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Sustainable Ingredients and Selected Herbs By-Products for Food Industry

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Abstract: This review presents sustainable ingredients from selected herbs by-products, processing, and extractions of bioactive compounds exploring the potential for utilization as novel "green" food ingredients used in food technology. To increase the sustainability of the food chain, the valorisation of food by-products and wastes has emerged as a key study area. Herbs by-products have recently been discovered as sources of a variety of phytochemicals, many of which have significant biological activity that could be useful for food industry by applying the appropriate extraction method. For the recovery of bioactive, new extraction methods including pulsed electric field and ultrasonic are generating a lot of interest in herbs by-products. Supercritical fluid extraction, a green and environmentally-friendly procedure for preparation of some herbs by-products is described in this review in the context of sustainable extractions to eliminate or reduce solvent consumption.

Keywords: bioactive, by-products, chamomile, herbs, oregano, sage, thyme.

Introduction

In recent years, in addition to by-products resulting from the industrial processing of fruits and vegetables, special consideration has been given to by-products resulting from the post-harvest and processing of medicinal herbs.

The processing of herbs materializes in the production of a significant amount of plant by-products; herbal material of inferior quality and/or unusable plant parts that are not commercially exploitable (Dina et al., 2022).

Regarding the processing of herbs, two extracts are produced as by-products of the steam distillation of herbs to produce essential oils: a

decoction and the water fraction of the distillate (hydrolate). Plant particles, different organic acids, proteins, and flavonoids are all present in the dark-coloured decoction. Since their relative vapour pressures are low under the conditions normal distillation conditions with steam, the decoction of newly collected herbs leaves a large amount of antioxidants.

Antioxidants are defined as food additives that protect foods from deterioration caused by oxidation (Iriondo-DeHond et al., 2018).

Technologists are constantly looking for new sources of natural antioxidants that are suitable for use in food. Early research on by-products of essential oil synthesis discovered that decoction was a more potent antioxidant resource than hydrolate (Mielnik et al., 2008).

Selected herbs by-products - processing and chemical characterization

In order to produce novel bioactive compounds employing by-products from the processing of farmed herbs as raw materials, a recent thorough investigation of native Greek species conducted by (Dina et al. 2022) highlighted the fact that many bioactive compounds remain in the residue resulting from the conditioning processes. Furthermore, the results revealed that by-products derived from the processing of the selected species comprise 64% thyme (*Thymus vulgaris*), 54% oregano (*Origanum vulgare* subsp. *Hirtum*), 37% Greek mountain tea (*Sideritis scardica*), and 24% chamomile (*Matricaria recutita*) of the total processed mass.

Some byproducts of essential oil production plants' hydrodistillation, such as lavender essential oil, solid pomace or residues, could be proposed a source of biologically active compounds such as ursolic and oleanolic acids. Furthermore, residual distillation waters have a variety of applications due to their aromatic and antimicrobial properties (Ciocarlan et al., 2021).

Powdered herbs material resulting from production of fractions with smaller particle sizes are usually discarded as a by-product after sieving and fractionation. On the report of the *Codex Alimentarius* for herbs and medicinal plants, the mill automatically divided the grated plant material into four grades: qualities A (4.5-1.0 mm), B (1.0-0.5 mm), and C (0.5 - 0.35 mm) are thought to be commercially admissible from the market (superior plant material), while the D quality (residual biomass) is thought to be non-commercial (Dina et al., 2022).

Using high performance thin layer chromatography (HPTLCLC) and liquid chromatography-mass spectrometry (LC-MS) analysis, herb

by-products revealed chemical content similar to the superior herbal material. Furthermore, strong free radical scavenging associated with a high phenolic content was observed in thyme, oregano, and Greek mountain tea. Gas chromatography/mass spectrometry (GC-MS) analyses of oregano and thyme by-product comparable with essential oils (EOs) revealed the presence of carvacrol, thymol, -terpinene, and p-cymene as major constituents. LC-MS analyses of aqueous extracts of mountain tea and chamomile by-products revealed the existence of a number of bioactive compounds, including flavonoids and phenylpropanoids. In general, the presence of bioactive components in by-products, such as terpenes, phenolic compounds, and flavonoids, underpins their powerful use as food antimicrobial and antioxidant additives, in the preparation of high added-value products, like enriched aromatic edible oils, and cutting-edge herbal teas, like instant beverages (Dina et al., 2022). Moreover, according to the findings, HPTLC and LC-MS analysis of herbal by-products indicated chemical compositions that were comparable to those of the superior herbal material. Thyme, oregano, and Greek mountain tea were also found to have significant free radical scavenging due to high phenolic content.

Wild *Thymus serpyllum* L. by-products extracts were subjected to phytochemical screening, which revealed the existence of a number of bioactives. This contains terpinoids, tannins, flavonoids, and other substances with hematological, antibacterial, antioxidant, anticancer, and other properties. Wild thyme by-products were used to extract natural antioxidant-rich terpenoids from filtered herbal infusions for use as natural additives in ground pork patties (Šojić et al., 2020; Jovanović et al., 2017).

SFEs (supercritical fluid extraction) SFE1 (100 bar and 40°C) as well as SFE2 (350 bar and 50°C) of wild thyme by-product reduced darkening in ground pork patties, effectively reduced lipid and protein oxidation, and inhibited microbial growth, according to the findings. Moreover, lowest degree of lipid oxidation was assessed in patties produced with 0.150 μL/g of SFE_1, while additionally, SFE_2 at concentration of 0.075 μL/g provided the extended ground meat patties shelf life (Šojić et al., 2020).

Aside from the plants, previous research revealed that utilizing extracts from agro-food industrial by-processing is difficult for future applications in the food industry (Pavlić et al., 2015; Pavlić et al., 2018).

It has been notice that the use of modern or artisanal plants processing plant material (aromatic and medicinal plants) directly in

the field has a positive influence on the value of the resulting essential oils and by-products (Ciocarlan et al., 2021).

One of the most valuable medicinal and aromatic herbs is lavender (*L. angustifolia*), which has historically been used to deal cramps, muscle spasms, burns, insect stings, and parasite infections (Denner, 2009)**.**

Regarding the chemical structure of lavender by-products (both etheric extracts of remanent water (RW) and solid waste residues (SWR) of Moldova origin, (Ciocarlan et al., 2021), data show that the isomeric oleanolic acid (OA) and ursolic acid (UA) in SWR ranged between 113.47-144.98 and 313.95-499.15 mg/100 g, respectively, with their amount accounting for about 1% of dry weight (DW).

Data consistent with other literature data reporting of lavender SWR values between 136.0–259.7 and 346.3–648.4 mg/100 g (Ivanov et al., 2018; Ciocarlan et al., 2021). Sources of structurally isomeric pentacyclic triterpenoids UA and OA include many medicinal or fragrant plant parts, in addition to pulp and peel of many fresh fruits. Additionally, over the past few years, UA/OA-enriched extracts, purified substances, and their synthetic derivatives have drawn more attention because of their potential to have anti-inflammatory and anticancer properties even neurodegenerative diseases (e.g., Alzheimer's or Parkinson's disease) and other brain illness such as ischemic stroke (Gudoityte et al., 2021).

A-terpineol (10.64%), 1,8-cineol (eucalyptol, 6.31%), linalool oxide (3.08%), linalool (78.05%), terpin-1-en-4-ol (1.92%), and linalool were all found in the etheric extracts of remanent water (RW) after GC-MS analysis (Ciocarlan et al., 2021). It should be noted that *L. angustifolia* by-products which resulted after hydrodistillation (solid residue—SWR (n = 3) and residual water—RW (n = 1)), were collected from the factories, dried, and bottled before being analysed, as mentioned by the authors.

Serial dilution techniques were used to test the effectiveness of lavender by-products (residual water (RW) and solid waste residue (SWR)) against a variety of non-pathogenic bacterial strains and fungus species, including phytopathogenic ones (e.g., *Xanthomonas campestris*, *Erwinia amylovora*, and *Erwinia carotovora*). According to the report's results, extracts from solid waste residues and residual distillation waste water have demonstrated strong antibacterial activity against 11 species of bacteria and fungus, including phytopathogenic one (Ciocarlan et al., 2021).

By-products resulting after steam distillation of essential oils extract from rosemary, sage and thyme, were investigated as a origin of antioxidants in marinades for turkey thigh meat (Mielnik et al., 2008). Lipid oxidation it is known as a big problem occurring during processing and storage of meat. Regarding free radical scavenging activity, 2,2-diphenylpicrylhydrazyl (DPPH) assay, sage displayed a much lower level of antioxidant activity (9.2 mg DPPH/ml marinade) compared to rosemary (85.7 mg DPPH/ml marinade), which had the maximum antioxidant activity measured by DPPH, while for thyme by-product recorded a value of (31.6 mg DPPH/ml marinade). Moreover, the concentration of antioxidant active components determines the lipid stability of meat products during a storage period, because the meat from the rosemary cooking liquid seemed to have the smallest TBARS tiers (mg malondialdehyd/kg meat, which exprim the oxidation rate), throughout the storage period, oxidation increased continuously in meat marinated with thyme and sage and was considerably higher than in meat marinated with rosemary.

Compared to control samples, turkey thighs marinated in a decoction of rosemary, sage, or thyme scored considerably higher for acidic flavour and odour. Additionally, turkey meat that had been marinated in a rosemary decoction received the greatest ratings for juiciness and the lowest ratings for turkey flavour (Mielnik et al., 2008).

Salvia officinalis L. herbal dust, discarded as by-product by filter tea factory was also investigated by (Pavlić et al., 2016), in terms of raw materials for extraction of polyphenol antioxidants with potentially utilized for its industrial production. In this sense subcritical water extraction of polyphenols from sage was optimized by simultaneous maximization of total phenols (TP) and total flavonoids (TF) yields, as well as maximized antioxidant activity, determined by DPPH, 2,2′-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) both radical scavenging tests and reducing power assay. Additionally, compared to the conventional extraction technique, the SWE method produced significantly more polyphenols in a noticeably shorter amount of time. This means that sage herbal dust, by-product, actually makes excellent raw material for extracting polyphenol antioxidants and may someday be used to manufacture them (Pavlić et al., 2016).

Emerging extraction techniques in the recovery of bioactives from herbs by-product

Novel extraction technologies, as well as pulsed electric field (PEF), ultrasound and their combination, as potential methods for the extraction of phenolic structure from fresh rosemary and thyme by-products was explore recently by (Tzima et al., 2021) by the reason that herb processors are unlikely to undertake a drying phase before their use because of the large energy inputs and cost involved. In the majority of cases, PEF pre-treatment considerably (p<0.05) enhanced the DPPH amounts of rosemary and thyme as well as thyme's total phenolic content (TPC). The PEF treated samples had greater antioxidant and phenolic indices than the ultrasound (US) treated separately, according to this finding.

Microwave-assisted versus ultrasound extraction was explored by (Zeković et al., 2017) use of sage by-products (*Salvia officinalis* L.) as raw material by filter tea factory (sage herbal dust) for phenolic antioxidants recovery. By simultaneously maximizing the yields of total phenols and flavonoids and the extraction of polyphenols from sage herbal dust using ultrasound-assisted (UAE) optimized at (40, 60 and 80°C), extraction time (40, 60 and 80 min), ultrasonic power (24, 42 and 60 W/L) and microwave-assisted (MAE), optimized parameters, ethanol concentration (40,60 and 80%), extraction time (10, 20 and 30 min) and liquid to solid ratio (20, 30 and 40 mL/g). The evidence shows that radical scavenging capacity of sage herbal powder extracts towards DPPH radicals, expressed as IC50 value, was between 9.02 and 21.44 μg/mL for sage extracts collected by UAE and from 10.40 to 17.24 μg /mL for extracts obtained by MAE. Those novel extraction techniques (UAE and MAE) provided significant advantages for recovery of sage polyphenols comparing to traditional methods.

The study of (Vladić et al., 2016) demonstrate that some wastes from the food sector, such as herbal dust from *Achillea millefolium*, can be used to create value-added like powder extracts. The study's goal was to use solid-liquid extraction followed by spray drying to valorise *Achillea millefolium* by-products from the food industry. According to the efficiency criteria, the drying process was deemed effective.

Conclusions

The addition of by-product extracts may affect the sensory qualities of the finished food product positively or negatively depending on the dosage, the kind of recovered by-product chemicals, and the food matrix in which it is included, although it generally has an antioxidant-proven influence.

According to evidences, decoctions, which are by-products from the distillation of essential oils, can be used as a source of antioxidants for marinades, especially rosemary. Furthermore, instead of being discarded from the filtertea factory as a by-product with a negative environmental impact, sage herbal dust could be considered as an interesting raw material for polyphenols extraction with a production isolate rich in antioxidants.

Supercritical fluid extraction was applied as environmental method to obtain extracts from thyme by-product with high contents of terpenoids, strong in vitro antioxidant activity and potential for utilization as novel “green” food additives.

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