Peppermint a medicinal herb and treasure of health: A review

Parv Nayak, Tankesh Kumar, AK Gupta and NU Joshi

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Abstract
High demand for aromatic herbs in the sectors of biotechnology, cosmetics, medicinal and food industries has enhanced their market values. Peppermint (Mentha piperita L.) is a prominent medicinal herb and largely acknowledged by medicinal and food processing industries due to its excellent health benefits. Though it is used as a flavoring agent in foods, they are mostly recognized in the world for their antimicrobial and antioxidant features. Peppermint oil and its other by-products are generally used for candies, teas, mouth freshener, toothpaste, beverages, alcoholic liqueurs, jellies, syrups, ice creams, cough drops, chewing gums, confectioneries, soaps, detergents, and mosquito repellents. It is a highly perishable and seasonal plant, therefore, it needs to be dried and make it available throughout the entire year. The drying of peppermint mint herbs is targeted to enhance the storage time, minimize the packaging and transport cost. Various studies on drying of mints were collected and analyzed the drying kinetics, to regulate the effect of several drying methods on drying time, drying rate and to improve its quality in terms of color and other characteristics. The present paper reviews the health aids of peppermint such as anti-viral, anti-bacterial, anti-inflammatory, anti-fungal, anti-asthmatic, allopathic, spasmodytic, anti-headache, anti-septic, and radioactive properties in detailed. Thus, peppermint has a wide scope of future research and studies and needs to be utilized its potential benefits for human prosperity.

Keywords: Peppermint, peppermint oil, medicinal herbs, drying of mints

Introduction
Mints (Mentha spp.) are popular aromatic and medicinal herb and it has a huge family of perennial herbs and usually cultivated globally, to acquire its superior herbal features such as antimicrobial and antioxidant properties (Kadam et al., 2011; Nayak et al., 2011) [64, 90]. This perennial herb has creeping regular branches and their leaves are an oval-shaped, rough surface with serrated margins. The genus Mentha belongs to the Lamiaceae family and includes 25 to 30 species (Hawryl et al., 2016) [57]. It was inborn to Europe, grows naturally in the northern USA, Canada, and produced worldwide (Hocking and Edwards (1955) [59]; Kavrayan and Aydemir (2001)) [70]. It is largely developed in the Mediterranean region as the core fragment of the vegetation. The world production of peppermint was about 92, 296 tonnes in 2014, led by Morocco contributing more than 90% of the world total (FAOSTAT, 2017) [40]. In India, Mint is generally produced in southern parts of the Himalayan zone covering Himachal Pradesh, Haryana, Punjab, Uttar Pradesh, and Bihar (Kripinand et al., 2015) [59]. This genus can be originated in many environments but best raised in moist soils and wet atmospheres. Due to their wide range of tolerance characteristics, it can also be grown in full sunlight (Maffei, 1999) [81]. Mints plant has about 10–120 cm height and can extend above an unstated region. Particular mints are labeled as invasive, because of their propensity to grow widely (Park et al., 2002) [98]. Most of the mint species are commercially seed sterile and nurtured by underground stolons (runners or rootstock) of existing plants (Douhan and Johnson, 2001) [34]. The stolons having high moisture content thus spoil promptly due to dryness and cannot be preserved for a longer period (Douhan and Johnson, 2001) [34]. The main ample active compounds of mints (Mentha spp.) are limonene, cineole, menthone, menthofuran, isomenthone, menthy acetate, isopulegol, menthol, pulegone and carvone (Alankar, 2009; Rohloff, 1999) [5]. Further components include flavonoid glycoside (e.g. Narirut, Luteolin-7-0-rutinoside, Isorhoifolin, and Hesperidin, etc.), polyphenols (e.g. Rosmaric acid, Eriocitrin, Cinamic acid, Caffeic acid, and Narigenin-7-0glucoside); luteolin-diglucoridone and eriodictyol glucopyranosyl-hamnopyranoside were also purified from aerial parts of mint (Areias et al., 2001; Umezu et al., 2001; Clark and Menary, 1980; Croteau and Venkatachalam, 1986; Mascher et al., 2001) [8, 13, 27, 31, 86].

Corresponding Author:
Parv Nayak
Ph.D., Scholar., Department of Agricultural Processing and Food Engineering, College of Agricultural Engineering and Technology (CAET), Odisha University of Agriculture and Technology, Bhubaneswar, Orissa, India
Several authors reported that (Wealth of India, 1962; Park et al., 2002; Columbia Electronic Encyclopedia, 2005; Thompson, 2003) [98, 129] mint leaves are mostly consumed either fresh or dried manner in the different form of serving dishes such as vegetable gravies, chutney, salad dressings, flavoring and garnishing of soups, meats, desserts, jellies, vinegar, tea infusions, and iced drinks, etc. They are originally recognized for their special qualities such as refreshing, anti-bacterial, stimulative, diaphoretic, stomachic, and anti-spasmodic. It relieves against cold, flu, fever, anorexia, nausea, motion sickness, food poisoning, rheumatism, hiccups, wounds, cramping, diarrhea, earaches, gassiness, esophagus and sinus illnesses (Saednia et al., 2005; Colak et al., 2008; Keifer et al., 2008; Therdthai and Zhou, 2009; Akpinar, 2010; Nayak et al., 2011) [112, 29, 70, 128, 80]. The best mint species with marketable or medical practice are shown in Table 1.

Constituents and applicability of peppermint
Peppermint (Mentha piperita, also known as Mentha balsamea) is a perennial herbal medicine and belongs to the mint family Lamiaceaeas shown in Fig. 1. Due to its strong anti-oxidant and anti-microbial properties, and the presence of active constituents, it plays a vital role in building up the immune system and enhancing appetite (Dorman et al., 2003; Yalcin et al., 2012) [13, 136]. The peppermint plant is a cross hybrid between watermint (Mentha aquatica) and spearmint (M. spicata) (Khalil et al., 2015) [71]. Indigenously, it is a plant of the Mediterranean region but also cultured in Europe, Asia, North America and extensively spread in various parts of the world (Abdel-Wareth and Lohakare, 2014; Beigi et al., 2018) [1, 6]. Peppermint has smooth dark green leaves with squared stems and blunt oblong bunches of pink lavender flowers. As with the help of stolons (underground stems), peppermint plants can be produced widely over a large area. Natural hybridization of peppermint with different wild species leads to yield a wide range of species of mint. The two most prominent varieties, popularized among the growers are black and white peppermint. Black peppermint has purplish stems, mostly cultured in the United States and also known as English peppermint or Mitchammint. Whereas, white peppermint has the lowest productivity and fetches higher commercial value due to its oil of desirable odor.

Peppermint leaves hold resilient sweetish odor and a spicy flavor with a freshening after mastication. The peppermint is a dynamic and good source of numerous minerals such as Na, Mg, K, Ca, Cr, Fe, Co, Cu, Zn, and Se (Padmini et al., 2010) [10]. It comprises around 0.5% to 4% essential oils, that are having the composition of about 25% to 78% menthol, 14% to 36% menthone, 1.5% to 10% isomenthone, 2.8% to 10% menthyl acetate, and 3.5% to 14% cineole (Grigoleit and Grigoleit, 2005; Bupesh et al., 2007; Aziz et al., 2011; Beigi et al., 2018) [64, 24, 14, 6]. Menthol, correspondingly named as peppermint camphor and it is used pharmaceutically as a relaxing balm. The essential oil of peppermint is obtained either from garden-fresh mint leaves or dried leaves by a hydro- distillation process. Peppermint oil is having compounds of mainly monoterpenes and sesquiterpene hydrocarbons, phenyl propanoids, and its oxygen derivatives (Adamiecand Kalemba, 2006) [37]. Clean and unadulterated oil of peppermint is found to be almost colorless. It contains mainly of menthol and menthone with some additional minor components includes pulegone, menthofuran, and limonene. Depending on its various factor such as topographical region, mint maturity, treatment, handling and storage environments of peppermint leaves, their chemical constituents may get differ (Riachi and Maria, 2015; Ansari et. al., 2000; Chen and Zhong, 2015; Beigi et al., 2018) [110, 7, 25, 6]. The major oil-producing nations are Bulgaria, Italy, China, and the USA, which gives nearly 90% of global peppermint oil production. Additionally, peppermint is a good source of polyphenol and thus exhibits resilient antioxidant qualities.

Duke (1985) [85] and Diwedi et al., (2004) [37] highlighted some of the principal uses of the peppermint oil encompass as a flavoring of pharmaceuticals, dental preparations, mouthwashes, cough drops, chewing gums, candies, confectionery, alcoholic liqueurs, perfumery, soaps and detergents, and mosquito repellent. Mint oil tends to utilize it as environmentally friendly insecticides and pesticides for its capability to destroy various pests like wasps, hornets, ants, and cockroaches. Peppermint essential oil is extensively used in pharmaceutical industries either for exterior or interior usage. For interior usage, mint oil is utilized in flatulence,
nausea, and gastralgia due to its presence of methanol as it tastes pleasant (Diwedi et al., 2004; Edris et al., 2003) [37, 40]. Methanol is one of the major constituents of peppermint and broadly used for nasal congestion (Eccles 1994; Eccles 2003) [38, 39], stuffiness and migraine problems (Haghighi et al., 2010) [55] and musculoskeletal pain (Patel et al., 2007) [99]. Due to its native antiseptic and anesthetic qualities, mint oil has a wide scope of exterior application in rheumatism, neuralgia, congestive headache, and toothache. As tobacco has a sour flavor, therefore extracts of peppermints in the form of an additive are usually employed in cigarettes, because it provides soothing throat without any bitterness. The prescribed amount of peppermint essential oil for intake in adults was mentioned that capsules consisting of around 0.2 to 0.4 ml of oil, thrice per day (Khanha et al., 2014) [72]. Ocak et al., 2008 [89]; Toghyani et al., 2010 [110]; Abdel-Wareth and Lohakare, 2014 [1] were reported some effective evidence associated with usage of peppermint constituents on broilers for their nutritional growth and results shows that peppermint leaves support to strengthen the lives of broilers during their early stage as well as helps to enhance the egg properties. Khempaka et al., (2013) [73] stated that peppermint shows the valuable impacts on antioxidant activity, collection of abdominal fat, and ammonia creation in broilers. Abdel-Wareth et al., (2019) [3], suggested that peppermint leaves can be used to raise the economic efficacy of broiler meat production and they have recommended the most optimum feed dosage (15g/kg peppermint leaves or 52 mg/kg menthol) for boilers chicks, to boost up their growth.

**Antiviral properties of peppermint**

The world is dealing with terrible communicable viral diseases since lots of viruses have a high resistance capability as compared to other microorganisms and this generates major health issues in humans as well as in animals (Fiore et al., 2008) [46]. Treatment of viral diseases creates a challenging condition worldwide, because of a lack in the accessibility of merely insufficient powerful antiviral medicines (Vijayan et al., 2004) [113]. Some researchers clarified that several peppermint extracts have potential sources of antiviral characteristics (Brand et al., 2016; Shalaye et al., 2016; Bekhit et al., 2011) [23, 122, 17]. The antiviral characteristics of diverse peppermint extracts (Aqueous, alcohol, and essential oil) are shown in Table 2.

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<th>Extracts</th>
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<td>Aqueous</td>
<td>HSV-2</td>
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<td>HIV-1</td>
<td>Influenza A virus</td>
<td>Shaikh et al., (2014) [121]</td>
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<td>Newcastle disease virus and VACV in egg</td>
<td>Arora et al., (2010) [111]</td>
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<td>Alcohol</td>
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<td>HSV</td>
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**Anti-bacterial properties of peppermint**

In the current scenario, there are huge demands for medicinal plants as secondary metabolites because of their applications in pharmaceutical units in the form of antimicrobial agents (Mahboubi and Kazempour, 2014; Almajano et al., 2008) [82, 6]. Some scientists revealed that peppermint oil and its extracts show the strong barrier against the growth of various microbes such as Escherichia coli, Salmonella pullorum, Comamon asterrigena, Streptococcus faecalis, Acinetobactersp, Streptococcus thermophiles, Lactobacillus bulgaricus, Staphylococcus pyogenes, Staphylococcus aureus, Streptococcus pyogenes, Serratiamarcescens, Mycobacterium avium, Salmonella typhi, Salmonella paratyphi A/B, Proteus vulgaris, Enterobacter aerogenes, Yersinia enterocolitica and Shigella dysenteriae (Shaikh et al., 2014; Bohnnett et al., 2016; Sun et al., 2014) [121, 125]. Many studies highlight that peppermint oil is having the maximum zone of inhibition (11.58 to 17.24 mm ± 0.87 SD) as compared to extract acquired from peppermint stem with the zone of inhibition of 15.82 mm ± 3.56 SD and thus peppermint shows the maximum antibacterial characteristics (Shaikh et al., 2014) [121].

**Anti-fungal properties of peppermint**

Researcher’s statistics showed that peppermint has excellent anti-fungal properties against Candida albicans, Aspergillus Albus, and dermatophytes fungi (Oumzil et al., 2002). Mentha spicata oils presented optimum anti-fungal property against Aspergillus fumigatus (zone of inhibition = 16 mm ± 0.5 SD) and A. niger (zone of inhibition = 14 mm ± 0.5 SD) (Bansod and Rai, 2008) [13].

**Allelopathic properties of peppermints**

Allelopathy is a key factor for the agricultural ecological system and influences the maturity, value, and developmental capacity of any plants (Goga et al., 2016; Shah et al., 2016) [52, 120]. Mahdavikia and Saharkhiz, (2016) [83] were recommended that peppermint extracts with a concentration (10% v/v) repressed the development of the tomato saplings. Skrzypek et al., 2015 [124] stated that aqueous peppermint extracts with a concentration of 15% v/v, declines the vitality index as well as photochemical and non-photochemical quenching in sunflower.

**Anti-inflammatory properties of peppermint**

Inflammation is considered as a vigorous factor mostly answerable for the occurrence of countless dreadful diseases includes tumor, septic shock, atherosclerotic, diabetes, and abdominal obesity (fatness) (Ku and Lin, 2013) [76]. Few reports presented that peppermint constituents have played a significant role in preventing diseases like angiogenesis and inflammation (Kaefer and Milner, 2008; Kale et al., 2008) [65, 66]. Liu et al., (2014) [80] reveal that the practical usage of methanol of peppermint on L1210 tumor cells results in cytotoxic impacts.

**Spasmyolytic properties of peppermint**

Consumption of peppermint oil lowers down the calcium inflow in the large intestine as well as jejunum (lies between...
ileum and duodenum) (Sadræi et al., 2016) [111] and thus, provides relaxation in the gastrointestinal tract (Nissen and Lau 2016) [93]. Menthol and oil of peppermint obstructed the calcium deposition motion in rats, pig atrial and papillary muscles, and broilers retinal neurons (Harris 2016; Jain et al., 2016) [86, 62].

Peppermint claim as a therapy for spastic bowel (Irritable bowel syndrome)

Irritable bowel syndrome (IBS) is considered as a long-lasting illness with dysfunction of bowel categorized by occurrence in signs of diarrhea, constiveness as well as anxiety or pain, and having additional symptoms such as swelling, bowel urgency, and inadequate emptying of the bowel. (Rees et al., 1979; Chey et al., 2015; Harris, 2016) [103, 26, 58]. IBS influences around 9% to 23% of peoples throughout the world (Saha, 2014) [114]. Peppermint oil can be used as a non-toxic and operative intervening action for a spastic bowel disorder. It lessens the symptoms of spastic bowel by preventing the calcium inflow in the gastrointestinal tract and potassium depolarization in the ileum (Korterink et al., 2015; Egan et al., 2015; Shaikh et al., 2014; Sagduyu, 2002) [74, 42, 121, 113]. Peppermint oil facilitates decisive impressions on inflammatory itching, serotonin, and cholinergic sense organ of the gastrointestinal tract and also effective against vomiting and nausea (Tate, 1997) [127]. Thus, peppermint herbs considered as extensively used for therapy of spastic bowel syndrome.

Anti-headache properties of peppermint

Historically, the herbal plant has been recognized for the medication of headache illness (Levin, 2012) [79]. Peppermint oil and its by-products intake ensure the purpose of headache healing. A report showed that the combined usage of peppermint and eucalyptus oil has efficiently relaxed the patients suffering from headache discomfort (Gobel et al., 1994) [51].

Radioactive features of peppermint

Alcohol extract of peppermint with the optimal quantity of 100 mg/Kg repeated for 3 days was found efficient against radiation-induced morbidity and mortality (Kaushik et al., 2012) [68]. It was reported that extracts of peppermint leaves exhibited effective anti-oxidant as well as free radical scavenging properties and successively it was found useful against radiation sources (Samarth et al., 2006) [116]. Gardiner (2000) [48] also advised that peppermint extract having extensive potential properties for radioprotection and chemoprevention, includes quick retrieval of bone marrow, immunity, efficient antioxidant features.

Drying of peppermint and other medicinal leaves.

Peppermint leaves have many applications in both fresh and dried forms. The dried leaves are extensively consumed in different cuisines as well as in medicines (Hedrick, 1972) [58]. Drying process of aromatic and medicinal herbs consists of removal of water up to a level at which microbial spoilage and deterioration reactions are highly minimized (Rocha et al., 2011) [107]. On one hand, drying of the peppermint leaves prevents deterioration and increase shelf life of the product, but on the other hand, it may alter their vibrant aroma and flavor (Consuelo et al., 2003) [10]. Volatile aroma compounds are the most sensitive components in the process of drying. Changes in the concentrations of the volatile compounds of mint during drying depend on several factors, such as drying conditions (temperature, air velocity), moisture content, variety and age of the plant, climate, soil, and harvesting method (Asekun et al., 2007; Tarhan et al., 2010; Braga et al., 2009; Rohloff et al., 2005) [12, 126, 22, 108]. There are several works done to study the effect of drying on oil yield and composition of various aromatic and medicinal herbs. Blanco et al. (2000) [19] conducted studies to show the effect of different temperatures in the drying process on the amount and quality of essential oils of peppermint (Mentha piperita L.). They observed that higher drying temperature sharply decreased the essential oil content (% v/w) from 1.0% (40 °C) to 0.14% (60 °C) and 0.12% (80 °C). They also concluded that the higher drying temperatures affected the composition too.

Omidbaigi et al. (2004) [37] studied the influence of different drying methods, including sun, shade, and oven at 40 °C, on quantitative and qualitative traits of the essential oil from Roman chamomile (Chamaemelum Nobile L. All. var. flora plena). The oil content of the shade-dried flowers was the largest (1.9% w/w) compared to sun-drying (0.4% w/w) and oven-drying at 40 °C (0.9% w/w). They further stated that the drying methods had no effect on the number of chemical components of the essential oil but had a significant effect on their proportion.

Sefidkon et al. (2006) [118] investigated the influence of drying and extraction methods on yield and chemical composition of the essential oil of Satureja hortensis. They found that the oil content of the shade-dried sample, obtained by hydro-distillation, was higher (0.94%) than that of the steam-distilled (0.27%). The results showed that extraction by hydro-distillation gave the best results for S. hortensis, based on oil yield and carvacrol percentage. Pirbalouti et al. (2013) [100] studied the effects of drying methods on qualitative and quantitative properties of essential oil of the purple landrace and the fresh sample of green landrace.

Increasing the drying temperature significantly decreased the essential oil content of all samples. The percentage of methyl chavicol in the oil decreased significantly when the plant material was dried in the oven at 60 °C or microwaved. Rahimmalek and Goli (2013) [103] evaluated six drying treatments (sun, shade, oven 50 °C, oven 70 °C, microwave, and freeze-drying) for essential oil yield, composition and color characteristics of Thymus daenensis subsp. daenensis. Celak leaves. They concluded that the highest essential oil yield was obtained by freeze-drying (1.7%). However, despite relatively low essential oil yield in microwave drying, it had many advantages such as shortening of drying time, high color quality, and increased major compounds of thyme leaves.

Argyropoulos and Muller (2014) [10] investigated the impact of hot-air drying on essential oil content and composition of lemon balm leaves (Melissa officinalis L.) at different temperatures. They observed that the essential oil loss was proportional to drying temperature (16%, 23%, and 65% at 30, 45, and 60 °C, respectively). They also reported that the pronounced changes in the major essential oil components occurred at 60 °C.

Drying methods and kinetics

The hot air drying is the most commonly used method, but it
leads to thermal damage and severely reduces the volatile compounds of herbs as well as the color (Antal et al., 2011) \[8\]. However, in the recent decade, many researchers have reported some advanced methods of drying aromatic herbs such as microwave drying, infrared drying, freeze-drying, and fluidized bed drying, which may have the potential to overcome these problems.

**Sun drying**

The open-air sun drying of thyme and mint leaves was investigated by Ismail and Beyribey (2013) \[63\]. They obtained the drying times as 440 minutes for thyme and 420 minutes for mint from the initial moisture content (73.80% for thyme and 84.70% for mint) to the final moisture content (7.6% for thyme and 4.85% for mint). L* values of fresh and dried herbs were found as 40.25 and 35.70 for thyme and as 44.01 and 33.08 for mint, respectively. The effective diffusivities were determined as 2.2571x10^{-10} m^2/s for thyme and as 1.2768x10^{-10} m^2/s for mint.

Muller et al. (1989) \[88\] used a greenhouse-type solar dryer for mint drying. They observed that the drying process from an initial moisture content of 80% (w.b.) to a final moisture content of 11% (w.b.) took 3-4 days.

**Tray drying**

Doymaz (2005) \[90\] studied the thin-layer drying behavior of mint leaves for a temperature range of 35-60 °C in a cabinet dryer. It was observed that the effective diffusivity varied from 3.067x10^{-9} to 1.941x10^{-8} m^2/s and increased with the air temperature. An Arrhenius relation with an activation energy value of 62.96 kJ/mol expressed the effect of temperature on the diffusivity.

**Advanced drying methods**

Ozbek and Dadali (2007) \[90\] investigated the drying kinetic of mint leaves in a microwave oven at various microwave output powers and sample amounts. Drying time decreased considerably with an increase in microwave output power and with a decrease in sample amount of mint leaves. This technique can be successfully used to dry mint leaves as compared to sun drying and hot air drying. Average drying rates of mint leaves at a constant rate period ranged from 0.571 to 3.083 g water/g dry base/min at various microwave output powers (from 180 to 900 W) and followed by falling rate period. On the other hand, average drying rates at a constant rate period ranged from 1.395 to 0.386 g water/g dry base/min for the sample amounts between 25 and 100 g and again followed by falling rate period.

Ertekin and Heybeli (2014) \[44\] studied the effects of thin-layer infrared drying of mint leaves. Drying time was obtained between 18 and 38 min at drying temperatures of 60-80 °C. The lightness and yellowness of the dried mint leaves were significantly increased when compared with fresh samples. The high drying temperature yielded in darker, less green and more yellow mint leaves. When the 38 models compared according to the statistical values, the rational function model (model-32) for drying temperatures of 60 and 70 °C and Modified Henderson Pabis-II model (model-5) were superior to the others.

Rubinskiene et al. (2015) \[110\] evaluated the effect of drying methods on the chemical composition and color of peppermint (Mentha piperitanL.) leaves. The highest content of essential oil (0.77%) and chlorophyll (1.69%) was found in the cv. ‘Peppermint’. Chlorophyll a to b ratio was different in the fresh peppermint leaves: in the cv. ‘Peppermint’ it was 1.35 and in the cv. ‘Krasnodarksaja’-1.44. Peppermint leaves were dried using active ventilation, convection, infrared, vacuum, microwave, and freeze-drying methods. The highest content of essential oil (0.64-0.68% of dry mass) was found in the variously dried peppermint leaves of the cv. ‘Krasnodarksaja’. The lowest content of essential oil (0.08% and 0.065% of dry mass) was determined in microwave dried herbs. The highest content of chlorophyll was found in the freeze-dried peppermint leaves (715.0 mg/100 g of dry mass) of the cv. ‘Peppermint’. Regardless of the drying method, significant differences between the ratio of chlorophyll a to b were observed in the dried herbs of the cv. ‘Krasnodarksaja’. The fresh and dried peppermint samples of the cv. ‘Peppermint’ had the lowest brightness L* value (from 22.61 to 35.24) and the lowest yellowness b* values (from 9.35 to 17.00). The biggest changes in greenness a* value were in microwave dried peppermint leaves.

The effect of oven drying at 30 °C and freeze-drying on the volatile compounds in thyme and sage has been minor, whereas losses at 60°C were 43% in thyme and 31% in sage (Venskutonis, 1996) \[116\]. Ratti (2001) \[102\] found out that freeze-drying can be used to avoid damage caused by heat, producing a product with superior physical and chemical qualities is considered a costly and time-consuming process. Ataei et al. (2015) \[13\] studied on vibro-fluidized bed heat pump drying of mint leaves. The effective moisture transfer of the samples was increased with air temperature and varied from 4.2665x10^{-10} to 2.9587x10^{-10} m^2/s for heat pump drying (HPD) method, and 3.7191x10^{-11} to 1.29196x10^{-10} m^2/s for none-heat pump drying (NHPD) method. The color indices for temperatures of 40 and 50 °C were very close to each other, whereas by increasing temperature to 60 °C, a remarkable loss of green color was observed. The highest phenolic content was found in methanolic extract for HPD at 60 °C, and NHPD at 50 °C contained the lowest amount of phenolic compounds. NHPD treatments showed lower antioxidant activity compared to HPD treatments at the same temperature due to the longer drying times.

Kadam et al. (2010) \[64\] conducted experiments on the thin layer convective drying of mint leaves. They stated that the drying time varied from 240 to 390 min to dry a 300 g of mint leaves samples at temperatures from 45 to 65 °C. The average thickness and moisture content of fresh mint leaves were 0.26 mm and 470.78% (d.b.), respectively. Drying temperatures had no significant effect on the color of dried mint leaves. The two-term model with the highest r² value of 0.998 represented thin layer drying behavior of mint leaves in the tunnel dryer. Effective moisture diffusivity was observed to increase with the increase in drying air temperature and ranged from 1.3235x10^{-10} to 2.6568x10^{-10} m^2/s.

Kane et al. (2009) \[67\] evaluated the drying parameters and sorption isotherm of mint leaves (M. pulegium). They found that the effective diffusivity varied from 1.9871x10^{-11} to 1.4221x10^{-10} m^2/s and increased with the air temperature. An Arrhenius relation with an activation energy value of 57.12 kJ/mol expressed the effect of temperature on the diffusivity. Park et al. (2002) \[98\] studied the drying parameters and desorption isotherms of garden mint leaves (Mentha Crispa L.). The sorption curves for the temperatures of 30 °C and 40 °C were better fitted with the pegleg model. The 50°C desorption isotherm was similar to the 40 °C model. The values of calculated effective diffusivity for drying at 30 °C, 40 °C and 50 °C of air temperature and 0.5 and 1.0 m/s of air velocity ranged from 4.765x10^{-13} to 2.945x10^{-12} m^2/s. The
effective diffusivity increases as air temperature and air velocity increases.

**Conclusion**

Since ancient times, herbs have fascinated the scientific attention of the biotechnology, cosmetic, pharmaceutical, and food industries and subsequently used for many purposes such as medicinal, flavoring, beverages, dyeing, fragrances, and other industrial practices. Concerning to well-being prosperities of peppermint, it can be stated that peppermint herb has enormous capabilities to handle human ailments, besides it has a great career in global trade. There is a need to explore more about its physicochemical characteristics as well as their compound's reaction to the human physique, to its maximum possibilities. Apart from its cheap and economic profits, some studies must be carried out about their side effects and harmfulness during the intake of peppermint. Drying is a strategy to preserve the perishable, perennial peppermint and consequently offers the product to be available during out of stocks. This study could be helpful to obtain a better aroma, the flavour of dried mint leaves powder, or the extraction of essential oil and its by-product from peppermint to its maximum efficiency by using the finest drying process and kinetics. These dehydrated peppermint leaves can be utilized for making spices, chilies powder to scatter on several kinds of foods. In the present scenario, there is a huge demand for the essential oil of peppermint across the world and in various urban nations, it can be categorized as a benchmark for medical and nutritional studies.

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