is known for its ability to retain bioactive compounds in biomaterials. This fact is because of the low drying temperature and under vacuum conditions prevent the degradation of chemical composition compared to heat-treated dried products. For example, total loss of chlorophyll in oven-dried Apium graveolens was 65%, which was 45% higher than freeze drying (Mahanom et al., 1999). However, freeze drying is an expensive form of drying because of the inherently slow drying rate that leads to prolonged freezing and drying duration. Also, the high capital cost involved and the high energy
demands of the vacuum and refrigeration systems limit more extensive applications due to the high operation cost. Therefore, many of the researchers use freeze drying as control and references. The use of freeze drying in the industry is rather scarce. We are profoundly sensitive to high capital cost and long drying duration; the influence of bioactive compounds is not always the top priority, and often drying characteristics that linked to drying duration is more critical.

5.2 Fundamental concepts in herbs drying

Drying of herbs consists of mass and heat exchange, which enables the transfer of water molecules from solids. Weight losses of herbs must be measured from initial weight until equilibrium is established. Each batch of herbs subjects to drying must be consistent in terms of initial weight to get a fair comparison in terms of drying characteristics and product quality. To quantify the water amount in the herbs using moisture content, the herbs need to be dried at $105^\circ$C for $24$ h to obtain bone dry weight, $W_{BD}$. Moisture content, $MC$, can be determined either in wet basis $MC_{wb}$ (Eq. 5.1) or dry basis format $MC_{db}$ (Eq. 5.2). In turn, the drying rate, $DR$, can be defined as a derivative of the function, representing the decrease in $MC$ concerning the drying time $t$ (Eq. 5.3).

Moisture content wet basis,

$$MC_{wb} = \frac{W_{S} - W_{BD}}{W_{S}}$$  \hspace{1cm} (5.1)

Moisture content dry basis,

$$MC_{db} = \frac{W_{S} - W_{BD}}{W_{BD}}$$  \hspace{1cm} (5.2)

Drying rate,

$$DR = \frac{dMC}{A dt}$$  \hspace{1cm} (5.3)

where $W_{S}$ is the weight of sample, $W_{BD}$ is the bone dry weight, $MC$ is the moisture content, $DR$ is the drying rate, $t$ is the time, and $A$ is the surface area.

Two typical drying characteristics are shown in Fig. 5.1. The standard drying characteristics curve includes (1) initial transient period, (2) constant rate period, (3) first falling rate period, and (4) second falling rate period; whereas hybrid drying characteristics curve consists of (1) initial transient period, (2) constant rate period, (3) first falling rate period, (4) second initial transient period associated with the implementation of VMFD, and (5) second falling rate period. Different drying curves occur due to different heating source or more effective operating conditions used in the drying of biomaterials. The solid and dotted lines represent the typical drying characteristic and hybrid drying characteristic curves, respectively. The example of hybrid drying is a combination of convective predrying followed by vacuum microwave finish drying (CPD-VMFD), which can induce intensive evaporation of water from the food material at the final stage of drying due to internal heating provided by microwaves. The intensive evaporation of water makes the drying time shorter at a lower temperature.
due to the cooling effect (Figiel, 2010). Shorter drying time at a lower temperature reduces nutritional, sensory, and chemical alterations (Drouzas and Schubert, 1996). Microwave drying has been gaining in popularity as the drying duration is concise, and the retention of bioactive compounds is acceptable. However, one of the drawbacks of microwave application is the scorching due to the inhomogeneity of the microwave field as well as the heterogenic structure of dried samples at the final stage of drying (Wray and Ramaswamy, 2015). To solve this issue, it leads to low-pressure microwave drying with rotational systems. The drying characteristics are highly dependent on the heat source used for drying. On top of vacuum and microwave, ultrasound and solar-assisted drying are widely used in herbs drying.

5.3 Example of drying characteristics of selected herbs

Figs. 5.2 and 5.3 show the herbs dried using the convective air drying (CD) and vacuum microwave (VM) techniques, respectively. Referring to the drying characteristics of herbs dried using the CD method, the MC of 1.8 and 0.3 kg H₂O/kg dm were identified as critical moisture contents. It is indicated using a vertical red color line in Fig. 5.2. The drying characteristics exhibited from this example are the initial transient period (right region), the first falling rate period (middle region), and the 2nd falling rate period (left region). The initial transitory period ranged from 1.8 to 3.0 kg H₂O/kg dm. No constant rate period due to the
fast moisture removal rate on the surface of the leaves. As the drying progressed, it crossed the vertical line and entered the middle zone, which was the 1st falling rate period with MC ranged from 0.3 to 1.8 kg H₂O/kg dm, the drying rate started to drop from 0.025 to 0.005 kg H₂O/kg dm min. The diffusion could cause the moisture losses via spaces between cells and pores of leave to the surface. The continuous diffusion of moisture reduces the efficiency of heat transfer. Furthermore, it was found that the drying duration ranged from 6 to 8 h at temperature and air velocity of 50°C and 0.8 m/s, respectively. Around 44% to 60% of total drying time fall under 2nd falling rate period, which ranged from 0 to 0.3 kg H₂O/kg dm with a decrease of drying rate from 0.005 kg H₂O/kg dm min to almost 0 kg H₂O/kg dm min. The diffusivity of the moisture from the internal part to the surface is relatively low, which prolongs the drying period.

For VM drying, the critical moisture points are indicated by the vertical red color line, which divides the constant drying rate period, 1st falling rate period, and 2nd falling rate period. The constant drying rate ranged from 0.20 to 0.25 kg H₂O/kg dm min at a MC of 1.0 to 3 kg H₂O/kg dm. It is swift compared to CD as the MC is removed using microwave energy with the aid of vacuum conditions. This technique reduces the vapor pressure, giving a more significant driving force for moisture to diffuse into the ambient and changes its physical states. As drying progressed from right to left, 1st falling rate period appeared, the drying rate decreased to 0.15 kg H₂O/kg dm min with MC ranged from 0.5 to 1.0 kg H₂O/kg dm. Microwave energy can generate heat to the internal part of the leaves, making the heat transfer and mass transfer happen effectively even the MC is low. Drying rate was still high as microwave energy generated heat by changing the electromagnetic field up to 2450 M times per second encouraged the mass transfer of moisture at the temperature of the material in the range of 50°C to 70°C.

### 5.4 Types of drying technology

#### 5.4.1 Sun drying

The history of sun drying was as long as 20,000 BC, and the mechanical drying developed extremely fast at the end of World War II (Hayashi, 1989). Back then, Human utilizes natural energy like high wind speed, low humidity, and strong sunlight to preserve food and
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AROMATIC HERBS IN FOOD
Bioactive Compounds, Processing and Applications

Edited by CHARIS M. GALANAKIS

Covers the latest developments of applications in foods from aromatic and medicinal herbs

Aromatic Herbs in Food: Bioactive Compounds, Processing, and Applications thoroughly explores the properties of aromatic and medicinal herbs in view of their bioactive compounds, new trends in procedures for their recovery, and their applications in food. Used in food supplements, packaging, and other products, bioactive compounds from herbs, spices, and other food products are functional from nutritive and technological standpoints and can offer significant wellness benefits.

Beginning with the health components and medicinal chemistry of spices and herbs, the book then presents current trends in herb applications with an emphasis on Mediterranean aromatic herbs and their culinary use, the analysis and extraction of bioactive compounds and essential oils from herbs using green technologies, and herbs drying and the encapsulation of herbs extracts. The book also discusses different applications of herbs and their bioactive ingredients, such as usage in active food packaging, in slimming products, and as natural sexual enhancers.

Aromatic Herbs in Food: Bioactive Compounds, Processing, and Applications is an ideal resource for food scientists, technologists, engineers, and chemists working in food science; nutrition researchers working in food applications and food processing; and anyone interested in the development of innovative products and functional foods.

Key Features

• Covers all important aspects of herbs, such as properties, processing and recovery issues, and applications
• Presents health components of spices and herbs, their culinary use, and legislation issues regarding the application of aromatic herbs in food
• Explores herbs’ processing, extraction technologies, green extraction technologies, encapsulation of recovered bioactives, applications, and interactions with food components

About the Editor
Charis M. Galanakis is a multidisciplinary scientist in agricultural sciences as well as food and environmental science, technology, and sustainability, with experience in both industry and academia. He is the research and innovation director of Galanakis Laboratories in Chania, Greece, an adjunct professor of King Saud University in Riyadh, Saudi Arabia, and the director of Food Waste Recovery Group (SIG5) of ISEKI Food Association in Vienna, Austria. He pioneered the new discipline of food waste recovery and has established the most prominent innovation network in the field. He also serves as a senior consultant for the food industry and expert evaluator for international and regional funded programs and proposals. He is an editorial board member of Food and Bioproducts Processing, Food Research International, and Foods, has edited over 45 books, and has published hundreds of research articles, reviews, monographs, chapters, and conference proceedings.