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Erasmus+

INNOVATIVE INTEGRATED TRAINING IN
HEALING PLANTS
BUSINESS

IO3 - The Total Business Plants Training Material

Module No.2

“Methods for harvest treatment”

1. Unit 4. Post-harvest treatment of healing/medicinal plants

- **Summary**

Unit 4 discusses the different aspects of post-harvest treatment. It includes simple tasks, such as avoiding moisture loss and cooling, and more sophisticated procedures, such as distillation and extractions, according to the needs of the final product. Unit 4 also explains the principals of the method of numerous post-harvest procedures and gives examples on how different procedures can affect the final product.

- **Learning outcome descriptors**

- **Knowledge, understanding and professional skills**

1. Discuss different procedures of post-harvest treatment
2. Explain the principles of different post-harvest methods
3. Outline the impact of different post-harvest procedures to the final product

- **General and transferable skills:**

1. Plan a research task
2. Work independently or with a minimal guidance where appropriate
3. Work in team with minimal guidance where appropriate
4. Show good written and oral communication skills
5. Demonstrate computer literacy
6. Perform online (computer) search to develop information technology skills in order to retrieve information from a variety of sources

4. Post-harvest treatment of healing/medicinal plants

The most crucial goals of post-harvest managing are retaining the product cool, avoiding moisture loss and gradual down unwanted chemical adjustments and averting physical damage like bruises, in order to delay spoilage. Sanitation is likewise a vital aspect, to lessen the possibility of pathogens that would be carried by using fresh product, such as residue from contaminated washing water.

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After the field, post-harvest processing is commonly endured in a storage house. This may be a simple shed, providing shade and running water, or a big-scale, sophisticated, mechanized facility, with conveyor belts, automated sorting and packing stations, walk-in coolers and other equipment similar to those. In mechanized harvesting, processing can also begin as part of the actual harvest procedure, with initial cleaning and sorting carried out through the harvesting machinery.

Primary post-harvest storage conditions are of high significance in order to retaining quality. Each crop has an ideal range of temperature and humidity, so when stored these rates should be taken into consideration. Additionally, certain plants can't be successfully saved together, as undesirable chemical interactions can result. Diverse techniques of high-speed cooling, and complicated refrigerated and atmosphere-controlled environments, are employed to extend freshness, mainly in huge-scale operations.

Irrespective of the dimensions of harvest, from domestic garden to industrialized farm, the simple principles of post-harvest handling for most crops are identical: treat them with care to keep them away from harm (for example bruising, cutting, crushing), cool them immediately and preserve the conditions cool, remove damaged items.

There are many aromatic, culinary and medicinal plants. Most secondary products in these plants can be altered by means of environmental elements as well as post-harvest managing practices, yet little is known about the stability of these plants and their active substances when they are exposed to either pre- or post-harvest environmental changes. Accelerated use of fresh and dried herbs, aromatic and medicinal plants have increased the call for high quality. Pre-harvest factors, together with cultural system, fertilization, and light exposure impact the yield and high-quality of these plants, however these plants, specifically whilst treated fresh, are very vulnerable to extended post-harvest senescence due to a high rate of metabolism, and viable microbiological issues. The successful marketing of high quality, particularly of fresh materials, requires extreme care and attention to post-harvest management. Some of the quality indicators that may be effortlessly deteriorated after harvest include active components, color, aroma, water loss, plus viable microbiological issues which could cause safety problems. Fresh green herbs (Labiatae family) are vulnerable to accelerated senescence due to an excessive price of metabolism which is increased further following harvesting and handling tactics.

Postharvest managing is very crucial to the improvement of material suitable for processing. All of the post-harvest ideas that practice to leafy green tissues practice to the managing of fresh herbs and a few other fresh aromatic and medicinal plants. Nevertheless, the post-harvest managing of those products is very challenging due to their outstanding variety, various components, and diverse utilization. As an instance, improving the quality of Australian echinacea via higher post-harvest handling practices was found to be complicated by the finding that the alkylamides and cichoric acid on occasion respond differently to the various handling operations used.

Drying

Freshly harvested medicinal plants occupy massive volumes and pose issue in transportation and storage. For handling and storage purposes, reducing the water content of freshly harvested medicinal plant is vital. By reducing the water content, the material turns into less difficult to handle and less

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vulnerable to microbial infection. The water content is typically eliminated via thermal drying. The existing methods for drying medicinal plants can be grouped into two categories, natural and mechanical drying, based on the heat source or energy utilization. In both processes, water present in the interior of the medicinal plant must move to the surface by internal diffusion. A big plant surface area combined with air motion favors brief evaporation of water from the plant's surface. The rate at which water is evaporated from the surface of the plant has to be balanced with the rate at which water is eliminated from the interior. Unbalanced evaporation rates can result in deterioration of the very last product. The reasons for drying grain crops also apply to medicinal plant drying: the intention is to control the moisture content of the medicinal plant crop to an appropriate level, which permits quality delivery of the herb to the place of final use, and probable make sure long-time storage with little deterioration.

Figure1. *Solar drying of oregano (Carlos Bertello, GIZ EnDev Peru)*

But, natural or mechanical drying may be catastrophic to medicinal plants if not properly performed, as extensive high-temperature drying can cause both physical and chemical changes. In natural drying (Figure 1), exposure to the sun and/or the desiccating impact of air currents promotes the removal of water from the material. That natural air-drying can be easily controlled and rarely damages the material. Natural drying is a common method of medicinal plant drying, constituting the method of choice in areas where maturity and harvesting of the plants concur with the beginning of the dry season, and their phytochemicals are not photosensitive. Cinnamon (*Cinnamonum cassia*) bark is commonly sun-dried after harvesting in July and August, since that is the period when the quality of the bark is high. However, it was reported that the reliance on favorable weather conditions limits the use of natural drying. Solar dryers can counteract in some level the dependence from weather. It was reported that the use of plastic house-type solar dryers, in drying of spices and medicinal plants, was quite successful. Plastic house-type solar dryers (Figure 2) were reported to be more economical and efficient than conventional drying systems, provided that supplementary heating was used. Wisniewski (1997) reported that, in Poland, about 60 commercially cultivated medicinal plants crops were dried in flat-type solar dryers.

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Figure 2. *Plastic house-type solar dryer (Carlos Bertello, GIZ EnDev Peru)*

Mechanical drying includes freeze drying, artificial drying, microwave drying, far infrared drying, vacuum drying and spray drying. Lyophilization or sublimation (freeze drying), consists of removing water by ice sublimation without passing through the liquid state. The principle of the method includes that the ice is converted into water vapor, under high vacuum, and removed. That leads the material in a dry state. The above method is ideal for preservation, but it is mostly used to dry high-value products because it is very expensive. Artificial drying uses fuels such as charcoal, natural gases, firewood or electricity to heat incoming air. Both labor and drying time of medicinal plants are minimized, when artificial dryers are in use. Artificial drying systems include, among others, plate chamber and conveyor dryers. In plate chamber dryers, warm air blows across plates on which plants are placed and usually has a low handling capacity, but is particularly useful for drying flowers and leaves. Plate chamber-style dryers usually count on manual labor. In conveyor dryers, fresh plants are transferred on a conveyor belt through a countercurrent flow of warm air. Drying times are between 2.5-6 h and drying temperature ranges of 40–80°C. Conveyer dryers may have high output with not too much labor input, but they need high capital and energy amounts. Medicinal plants have to be dried for preservation purposes. However it is necessary for drying protocols to be designed in such a way that they do not cause a decrease in phytochemical concentrations.

Extraction of essential oils

The extraction of essential oils from plant material can be managed by various methods and these are shown in the generalized flow diagram (Figure 3). There are five main methods of extraction:

- Expression
- Hydro or water distillation.
- Water and steam distillation
- Steam distillation
- Solvent extraction

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For every technique there can be many versions and refinements and the extraction can be conducted under reduced pressure (vacuum), ambient pressure or excess pressure. The selection of extraction technique will be based on the nature of the material, the stability of the chemical components and the specification of the targeted product.

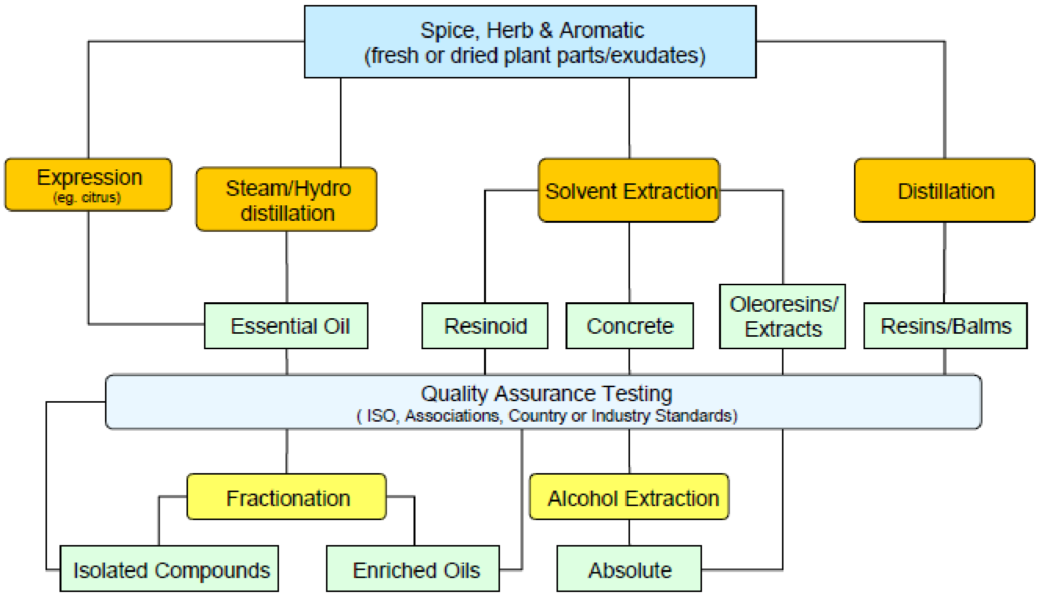

Figure 3. *Extraction processes used and products from spice, herb and aromatic plants*

Flowers are generally solvent-extracted and not steam distilled excluding rose, ylang ylang and orange blossom. In some cases an isolate or essential oil fraction is preferred to the total oil. Some well-known examples of fractionated essential oils with higher quality than the whole oil, are the terpeneless oils and folded citrus oils. Other processing steps can be implemented to lessen instability of certain oils (for example lemon oil which is known to be unstable in soft drinks due to the level of citral). The production of some special oils, oleoresins, absolutes and concretes requires much greater technologically-advanced facilities, labor abilities and safety systems. These processing facilities are commonly past the ability of the small individual producer. The excessive capital cost and the highly-skilled labor requirements of a supercritical carbon dioxide extraction plant additionally limits the widespread application of this extraction process besides for massive flavor, fragrance or pharmaceutical manufacturers. Expression is used solely for the extraction of citrus oil from the fruit peel, due to the fact that the chemical components of the oil are easily damaged by the heat. Citrus oil manufacturing is now a major process of the juice enterprise.

Distillation remains the most low-priced technique of extracting essential oil from spices and aromatic plant material. The principle gain of distillation is that it could commonly be carried out with some quite simple equipment, close to the location of plant production. Distillation requires less intensive labor and less labor skill requirements than solvent extraction. However, using the simplest and lowest-cost extraction technique may be a false financial planning due to low yield, poor or highly variable oil quality and low market value. Water distillation is the simplest of the three distillation techniques. The plant

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material is mixed without delay with water in a still pot. The existence of a perforated grid, above the base of the still pot, is desirable in order to prevent the plant material settling on the bottom and coming in direct contact with the heated base of the still. (Figure 4). Water distillation is probably the most effective and cheapest technique of extracting essential oils, but the quality of the oil has the best capacity to be modified due to the consequences of direct heating and the water contact.

• The plant material will be over-heated and charred, if the water present in the still isn't more than enough to last the duration of the distillation..

• It is very easy for still 'off-notes' to be generated, since some substances of the oil are more sensitive to chemical change and oxygenated components tend to dissolve in the still water that prevents the complete extraction of the oil.

• The plant material will settle in the bottom of the still and the heat will damage it, if it is not kept agitated as the water boils. In order to keep the material scattered in the water, it would be useful to chop it or grind it into fine particles.

• Some plant materials, like cinnamon bark, have high levels of mucilages. When these are leached out the viscosity of the water increases and there is a high risk of charring

• The stills are relatively small and as a result many circles of extraction will be needed in order to produce enough oil amounts. This will increase the possibility of mixing high quality oil with low quality, since each circle may give oil of different quality.

• Water distillation needs more energy, since it is a slower extraction procedure than the other two distillation types

• The main advantage of water distillation is that the cost of the equipment tends to be rather low and the designs of the stills, condensers and oil separator are simple.

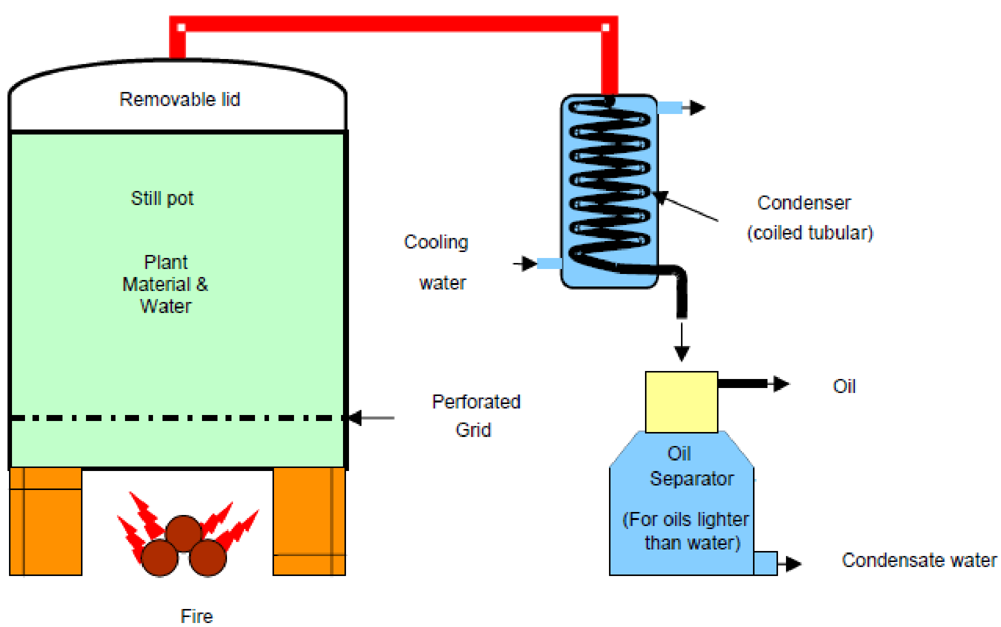

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Figure 4. *Diagrammatic representation of water distillation unit where the plant material is suspended in the water*

The water-distilled oils are generally darker in color and have stronger still 'off-note' odors than oils produced via the other techniques, and consequently tend to be of the lowest value. The negative aspects of the water distillation technique might typically outweigh the advantages besides for local market use.

In steam-and-water distillation the basic still layout is quite alike to that of water distillation (Figure 5). The plant material is placed into the still pot that is put on a grill or perforated plate above the boiling water. The capacity of the still pot volume is decreased however it may be possible to achieve high packing density because the plant material is not suspended in water. The benefits of steam and water distillation over water distillation are as follows:

• Higher oil yield.

• Oil component less sensitive to change due to wetness and thermal conductivity of the still from the heat source.

• The effect of refluxing is minimized.

• Reproducible oil quality.

• Faster process

• Energy efficient

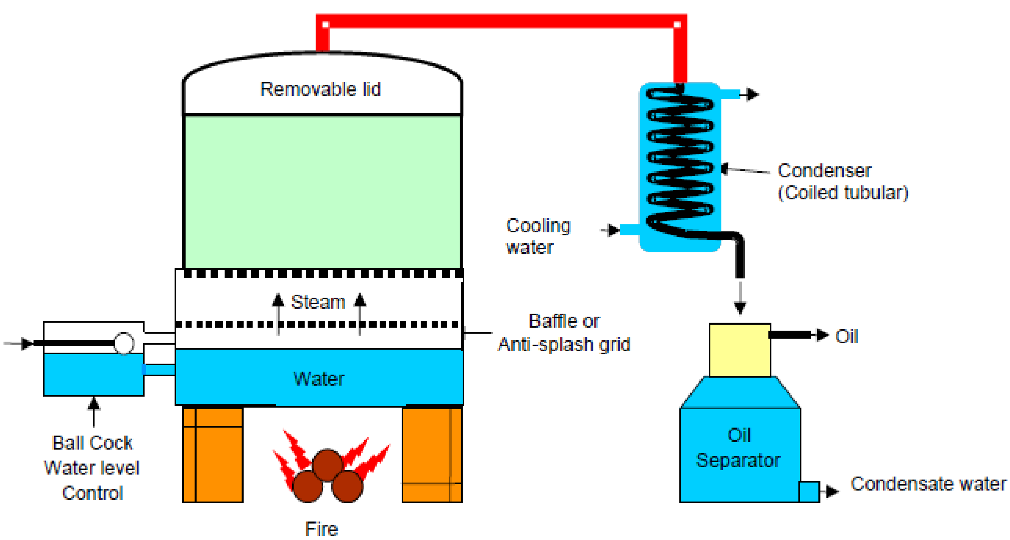

Figure 5. *Diagrammatic representation of a steam and water distillation unit with a baffle, to prevent direct water contact with plant material on the perforated grid.*

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The process of distilling plant material with the steam produced outside the still in a stand-alone boiler is called steam distillation (Figure 6). The plant material is supported on a perforated grid above the steam inlet just like in the steam-and-water distillation process. The benefits and disadvantages of steam distillation are as follows:

• The quantity of steam and the quality of the steam can be controlled.

• Less risk of thermal damage as temperature generally not above 100°C.

• Most common process for the extraction of essential oils on a large scale.

• It is the preferable extraction method for the fragrance and flavor supply industry.

• There is a much higher capital requirement and with low-priced oils the payback duration can be over 10 years.

• Demands higher level of technical skill and fabrication

• Higher level of skill, regarding repaining and maintenance

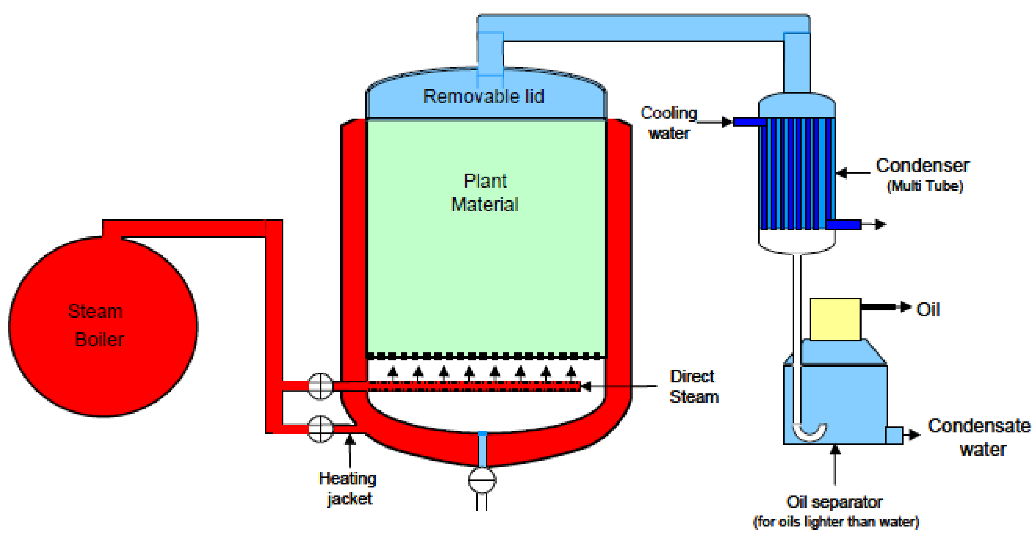

Figure 6. *Diagrammatic representation of steam distillation unit.*

When designing a distillation system, a number of issues must be taken inconsideration:

Site

• Availability of adequate water

• Energy source: electricity, boiler fuel

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• Easy transport access

• Skilled and unskilled labor

• Close proximity to plant material

• Access to fabricators and machine shop for repairs

• Environmental zoning and waste management

Distillation Charge

(how much material can be processed in one circle)

• Still size

• Plant species and oil content

• Oil content

• Daily volume and condition of plant material

• Frequency of material supply

• Preprocess (chopping, crushing, powdering, maceration)

• Time consumed to charge and discharge the still

• Storage capability of plant material before distilling under poor weather conditions

• After distillation waste disposal

Still

• Design based on distillation method; seek professional advice

• Preferably constructed of stainless steel

• Size based on boiler capacity

• Distillation time affected by height of the charge, flow rate and pressure of steam

• Easy to charge and discharge

Boiler

• Must produce sufficient steam to adequately remove the oil from the plant material

• Low pressure (saturated steam) or pressurized (dry steam)

• Seek professional advice on design and access for repairs and maintenance

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Condenser

• The role of the condenser is to change the oil and water vapor back to a liquid

• Two main types: coiled tube or multitube

• Multitube hard to make, requires running water, has good heat transfer, effective water use and doesn't build up pressure

• Coiled tube easy to make, just needs a tank of water and sparse use of running water, but has poor heat transfer, risk of high pressure builds up during distillation and poor use of water

Oil Separator

• Design of separator depends on density of the oil

• Large enough capacity to allow the oil particles to form droplets and readily separate from the water

• Controlling temperature can be used for more efficient separation

• Seek professional advice on design as poor separation affects all the effort of distillation to extract oil

Storage

• System to filter separated oil

• Storage in appropriate containers that shut out light

• Method to remove dissolved water

• Removal of residual still notes and dissolved oxygen

When possible the still vessel condenser and separator must be manufactured from stainless steel. In developing countries access to expert manufacturers, equipment and skills for preservation and repair, must be of prior consideration in the design of the distillation system. The majority of essential oils float on water i.e. their precise gravity is less than 1, but there are some of the wood and root oils which are heavier than water. Separation of oils whose density is near that of water or where the oil includes one major component, whose density is greater than 1, while the other components have density less than 1, is much more difficult. The layout and operation of the separator have to be specific to the oil being extracted. In addition to steam distillation, particular crops, in particular the expensive spices, are now additionally extracted by using solvents and carbon dioxide as this provides standardized extracts of high quality and without contaminants. Super critical fluid or gaseous extraction techniques are getting more common because of the problem of solvent residues in food.

Extraction

Extraction is a basic function for botanical preparations and refers to the mass diffusion of soluble target substances from an insoluble plant solid into its environment. Briefly, the following steps can describe extraction: transferring the solvent to particles, desorbing compounds from the plant matrices;

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dissolving the solvents in the solvent and transferring the solutes to the main liquid. Because solutes or phytochemicals are of a different nature, selection of the appropriate solvent and extraction technique is critical for botanical preparations. A variety of techniques are available, such as liquid-solid, supercritical fluid, pressurized fluid and pressurized hot water extraction.

Solid-liquid extraction (SLE)

In industry, conventional methods for solid–liquid extraction (SLE) in industry consist of infusion, decoction, maceration and percolation, which are all commonly performed under atmospheric pressure with organic solvents. In the USA, phytochemicals are extracted with generally regarded as safe (GRAS) solvents, like water, acetone, methanol, methylene glycol, ethyl acetate, ethylene dichloride, isopropyl alcohol, methylene chloride and hexane. Due to their differences in polarity, different solvents show different selectivities toward the target compounds. The choice of the appropriate solvent depends on the solubility and polarity of the target compound in the liquid-solid extraction. If this technique is chosen, all necessary efforts should be made to remove residual organic solvents from the extracts. Extraction of hyperforin from the balm with 50 and 100% ethanol yielded 21 and 64%, respectively, of the total recoverable amount. Hyperforin extraction was not possible when only water was used as a solvent.

Increasing the temperature from 40 to 60°C did not improve the extraction yields. Although no yields are given, flavonol glycosides and terpene trilactones are allegedly extracted from dried Ginkgo biloba leaves with a mixture of acetone and water, before being concentrated, dried and reconstituted with ethanol. The iridoid glycosides, catalpol and aucubin, were extracted from Veronica longifolia leaves with methanol, ethanol, 2-propanol and ether. Catalpol yields of 0.8 ± 0.1, 0.4 ± 0.1, 0.2 ± 0.0 and 0 ± 0.0 mg/g dry weight and aucubin yields of 0.6 ± 0.1, 0.3 ± 0.1, 0.2 ± 0.0 and 0 ± 0.0 mg/g dry weight were obtained with methanol, ethanol, 2-propanol and ether extractions, respectively. The use of ethanol, methanol, acetonitrile and acetone for extracting silybinin A from milk thistle seeds returned 4.0 ± 0.1, 1.5 ± 0.1, 1.5 ± 0.1 and 2.0 ± 0.1 mg/g dry weight, respectively. Gafner and his colleagues reported total saponins recovery from P. quinquefolius roots of 61.7 ± 0.1, 59.4 ± 0.5 and 51.5 ± 0.2 mg/g dry weight for extraction with 50% ethanol, ethanol–glycerin–water (20:40:40) and 65% glycerin solvent systems, respectively. Iridoid glycoside, flavanolignan and saponin recoveries illustrate the importance of solvent selection in SLE processing.

Supercritical fluid extraction (SFE)

Supercritical fluid extraction (SFE) is primarily based on the solvating power of fluids, which is maintained above their critical point. Supercritical fluids have mass transfer capabilities like gas and solvating strength like liquids. Their very low surface tensions make easy penetration into microporous substances, such as herb matrices. In SFE, density is associated with solvating power. Increases in solvating power can be acquired by manipulating two parameters: temperature and pressure. But, the alternations of these parameters do not always have the result of increased yields. In the phytochemical extraction industry, carbon dioxide is usually the SFE solvent of choice due to low toxicity, chemical

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inactivity and ease of recovery by venting gaseous CO_2. Nevertheless, two disadvantages ought to be stated: the essential equipment is costly and the technique is not suitable for the extraction of all phytochemicals. Then again, for certain phytochemicals, SFE-CO_2 has determined tremendous use. Total v-3 fatty acids extracted from brown seaweed (Sargassum hemiphyllum) by SFECO2 at 37.9 MPa and 50°C were 16.2 ± 1.3 mg/g dry weight, compared to 13.1 ± 1.3 mg/g dry weight when extracted by Soxhlet with a chloroform–methanol mixture. Similar total vitamin E recoveries of about 22 mg/g dry weight were obtained either with SFE-CO_2 at 27.6 MPa and 40°C, or with SLE with a chloroform–methanol mixture. SFE-CO_2 processes can also include the use of modifiers, where ethanol can be added to CO2 to increase its polarity. In a G. biloba phytochemical preparation, the combination of primary extraction with 70% ethanol, followed by SFE-CO_2 with 5% ethanol modifier at 300 MPa and 60°C, returned 2.1% of the terpenoids and flavonoids, while SLE with chloroform and acetone resulted in a 1.8% yield. However, for certain classes of compounds, the addition of modifier does not increase recovery. For example, hypericin and flavonoids could not be extracted using SFE-CO_2 with modifier from St John'sWort biomass. It has also been reported that SFE-CO_2 with ethanol mixtures could not solvate chichoric or polyphenolics from E. purpurea biomass. Furthermore, the addition of a modifier presents severe drawbacks. The presence of a modifier can result in a higher critical temperature, which may lead to thermal degradation. For example, to remain in the supercritical region of the phase diagram, CO_2 mixed with 10% methanol should be maintained at 7.446 MPa and 60°C. However, when increasing the methanol concentration by 5%, the SFE-CO_2 operating parameters need to be increased to 7.476 MPa and 73.48°C. The increase in temperature may favor the degradation of certain phytochemicals. Moreover, the modifier may condense upon depressurization and leave organic residue, undermining the gain of SFE-CO_2 extraction as an environmentally friendly extraction method.

Pressurized liquid extraction (PLE)

Pressurized liquid extraction (PLE), also known as accelerated solvent extraction, grew relatively recently and uses organic solvents at pressures of about 14MPa, and extraction temperatures above the solvent boiling point. By pressurizing and operating at or above boiling point solvent temperatures, PLE has the benefit of short extraction times, low solvent consumption and high extraction yields. The improved performance when using PLE happens because of the following reasons: the solubility of solutes increases with increasing solvent temperature ; high solvent temperatures lead to greater diffusion and better solute-solvent interactions. The extraction of hypericin from St John's Wort using PLE at 14 MPa, 60°C and methanol produced 3.5 mg/g dry weight, compared to 2.8 mg/g dry weight by Soxhlet extraction.

References

1. UNIDO and FAO (2005). Herb, spices and essential oils. Post-harvest operations in developing countries.

2. Hakibu Tanko, Danielle Julie Carrier, Lijun Duan and Ed Clausen (2005). Pre- and post-harvest processing of medicinal plants. Plant Genetic Resources, Volume 3, Issue 2, 304-313.

3. Janet Bachmann and Richard Earles (August 2000). Postharvest Handling of Fruits and Vegetables. NCAT. Archived from the original on 2002-02-11.

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This publication reflects the views only of the author and the Commission cannot be held responsible for any use which may be made of the information contained therein

Co-funded by the Erasmus+ Programme of the European Union

4. Elhadi M. Yahia (2006). Postharvest handling of aromatic and medicinal plants.

5. Cai T, Chen F and Qi J (2004) Dehydrated oriental mushrooms, leafy vegetables, and food preparation herbs and condiments. In: Handbook of Vegetable Preservation and Processing, pp. 373–393.

6. Downs S and Compton E (1955) Crop drying with heated air. Agricultural Engineering 36: 90–92.

7. Muller J, Conrad T, Tesic M and Sabo J (1993) Drying of medicinal plants in a plastic-house types solar dryer. Acta Horticulturae 344: 79–85.

8. Wisniewski G (1997) Drying of medicinal plants with solar energy utilization. Drying Technology 15: 6–8.

9. De Silva, K.T. (1995). A manual on the essential oil industry. Vienna: UNIDO. 232

10. Schwartzberg H (1975) Mathmatical analysis of solubilization kinetics and diffusion in foods. Journal of Food Science 40: 211–213.

11. Sanders N (1993) Food legislation and the scope for increased use of near-critical fluid extraction operations in the food, flavoring and pharmaceutical industries. In: King MB and Bott TR (eds) Extraction of Natural Products Using Near-critical Solvents. New York: Chapman & Hall pp. 37–38.

12. Ollanketo M, Peltoketo A and Hartonen K (2002) Extraction of sage (Salvia officinalis L.) by pressurized hot water and conventional methods: antioxidant activity of the extracts. European Food Research Technology 215: 158–163.

13. Meier B (2003) Herbal medicinal products of St John's Wort manufacturing and quality control. Medicinal and Aromatic Plants—Industrial Profiles 31: 106–136.

14. O'Reilly J (2000) Ginkgo biloba—large scale extraction and processing. Medicinal and Aromatic Plants—Industrial Profiles 12: 99–108.

15. Suomi J, Siren H, Hartonen K and Riekkola M (2000) Extraction of iridoid glycosides and their determination by micellar electrokinetic capillary chromatography. Journal of Chromatography A 868: 73–83.

16. Wallace S, Carrier DJ and Clausen E (2004). Batch solvent extraction of flavanolignans from milk thistle (Silybum marianum). Phytochemical Analysis 16:7-16.

17. Gafner S, Bergeron C, McColom M, Cooper L, McPhail K, Gerwick Wand Angerhofer C (2004) Evaluation of the efficiency of three different solvent systems to extract triterpene saponins from roots of Panax quinquefolius using HPLC. Journal of Agricultural and Food Chemistry 52: 1546–1550.

18. Taylor LT (1996) Supercritical Fluid Extraction. New York: Wiley.van Beek T and Lelyfeld G (1992) Concentration of ginkgolides and bilobalide in Ginkgo biloba leaves in relation to the time of year. Planta Medica 58: 413–416.

19. Cheung C, Leung A and Ang P (1998) Comparison of supercritical carbon dioxide and Soxhlet extraction of lipids from brown seaweed Sargassum hemiphyllum. Journal of Agricultural and Food Chemistry 46: 4228–4232.

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20. Ge Y, Yan H, Hui B, Ni Y, Wang S and Cai T (2002) Extraction of natural vitamin E from wheat germ by supercritical carbon dioxide. Journal of Agricultural and Food Chemistry 50: 685–689.

21. Yang C, Xu Y and Yao W (2002) Extraction of pharmaceutical components from Ginkgo biloba leaves using supercritical carbon dioxide. Journal of Agricultural and Food Chemistry 50: 846–849.

22. Catchpole O, Perry N, da Silva B, Grey J and Smallfield B (2002) Supercritical extraction of herbs I: Saw Palmetto, St John's Wort, Kava root and Echinacea. Journal of Supercritical Fluids 22: 129–138.

23. Mannila M, Kim H, Isaacson C and Wai C (2002) Optimization of supercritical fluid extraction for the separation of hyperforin aand adhyperforin in St. John's Wort (Hypericum perforatum L.). Green Chemistry 4: 331–336.

24. de Lourdes M, Moraes L, Viegas J and Lancas F (1997) Supercritical fluid extraction of glycosylated flavonoids from passiflora leaves. Phytochemical Analysis 8: 257–260.

25. Richter B, Jones B, Ezzell J and Porter N (1996) Accelerated solvent extraction: a technique for sample preparation. Analytical Chemistry 68: 1033–1039.

26. Benthin B, Danz H and Hamnurger M (1999) Pressurized liquid extraction of medicinal plants. Journal of Chromatography A 837: 211–219.

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