

PATENTED AND COMMERCIALIZED APPLICATIONS

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15.1 SCALE-UP AND COMMERCIALIZATION PROBLEMS

The industrialization of processes dealing with the recovery of compounds from food wastes includes numerous issues such as laboratory research, transfer to pilot plan and full-scale production, protection of intellectual properties, and development of definite applications. These parameters are necessary in order to ensure the sustainability of the process, the economic benefit for the involved food industry, and the perpetual establishment of the derived products in the market. In addition, a working scenario focused absolutely on the extraction technologies and not on the investigation of tailor-made applications is doomed to fail (Galanakis, 2012, 2013).

A scale-up process should be conducted without diminishing the functional properties (e.g. antioxidant, viscoelastic, etc.) of the target compounds and at the same time a product should be developed that meets consumers' high quality organoleptic standards. This is difficult since compounds recovery development challenges the typical scale-up problems as well as other more complicated procedures related to the particular nature of the recapture procedure (Galanakis and Schieber, 2014).

For instance, scale-up of recovery processes meets the same limitations (e.g. mixing and heating time) as any food manufacture procedure. Transition of batch to continuous processes is usually accompanied with extension of mixing and heating time, heavier handling, increased air incorporation, and higher degree of scrutiny (Galanakis, 2012). All of these parameters generate numerous interactions and loss of product functionality. Subsequently, process cost is increased, as industrially recovered compounds are used in food formulations in higher concentrations compared with laboratory-recovered compounds.

On the other hand, a more specific problem could be waste collection at the source that often requires additional transportation cost and control of microbial growth. Proper management of the collection process, cooling/freezing of the material, and/or addition of chemical preservatives can provide solutions in a particular case. Another complicated problem is the broad variation of target and nontarget compounds from source to source. This fact affects the mass and energy balances as well as the functionality and the organoleptic character of the final products, especially of more crude extracts. The above problem may be monitored by adding a modification pretreatment step. The latter usually includes a selective mixing of by-product streams at the beginning of the process, taking into account basic parameters (e.g. total antioxidants concentration),

or a vacuum concentration of wastewater streams taking into account macroscopic characteristics such as water and solids content.

15.2 PROTECTION OF INTELLECTUAL PROPERTIES

Intellectual property is an important asset of any organization (start-up, spin-off, etc.) involved in the field of valuable compounds recovery from food wastes. Moreover in recent years, recovery of high added-value compounds from food waste streams of special interest often involves development of new methods, industrial processes, and new applications of recovered compounds in food products, for example as food additives, e.g. natural pigments such as recovered lycopene instead of carmine (red), or as food supplements, i.e. antioxidants such as hydroxytyrosol, etc. This new knowledge is a valued asset for the researchers and related organizations and it should be protected and exploited following appropriate scientific and commercial strategies. Intellectual property law is often complex and it is important to know the basic rules regarding the best way to protect intellectual property assets. Nowadays, it is equally important for start-up companies, research organizations, and individual researchers to protect their intellectual property and therefore to be informed as to procedures, filing rules, costs, expected revenues, etc.

Intellectual property has a commercial value since it allows early protection of competitive advantages, applications as a marketing edge, increase of business value, and implementation as a potential revenue stream through licensing or investment attraction. Companies need to take precautionary steps to protect intellectual property by filing patent applications where appropriate, registering trademarks and copyrights as well as taking appropriate steps to protect trade secrets. Protecting intellectual property early during business formation provides safety to investors, builds credibility, and creates a solid foundation that can be capitalized on later. Indeed, it is imperative to be aware of others' intellectual property rights in order to ensure that nobody could prevent or restrict operation of the specific business (e.g. start-up companies). Intellectual property is often created during the earliest stages of company life. In the case of start-up companies, there is a need to develop a specific and robust intellectual property strategy in order to maximize the value of these important assets.

Different types of intellectual property rights exist, meeting the different needs for protection, products, costs, period, etc. Registered intellectual property includes:

1. patents,
2. utility models,
3. designs, and
4. trademarks.

Copyright is intellectual property that is protected without registration (e.g. literature, paintings, films, other forms of artistic or scientific works) and is in force for 70 years after the death of the writer or the originator. Patents and utility models are the most common forms of protection for industrial property, namely inventions of products or processes. A patent is an exclusive right to exploit commercially the invention in the country where the patent is granted. Protection is valid for up to 20 years. A patent forbids others to produce, sell, work, use, import, and possess the invention. However, it does not extend to acts performed for noncommercial purposes, experimental purposes, or other concerning products, which are commercially worked by (or with the consent of) the patentee and individual production of a medicinal product. A patentable invention can be (i) a product, (ii) the apparatus for

producing the product, (iii) the process for producing the product, or (iv) the use of the product. A patentable invention must fulfill the following criteria:

1. it must have industrial application,
2. it should be new (e.g. above the state of the art), and
3. it must differ essentially from what is already known (e.g. involve an inventive step).

The invention must have at least one practical purpose, and must be reproducible.

When a new product or process is invented, or when a need must be fulfilled by inventing the appropriate solution, the inventor must adhere to defining a patent/intellectual property rights strategy (at an early stage, prior to filing of a patent or taking any important decisions).

Some integral steps of an intellectual property rights strategy are:

1. to think of the idea as a financial asset,
2. to implement policies and processes for identifying, disclosing, and assigning patentable inventions as an integral part of research and development efforts of the organization,
3. to consider advantages and disadvantages of patent protection and to check alternatives (secrecy, utility models, etc.). Also a cost/benefit analysis is crucial as applying for a patent at the right time without neglecting to evaluate if the invention is more complex than the problem merits.

Following a consideration of the patentability requirements and the details of what is patentable in your own country is crucial.

At this point, a prior art search should be conducted in order to verify if the invention is not already claimed by another individual or business, and identify who the competitors or potential partners are and what they do. Moreover, all issues relating to rights over the invention between the organization, its employees, and any other business partner (who may have participated either financially or technically in developing the invention) should be clarified. Problems concerning invalidity and/or noninfringement before launching potentially infringing products must be solved. Finally, the invention should be kept secret until the date of filing to protect novelty.

The decision to file an application for a patent should be cautious since legal systems vary between countries and several options are offered. Patent protection can be achieved by filling an application for a national, international, or regional patent. A national patent is typically used to protect invention within the home country market and as a basis to extend protection to other countries (or regions) by providing “priority”. International patent applications can be used to protect invention in many countries and extend the prepublication period up to 30 months. A regional patent protects invention in a number of countries within the same region, at a lower cost. Within one year from filling the first patent application, applications can be filled in other countries, too, with a priority inclusion established in the first country. Thereby, novelty is valid from the application filling date of the first country.

The main international/regional patent systems are based on legal agreements:

- Patent Cooperation Treaty (PCT)
- European Patent Convention (EPC)
- Other regional systems (African Intellectual Property Organization, African Regional Intellectual Property Organization, Eurasian Patent Organization)

The World Intellectual Property Office (WIPO) provides international novelty and patentability search, a single place for filing and final decision for countries based on common rules and postponement

for 30 months from the priority date. At the European level, the European Patent Organization (EPO) provides a single place for filing, completion, and patent granting for the 27 EPC member countries at lower costs compared with filing in each country separately.

A most decisive step – or more precisely an ongoing process towards achieving successful market introduction and establishment of new products from recovered compounds – is, as stipulated earlier, the choice of a coherent and flexible patent and general intellectual property rights strategy. Olive waste by products valorization is a new promising field for the recovery of phenolic compounds and it could be used to exemplify the process and important decisions to elect an effective intellectual property rights strategy. A modest – only in terms of financial recourses – strategy could be to apply a national patent in the country of origin of the invention (e.g. in Greece) both for the novel processes used for the recovery of phenolic compounds in this example and for all the possible products that could be marketed, e.g. products having very good antioxidant properties and that can be marketed as functional foods, improving health, etc. It is important to note that patent protection is only provided to what is explicitly stated in the claims section of a patent application. This initial step provides one year priority and protects both processes and possible marketable products with low early investment. The second step could be to apply/extend to a regional patent, e.g. an EPO patent if the anticipated product could be marketed in some or all countries in Europe or world patent through WIPO, or if the market is limited to, e.g. a few countries to apply/extend national patents. Another approach after filing a national patent could be to find an investor or licensee who invests in the early stage of marketing products, providing the patent holder finance to develop new research and/or products. An antioxidant phenolic compound recovered from olive waste by-products is hydroxytyrosol. Several commercial products involving hydroxytyrosol are marketed already in the United States where the Food and Drug Administration (FDA) granted generally recognized as safe (GRAS) status, and the European Food Safety Authority (EFSA) handles market release of most products with health claims, such as hydroxytyrosol products, in a preserved manner. Hydroxytyrosol has received European market release acceptance only for low cholesterol spreads. This significantly different approach of market release between FDA and EFSA should be taken into account at an early stage when electing patent filing strategy and exploitation of research results.

15.3 APPLICATIONS AND MARKET PRODUCTS

15.3.1 VEGETABLE AND PLANT BY-PRODUCTS

A collection of valuable compounds recovered from vegetable and plant by-products at a commercial scale are shown in [Table 15.1](#). Verification of market existing products matching with a patented process was herein conducted using a patent applicant name in each case. However, this matching may not always be correct as companies typically are secretive about their production methods and respective data cannot be found in the literature.

For example, industrial commercialization of citrus peel has been practiced for more than 30 years, whereas the solvent extracted “sugar syrup” contains essential oils, flavonoids, sugar, and pectin ([Bonnell, 1983](#)). Sugar syrup provides sweetness and flavor in juices, while it replaces artificial sweeteners (e.g. saccharine or aspartame) in foods. Another commercialized application concerns the recovery of albumin from soy protein wastewater, using membrane technology, flash distillation, and spray drying. The albumin-rich powder is applied as a nutritional supplement similar to whey protein concentrates

Table 15.1 Patented Methodologies Leading to Commercial Applications of Fruit, Vegetable, and Plant By-Products

Source	Patents Application Number	Applicant/ Company	Title/Treatment Steps	Products/Brand Names	Potential/ Commercialized Applications	Inventors/ References
Citrus peel waste	AU1983/0011308D	Tropicana Products Inc. (Florida, USA)	Treatment of citrus fruit peel	Sugar syrup	Food natural sweetener	Bonnell (1983)
Fruit and vegetable residues, unsellable fruits with defects	US2001/6296888	Provalor (Hoofddorp, The Netherlands)	Squeezing/ decantation/ centrifugation	Juices	Health drinks	Nell (2001)
	–	Indulleida S.A., Spain	Drying, solvent extraction	Fibers, sugars, polyphenols, and aromas	Food additives	http://www.indulleida.com/
Tomato waste	PCT/ EP2007/061923	Biolycy SRL (Lecce, Italy)	Process for the extraction of lycopene	Lycopene	Food antioxidant and supplement	Lavecchia and Zuorro (2008)
Soy protein isolate wastewater	CN2008/10238791	ShanDong Wonderful Industry Group Co. Ltd (Shandong, China)	Method for extracting and recycling albumin from whey wastewater from production of soy protein isolate	Soybean albumin	Food additive and supplement	Jishan et al. (2009)
Edible biological materials derived from plants (fruits, flowers, leaves, stems, herbs)	WO/2006/099553	Innovative Foods, Inc., South San Francisco, USA	Methods for preparing freeze-dried foods	Dried fruits and vegetables	Snacks and additives in prepared foods and commercially available meals, confectionary	Hirschberg et al. (2006)
Depectinated apple pomace	CN2008/1139768	Yantai Andre Pectin Co. Ltd (Yantai, China)	Process for extracting nonpectin soluble pomace dietary fibers	Apple dietary fiber granules	Dietary supplement	Anming et al. (2010)
Grape and cranberry seed	JP1998/0075070	Kikkoman Corp. (Chiba, Japan)	Protein food	Proanthocyanidin	Coloring additive in soy sauce	Ariga et al. (1999)

(Continued)

Table 15.1 Patented Methodologies Leading to Commercial Applications of Fruit, Vegetable, and Plant By-Products (cont.)

Source	Patents Application Number	Applicant/ Company	Title/Treatment Steps	Products/Brand Names	Potential/ Commercialized Applications	Inventors/ References
Wine grapes pomace and seeds	–	WholeVine, Santa Rosa, California, USA	Milling and oil extraction	Grape skin and seed flour	Additives in gluten-free baked goods	http://m.wholevine.com/
Grape pomace or seed	WO/1999/030724	Pierre Fabre Sante (France)	–	Polyphenols	Food supplements, functional foods, cosmetics, and pharmaceutical applications	Rouanet et al. (1999)
Pomegranate rind and seedcase residues	CN2010/1531940	Xi'an App Chem-Bio(Tech) Co., Ltd. (Xi'an, China)	Method for preparing punicalagin and ellagic acid from pomegranate rind	Ellagic acid (40%) and punicalagin (40%)	Food antioxidants and cosmetics	Guangyu & Xiaoyan (2011)
Conifer and pine bark	US1987/4698360	Societe Civile d'Investigations Pharmacologiques d'Aquitane Horphag Overseas Ltd (Bordeaux, France)	Boiling, filtering, and solvent extraction	Proanthocyanidins	Cardiovascular health, oral and topical skin care, and eye health	Masquelier (1987)

(Jishan et al., 2009). Natural shrimp and crab shells have been used as substrates for the extraction of food-grade chitosan with alkali and chloroacetic acid treatment (Shenghui, 1995). This product is sold as thickener in vegetable oils or as an antirancidity agent in meat (Kanatt et al., 2008).

The industrial recovery of water insoluble carotenoids from food wastes is in progress, too. Lycopene is one of the most popular natural pigments (red). Recently, the FDA approved the use of higher levels of tomato lycopene to color-processed meats as an alternative to carmine (USDA, 2014). Moreover, in vitro, in vivo, and ex vivo studies have demonstrated that its addition to foods is inversely associated with cancers and cardiovascular diseases (Kong et al., 2010). Besides, the Food Safety and Inspection Service has established that tomato lycopene extracts and concentrates (GRN 000156) of ≤ 50 and ≤ 100 mg/kg, respectively, could be used as coloring agent in ready-to-eat meat, poultry, and egg products (USDA, 2014). This fact will probably lead to wide-scale applications around the world and could open the door for the commercial recovery of lycopene from food by-products. Today, the extraction of lycopene is under industrial development using sequential extraction with a nonpolar and a polar protic solvent (Lavecchia and Zuurro, 2008).

Figure 15.1 illustrates an example of apple pomace valorization for recovery purposes. Specifically, pretreatment of apple pomace (peel, pulp, and seed mixture) includes a sieving process for the separation of the seeds. The latter are rich in oil and proteins. Separation of macro- and micromolecules could be performed using alcohol precipitation, after malaxation of the remaining mixture with hot water. Ethanol would solubilize a major part of the contained polyphenols (Tsakona et al., 2012; Galanakis et al., 2013a;

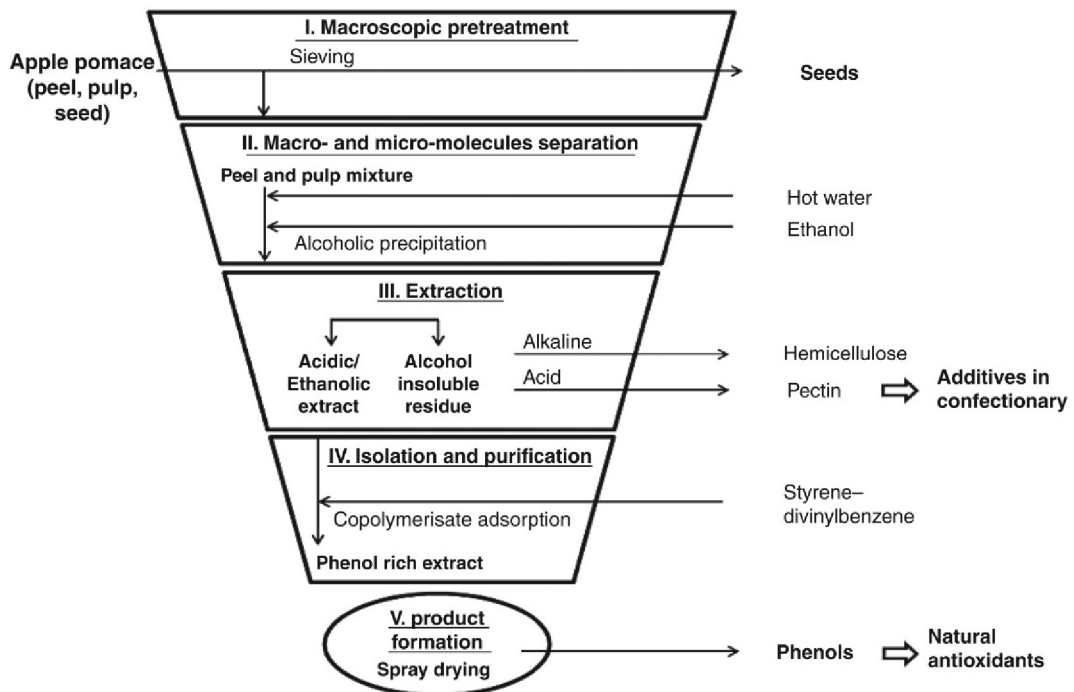


FIGURE 15.1 Recovery of Valuable Compounds from Apple Pomace and Reutilization in Different Products

Heng et al., 2015). Extraction of hemicellulose from the alcohol insoluble residue could be conducted using alkaline solution, whereas the recovery of pectin could be performed using acidic extraction. Water-soluble dietary fibers (e.g. hemicellulose and pectin) could be incorporated into food and confectionary products as cheap noncaloric bulking agents instead of flour, fat, or sugar, due to their ability to retain water, improve emulsions, and oxidative stability. On the other hand, sequential extraction of peel and pulp mixture with inorganic acid and alcohol precipitation can generate an acidic/ethanolic extract used for the isolation of phenolic compounds with adsorption on a hydrophobic styrene–divinylbenzene copolymerisate material (Schieber et al., 2001). Fractionation of phenolic compounds can also be performed using ultrafiltration (Galanakis et al., 2013b, 2015).

15.3.2 OLIVE BY-PRODUCTS

A new tendency in the field of food waste recovery concerns the valorization of olive by-products as a source of phenolic compounds (Galanakis, 2011; Galanakis et al., 2010d, e; Rahmanian et al., 2014; Roselló-Soto et al., 2015) (Table 15.2). For example, commercial hydroxytyrosol has been recovered from olive mill waste in pure form (99.5% per weight) using chromatographic columns filled with two resins: nonactivated ionic and XAD-type nonionic (Fernández-Bolaños et al., 2002). Another popular process is performed using acid treatment of olive mill wastewater, prior to an incubation process that converts oleuropein to hydroxytyrosol. Thereafter, extraction is performed using supercritical fluid extraction and a column operating in the counter-current mode, where a nonselective porous membrane is the barrier interface between the hydroxytyrosol-containing fluid and the dense gas. Encapsulation is conducted using either freeze or spray drying (Crea, 2002a, b). Ultimately, hydroxytyrosol possesses advanced antiradical properties compared with vitamins E and C, and prevents the oxidation of lipids in fish (Fernández-Bolaños et al., 2006). Thereby, it could be used as a functional supplement, a food preservative in bakery products, or as a life prolonging agent (Liu et al., 2008). Hidrox is a commercially available product from CreAgri (Hayward, USA), granting a GRAS status. According to several scientific studies, Hidrox possesses several beneficial (e.g. anti-inflammatory and antimicrobial) properties.

Other commercially available products include: (i) Olnactiv (Glanbia, Milan, Italy), Oleaselect, and Opextan (Indena, Milan, Italy), (ii) Olive Braun Standard 500 (containing 1.0–2.2 g of hydroxytyrosol and 0.2–0.7 g of tyrosol/kg) from Naturex, (iii) olive polyphenols from Albert Isliker (containing 22–23 g hydroxytyrosol and 6.5–8.0 g tyrosol/kg), (iv) Prolivols (containing 35% polyphenols, 2% hydroxytyrosol, and 3% tyrosol) from Seppic Inc., and (v) Olive Polyphenols NLT from Lalilab Inc. (containing 2.0–6% hydroxytyrosol and 0.7–1.1% tyrosol). Another product is Phenolea Complex, which is a natural hydrophilic extract, obtained directly from aqueous olive pulp and olive mill wastewater. This product is produced without any kind of organic solvent, so the biochemical composition of the final extract reflects the original composition of olive fruit but in a more concentrated formulation. The production process comprises the following steps: (i) collection of olive pulp and mill wastewater after the milling process, (ii) pretreatment of the material, (iii) tangential microfiltration with ceramic membranes, and (iv) vacuum evaporation of the permeate (FDA, 2012). Olive pulp extracts (in general) have been approved by FDA with GRAS status (GRN No. 459) for being used as an antioxidant in baked goods, beverages, cereals, sauces and dressings, seasonings, snacks, and functional foods at a level of up to 3000 mg/kg in the final food (FDA, 2014).

Table 15.2 Patented Methodologies Leading to Commercial Applications of Olive Wastes and By-Products

Food Waste Source	Patents Application Number	Applicant/ Company	Title/Treatment Steps	Products/Brand Names	Potential/ Commercialized Applications	Inventors/ References
Olive mill waste	PCT/US2001/027132	CreAgri, Inc. (Hayard, USA)	Method of obtaining a hydroxytyrosol-rich composition from vegetation water	Hydroxytyrosol/ Hidrox	Food supplements and cosmetics	Crea (2002a, b)
	PCT/ES2002/000058	Consejo Superior de Investigaciones Cientificas (Madrid, Spain)/ Genosa I+D S.A. (Malaga, Spain)	Method for obtaining purified hydroxytyrosol from products and by-products derived from olive trees	Hydroxytyrosol (99.5%)/Hytolive	Conserving foods, functional ingredient in bread	Fernández-Bolaños et al. (2002)
	GR2010/1006660	Polyhealth (Larissa, Greece)	Ultrafiltration, ion exchange resin adsorption, solvent elution, spray drying	Medoliva (hydroxytyrosol, tyrosol, caffeic acid and <i>p</i> -coumaric acid)	Food supplements and antioxidants, cosmetics, personal care products	Petrotos et al. (2010)
	PCT/SE2007/001177	Phenoliv AB (Lund, Sweden)	Olive waste recovery	Olive phenols and dietary fibers containing powders	Natural antioxidants in foodstuff and fat replacement in meatballs, respectively	Tornberg and Galanakis (2008)
	US patent 6361803 B1	Usana, Inc. (USA)	Wastewater from olive oil production	Antioxidant compounds	Food supplements and antioxidants, cosmetics, personal care products	Cuomo and Rabovski (2004)

(Continued)

Table 15.2 Patented Methodologies Leading to Commercial Applications of Olive Wastes and By-Products (cont.)

Food Waste Source	Patents Application Number	Applicant/ Company	Title/Treatment Steps	Products/Brand Names	Potential/ Commercialized Applications	Inventors/ References
Olive leaves extracts	EP 1582512 A1	Cognis IP Management GmbH (Düsseldorf, Germany)	Olive waste recovery	Olive hydroxytyrosol	Natural antioxidants in foodstuff	Beverungen (2005)
Vegetation water from olives	US Patent/ 2005/0103711 A1		Olive waste recovery	Oleuropein aglycon	Natural antioxidant	Emmons and Guttersen (2005)

There are several patents that deal with the extraction of oleuropein and/or hydroxytyrosol from olive and water vegetation (WO/2002/0218310, US/2002/0198415, US 2002/0058078, WO2004/005228, US 6414808, EP-A 1 582 512) (Crea, 2002a, b, 2004; Crea and Caglioti, 2005). In addition, a method for obtaining hydroxytyrosol and/or oleuropein from the vegetation water of depitted olives is disclosed in US 2004/0039066 A1. In most patents, an acidic hydrolysis of the substrate (olive leaves or vegetation water) for 2–12 months is suggested in order to convert at least 90% of the present oleuropein to hydroxytyrosol (Liu et al., 2008). Moreover, a method for the extraction of phenolic compounds from olives, olive pulps, olive oil, and oil mill wastewater has been described by Usana Inc. patents US 6,361,803 and WO01/45514 and in US2002/0004077 (Cuomo and Rabovskiy, 2002, 2004).

Figure 15.2 illustrates an example for the recovery of valuable compounds from olive mill wastewater, which is adapted to the 5-Stage Universal Recovery Process. In this case, pretreatment includes two processes (centrifugation and skimming) in order to remove remaining fats from three-phase olive mill wastewater. Thereafter, a vacuum concentration process can remove part of the contained water. Treatment of concentrated and defatted olive mill wastewater with acids and ethanol can generate two streams: an alcohol insoluble residue rich in dietary fibers and an ethanolic extract rich in polyphenols. Isolation of the latter compounds can be performed using resin adsorption or chromatography. On the other hand, purification of the water-soluble fraction (mainly pectin) of the residue can be conducted

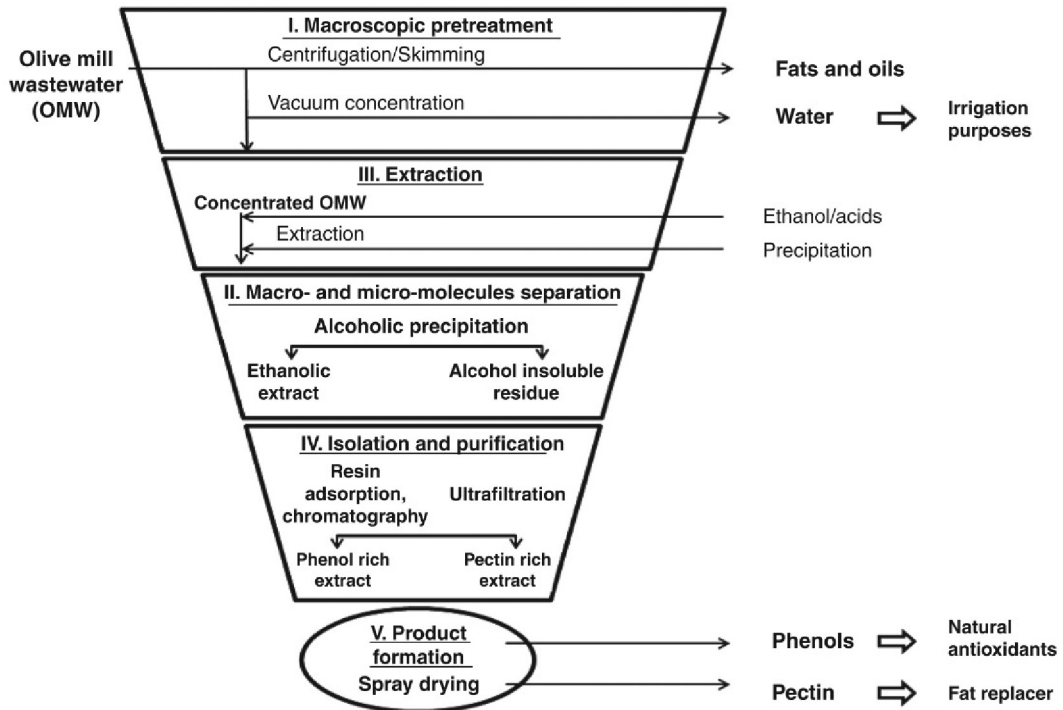


FIGURE 15.2 Recovery of Valuable Compounds from Olive Mill Wastewater and Reutilization in Different Products

using ultrafiltration (Galanakis, 2015). Pectin derived from olive mill wastewater has been proved to restrict oil uptake of low fat meatballs during deep fat frying (Galanakis et al., 2010a, b, c, d, e).

15.3.3 COFFEE BY-PRODUCTS

Coffee is one of the most consumed beverages in the world. Due to the great demand for this product, large amounts of wastes are generated in the coffee industry. Coffee silverskin (CS) and spent coffee grounds (SCG) are the main coffee industry wastes or by-products, obtained during roasting and brewing processes, respectively. CS contains several bioactive compounds such as prebiotic carbohydrates, dietary fiber, and antioxidants (Borrelli et al., 2004; Napolitano et al., 2007; Ballesteros et al., 2014). In agreement, CS has been proposed as a natural source of health promoters or functional food ingredients (Esquivel and Jimenez, 2012; Pourfarzad et al., 2013).

Figure 15.3 illustrates the process for the recovery of bioactive compounds from CS patented by del Castillo et al. (2013). The procedure consists of the extraction of the CS (without prior milling) using subcritical water at moderate temperature (50°C or higher) and high pressure (1500 psi), although unpressurized water at 100°C can be used as well. Under these conditions, extracts with high antioxidant properties are obtained in 10–20 min, with antioxidant activity depending on the extraction conditions: 0.85–3.7 g of equivalents of chlorogenic acid and 150–450 mg of caffeine, both per 100 mg of silver-skin, when extracted with only hot water or under subcritical conditions, respectively. The antioxidant properties of the extract resist the *in vitro* gastrointestinal digestion process. It maintains the antioxidant

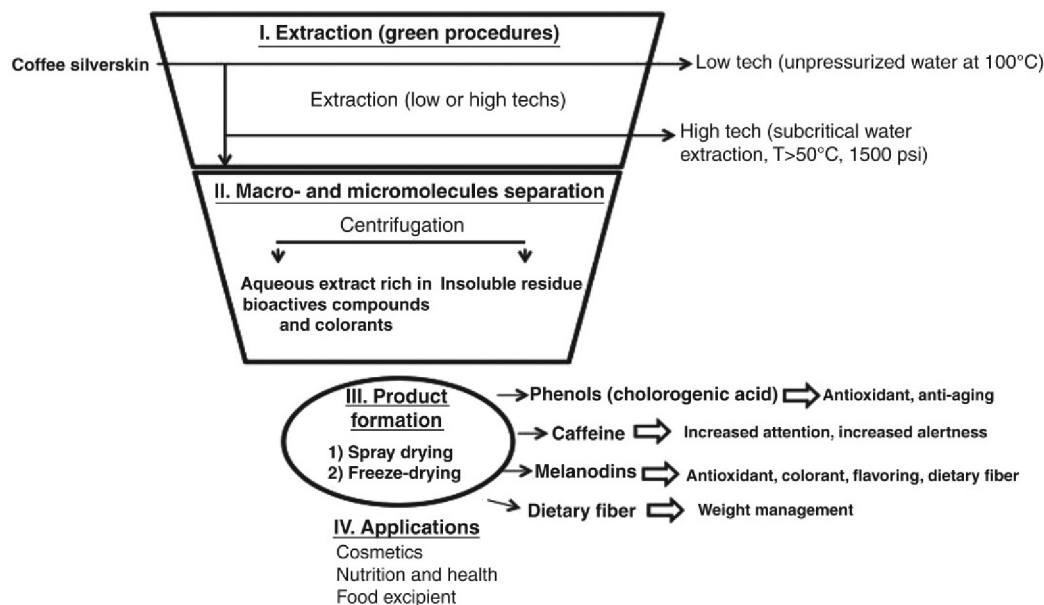


FIGURE 15.3 Recovery of Valuable Compounds from Coffee Silverskin and Reutilization in Different Products

properties for more than 6 months at room temperature and in dry conditions. Therefore, it has been proposed as an antioxidant additive in food and cosmetics manufacture, with potential excipient (preservative, flavoring) functions as well as antioxidant, antiageing, and anticellulite activities. The patented extract also has a potential to reduce body fat accumulation (Martinez-Saez et al., 2014), scavenge dicarbonyls and inhibit the formation of advanced glycation end-products (Mesías et al., 2014). The insoluble residue generated during the extraction process may be recycled as dietary fiber. The patent has been granted and licensed to a Spanish company. Currently, the development of products using the patented extract is being carried out.

Another example is the invention of a CS-containing paper and the production method thereof (Sato and Morikawa, 2011). The inventors of this application have focused on the oil absorbency of silverskin, and they have studied a method for providing oil absorbent paper. The latter shows low water absorbency and it is produced by mixing silverskin with paper pulp. The patented procedure produces useful and highly functional paper that has characteristics of roasting residues such as oil absorbency and low water absorbency. Coffee silverskin discarded during beverage production is effectively used for paper manufacture.

SCG is generated in large amounts, with a worldwide annual generation of 6 million tons (Tokimoto et al., 2005). Consequently, there is an increased interest in new alternatives to add value to this by-product. Information regarding the chemical composition of this food matrix has been recently reviewed by Ballesteros et al. (2014). Some examples of patented applications for SCG are shown in Table 15.3. Mussatto et al. (2013) successfully used SCG for the production of a distilled beverage with coffee aroma. The global process was based on an aqueous extraction of aromatic compounds from SCG, supplementation with sugar, and production of ethanol. This developed spirit showed acceptable flavor, volatile compounds, and different organoleptic character compared with the commercially available spirits. Another patented application for SCG is its use as an ingredient in healthy bakery products (with high level of dietary antioxidant fiber), pastry, confectionary, biscuits, breakfast, cereals, etc. (del Castillo et al., 2014). This patent is under commercialization, whereas national and international applications have been performed. The preparation of this ingredient involves a simple and low-cost method with minimum treatment and direct application of the by-product. The developed formulation employs a coffee by-product as a source of antioxidant fiber in diverse combinations with other basic and/or novel ingredients, e.g. stevia. The resulting formula is rich in insoluble dietary fiber (3–7%) and its content in acrylamide is low. These products might be appropriate for special nutritional needs due to their low glycemic index and low energetic value.

SCG have also been employed for the invention of foods and beverages containing mannoooligosaccharides to reduce blood pressure, elevate suppressing effect (Takao et al., 2009), and reduce body fat (especially abdominal) (Asano et al., 2006). The mannoooligosaccharides may be produced by the hydrolysis of mannan from coffee materials (especially spent coffee residues and other coffee-containing materials from commercial multistage coffee extraction systems). The object is to provide an economical and simple food or drink, with excellent blood pressure reducing, elevation suppressing, and fat reducing effects, without changing ordinary eating habits. Additionally, Asano et al. (2002) described a nonpatented but important application. In this case, mannoooligosaccharides obtained by thermal hydrolysis of SCG resistant to α -amylase, artificial gastric juice, porcine pancreatic enzymes, and enzymes of the intestine of rats were fermented by fecal bacteria in human beings. This suggests that under these hydrolysis conditions, mannoooligosaccharides are indigestible for humans. Thus, they could potentially be used as a prebiotic for the probiotic microorganisms present in the large intestine.

Table 15.3 Patented Methodologies Leading to Commercial Applications of Coffee Wastes and By-Products

Source	Patents Application Number	Applicant/ Company	Title/Treatment Steps	Products/Brand Names	Potential/ Commercialized Applications	Inventors/ References
Coffee silverskin	US 7,927,460	Ito En, Ltd, (Tokyo, Japan)	Silverskin-containing paper and method for producing the same	Functional silverskin-containing paper	Paper industry	Sato and Morikawa (2011)
	WO 2013/004873	Consejo Superior de Investigaciones Cientificas/CIAL (Madrid, Spain)	Application of products of coffee silverskin antiageing cosmetics and functional food	Bioactive silversink extract	Cosmetics, nutrition, and health	del Castillo et al. (2013)
Spent coffee grounds	WO 2006/036208	Ajinomoto General Foods, Inc. (Tokyo, Japan), Kraft Foods Global Brands LLC (Northfield, Illinois, USA)	Mannooligosaccharide composition for body fat reduction	Mannooligosaccharides	Functional food ingredient	Asano et al. (2006)
	US2009/0005342 (PCT/JP2006/301025)	Ajinomoto General Foods, Inc. (Japan)	Composition having blood pressure reducing and/ or elevation suppressing effect and food and drink containing the same	Mannologosaccharides	Functional food ingredient	Takao et al. (2009)
	PCT/ES2014/070062	Consejo Superior de Investigaciones Cientificas/CIAL (Madrid, Spain)	Healthy bakery products with high level of dietary antioxidant fiber	Antioxidant insoluble dietary fiber	Functional food ingredient	del Castillo et al. (2013)
	PT 105346	University of Minho. CEB – Centre of Biological Engineering (Braga, Portugal)	Distilled beverage from spent coffee grounds and respective production method	Distilled beverage	Aroma	Mussatto et al. (2013)

Another waste obtained from the coffee bean is the surrounding pulp, known as the coffee cherry, which is discarded during coffee processing. A new interesting ingredient has been developed ([Coffee flour](http://www.coffeeflour.com/), <http://www.coffeeflour.com/>) which can be used in different formulations such as breads, cookies, muffins, squares, brownies, pastas, sauces, and beverages. This flour has achieved cooking and baking success. It does not taste like coffee, but rather expresses more floral, citrus, and roasted fruit-type notes. In addition, it is gluten free, possesses fivefold more fiber than the whole grain of wheat flour, and has 84% less fat and 42% more fiber than coconut flour. Coffee flour is set for commercial rollout in 2015.

15.3.4 DAIRY, ANIMAL, AND FISHERY BY-PRODUCTS

Whey is the most known food waste source used for recovery and valorization purposes ([Table 15.4](#)). It is generated in different forms and compositions depending on the characteristics of cheese manufacturing, whereas protein concentrates, lactose, and respective monosaccharides (glucose and lactose) comprise the target compounds. [Figure 15.4](#) illustrates different technologies adapted in the *5-Stage Universal Recovery Process* as well as commercial applications for the derived products. Initially, skimming is used to remove casein fines and whey cream. Both ingredients are today used in confectionary. Membrane filtration comes next to concentrate proteins from the defatted whey ([Galanakis et al., 2014](#)). For instance, [Jensen and Larsen \(1993\)](#) reported a two-step microfiltration process for the sequential concentration of α -lactoalbumin and β -lactoglobulin. Whey protein concentrates and liquid glycoproteins can be further treated using electrodialysis in an alkaline environment. Ion-exchange chromatography has also been industrially employed to deflavor whey protein concentrates and clarify glycoproteins, prior to drying by either spray or freeze drying. Proteins are typically used as nutritional supplements in bodybuilding. Moreover, hydrolyzed whey proteins are known for their ability to reduce total and LDL-cholesterol levels in mammals ([Davis et al., 2003](#)) and thus could be used for the production of functional foods. Heat coagulation of the residual deproteinized whey causes precipitation and subsequent removal of glycoproteins from the liquid stream ([Davis et al., 2002](#)). Finally, crystallization of the deproteinized whey using seed crystals causes lactose precipitation. Crude lactose is used as a supplement in diet food or as an aroma stabilizer. It can also be hydrolyzed with enzymes to produce galactose- and glucose-rich syrup ([Galanakis et al., 2014](#)). The latter can be used as sweetener.

On the other hand, the meat industry generates a large amount of wastes and by-products, which are a good source of nutrients and can be used as food ingredients and additives. Among the different meat by-products, air flotation skimming sludge typically has an important nutritive value. However, it is lost due to microbial degradation. On the other hand, a practical precipitation process of food waste sludge from dissolved air flotation units and sugar by-products has been patented ([Lee, 2002](#)). The process is based on the transformation of the skimming sludge and animal blood into a precipitate using centrifugation, screening, or pressing. The precipitate binds most nutrients. Moreover, as water feed is eliminated and product surface area is increased during the process, the cost is reduced. The process can convert the waste skimming sludge into a safe and valuable product for feed and nutritional applications, e.g. it can be used for improving the properties of animal feed block products ([Lee, 2002](#)). Moreover, chicken feathers have been used as a source of keratin for packaging ([Table 15.4](#)).

The fishery industry generates a large amount of wastes and by-products, rich in fish oils. The latter contains omega-3 and omega-6 fatty acids that could be used in the food and pharmaceutical industries. Several groups have proposed different projects for the valorization of fishery wastes and by-products ([Table 15.4](#)). For example, [Shenghui \(1995\)](#) developed a patent for the preparation of a chitosan derivative

Table 15.4 Patented Methodologies Leading to Commercial Applications of Fruit, Dairy, Animal, and Fishery By-Products

Source	Patents Application Number	Applicant/ Company	Title/Treatment Steps	Products/Brand Names	Potential/ Commercialized Applications	Inventors/ References
Cheese whey	PCT/ SE1993/000378	Alfa-Laval Food Engineering AB (Lund, Sweden)	Method for obtaining high-quality protein products from whey	α -Lactoalbumin and β -lactoglobulin containing product	Food supplements and additives	Jensen and Larsen (1993)
	PCT/ US2002/010485	Davisco International Foods Inc. (Le Sueur, USA)	Isolation of glycoproteins from bovine milk	Whey protein isolate/Bipro	Food supplements	Davis et al. (2002)
	US2009/7582326	Kraft Foods Global Brands Llc (Northfield, USA)	Method of de-flavoring whey protein using membrane electro dialysis	De-flavored whey proteins	Food supplements	Brown & Crowley C.P. (2009)
Shrimp and crab shell	CN1994/1001978	Qingdao Zhengzhongjiahe Export & Import Co., Ltd (Shandong, China)	Preparation of chitosan derivative fruit and vegetable antistaling agent	Chitosan ($\geq 85\%$) food grade	Food thickener and fruit antistaling agent	Shenghui (1995)
Salmon viscera, heads, skin, frames, and trimmings	–	Aquaprotein, Chile	Hydrolysis, mechanical extraction, and spray drying	Protein hydrolysates and salmon oil	Petfood, pig weaning, animal breeding, injuries recuperation in animals	http://www.aquaprotein.com/
Chicken feathers	US2012/08182551	Eastern Bioplastics LLC	Washing, grinding, perforated rotating spiral drum, skimming, compounding	Keratin	Polypropylene packaging, as a sorbent of hydrocarbons	Meyerhoeffer and Showalter (2012)

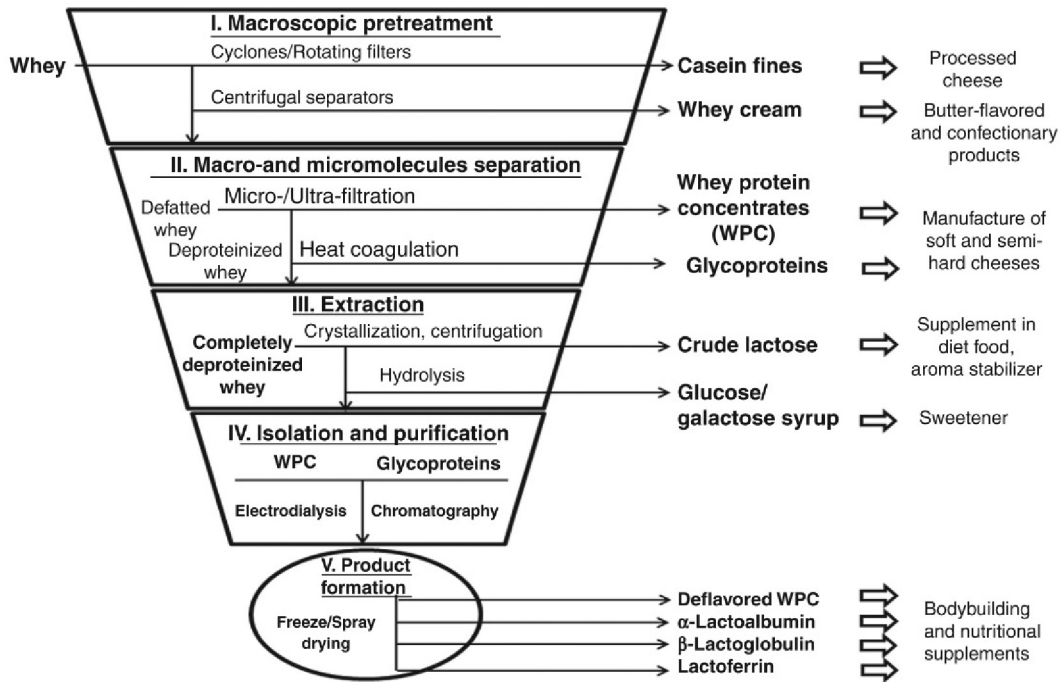


FIGURE 15.4 Recovery of Valuable Compounds from Cheese Whey and Reutilization in Different Products

(Galanakis 2012)

fruit and vegetable antistaling agent from shrimp and crab shell, which is used as a food thickener and fruit antistaling agent. Other commercial applications are based on the recapture of fish protein hydrolysates and fish oil for feed from fish guts, skins, heads, and bones. Finally, fish skin has been used to obtain gelatin. The latter could be used in the preparation of fresh and smoked salmon as well as in salmon oil.

15.4 POTENTIAL USE OF EMERGING TECHNOLOGIES

In recent decades, there has been a considerable increase in the number of commercially available foods processed by high pressure processing (HPP) for food preservation. For example, products have been marketed in Japan since 1990 and in the United States and Europe since 1996 (Zhang et al., 1995; Rizvi and Tong, 1997; Körmendy et al., 1998). Table 15.5 shows fruits, vegetables, and derivatives treated by HPP that are currently in the market. These applications reveal the potential use of HPP for food waste recovery in two different ways: first, reutilization of wastes from food industries, supermarkets, etc., and second, recovery of valuable compounds using HPP as an extraction or pretreatment technique. Other emerging technologies, e.g. ultrasonication, have been used in soy processing in order to enhance protein and sugar yields as well as nisin production (Khanal, 2007). In the last two decades, pulsed electric fields (PEF) and high voltage electrical discharges (HVED) have been

Table 15.5 Recently Marketed Foodstuffs Treated by High Pressure Processing

Country	Products	Treatment			Shelf-Life
		Pressure (MPa)	Temperature (°C)	Time (min)	
Czech Republic	Broccoli and apple or carrot juice (Beskyd Fryčovice)	500	20	10	21 d
France	Juices (Pampryl)	400	20	10	18 d, 4°C
	Orange juice (Ultrafruit)	500	20	5–10	–
Italy	Fruit juices, fruit desserts (Ortogel)	600	17	3–5	1–2 m
Japan	Jams, sauces, jellies (Meidi-Ya Co.)	400	20	10–30	2–3 m, 4°C
	Grape juice (Pokka Co.)	120–400	23	2–20	–
	Mandarin juice (Wakayama Food Industries)	300–400	23	2–20	–
	Sake (Chiyonosono)	400	15	30	6–12 m, 4°C
Lebanon	Fruit juices	500	–	–	1 m
Mexico	Smoothies, citrus juices (Jumex)	500	–	–	–
Portugal	Juices (Frucalba)	450	12	0.33–1.5	28 d
Spain	Prepared vegetable dishes	500	–	–	–
Sweden	Fruit juices (Västerås)	500–600	–	–	–
UK	Orange juice (Orchard House Foods)	500	20	–	–
USA	Avocado purée (Avomex)	700	–	10	–
	Apple juice (Odwalla)		–	–	2–3 times more than fresh
	Avocado products, vegetable salads, orange juice, lemonade, sliced onions				45 d

M, months; D, days.

proposed as a potential tool to recover valuable compounds from different bioresources, including plant and animal food wastes and by-products (Roselló-Soto et al., 2015; Deng et al., 2015). For instance, several patents have been developed by different authors: Kortschack (2007) developed an electroporation method for the processing of meat, fish, and seafood by-products. This trend allows the development of food products based on animal wastes. Moreover, the use of pulsed electric treatments for the recovery of high added-value components from plant food materials has been widely reported recently and some patents have been developed, too (Table 15.6). For instance, a method for extracting liquid from a cellular material using a combination of mechanical pressing and moderated

Table 15.6 Nonconventional Patented Methodologies with Potential to Valorize Food Wastes and By-Products

Food Waste Source	Patents Application Number	Applicant/ Company	Title/Technology	Potential/ Commercialized Applications	References
Cellular material	PCT/ FR2001/000490	Association Gradient (Compiègne, France)/ Fonderies & Ateliers Lucien Choquet (Chauny, France)	Treatment of cellular material/PEF	Functional food ingredients	Andre et al. (2001)
Vegetal matrix	PCT/ EP2011/070597	Universite Technologie De Compiègne-UTC (Compiègne, France)	Procede d'extraction de molecules d'interet a partir de tout ou partie d'une matrice vegetale/PEF-HVED	Food supplements and additives	Bousseta et al. (2013)
Plant materials	PCT/ CA2007/001,652/ US Patent 8147879	–	Pulsed electric field enhanced method of extraction/PEF	Food supplements	Gachovska et al. (2008); Ngadi et al. (2012)
Meat, meat by-products, fish, and seafood	CA 2620122	Triton GmbH, Fritz Kortschack	Method for processing raw materials having a cell structure in the meat, meat by-products, fish, and seafood processing industry/PEF	Cosmetics, nutrition, and health	Kortschack (2007)
Vegetable tissues	US Patent App. 13/696040; EP20,110,716,571	Maguin Sas	Method and apparatus for treating vegetable tissues in order to extract therefrom a vegetable substance, in particular a juice/ PEF	Juice obtention	Vidal and Vorobiev (2013a, b)
Plant materials	US Patent 7943190	Minister of Agriculture and Agri-Food, Canada	Extraction of phytochemicals/SCW	Functional food ingredients	Mazza and Cacace (2011)
Capsicum solids	US Patent 6074687	Kalamazoo Holdings, Inc.	High temperature countercurrent solvent extraction of capsicum solids	Cosmetics, nutrition, and health	Todd (2000)

PEF, pulsed electric fields; HVED, high voltage electrical discharges; SCW, subcritical water extraction.

power PEF applied by short and repeated high voltage pulse bursts was developed (Andre et al., 2001). Moreover, this invention has the potential to be used for implementing the extraction of liquid from a cellular material (Andre et al., 2001). PEF can also be used to recover high added-value compounds from vegetable tissue (Gachovska et al., 2008; Ngadi et al., 2012; Vidal and Vorobiev, 2013a, b). For example, some patents have been developed involving a process of compacting the plant tissues and at least one treatment chamber. Subsequently, PEF treatment was applied to the compacted tissues (Vidal and Vorobiev, 2013a, b). In addition, the extraction of a molecule of interest from a plant or similar matrix, especially phenolic compounds from winery by-products such as grape marc and lees by using HVED and/or PEF, has been patented recently (Bousseta et al., 2013).

On the other hand, a patent was developed to extract and concentrate the carotenoid pigments from paprika, red pepper, pungent chili, and other plants of the genus *Capsicum* by using an edible solvent in a series of mixing and high temperature and pressure mechanical pressing steps (Todd, 2000).

Finally, a patent involving the use of a subcritical water extraction process was developed for the extraction of phytochemicals from plant food materials (Mazza and Cacace, 2011). The processing system includes a water supply interconnected with a high pressure pump, diverter valve, a temperature-controllable extraction vessel, a cooler, a pressure relief valve, and a collection apparatus for collecting eluant fractions from the extraction vessel.

15.5 CONCLUSIONS

The key point for commercialization is to develop a recovery strategy that allows flexibility and provides alternative scenarios for each stage of processing. Implementation of nonthermal technologies, addition of green solvents, and safer materials (possessing GRAS status) are strongly recommended. The conducting of integral investigations that include recovery protocols and preservation assays are necessary, too. These parameters will ensure industrial exploitation and sustainability of the final product. Methodologies with fewer recovery steps are cheaper and scale-up is easier, but at the same time they generate cruder products with lower concentrations of target compounds. This fact alters the functional properties of the developed products since some of the target compounds are replaced with coextracted ingredients. Nevertheless, safety assessment and market release permission of purified active compounds is rather demanding. This procedure includes long and sophisticated tests on different species of laboratory animals (similar to synthetic antioxidants). In the case of enriched natural extracts, the criteria are not so strict. This is because natural extracts are considered to exist inherently in foods and thus safety concerns are limited. In any case, the development of tailor-made applications for the recovered products (crude or highly purified) is necessary, as target compounds may not be as beneficial as proposed theoretically, and more importantly, it is difficult to survive competition in the functional foods market. With regard to the recovery stages, the fifth stage (product formation) is the more essential and thus needs deeper investigation. Indeed, encapsulation enhances functionality and extends the shelf-life of the products. Conclusively, researchers will soon deal with the prospect of applying emerging technologies and particularly nanotechniques with an ultimate goal of optimizing overall efficiency of suggested methodologies. This concept will definitely reopen the debate concerning the safety of products recovered from food wastes and the impact (beneficial or not) of recycling them inside the food chain (Galanakis, 2012).

Other problems may arise from the market needs for healthier products. Authorities around the world (especially in Europe via the European Food Safety Authority) have tightened up the way in

which companies can advertise health benefits. This policy is driven by the need to protect consumers from false or dubious claims. On the other hand, demonstration of proven health benefits is very costly for companies active in the field. For instance, health claims have only been approved for a small number of compounds (e.g. hydroxytyrosol in olive oil) and products (e.g. cholesterol-reducing yogurts and butters). This fact creates implications for stifling innovation in the field, as the required data are too much and most companies (typically start-ups with low funding) cannot afford them. Besides, the risk of claims rejection by the corresponding authorities is too high. This is not only a problem for the companies involved. A broader discussion is also needed about the implementation of real sustainability in the food industry and the way that research and innovation efforts encourage the development of licensed novel foods. Perhaps the establishment of a new label (similar to organic foods) or establishment of a tax reduction to relevant products could reveal the potentiality of recovering valuable compounds from food waste and reutilizing them in food products.

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