THE TRANSFORMATION OF CITRUS WASTE IN BIOPRODUCTS. TECHNIQUES, METHODOLOGIES AND TECHNOLOGIES.

MANUAL FOR AGRICULTURAL VET TEACHERS.

2019

Erasmus+

Edition: CitriVET Project Consortium

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ISBN: 978-989-8859-89-1

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This book was produced under the ERASMUS project CitriVET
"Enhancing green-skills in VET through citrus waste valorization".

This project is co-funded by the European Union

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Contents

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The transformation of citrus waste in bioproducts. Techniques, methodologies and technologies

Manual for agricultural VET teachers

PREFACE

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This Intellectual Output (IO) is one the result of the CitriVET project that aims at developing, transfer and implement innovative practices that enhance agricultural Vocational and Educational Training (VET) studies through the transformation of citrus waste in bioproducts (essential oils, biofuel and animal food).

According to the European Environment Agency (2016), agriculture has a direct effect in climate change, being responsible of 10% of the EU's greenhouse-gas emissions. Agriculture accounts for 70% of potable water consumption and is responsible for occupying an area of about 40% of the earth's surface[1]. About 1.3 billion tons of food is lost or wasted annually, equivalent to the emission of 3.3 billion tons of greenhouse gases[2]. The waste of citrus farming, mainly eliminated through controlled burning or crushing (to add to the field), generate considerable amounts of influential greenhouse gases as methane and nitrous oxide.

At the same time, employment in the environmental goods and services sector in the EU has been growing by 20% since 2000, providing nowadays 4.2 million jobs (Eurostat, 2018). Nevertheless, although there is a consensus about the benefits of green employment, specialists highlight the "green skills gap" and the urgent need of upgrading the competences required for the eco-industry (EU Green Week, 2017).

In that sense, this IO aims at promoting the professional development of VET teachers strengthening their competences to introduce in VET curricula the transformation of citrus waste. More in depth, the Intellectual Output is a technical manual that integrates technical and entrepreneurial knowledge related to the citrus valorisation with the aim of helping teachers in the acquisition of knowledge about techniques, methods and technologies to develop new business models derived from the valorisation of citrus waste.

The contents of the IO are based in the experience of the no-VET project partners and it will be used in the blended course for VET teachers, composed of the e-learning course and the short-term joint staff training event. After the project end, the manual will be available for other VER teachers or stakeholders from public and private sector that are interested in citrus waste valorisation.

The IO is organised in the following parts:

Module 1. Introduction to the citrus valorisation: it contains an introduction to the new concepts of valorisation, circular economy, relevant actors, business models, environmental problems;

Module 2. Methods and technologies for citrus waste valorisation: it explains the main concepts about the management and logistics of citrus waste and new techniques and methods to produce bioproducts from citrus waste (essential oil, biomass and animal feed);

Module 3. Bioproducts market: it describes the market analysis for the bio-based product and the innovative business opportunities.

[1] Source: https://datos.bancomundial.org/indicator/AG.LND.AGRI.ZS?end=2016&start=1961

[2] Source: https://nacoesunidas.org/fao-reduzir-desperdicio-de-alimentos-contribui-para-combate-as-mudancas-climaticas/

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In order to ensure the high quality of the proposed work, the IO has been reviewed by the VET teachers involved in the projects and 4 external specialists. The profiles of the external specialists are reported as follow:

Ana Isabel de Sousa Arsénio has as academic path a degree in Horticultural Engineering (1998) and a master in Horticulture (2015) from the University of Algarve. Works in Rural Development at "Association In Loco" since 1998, having worked on projects in the areas of: Organic Farming, Local Farm, Agriculture and Biodiversity, Sustainable Tourism; Food Waste and Healthy Eating; Responsible and Sustainable Consumption; Local Production and Short Supply Food and Marketing Circuits; Awareness and Information (forest fires, good agro-forestry practices, organic farming). Also collaborated in other organizations like INE - National Institute of Statistics; SALVA - Organic Farming Producers Organization and FCT - University of Algarve as a collaborator in the project "Wastewater Reuse".

Enrico Balugani is an Environmental Scientist (MSc, Bologna University, Italy) specialized in modelling environmental systems and in hydrogeology and soil physics (ongoing PhD, Twente University, The Netherland). He worked both in the university (monitoring and modelling of the coastal aquifer in Ravenna, Italy) and in the private sector (Identifying recharge areas and modelling regional aquifer in Huila department, Colombia). He is currently working with Bologna University as a modeller for the STAR-ProBio H2020 European project, developing and implementing a dynamic model to estimate the indirect land use changes (ILUC) effects of an increase in the production of bio-based materials. His experience includes remote sensing, data science, modelling (statistical, numerical), meta-modelling (model uncertainty estimation, sensitivity analysis), managing interdisciplinary studies, soil physics, hydrogeology.

Emanuela D'Agostino born in Palermo in 1985, she studied Anthropology and Intercultural Communication at the University of Turin. After attending a Master Course in Organization and Management of Events, she travelled to Brazil to discover the local medicinal plants and natural remedies. Once came back in Sicily, she attended a Naturopath course at Naturovaloris School of Naturopath in Catania and in haunt Qualiterbe, a phytocosmetics and phytoterapics herbal laboratory near Pitigliano (GR). In 2017 she obtained the diploma and started to be a Naturopath at Pura Vita Centre in Polizzi Generosa(PA). In 2018 she obtained the European certificate GACP in Scariff, Ireland. Since the last two years, she collaborates in the organization of Erasmus+ Youth Exchanges as a trainer in herbalism, naturopath and medical plant matters. She is specialised in phytotherapy and essential oils.

José Castro is a senior expert in Innovation mainly working in agriculture production, bioenergy and social innovation. He is an agriculture engineer (1992) and MBA Ex (2005). He has been general management in LA UNIO with a long knowledge on agriculture culture and socio-economic aspects. He is also co-editor of the Magazine "Camp Valencià". He is a part of a Focus Group in EIP-AGRI, also, he is advisor in European program Climate KIC and evaluator (H2020 program) to EC. Currently he is working in several European projects related farming, agro-food and environmental issues. His current job is Director of Projects Department of LA UNIO.

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Luana Ladu holds a M. Sc. in Economics from UFBA (Brazil) and a Degree in Law and Business Administration (Master equivalent) from Bocconi University (Italy). She has several years of experience as consultant and researcher in the field of international development and sustainable development, with a focus on sustainability, circularity and bio-based economy. She is currently working as a Research Fellow at the Chair of Innovation Economics in the framework of the STARPROBIO and STAR4BBI projects, where she is responsible for the implementation of different foresight exercises (including scenario development and Delphi surveys), regulatory framework analysis and market studies. She is also finalizing her PHD in economics. She counts with many years of professional experiences abroad, including 3 years as a consultant at the ICT for Development Division of the Inter-American Development Bank (IADB), developing and implementing its “ICT in Governance and ICT security for the public sector” program as well as its ICT strategy entitled “Connecting the Majority”. During her professional experience as project manager and project director in a consulting firm, she was involved in the implementation of numerous donor-finances projects in the field of Education, Vocational Training and Capacity Building sector.

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GLOSSARY

Bioeconomy	Economy based on the production of renewable resources such as plants, wood and waste, and their conversion into food, feed, biobased products and bioenergy
Bio-based products	Products wholly or partly derived from organic material, such as plants, trees or animals (the biomass can have undergone physical, chemical or biological treatment). (European Standard EN 16575:2014 'Bio-based products)
Biomass	Plant or animal material used for energy production, heat production, or in various industrial processes as raw material for a range of products
Benchmark	Point of reference against which information may be compared
Best practice	description of an applied successful strategy that can serve as lesson for other cases
Circular economy	Circular economy is an economic system aimed at minimizing subproducts and making the most of resources. This regenerative approach contrasts with the traditional linear economy, which has a 'take, make, dispose' model of production
Ecosystem	An ecosystem includes all the living things (plants, animals, and organisms) in a given area that interact with each other, as well as the non-living environments (weather, earth, sun, soil, climate, atmosphere) that surround the living things.
Feedstock	Raw material (input) fed into a process for conversion into something different (output). Crude oil is a feedstock in a refining process which produces gasoline (petroleum).
Fossil-based products	Products derived from non-renewable resources (like oil) to build polymers and/or chemicals

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MODULE 1

INTRODUCTION TO THE CITRUS WASTE VALORISATION

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1.1. TRADITIONAL CONSUMPTION AND NEW DEMANDS FOR HIGH QUALITY CITRUS PRODUCTS

The term citrus is used to denote a wide range of fruit species, among which the most important are sweet orange, mandarin, lemon and grapefruit. In addition to being used as fruit trees, some citrus species are also used as ornamental plants in public spaces, in private gardens and as indoor plants. This group of species are originated from Asia and the Malay Archipelago (Vavilov, 1926), but they found in the Mediterranean a second homeland, where their production has been going on for centuries and where the quality of the fruits reaches very high levels, even higher than in their areas of origin. Mediterranean Basin became an important citrus production zone, especially mandarins, and much of this fruit is exported as fresh fruit. Some Mediterranean countries are important citrus producers and exporters. Spain is the most important exporter of fresh citrus fruits in the world. This country exports more than one and a half million tons of oranges each year, nearly the same amount of tangerines and about six hundred thousand tons of lemons (FAO, 2019). Italy is the most important producer of blood oranges.

Some of today's citrus fruits originated in the Mediterranean through natural mutations or hybridizations. This is the case of clementines, very popular for their ease of consumption and the almost absence of seeds.

Citrus fruits have been part of the Mediterranean diet for many years, being consumed as fresh fruit, but also used to make various dishes and desserts (Duarte *et al.*, 2016). However, in the last decades, citrus consumption has evolved considerably, following what happens with almost all kinds of food. Consumers and society demand from farmers the supply of food with guarantees of quality and with a low environmental impact. However, the prices paid to the farmers are many times a small part of the value paid by consumer in the supermarket. Packaging, marketing and transporter structures retain most of this value. These conditions bring the farmer to rationalize the resources application. In this context, the fact that production residues can be regarded as a resource potentially provides an economic advantage for farmer and has also a positive effect on society's image of citrus production.

1.2. BUSINESS MODELS IN THE CITRUS SECTOR OF THE MEDITERRANEAN COUNTRIES

In Mediterranean countries citrus trees were cultivated together with other fruit trees, in a polyculture system on familiar farms. Almost all those farms included also livestock. In these complex systems the waste of a sector was a resource to other(s). Damaged fruits were used to feed swine or other livestock species. The chickens grazing in the field took advantage of all the uncollected fruits and still controlled the weeds and some pests in the garden. Wood resulting from pruning was used as fuel in the farm itself or at the home of farmers or rural workers.

In the last decades this type of farm has been disappearing. In their place appeared specialized farms. Those engaged in citrus production usually have no other productions. Those farms achieve

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greater productive efficiency as a result of a greater dominance of production technology. It is easier to master the production technology from a single crop than to do so for a broad set of crops of different groups. However, these specialized farms acquire all the production factors and sell almost all production, since self-consumption has almost no expression. On these farms everything the orchard produces but is not accepted on the market is a waste and represents an additional production cost due to waste management. There are no other farm activities that can absorb/use this waste. The conversion of the farms to the monoculture leads to a reduction in the environmental sustainability of the farms themselves and of the territories in which they are located (Jacques & Jacques, 2012; Fernandes et al., 2016).

The shift from polyculture to specialized production has been accompanied by a shift from the closer marketing model to a larger scale marketing model that focuses on distant national markets and export. Marketing is now done through fruit packing plants owned by private companies, POs or Groupings that centralize production for larger markets.

1.3. AGRICULTURAL PRODUCTION MODES AND QUALITY CERTIFICATION

In recent years different farms have taken different strategies in terms of production mode. Integrated production is the minimum in terms of production sustainability that all farms had to adopt. Some have gone further and have been converting to organic farming. Some companies continue to have a strategy of intensifying production and there are even some experiences towards the establishment of super intensive orchards. The most sustainable modes of production are certified by independent certifying organizations.

1.3.1. INTEGRATED PRODUCTION

Integrated Plant Protection (IPP) has been adopted by most citrus growers for several decades. This consists of a balanced approach to managing crop production systems for the effective, economical and environmentally sound suppression of pests and diseases. IPP is not a stand-alone concept but should be integrated into the production system since many other components of tree fruit production can impact the prevalence of weeds and plant pests and diseases. The successful application of most IPP components is very dependent on the proper management of other production practices. For this reason, integrated production turned out to be the production system adopted by almost all farmers.

Integrated production is regulated in each of the countries of the European Union and in some cases, regulations may be specific to each region.

In the case of Portugal, integrated production standards are applied throughout the national territory and, as regards pruning, stipulate that pruning is advisable to be carried out after harvesting as often as is appropriate to avoid problems of alternate bearing, improve fruit quality, improve tree aeration and lighting (Fig. 1), facilitate harvesting and increase the effectiveness of

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pesticide treatments (Cavaco & Calouro, 2005). About the destination to be given to pruning waste establishes that the burning of pruning residues in the parcels is prohibited. In orchards in good sanitary conditions it is advisable to incorporate pruning residues into the soil after it has been fragmented and shredded on site. In cases of doubt about sanitary conditions of the pruning waste, composting is recommended whenever possible (Cavaco & Calouro, 2005).

Figure 1 – Good fruit production inside the canopy on a 'Washington Navel' orange tree, pruned to improve tree aeration and lighting.

In the case of Spain, integrated production standards for citrus fruit have been established for the different autonomous communities in which the citriculture is of major economic importance.
For the Comunitat Valenciana the standards for integrated production in citrus were approved by the Regional Government [Conselleria de Agricultura, Medio Ambiente, Cambio Climático y Desarrollo Rural (CAMACCDR)]. In this region, burning of pruning waste is not completely prohibited It is only said that the burning of pruning waste is prohibited under uncontrolled conditions and when there is a risk of fire spread. In these norms it is recommended to incorporate the pruning waste by means of cutting and crushing it in situ, except in the case that they show symptoms of attack by pests or diseases (*Alternaria* and other fungi). In this case, pruning waste will be removed from the field and burned immediately (CAMACCDR, 2017).

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The integrated production standards of the Community of Murcia recommend the "destruction of pruning waste outside the crop plot, preferably by fire (Fig. 2). In case of crushing within the plot itself, make sure that the size of the remaining chips is smaller than 10-15 cm" (CAA-CARM, 2007).

Figure 2 - Burning pruning waste inside a citrus orchard.

The Andalusian Integrated Production Standards recommend "incorporating pruning waste into the field by cutting and crushing in situ, except in plantations affected by diseases in which pruning waste may contain the disease inoculum" (CAPDR-JA, 2015).

In Italy, Sicily and Calabria's integrated production technical standards refer to citrus pruning as an important cultural operation, but do not determine the destination of pruning waste (ARASPM-RS, 2017; DARASFR, 2018). Thus, the adoption of integrated production does not guarantee that pruning waste will be recovered in all Mediterranean countries.

1.3.2. SUPER INTENSIVE ORCHARDS

The super intensive production technology that has been developed for olive and other fruit crops is being adapted to citrus trees. But so far, this technology is limited to a few trials. This production technology is based on annual pruning with the elimination of all branches that go outside the boundaries of a hedge and topping (Fig. 3). Thus, the amount of pruning waste to be produced by this form of citrus training system will be very high. This makes the valorisation of pruning waste very important if this technology will be adopted on a large scale.

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Figure 3 - Mechanical pruning of an experimental super intensive citrus orchard.

1.3.3. ORGANIC FARMING

Organic farming, also known as "agricultura ecologica" (Spain), "agricoltura biologica" (Italy) or "agricultura biológica" (Portugal), is an environmentally friendly mode of production whose importance has increased in recent decades. Organic growers are prohibited from using most synthetic pesticides and fertilizers and must take measures to protect water and soil quality. The Organic Farming logo is a guarantee that the food we are buying was produced in ways that minimize harm to our health and the environment. The organic logo can only be used on products that have been certified as organic by an authorised control agency or body. This means that they have fulfilled strict conditions on how they must be produced, processed, transported and stored. The logo can only be used on products when they contain at least 95% of organic ingredients and additionally respect further strict conditions for the remaining 5%. So, it is a high-quality fruit production for local markets and for export.

European Regulation (EU) No 848 (2018) did not lay down specific rules on pruning or pruning waste in organic farming. However, this mode of production is based on the use of local resources and the minimization of waste generation, integrating in the spirit of the circular economy. Pruning citrus grown in organic farming is important for pest and disease control. In this production mode it makes no sense to burn pruning waste. The most recommended is its incorporation in the soil, to increase its organic matter content. One of the principles of organic farming regulation is to improve or

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maintain soil fertility, so any operation that allows organic matter to be returned to the soil is advisable, such as shredding pruning waste and incorporating it into the soil.

1.3.4. GEOGRAPHICAL INDICATIONS

Citrus fruits produced in some regions of the Mediterranean Basin have a high quality, recognized by consumers and markets. The European Union has been recognizing the quality of these products and establishing protected names that are used to value products that go through a certification process which ensures their authenticity. At this moment there are at least 5 protected geographical indications (PGI) for citrus fruits: *Citrinos do Algarve* (Portugal), *Cítricos Valencianos / Cítrics Valencians* (Spain), *Arancia Rossa di Sicilia* (Italy), *Arancia del Gargano* (Italy), and *Citron de Menton* (France). There is also a protected designations of origin (PDO): *Arancia di Ribera* (Italy). Even when the fruit certified under these denominations does not receive the deserved price appreciation, the certification seal facilitates the marketing of the fruits.

Each geographical indication has a specification setting out the rules to be respected for fruit production. Some of the geographical indications include norms regarding the level of sustainability of production.

1.4. RELEVANT ACTORS IN THE PRODUCTION AND MARKETING OF CITRUS

Citrus production is increasingly concentrated in a small number of farmers. This process is most evident in some regions such as Andalusia in Spain or Alentejo in Portugal. These larger farmers play an important role in the dissemination of new citrus production strategies. In regions such as Valencia, Spain, or the Algarve, Portugal, rural property is more divided and citrus farms are smaller. In these regions, producer organizations, which concentrate and market the production of dozens (or hundreds) of farmers, are the most relevant actors in the production and marketing of citrus.

Changing farming practices obviously must go through changing the mindset of farmers and changing the factors that contribute to their decisions. Farmers' associations and producer organizations play a relevant role in disseminating information leading to the modernization of farms or the adoption of new production strategies. Awareness-raising campaigns on the need to make agriculture more sustainable include, in the case of citrus, recommendations for a more sustainable treatment of pruning waste. However, given farmers' short margins of profit, cultural practices change in mass only when legislation / regulation requires it or when new practices are economically viable (by changing prices or by consumer demands).

Producers organizations, cooperatives, private packinghouses and juice industries often place new demands and disseminate information that contributes to changes in agriculture. Often the certifications required by commercial chains through packinghouses and juice industries are stricter than official regulations. In this case, farmers, in order to be able to sell their produce, are obliged

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to change the way they produce. For this it is also important that the certifying entities do their work well, advising and demanding compliance with the established rules.

1.5. CONCEPT OF CIRCULAR ECONOMY AND ITS APPLICATION TO CITRICULTURE

The concept of circular economy began to be developed by Kenneth Ewart Boulding in 1966, although he did not use the term "circular economy". This author created the concept of "spaceman economy" or closed economy, as an economy model that should replace the "cowboy economy" or open economy (Boulding, 1966). He called the "open economy the "cowboy economy," the cowboy being symbolic of the illimitable plains and associated with reckless, exploitative, romantic, and violent behaviour, which is characteristic of open societies" (Boulding, 1966). The closed economy was considered by Boulding as the economy of the future which he called the "spaceman" economy, "in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy" (Boulding, 1966).

The term "circular economy" appears to be first used by Pearce & Turner (1990) as an economic model based on the principle that 'everything is an input to everything else'. Indeed, the concept is very similar to Boulding's "closed economy" concept. In recent decades, a growing body of literature has emerged that has influenced our current understanding and interpretation of the term "circular economy" (Lieder & Rashid, 2016; Rizos *et al*., 2017).

To understand the concept of circular economics, it is necessary to draw on the knowledge and concepts of industrial ecology that involves a holistic perspective in dealing with human economic activity and sustainability. This discipline introduces the notion that the natural ecosystem and the man-made industrial (or agricultural) system operate similarly, and both are characterized by flows of materials, energy and information (Erkman, 1997; Ehrenfeld, 2007).

Currently, there are several possible definitions for the term "circular economy". Several authors have provided resource-oriented definitions, emphasizing the need to create closed-loop material flows and reduce the consumption of virgin resources, while also mitigating the detrimental environmental impacts of their extraction. Sauvé *et al*. (2016), defined the circular economy as the "production and consumption of goods through closed loop material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)''. For these authors, the circular economy implies above all the reduction of resource consumption, pollution and waste at each stage of the product life cycle. Keeping resources in use for as long as possible and extracting the maximum value from products and materials, using them for as long as possible and then recovering and reusing them are also important aspects of circular economy (Mitchell, 2015). Other authors stress that the transition to

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a circular economy requires facing the challenge of establishing a sustainable supply of energy, as well as decisive action in several other areas, such as agriculture, water, soil and biodiversity (Heck, 2006). Circular economy can also be defined as "an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models'' (Ellen MacArthur Foundation, 2013)

Applying the circular economy principles to citriculture requires a reduction in pesticide application, an increase in the life of the orchard, the reuse of all residues resulting from the production and processing of fruits, the use of residues from other crops or other agricultural activities (for example, livestock) (Raimondo *et al*., 2018). The adoption of this new approach may lead to an increase in fruit quality, namely an increase in vitamin C content in the juice (Duarte *et al*., 2010). From a circular economy perspective, branches and leaves removed from trees during citrus pruning should not be considered as waste, but as a by-product with some use.

1.6. ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE PRODUCTION AND MARKETING OF CITRUS FRUITS.

In citrus orchards the waste produced in bigger quantity are the pruning waste (branches and leaves removed) and the fruits damaged by pests, diseases or physiological disorders.

Traditionally, pruning residues were eliminated from the orchard and burned. In recent years, farmers have started grinding the pruning wood between the tree lines (Hondebrink *et al*., 2017). This leads to the enrichment of the soil in organic matter, creating a dead blanket on the ground (Fig. 4). This enrichment in organic matter improves soil structure, increases water infiltration, decreasing rainwater runoff (Hondebrink *et al*., 2017). The crushing of the pruning wood is done simultaneously with the destruction of the weeds (Duarte & Martins, 2005), which also, end up enriching the surface layer of the soil in organic matter.

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Figure 4 - Crunched pruned branches between tree lines.

Compared with the burning of the pruned branches, crushing it is economically more viable and environmentally more sustainable. However, it is not yet clear what effect the existence of citrus wood chips can have on the surrounding trees. This dead wood provides the development of fungi, which can pass into the trees themselves. In cases of serious diseases, removing pruned branches from the orchard is a necessary measure.

Removing pruned branches out of the orchard and using them as a resource elsewhere may be the most sustainable solution.

As regards the marketing of citrus fruits, their packaging and transport to distant markets has a significant environmental impact.

1.7. VALORISATION OF CITRUS BY-PRODUCTS

For valorisation of citrus waste, we need to consider it as a by-product that should be of some use. The richness of citrus tree branches and leaves in essential oils and energy makes it easier to find use for these materials.

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The leaves of citrus fruits are rich in essential oils, widely used in the cosmetics industry, among other uses. On the other hand, the thicker branches can be used as renewable fuel. Thus, the use of the leaves of pruned branches for the manufacture of essential oils seems to be a good solution for the residue and increases the availability of essential oils on the market, which have potential for wide use, including the replacement of products from chemical industry. Unmarketable fruits can be used for extraction of essential oils or composting.

1.8. CITRUS BY-PRODUCTS AS A SOURCE OF ENERGY

Agricultural resources are important sources of energy, indispensable for further technological development, especially in rural communities (Bentsen & Felby, 2012; Berthet *et al*., 2016). In this regards, in the last decade, an energy strategy to mitigate climate change was discussed by the European social media emphasizing the achievement of definite environmental goals of energy strategy and advancement (Banja *et al*., e2017) of agriculture-based bioenergy and biofuels (Lyytimäki, 2018; Isoaho & Karhunmaa, 2019).

However, the use of biofuels also has drawbacks and, from a negative perspective, the use of agricultural areas for energy crop cultivation may decrease future availability of arable land for food production, which may result in food deficiency (Srirangan *et al*., 2012). Installing a biomass plant in regions producing biomass from forest or agricultural activities is a more sustainable solution. (Bonazi *et al*., 2018).

Considering these trade-offs, the development of new technologies for the valorisation of pruning wood as a resource and the dissemination of this technology among trainees in vocational schools are an important contribution to circular agriculture and circular economy as well as to minimise the effect of citrus production on climate changes.

In rural areas, the establishment of self-sufficient agro-energy districts is a viable alternative as long as local resources are properly harnessed (Colantoni *et al*., 2016a, 2016b; Zambon *et al*., 2016; Al-Hamamre, 2017; Carlini *et al*., 2017; Moulogianni & Bournaris, 2017). In these areas, the implementation of these new technologies can contribute to significant increases in the welfare of the population (Walter, 2003).

The use of waste as a source of energy is one of the elements of agricultural innovation that must be considered as a co-evolutionary process where technological, socioeconomic and institutional changes are combined (Leeuwis & Aarts, 2011; Klerkx *et al*., 2012). In some cases, the pruned thicker branches are separated and used in ovens (Fig. 5).

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Figure 5 - After pruning, the pruned thick branches were separated for later burning in bread ovens.

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The transformation of citrus waste in bioproducts. Techniques, methodologies and technologies

Manual for agricultural VET teachers

MODULE 2

METHODS AND TECHNOLOGIES OF VALORISATION

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UNIT 1. ECOCITRIC PROJECT

Summary

The main characteristics of the ECOCITRIC process for the valorisation of citrus waste will be studied in this subunit. The first step will be the citrus territory ordination. This ordination has as goal to obtain information about the different citrus parcels in the plant surroundings, to manage this information in order to calculate suitable routes for the waste collection.

Among the logistic models with whom the ECOCITRIC process has worked, the first alternative for the citrus waste pruning collection will be analysed: the direct waste collection in the field and the subsequent crushing in the unit. Later, another studied alternative is detailed: the direct pruning crushing in the field and its transportation to the unit. Moreover, an economic and environmental comparison will be performed, reaching conclusions.

2.1.1. INTRODUCTION TO THE ECOCITRIC PROJECT

The LIFE ECOCITRIC project started due to the lack of an efficient process for the management of citrus pruning waste. As seen in the previous units, the direct burn is the main process of elimination, especially in the geographic area of the project (Castellón province), presenting a grave environmental problem.

The project was carried out from 1st June 2014 to November 2016, achieving a grant from the European Union. The project led by the council of La Vall d'Uixó had as goal to prove the technic, economic and environmental viability of a new integral exploitation system of farming waste coming from the citrus pruning in the municipal term.
Therefore, the ECOCITRIC system is an innovative industrial process that allows the integral usage of the fruit trees' waste (mainly leaves and branches) and its valorisation through its transformation in different value-added subproducts. These subproducts are mainly: essential oils, foliar fertilizers, animal feed, livestock bedding and biofuel.

Moreover, the ECOCITRIC process has been designed to maximize performances and reduce energy consumption of the subprocesses using the biofuel to generate heat.

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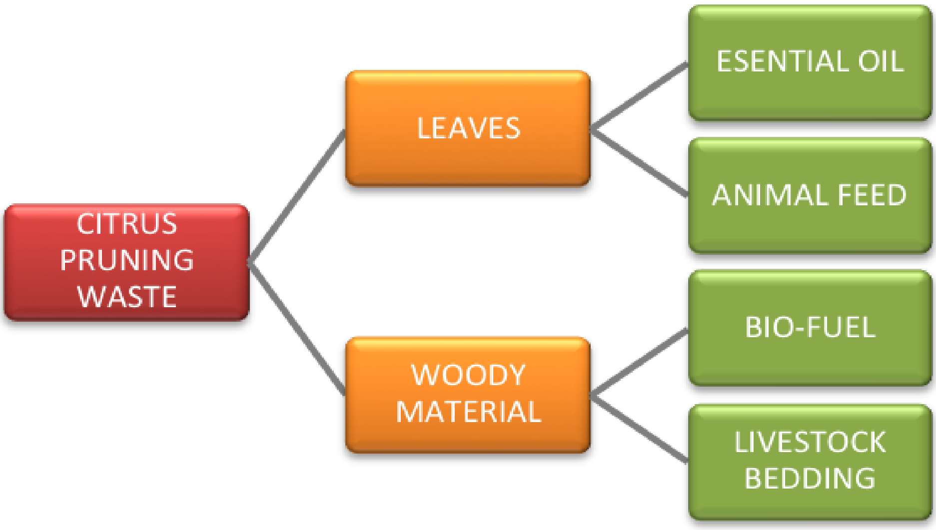

Figure 1. Subproducts outputs in the ECOCITRIC process

Finally, the specific goals within the ECOCITRIC project to be highlighted are:

- **Solving the problems of citrus waste**. This goal is framed by trying to stop the burn of citrus pruning waste and, therefore, reducing the atmospheric and terrestrial pollution, at the same time that achieves a better fire prevention.

- **Reducing CO_2 emissions**. The waste burning can generate up to 1.83 T/CO_2 per waste tone. Consequently, the valorisation done in the processes allows to mitigate the emissions of greenhouse gases.

- **Producing high value-added subproducts.** Quality products using citrus waste: essential oil, animal food, foliar fertilizer, biofuel and bedding.

- **Planning of the agricultural territory (GIS).** Creation of a citrus map to know the amount of waste generated by the municipal term of La Vall d'Uixó, as well as the species and cultivated hectares.

- **Laying the foundation for future ordinances and regulations to promote the correct waste management.** Increase farming interest about the environment-friendly waste management to avoid its burning.

- **Demonstration effect.** Installation of the ECOCITRIC process in an industrial plant to encourage its replicability in other territories.

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2.1.2. HOW IS THE CIRCULAR ECONOMY IMPLEMENTED?

As already seen in subunit 1, circular economy is a model that seek to produce goods and services in such a way that the consumption and the waste of raw materials, energy sources and water are reduced. In recent years, a lot of policy, business and social proposals are oriented to favour the circular economy, due to its benefits.

On the second of July 2014, the European Commission published the communication "towards a circular economy: a zero-waste program for Europe". With this communication the European Commission asked to cut the growth pattern based on "take-make-consume and dispose”. On this path, from Brussels, it is recommended to advance towards models that support the circular economy, reducing the environment deterioration while rising the European competitiveness.

In this frame, the Life program is a European Union financial tool dedicated to the environment. As detailed in **i-ambientet.es**, “Life Ecocitric is an example of the type of business model that Europe should be addressed to. Through branches and leaves coming from the pruning of this project, which started in La Vall d’Uixó (Castellón), essential oils, foliar fertiliser, animal food, livestock bedding and biofuel are produced”.

Therefore, these subproducts come from a circular economy process, due to its obtention from waste.

Moreover, some parts of the biomass elaborated is used in the same heat generator process through a biomass boiler. This allows to create resource flows, achieving a higher energetic independence of the process compared to external companies.

2.1.3. PARTS OF THE ECOCITRIC PROCESS

This point will be used as introduction to the different parts of the ECOCITRIC process that will be studied in the following units. This study comes from the project planification to the transformative process in the industrial plant (Fig. 2).

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Figure 2 – ECOCITRIC front plant

The first point would be the **citrus territory ordination**. This phase is linked with the plan for gathering raw materials, in this case citrus pruning waste.

The detection of parcels and its characterisation is also included within the territory ordinance to perform this task. Potential parcels containing citrus crops are studied, including the type of crop, the parcel's hectares and its perimeter. Once the data is obtained, a geographic information system (GIS) is planned to classify the parcels in areas, making information more accessible. From all the available information, the calculation of the pickup route can be performed more ideally in each case.

The next step is to conduct the project logistics for the waste **pruning and collection**. In this section there are different alternatives to perform these tasks: pickup in the field and crushing in the unit or crushing in the field and transport to the unit. Pros and cons are analysed for both cases from the economic and environmental point of view.

Finally, the process performed in the **ECOCITRIC plant** is described, where the raw material is transformed in value-added products. In Unit 3, the type of machines used will be studied, as well as the material flows of the process. Besides, the main features of the three main products obtained in the process will be detailed: animal feed, essential oils and biofuel.

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UNIT 2. SOLUTIONS FOR THE COLLECTION AND LOGISTICS OF CITRUS WASTE

Summary

The main characteristics of the ECOCITRIC process for the valorisation of citrus waste will be studied in this subunit. The first step will be the citrus territory ordination. This ordination has as goal to obtain information about the different citrus parcels in the plant surroundings, to manage this information in order to calculate suitable routes for the waste collection.

Among the logistic models with whom the ECOCITRIC process has worked, the first alternative for the citrus waste pruning collection will be analysed: the direct waste collection in the field and the subsequent crushing in the unit. Later, another studied alternative is detailed: the direct pruning crushing in the field and its transportation to the unit. Moreover, an economic and environmental comparison will be performed, reaching conclusions.

2.2.1. INTRODUCTION TO LOGISTICS

In the ECOCITRIC project a study and comparison of diverse logistic system for collection and possible transport was made with the goal of optimising the waste integral valorisation, for selecting the better option among all the considered alternatives related with the citrus pruning waste management.

In order to achieve an efficient management of the citrus pruning waste, first a working plan needs to be elaborated regarding the logistic and transport of this material from the origin to its treatment in the pilot unit. For this reason, the perfect usage of logistic and transport media needs to be ensured with the goal of achieving the lowest costs possible.

Logistics include the storage management, and the goods and information movement. Good logistics reduces costs and improves the service level in the eyes of the end consumer. Logistics is then the raw material flow (citrus pruning waste) process of planning, implementing and controlling, from the transformation point to the origin point, in an efficient way and as economic as possible in order to recuperate its own value or the value of its return.

In this logistics and transport plan the following variables will be taken into account:

- **Costs:** a good logistics and transport plan will reduce the pruning waste management cost.
- **Time:** with the application of the current plan supply, shipment and delivery times will diminish, what equals to the reduction of costs.

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- **Quantity:** the quantity must be suitable to do the process without degrading or hoarding it, what would represent a problem for the process.
- **Handling of raw materials:** all the time dedicated to the optimum arrival of the material for the valorisation process.
- **Staff:** with the suitable staff for the pruning waste transport and logistics, costs will diminish.
- **Logistics and transport means:** transport and machinery used. The most recommendable physical means will be used for the valorisation process.

Logistics and transport management will also include the route for the material movement, esteemed:

- **Physical distribution:** meaning each stage of the mode of transport and the transport operator. Physical distribution is not only a significant cost, also has a direct impact in its competitivity by optimizing the delivery of the material on time.
- **Transport modes of the raw material:** it is extremely important to choose the pickup method and transport of the material, as the success of the project depends partly on this.

2.2.2. STUDY OF THE DIFFERENT COLLECTION AND TRANSPORT METHODS

Next, the different trials conducted for the Life ECOCITRIC project for the pruning waste transport and collection optimisation to the valorisation pilot plant are detailed.

The following trials for the technic and economical optimisation of the pruning waste are analysed:

- Pruning waste shredding in the field, direct loading in Big-Bags and subsequent transport to unit.
- Pruning waste shredding in the field, direct loading in an integrated dump truck and subsequent transport to unit.
- Pruning waste truck transportation and subsequent shredding in unit.

Next, the proven methodologies are detailed.

2.2.2.1. Field pruning waste shredding, direct loading in big-bags and subsequent transport to unit.

For the implementation of this test, the citrus pruning waste is shredded in the field and added, already shredded, in big-bags to facilitate its subsequent transportation. The shredding is performed by a modified tool operated by the tractor's power take-off, shredding by movement (Fig. 3). The test made was for the varieties of mandarin ‘Clemenules’ and ‘Navelate’ oranges in different parcels of the municipal term of La Vall d’Uixó.

Thirty-four big-bags were filled with the shredded waste and transported by boom truck to the pilot plant.

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Figure 3 - Tractor with shredding equipment with direct loading in big-bags (Source: Life Ecocitric).

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2.2.2.2. Pruning waste shredding in the field, direct loading in an integrated dump truck and subsequent transport to unit.

Another test made in the ECOCITRIC project was the direct loading of pruning waste shredded to a dump truck. The pruning waste shredding is done again in the same parcel by a tool operated by the tractor's power take-off, shredding by the machine's movement. The main difference of this tool is the addition of a built-in tipper where the shredded material is automatically introduced. With the goal of facilitating the pruning waste transport to the plant, the built-in tipper is emptied in a bigger container and transported to the plant when it is full.

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Figure 4 – Shredding tool with tipper integrated (Source: Life Ecocitric)

2.2.2.3. Pruning waste truck transportation and subsequent shredding in the plant

In this case, the citrus pruning waste transportation to the pilot unit was done by a loading truck in order to shred it in the same pilot plant. The transport of the ECOCITRIC project was done in a standard truck equipped with a boom to collect the pruning waste and introduce them in the truck. Previously, the farmer must have transported the parcel's pruning waste to a suitable place to

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facilitate the truck loading.

This test was done several times, in 5 different parcels, and all of them within the municipal area of La Vall d'Uixó. Measurements of the time spent and the quantity of material transported are noted. The farms where the tests were carried out are the following: Sagunto, Onda, Perlo, Pla de Llobet and Pla de Pinar.

Figure 5 – Pruning waste loading in truck (Source: Life Ecocitric)

2.2.3. RESULTS OF THE APPLICATION OF DIFFERENT COLLECTION AND TRANSPORT METHODS

2.2.3.1. Pruning waste shredding in the field, direct loading in Big-Bags and subsequent transport to unit.

Some issues of this method observed while performing the Life ECOCITRIC project are described below:

- Scarce suitability of the field for the shredding equipment (high peaks in some streets) and difficult tractor manoeuvrability with the equipment.
- Breaking of some parts of the tractor (side mirror, door…) due to the tightness of the parcel streets.
- Breaking of 4 sieves of the shredding equipment, attached with screws that loosened up with the equipment vibration.

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- Part of the shredding is lost in the field because the sack or big-bag does not attach well to the equipment.
- Difficulty for shredding all the pruning of the streets, due to the pruning excess (material build-up blocks the tractor's progress) or by default (the material falls on the tractor's side, outside the shredding equipment area). All of it causes time loss due to the properly relocation of accumulated pruning or to the failure of collecting the material for its shredding.

All the equipment must be greased with oil each 2 hours and this causes time loss.

With all this, it takes 22 hours to fill a total of 34 big-bags, placing them in sacks by the field road edges to facilitate its subsequent collection.

For the transportation to plant, in the Life ECOCITRIC project, a boom tractor was used to pick up big-bags and place them in the loading area of the boom truck, to facilitate its subsequent transport to the pilot plant. Another issue was the delay times to fill the trucks with the big-bags, task that needs a lot of time.

The big-bags weighted approximately a total of 6600 kg (around 194,1 kg each big-bag). The maximum daily quantity of citrus pruning that could be done by this method, and having in mind that the working day is 8 hours, would be of roughly 2200 kg daily.

Considering the shredding tool rental that costs 50€/day and the boom trucks that cost 36€/hour for 10 hours, the total price of this method rises up to 77,27 €/Tn.

2.2.3.2. Pruning waste shredding in the field, direct loading in an integrated dump truck and subsequent transport to unit.

Other issues were also observed in the application of this method described below:

- The main problem is the slow pace of the process. During 8 hours roughly one tone was shredded.
- The high quantity of material that is prepared without being collected in the parcel. This way a big quantity of leaves is wasted.
- Dumping difficulty from the tipper to the tow of the boom truck. Apart from being a slow process, the tow cannot be too tall since it would overturn the material placed inside.

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The rental price of the shredding tool is 65€/day. The rental price of the boom truck is 36€/hour. Therefore, and considering that the material is rented for 1 hour, the final cost of this method application amounts to 101€/Tn.

2.2.3.3. Pruning waste truck transportation and subsequent shredding in unit

Results of the transport tests with boom trucks for the pruning waste for shredding it later in the plant are shown in the following table:

FARM	SURFACE (HG)	PRUNING QUANTITY (Tn m.h.)	COLLECTION TIME (hr)
Elodia Farm	36	19,18	15,1
Segarra Quarry	12	6,07	4,9
Alajaria-Pla Pinar	23	13,32	12,5
Perlo I	13	6,6	5,5
Perlo II	13	6,5	5,1
Pla de Pinar	8	3,46	2,26
Onda	23	9,47	11,14

The following data was obtained from the 6 parcels:

- Average quantity of pruning per bushel = 0,505 Tn (m.h.)/hg
- Average collection time (hours/Tn) = 0,87 hours/Tn (m.h.)

Considering that the truck transportation costs amounts to 34€/h, the total cost per pruning waste transport is 29,58 €/Tn.

Then the pruning waste shredding costs in the plant must be added.

The advantage with the application of this method is that the pruning waste is not early shredded, therefore the waste stays in the branch more time. When the pruning waste is fresh and without shredding, it can last much longer until the fermentation starts. As consequence, a big quantity can be collected and the shredding will start once there is a high amount of pruning, minimizing the shredding plant costs.

2.2.4. ANALYSIS AND RESULT COMPARISON. CONCLUSIONS.

Among the three tests done in the Collection and Transportation Logistics Plan, it was decided that the most suitable method, from both the technical and the economical level, is the truck

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transportation of the pruning waste and its subsequent shredding in the plant. Many are the reasons for selecting this method as the ideal one.
Firstly, it is clearly observed that is the most economical method. In the two first tests the conclusion was that the shredding in the field was very slow and inefficient. The spent time in the pruning waste shredding was high and it translates in a major economic cost. Moreover, it adds the issue of having just one shredding tool, the amount of pruning waste shredded was scarce from an industrial use perspective. However, there is a major number of boom trucks to be considered to pick up the pruning waste and transport it to the plant. Thus, the pruning quantity collected would be higher.

In this sense, it should be noted that the pruning waste of this process have to be taken from the inside streets, where the waste is located after the pruning, and placing it in an easy-access place in order to being collected by trucks. This task is done by the field owner, who would afford the burning costs of pruning waste included in the traditional management of the citrus pruning waste. Owners and farmers that have been in contact with the project and where the tests were carried out have shown a high grade of satisfaction and interest on this, as it would suppose an important financial saving.

On the other hand, one of the disadvantages of the two first methods is the scarce "lifespan" of the shredded pruning waste. As said before, the degrading starts very quickly. However, in the third method, the collected pruning waste stays longer without degrading. This makes possible that some quantity can be amounted to its subsequent valorisation, which is not the case of the shredding in the field.
Moreover, the required machinery for the pruning waste valorisation in case of the truck transportation and its subsequent shredding is simple and with an easy placement, due to the common machinery and its usual usage in the area of the project. By contrast, in the previous methods, specific machinery was needed for the work, which had a lower availability in the market, a higher economic cost and needed more time to get the specific tools for its valorisation, as well as its possible repair costs.

2.2.5. CITRUS PRUNING WASTE TRANSPORT AND LOGISTIC PROCEDURE

Once the transport route is settled, an ordinary itinerary is usually designed for the collection of the pruning waste plant material. In said itinerary, the collection truck route will be settled, specifying the collection places of the pruning waste in each parcel, the type of material that will be transported (variety, time elapsed since the pruning…) and the approximate amount of material. For it, the farmer must take out the pruning waste previously to the street and place it in suitable places for its subsequent collection.

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With all these premises, and considering the time for each material transportation, the needed trucks to cover the daily citrus pruning waste demand for its valorisation in the pilot plant of the Life ECOCITRIC project is outsourced to different companies. In this sense, the average quantity of the pruning waste that trucks can transport is approximately 4 tons (average of the tests done up to date). In addition, from the ECOCITRIC project pilot plant the daily quantity collected and stored of the vegetal material for its valorisation will be specified, considering the quantity of material that can be accumulated in the plant before its valorisation and cadence within the process.

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UNIT 3. SOLUTIONS FOR THE VALORISATION AND PRODUCTION OF BIOPRODUCTS

Summary

The waste valorisation and the bioproduct production from the pruning waste are the points that will be discussed in the following chapter. Concretely, in this subunit, it will be studied the waste transformation process into bioproducts in the ECOCITRIC plant, stressing characteristics of the different machines and its sub-processes.

2.3.1. GENERAL DESCRIPTION OF THE PROCESS

The process followed in the ECOCITRIC project obtains, from citrus pruning waste as raw material, a number of products (Fig. 6) such as: essential oils, animal food, foliar fertilizer, livestock bedding and biofuel.

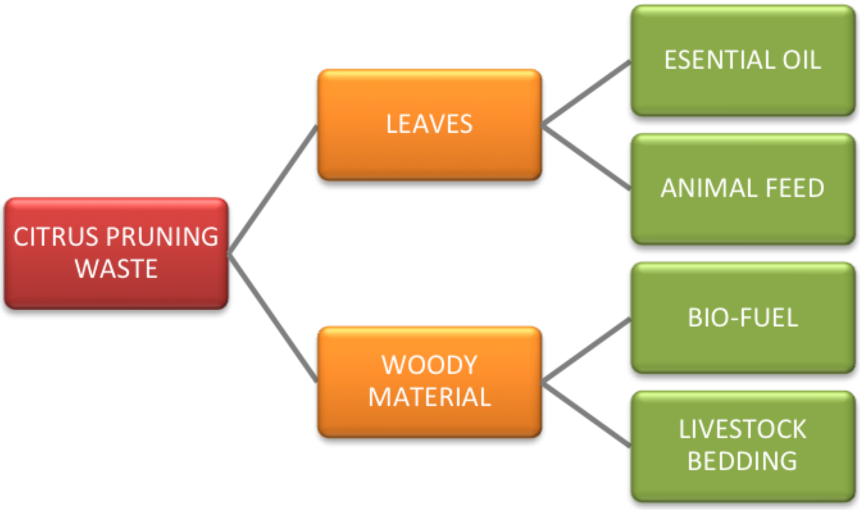

Figure 6 - Bioproducts of the ECOCITRIC process.

On the basis of the waste shredding, including not only leaves but also woody material, different products are obtained. To produce the final products, the leaves must be separated from the woody material, because both materials will need different processing lines to get diverse bioproducts. While is true that some equipment is common for both treatments, leaves and woody material (Fig 7)

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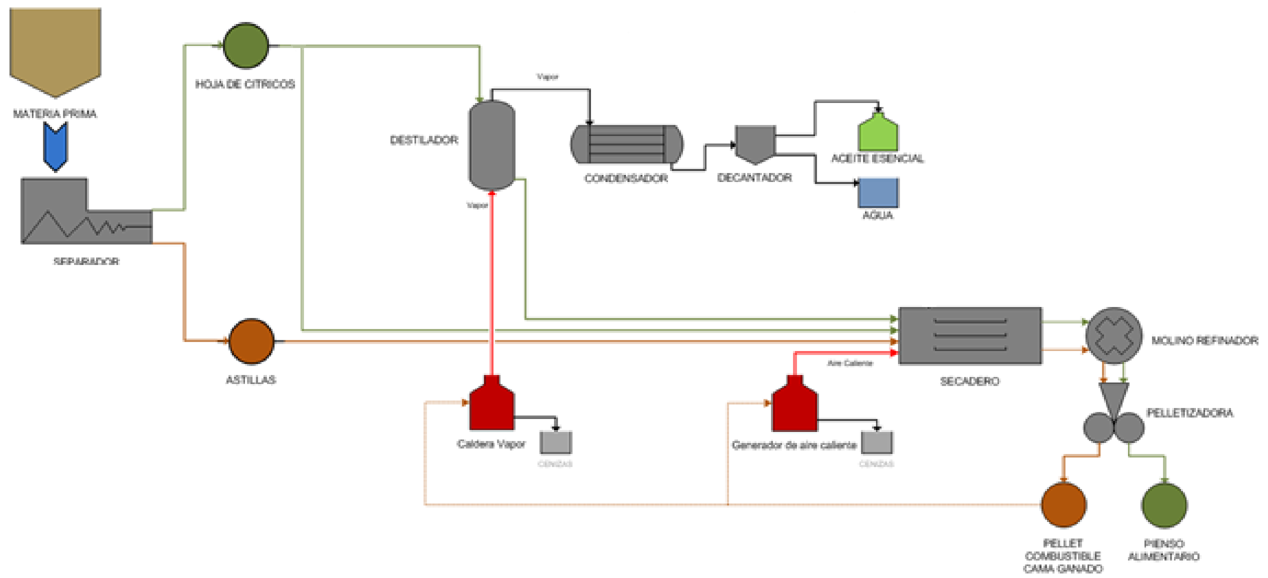

Figure 7 - Production process general diagram.

From the leaf line (green line) essential oils and animal food is obtained. Instead, from the woody line (orange line) livestock bedding and biofuel is made.

In the first case, the leaf is used in the essential oil and animal food process (Fig. 8).

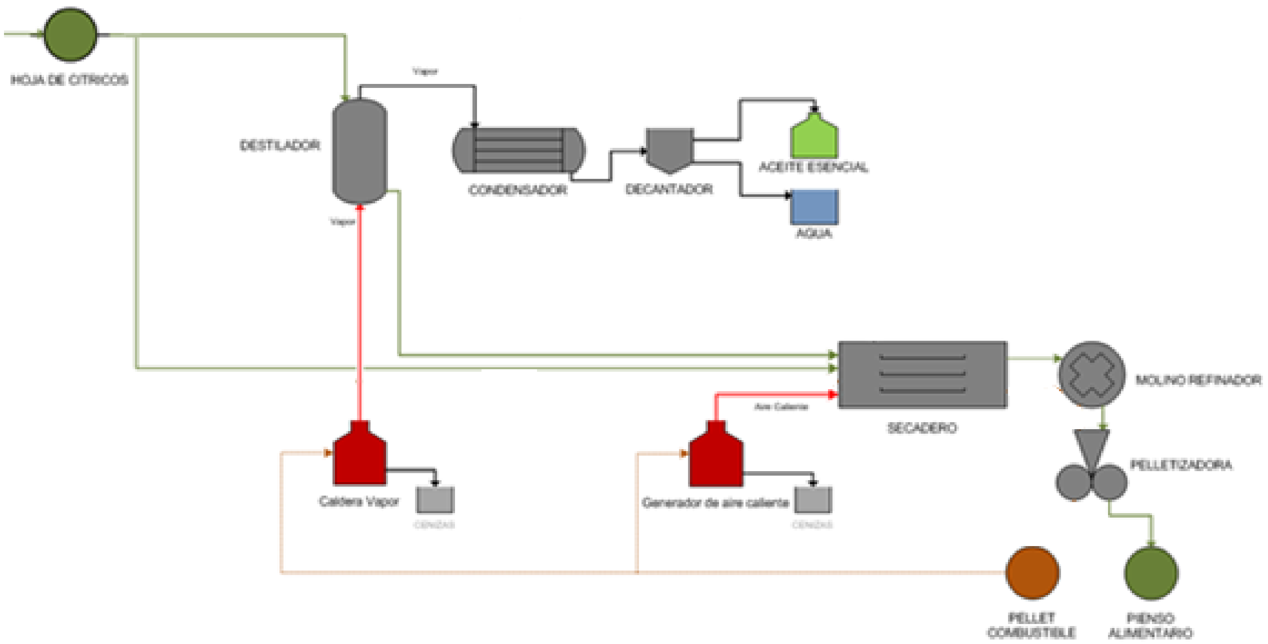

Figure 8 - Leaf processing line.

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To produce the essential oil, the leaf is introduced in the still fuelled by steam of the biofuel boiler. The steam made from the still contains the leaf essences, transformed into liquid in the condenser. The liquid is carried to a decanter, where the pure essential oil is separated from water where it is diluted.

The leaf not intended for the extraction of essential oil and the leaves mass already distilled (bagasse), are used in the animal food production. As first step, it is introduced in the drier. Once dried, the material goes through the refiner mill to improve the pelletizing to obtain high quality animal food.

As said in previous chapters, both the biofuel boiler that provides stem to the distiller and the dryer's hot air generator, are fuelled through the pellet coming from the woody material, therefore following the principles of circular economy.

In the second case, the woody material is used in the productive process for getting livestock bedding and biofuel (Fig. 9).

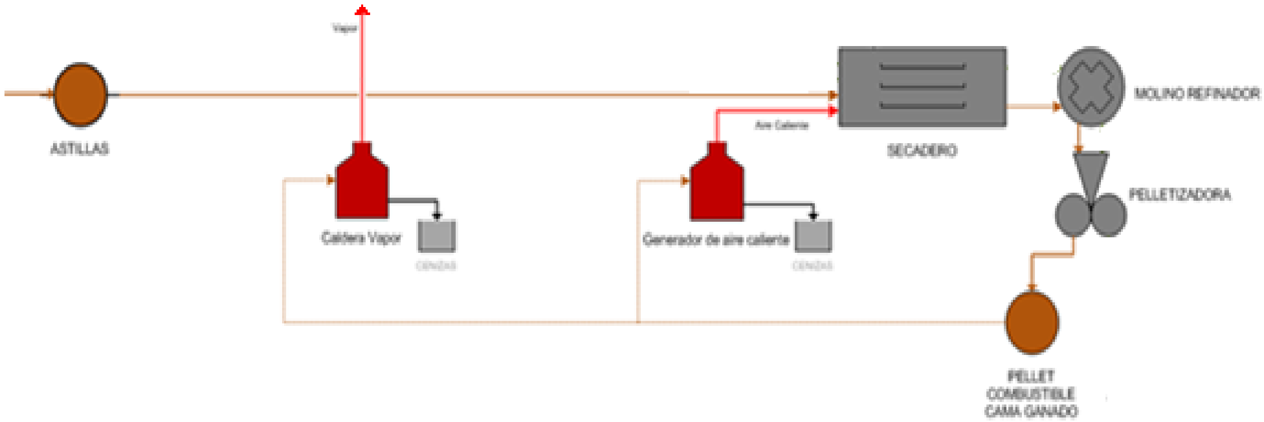

Figure 9 - Woody material processing line.

The woody material from the separator, made up of splinters and shavings, is directly sent to the dryer room. This can be done through natural drying (requiring several days and stock) or with the dryer.

Once the product is dried, it is refined with the refiner mill, achieving a homogeneous material for the pellet through the pelletizing system. The pellet produced can be used for both the livestock bedding (due to its high absorption power) and the biofuel.

A noteworthy alternative in the woody material line is to obtain directly untreated splinters as final product after the drying process.

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Part of the biofuel is used for the heat creation within the process and the other part is the final product intended for sale.

2.3.2. SYSTEMS AND EQUIPMENTS DESCRIPTION

Below, the different stages and general operations made for the ECOCITRIC process are described, as well as the equipment and machinery used in each of the parts.

2.3.2.1. Raw material collection and separation

Depending on the logistic and transport plan, the raw material will arrive shredded to the unit or it will be shredded there. As seen in the previous chapter, it is better to collect the pruning in the field and transport it to the unit in order to shred it there, from both the technical and the economical point of view. Nevertheless, the collection and separation phase start once the raw material is shredded.

Figure 10 - Separation tower and collection system of raw material

The collection and separation system used in ECOCITRIC (Fig. 10) is composed by:

- Raw material collection system by a hopper.
- Feed system through conveyor belt.
- Separation tower.
- Hot air generation system and leaves transport, made by a centrifugal fan.
- Woody material collection system through conveyor belt.

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The product is unloaded in a hopper. In the lower part of the tolva there is a belt that will transport the material to the separator entrace.

The separation is done through air flows on varying densities and drag coefficient particles.
On one side, due to the leaves minor density and drag coefficient, the flow will push them to the upper side of the separator, while the woody material will go downward trend.

The air flows are produced by a centrifugal fan with variable speed through a frequency shifter in the upper side of the separation tower.

2.3.2.2. Leaf distillation systems

The essential oils are biosynthesized substances by plants, with a characteristic aroma of some flowers, trees, fruits, herbs, spices, seeds and certain extracts of animal origin. Its main characteristics are:

- Oil-free products.
- Intensely aromatic.
- Highly volatile and los dense.
- Insoluble in water, low soluble in vinegar and soluble in alcohols, oils, waxes and vegetal oils.
- It oxides by air exposure.

Up to today, a big quantity of essential oils have been extracted, each of them with their own aroma and unique curative virtues. To get the best out of it, the processed ingredients need to be natural and raw, remaining the most pure possible.

Therefore, from a technic-economical point of view it will be explained how to obtain a suitable distillation system, such as the one with the quality oil obtained, to produce essential oils from citrus leaves.

Study of the different distillation systems

As early mentioned, the essential oils come from flowers, fruits, leaves, roots, seeds and plant barks. Oils are made in vegetal green parts (with chlorophyll) and when growing it is transported to other tissues, specifically in flower sprouts.

To create these essential oils, the following methods are mainly used due to their already mentioned features:

low carbon economy · AREA EUROPA DEVELOPMENT CONSULTING · ARCES · UAlg UNIVERSIDADE DO ALGARVE · Escola Profissional Cândido Guerreiro Alte · EFA LA MALVESIA

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I. Water distillation or hydrodistillation

The water distillation principle is to produce the boiling point in water suspension of an aromatic plan material, so as to collect and condense the generated steam. Oils that are immiscible with water are later separeted.

This extraction system is particulary used in rural areas that do not count with side installations for steam creation. In the hydrodistillation the material have to be always in contact with water. A major factor to consider is, if the still heating comes from the direct fire, the water within the still needs to be enough and permanent to perform all the distillation to avoid an overheat and carbonisation of the plant material, as this provoques other unpleasant odours in the final product. The plant material inside the still must be kept in constant shaking to avoid agglomerations or sedimentation within the bottom of the vessel, what could cause its thermal degradation.

II. Water/steam distillation

In this case the steam can be generated by external supply or within its own still, but separated from the plant material. Herbs are placed on a perforated base or sieve, located in a tank called retort to certain distance from the bottom.

Its lower part contains water up to a height lower than the sieve level. The heating is produced with saturated steam from a heat source by the equipment, in wet flow and low pressure, entering through the plant material.

If the water within the still is not enough to sustain the distillation process, it is advisable to use a cohobation system whereby the condensed water is returned to the still body to be reheated again.

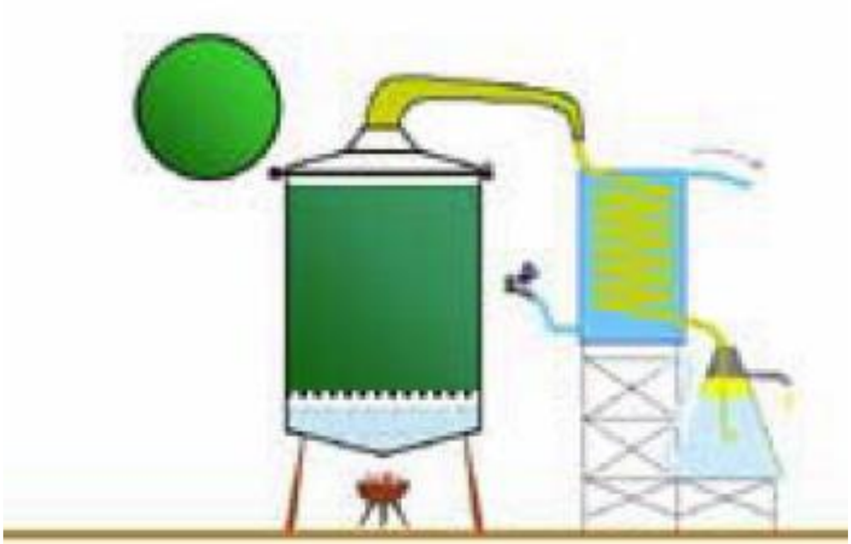

Figure 11 - Distillation system with water/steam.

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III. Puling steam distillation

The pulling steam distillation is similar to the previous, but there is no water in the retort bottom. Steam pressure is one of the working variables, selected for the type of processed plant material.

This distillation method can be considered more simple, secure and inclusive, the oldest. The process is technically linked with the alchol production and based on the dragging by water stem of most of the odorous substances in plant material. The pulling steam distillation used to extract most of the essential oils is a mixed of two immiscible liquids and consist on, briely, a vaporisation of temperatures lower than the boiling point of each volatile component as a result of a direct current of water steam, which performs the dual function of heating the mixture up to the boiling point and reduce the boiling temperature by adding the steam pressure, steam that is injected to the volatile components of the essential oils.

The steam out of the gooseneck is cooled in a condenser where it comes back to the liquid phase, both immiscibles products water and essential oil, to be finally separated in a separator or a florentine flask.

In the pulling steam distillation, the wet or dry steam is produced separately in a pot and injected though the bottom part of the container with the plant material. The advantages of the "dry" distillation is its speed, its lower energy consumption and the lesser chemical transformations to the labile components or the essential oils reactives.

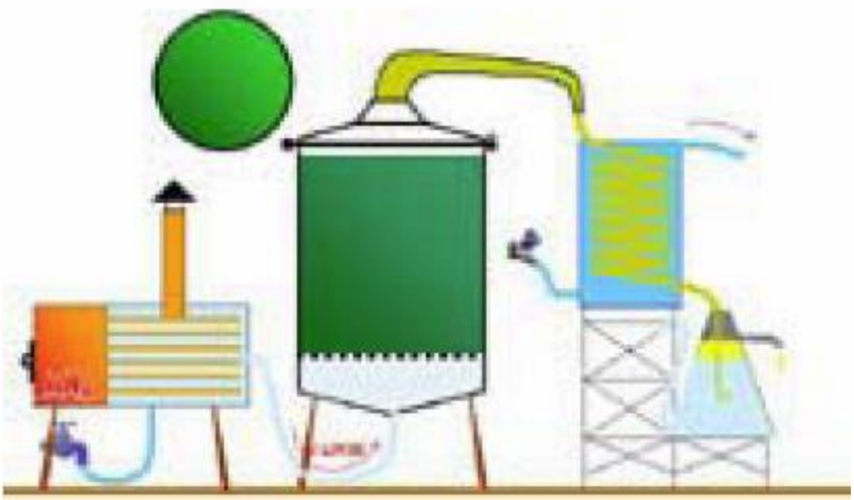

Figure 12 - Pulling steam distillation system.

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ECOCITRIC distillation system.

The ECOCITRIC project leaf distillation system for obtaining essential oils is made up of the following equipment (Figure 20):

- Steam pot generator by biomass.
- 19 litres distillator manufactured from stainless steel.
- 200 litres distillator manufactured from stainless steel.
- Small condenser: counterflow heat exchanger.
- 120 litres condenser: coil.
- Florentine flask.
- 2 litres decanter.
- Auxiliary elements: connections, valves, etc.

Figure 13 - Distillation system.

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Citrus leaves coming from the separator are introduced in the distillator creating a thin, solid bed. The water steam's in working pressure is 0.5 bars, produced by the biomass steam generator, is injected by the bottom part of the bed heating it and extracting the steam essence.

This steam travels to the condensor where it is condensed and cooled, creating a liquid mixture. This liquid emulsion is separated through a decanter or floretine flask, thanks to the different density among the components, producing essential oil on one side and water with traces of other elements called hydrolat.

2.3.2.3. Dryer system

The leaf dryer must be differentiated from the woody material. While the leaf is dried with a dryer, the woody material is dried preferably by natural drying (altough it can be dried in the same dryer).

The heat generator system (Fig. 14) is made of the following elements:

- Entry chamber: material collection by a small hopper
- Conveyor belt
- Speed governor of the conveyor belt
- Tunnel: the admission bed and the conveyor belt are encapsulated to improve the heat transference
- Air heater by biomass

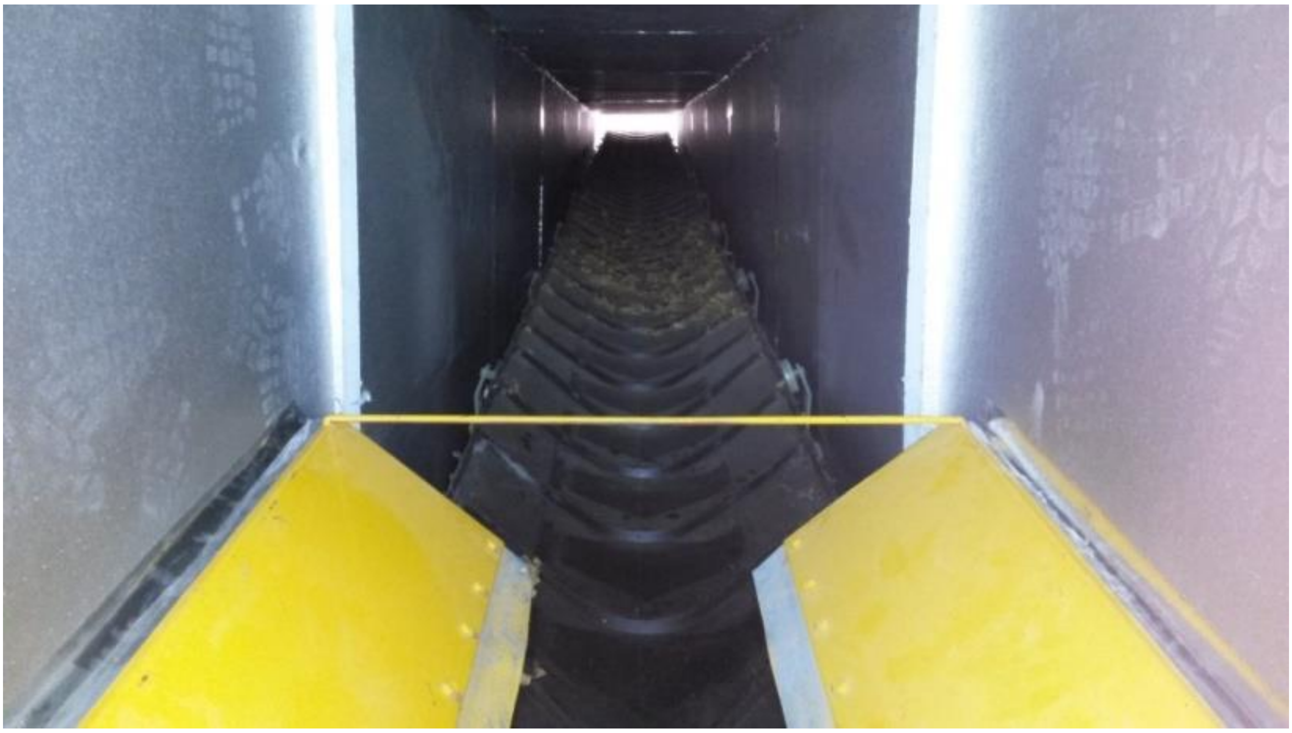

Figure 14 - Dryer system

The foliar material originating directly from the separation and the bagasse from the distillarion, are subjected to a low temperature dryer to reduce its dampness (approximately up to 15%), achieving better characteristics for an optimal pelletizing.

The process starts with the introduction of the material inside the tunnel and a constant supply of hot air coming from the air heater by biomass. According to the initial degree of moisture, the speed is controlled to obtain a suitable drying.

On the other side, the splinter natural dry is done by placing the woody material in crates by the separation process conveyor belt. Those crates are kept in the drying room. The crates are kept inside the room since the splinter reaches the valid moisture levels for the refinement process and subsequent pelletizing. Moreover, while the leaf drying tunnel is functionning, the generated heat is also used to divert the air of the chamber. The rest of the time, the splinter crates are left to air dry.

In case of wanting to speed up the process, the dryer can be used when having finished with the leaves to increase the production.

2.3.2.4. Shredding system

The shredding process is done for both the leaves and the woody material with the following system:

- Conveyor belt between the dryer and the refiner mill.
- Refiner mill with centrifugal fan.

While the dried foliar material is transported directly from the dryer by the conveyor belt, the woody material from the drying room is placed by hand to the mill entrance (Fig. 15). The mill will shred the material, achieving a homogenous and small-sized product to get the ideal pelletizing conditions.

The built-in fan will distribute the shredded material to the following pelletizing process.

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Figure 15 - Refiner mill

2.3.2.5. Pelletizing

The pelletizing system is made of:

- Flat die pelletizing press.
- Screw conveyor.

The shred foliar or woody material from the refiner mill is introduced by the centrifugal fan built-in in the pelletizing entrace of the mill (Fig. 16). It is in charge of the 6 mm diameter pellet production.

In the pelletizer exit there is a conveyor belt that arises the produced material to the storage silo. The silo has a manual valve built-in on the bottom part, enabling an easy and correct big-bags filling.

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Figure 16 – Pellet mill

2.3.3. INDUSTRIAL PROCESS AND COMMERCIAL VIABILITY

The ECOCITRIC plant is a pilot valorisation process of the citrus waste for obtaining value-added products. The plant goal is to validate the technical process in order to perform a bigger industrial plant to increase the production, and therefore, the process profit.

The industrial plant building involves greater initial investment, as well as a biggest production and maintenance cost. Nevertheless, by rising the production, the energy consumption ratios and cost by quantity of produced products lessen due to the scale economy. Moreover, the process efficiency is improved, by rising the quantity of outputs produced through the quantity of needed raw material. Likewise, the maintenance expenses of the plant decrease in percentage. All this leads to a cost reduction in comparison to the turnover, improving the financial viability of the process.

If the financial viability of the pilot plant is compared to the industrial process based on the ECOCITRIC process, there is a big difference.

The pilot plant of the ECOCITRIC project presents high production and maintenance costs in comparison to the economic benefit that could be obtained from the sale of goods. Thus, the pilot plant is only useful to validate the technical process.

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To procure a system financially viable the production obtained must increase in order to reduce costs while increasing benefits. Within the ECOCITRIC project it was studied the process's economic viability for 10 tonnes per day of raw material, what means multiplying by 10 the quantity produced in the pilot plant. For this production at industrial scale is identified that by rising benefits and reducing the ratio costs, revenues will exceed expenses. Thus, the industrial process of the ECOCITRIC project, will be financially worthy from the financial point of view.

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The transformation of citrus waste in bioproducts. Techniques, methodologies and technologies

Manual for agricultural VET teachers

MODULE 3

BIOPRODUCTS MARKET

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3.1. THE BIOECONOMY

The European Commission defines the bioeconomy as "the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge" (EU, 2012).

The European Commission adopted the **European Bioeconomy Strategy** in February 2012 that aims to pave "the way to a more innovative, resource efficient and competitive society that reconciles food security with the sustainable use of renewable resources for industrial purposes, while ensuring environmental protection" (European Commission, 2018a, p.8). The strategy was updated in 2018 to accelerate the deployment of a sustainable European bioeconomy so as to maximise its contribution towards the 2030 Agenda and its Sustainable Development Goals (SDGs), as well as the Paris Agreement (see European Commission, 2018b).

The European Strategy 2030 believes that: smart growth can be achieved through the development of knowledge; that this growth will be sustainably provided by the green economy; that the growth should be more inclusive; and that it should support employment in the bioeconomy sector.

The bioeconomy is an emerging and important phenomenon of the 21st century, reaching the paradigm shift from the established fossil-based economy toward a bio-based economy, which is an ambitious goal. The most important driver of this transition is the need to establish a more sustainable economy. This will allow sustainability to become a successful market driver.

In 2016, a study conducted by nova-Institute on behalf of the Bio-based Industries Consortium showed for the first time which macroeconomic effects are generated by these activities, with 2.3 trillion euro turnover and 18.5 million employees in the European Bioeconomy in 2015, meanining a continuous increase of 10% since 2008 (Piotrowski et al., 2019).

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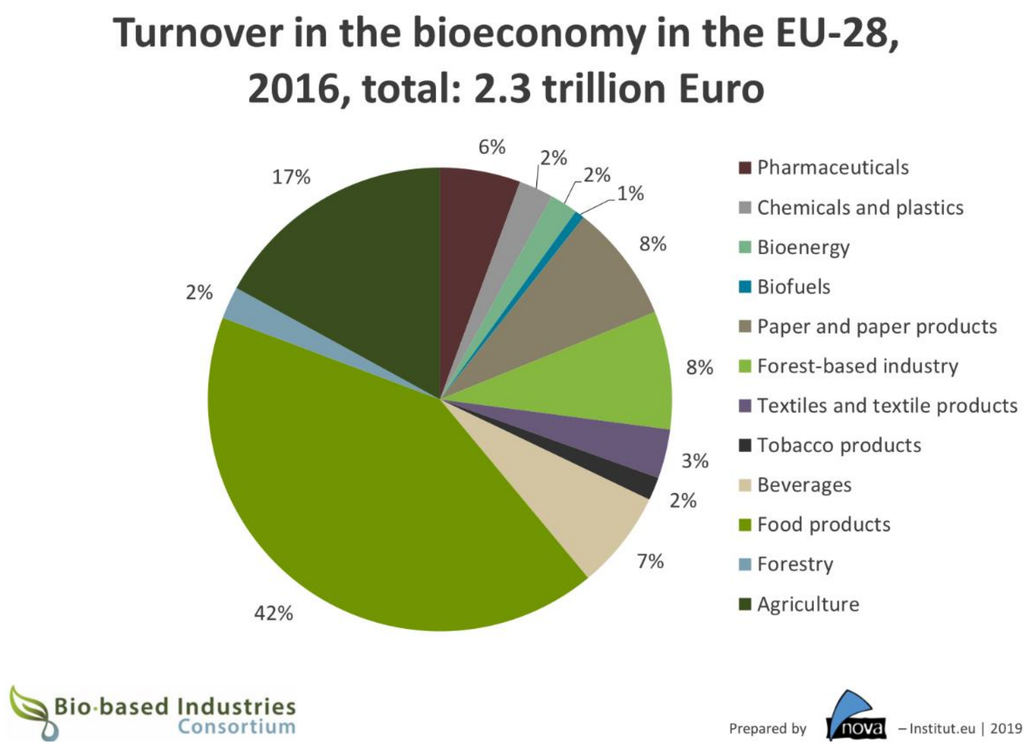

Nowadays, according to forecasts, the bio-based share of all chemical sales will rise to 12.3% by 2015 and to **22% by 2020**, with a compounded **annual growth rate of close to 20%**.

Nevertheless, companies, governments and consumers are confronted with numerous uncertainties. These may limit new products and technologies from growing into full-scale commercial applications.

To overcome the perception of uncertainty about their technical properties and the lack of market transparency in the sector, it is necessary to create standards, labels and certification schemes for bio-based products. The European Commission has charged the European standardization body, the Comité Europeen de Normalization or CEN, to develop standards and technical specifications for biopolymers and biolubricants (Mandate M / 430) and to draw up a standardization program for bio-based products, starting from the definition of the term "bio-based" (Mandate M / 429).

The bioeconomy is conceptually linked to the circular economy (see section 1.5 of this module) since they have concepts in common, such as the chain approach, sustainability, biorefining and the

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cascading use[3] of biomass. Both of these policy agendas converge with respect to economic and environmental concerns, research and innovation, and societal transition towards sustainability. The Bioeconomy Strategy, however, pays little attention to ecodesign and waste collection, sorting and suitability for high-grade recycling treatment and innovative business models and the role of small and medium-sized enterprises (SMEs) for closing local biomaterial loops would merit more attention.

The real challenge towards the sustainability is to create the right preconditions for the development of a **sustainable circular bioeconomy.**

3.2. THE BIO-BASED PRODUCTS

The European Union has strengthened the innovative potential of bio-based products, within its member states, through the Lead Market Initiative[4]. Bio-based products can make the economy more sustainable and lower its dependence on fossil fuels. For this reason, the EU has declared the bio-based products sector to be a priority area with high potential for future growth, reindustrialisation, and addressing societal challenges.

As reported in the CEN TC411[5], "the term bio-based product refers to products wholly or partly derived from biomass, such as plants, trees or animals (the biomass can have undergone physical, chemical or biological treatment). Some of the reasons of the increasing interest in bio-based products lay in their benefits in relation to depletion of resources and climate change. Bio-based products could provide additional product functionalities, less resource intensive production and efficient use of all natural resources".

[3] Cascading is a strategy for using wood and other biomass in a more efficient way by reusing residues and recycled materials in sequential steps for as long as possible, before turning them into energy. Cascading extends the total biomass resource base within a given system (Vis et al., 2016). Different definitions of cascading exist in the literature. The concept was introduced in the 1990 (Sirkin and ten Houten, 1994) and further elaborated on by different authors. Often, a differentiation is made between cascading-in-time, -in-value or -in-function (Odegard et al., 2012; Keegan et al., 2013). Furthermore, a differentiation can be made between single-stage and multistage cascades, depending on the number of material applications before a biomass resource is turned into energy (Essel et al., 2014). Cascading-in-time is the most commonly used concept and is used in this report when mentioning 'cascading' (EEA, 2018).

[4] The Lead Market Initiative (LMI) is the European innovation policy for 6 important sectors that are supported by actions to lower barriers to bring new products or services onto the market. As far for the bio-based products, mandates for several new European standards, such as bioplastics that are used in packaging, have been issued and accomplished. Good industry standards are a decisive tool in international competition, as they will lead to higher use in supply chains, can ease consumers' life, and promote sustainability.

[5] CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 34 European countries. The main objective of the CENTechnical Committee 411 is to develop standards for bio-based products covering horizontal aspects.This includes a consistent terminology for bio-based products, sampling, bio-based content, application of and correlation towards LCA and sustainability of biomass used, and guidance on the use of existing standards for the end-of-life options.

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An example of bio-based products with expanding markets are biopolymers, which include bioplastics and all other partially or fully -based polymers products, and which are wholly or partly derived from material of biological origin, excluding materials embedded in geological formations and / or fossilized.

Bio-based products can include:
1. Adhesives;
2. Construction materials and composites;
3. Fibers, paper, and packaging;
4. Fuel additives;
5. Landscaping materials, compost, and fertilizer;
6. Lubricants and functional fluids;
7. Plastics;
8. Paints and coatings;
9. Solvents and cleaners;
10. Sorbents;
11. Plant and vegetable inks.

In order to have a general overview of the bio-based products, the main bio-based product databases are reported as follows:

https://www.biopreferred.gov/BioPreferred/faces/catalog/Catalog.xhtml
https://www.biobasedconsultancy.com/en/database
https://datenbank.fnr.de/
https://www.coebbe.nl/biobased-wiki/
https://www.biobasedbouwen.nl/producten/
https://www.agro-chemie.nl/biobased-products

3.2.1. BIO-BASED ARE BETTER THAN FOSSIL-BASED PRODUCTS; IS THIS TRUE? OPPORTUNITY OR DISRUPTIVE FACTOR IN AGRICULTURE?

In some situations, it can be better to use bio-based materials than fossil-based materials. However, it's important to know that bio-based materials also can result in significant impacts. Some of the bio-based products benefits are reports as followed:

- They have the potential to mitigate climate change, since biomass absorbs carbon dioxide (CO2) during its growth, which can be released during the use or waste phase. In another word, bio-based products can be considered climate-neutral.
- They help reduce the dependence on fossil fuels, a finite resource with associated negative impacts on the environment.
- They can also help tackle social and economic issues, creating employment, new business and rural development.

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However, there are also some negative aspects related to the bio-based products production (see the Focus box). For example, the production of biomass requires the use of fertilisers, which is connected to the emission of Nitrogen oxide, a greenhouse gas 298 times stronger than CO2. Furthermore, for the production of bio-based products, more arable land is needed and this land could come at the expense of forests and grass lands (carbon sinks). This phenomenon, that can lead to higher levels of CO2 and hence aggravate the greenhouse effect instead of reducing it, takes the name of Lan Use Change (LUC).

Another phenomenon related to land use and the bio-based economy is Indirect Land Use Change (ILUC). This phenomenon can be described by the following example. A farmer who has produced food on a certain piece of land decides to switch to the production of biofuel crops or food crops for the energy market on that piece of land. The result is that, since the demand for food is not decreasing, the amount of food that this farmer produced before now has to be produced somewhere else. This often means that grassland or forests somewhere else are changed into arable land for food production. In this sense the production of biofuels leads indirectly to changes in land use. ILUC CO2 emissions are thus indirectly caused by Europe's demand for biofuels (Eickhout, 2012).

Another important consideration is the type of bio-based source we are referring to. In the case of biofuels, there are big differences in impact between first and second-generation biofuels. **First-generation biofuels** are generally made from commodity crops that can also be used as food or feed, for example: corn, wheat, or sugar cane. **Second-generation biofuels** utilise non-food crops: **co-products, agricultural residues and waste**. In that case, the second-generation biofuels can have less negative impacts, as they generally don't require new production of crops and reutilise residues which would otherwise **end up as waste**.

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FOCUS BOX: The bioeconomy potential impacts

The European Union (EU) is particularly active in promoting bio-based transformations and seeks to respond to global social-environmental challenges through its Bioeconomy Strategy. The bioeconomy has been envisioned as an important component for smart and green growth while simultaneously achieving the EU's climate and other environmental targets and the 2030 Agenda. However the sustainability of the EU's expanding bioeconomy has to be considered (Pfau *et al* 2014, O'Brien *et al* 2015, O'Brien *et al* 2017, Ramcilovic-Suominen and Pülzl 2018).

Evidence is rising that an expanding industrial bioeconomy, for instance, can cause:

- direct and indirect land use change (LUC and ILUC), thereby generating greenhouse gas emissions (Searchinger *et al* 2008)
- implications for water quality and quantity (Thomas *et al* 2009)
- negative consequences for ecosystems in distant places, importing feedstock for the EU bioeconomy: a ILUC-related effect (Deininger 2013)
- social impacts due to the dislocation of vulnerable socio-demographic groups in developing countries, such as subsistence farmers with unclear land access rights (McMichael 2012), and the commodification of land and food crops (Birch *et al* 2010).

Particular attention should be given to the non-food sector, as it is the main driver of growing biomass demand in recent years, particularly due to increasing vegetable oil demand for fuel use. A recent study shows that the EU increasingly sources non-food biomass feedstocks from tropical regions, which have been identified as hotspots of both deforestation and biodiversity loss (Bruckner *et al*., 2019; Sodhi *et al* 2004, Koh and Wilcove 2008). In fact, the 65% of the cropland (18.3 Mha) for non-food products was imported from outside the EU-28. Large amounts of embodied land (7.3 Mha) were also imported to serve manufacturing processes in the EU. Figure 1 provides a probability distribution of the EU's footprint for selected crops: (a) maize and sugarcane, which together represent more than 90% of the global ethanol feedstock and, in addition, are used for material purposes e.g. in the production of adhesives or bioplastics; (b) oil crops, which is the biggest crop category in the EU's non-food cropland footprint; and (c) fibre crops, mainly represented by cotton used in the textile industry.

Anthropogenic land modification, in particular deforestation, has already transgressed the planetary boundary for land system change, causing increasing pressure on climate and biodiversity. Many global energy and land use scenarios envision that the systemic change towards a bio-based economy will be more heavily reliant on terrestrial ecosystems and land resources. The expanding bioeconomy will then add to the already high land demand for food supply, resulting in growing pressure on planetary boundaries.

Therefore, the EU's bioeconomy should be considered and assessed not only territorially but from a global consumption-based perspective. Further research and policy development should pay attention to how the bioeconomy could contribute to sustainable development.

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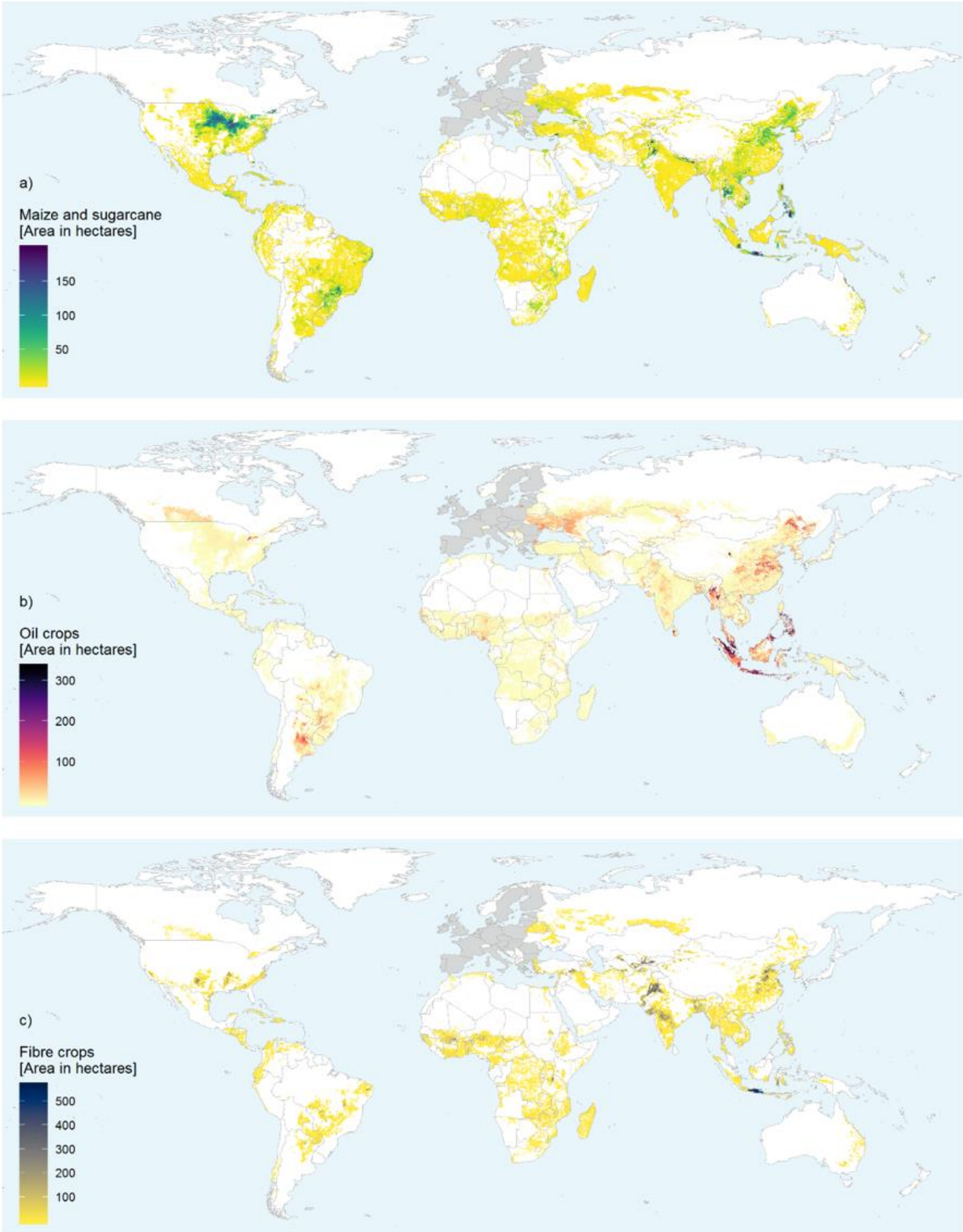

Figure 1 - European Union's non-food related cropland use outside the EU in hectares per grid cell for a) maize and sugarcane, b) oil crops, and c) fibre crops. The colour scale indicates the number of hectares of cropland used by the EU in each grid-cell (5 arcminutes) (Bruckner *et al.*, 2019).

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3.3. AGRICULTURAL RESIDUES AS AN OPPORTUNITY

In the framework of the shift towards a circular bioeconomy, there are significant opportunities for agriculture in the deployment of sustainable bioenergy and bio-based product supply chains. The main feedstocks from agriculture are dedicated crops (mainly sugar, starch and oil) and agricultural residues.

Agricultural residues are carbon-based materials generated as a by-product during the harvesting and processing of agricultural crops. Agricultural residues which are produced during harvesting are primary or field-based residues while those produced along with the product during processing are secondary or processed based residues.

Moreover, the agricultural residues is becoming significant from an economic point of view.

The largest source of crop residues is the straw and stover (leaves and stems) of grain crops, barley and corn. For the use of such residues, on the assumption that a third of them must remain on the agricultural fields to maintain the high quality of the soil and another third for conventional uses, the study *"Wasted"* estimates that about 122 million tons of agricultural residues are currently available to be recycled with an annual growth that takes us up to about 139 million tons by 2030. Other studies, which do not have such severe restrictions on the permanence of waste on the ground, estimate that in the year 2030 the amount of agricultural residues available will range between186 million to 252 million tons.

However, there are several obstacles to the transportation of crop waste as a raw material to be used for the production of bio-products and / or biofuels.

- The first and most important obstacle is the cost related to the collection and transportation to processing plants and / or processing of agricultural residues. Since these are highly dispersed in the territories, their collection implies an organization, which may not be the ends of the individual producer, as well as transportation, which should be optimized by providing the ability to aggregate the individuals in cooperatives or consortia forms.
- A second obstacle to be taken into consideration is the distance of the plant / s materials processing.
- A third obstacle is that farms are rarely equipped with adequate machinery for the first treatment and storage of waste.
- One last, but perhaps the most insidious, obstacle is the lack of sensitivity and environmental tradition, especially widespread among the elderly in adopting ancient practices and the consequent reluctance to give them up.

It is estimated that the cost of collection of crop residues is four times higher than the price that buyers are willing to pay. Therefore, that biomass is much more palatable to bio-refineries to produce higher-priced products, such as chemical platform products.

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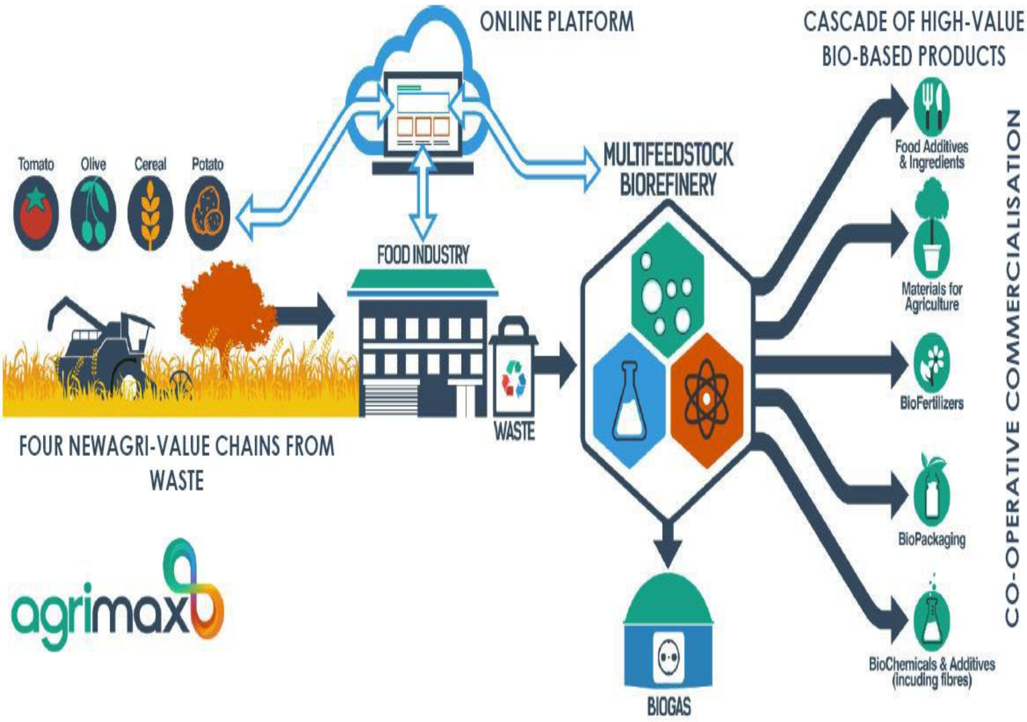
However, it is estimated that the potential of EU agricultural residues will remain highly underutilized by 2020, and in 2030 only 11% of it will be recycled.

FOCUX BOX: project "AGRIMAX": from agricultural and food waste to bioproducts

The project explores and expands economically competitive pathways for the commercialization of these products, by using flexible processing facilities that will maximize sustainability of the EU, while providing new bio-based compounds for the sectors chemicals, food and agriculture.



This four-year project, funded by the EU, involves 29 partners in 11 European countries and is developing and demonstrating the production of more high value products from waste crops and foods. The project is also developing economically competitive pathways for the commercialization of these products, by using flexible processing facilities and possibly operated cooperatively. The goal is to maximize sustainability of the EU, while providing new bio-based compounds for the sectors chemicals, food and agriculture, converting 40% of the waste they receive in high-value material. An online platform to coordinate the provision of this waste will help to maximize the use of these pilot plants throughout the year.

Expected impacts:

- *demonstrate new value chains for products with higher added value, open new markets, connect organizations and sectors that have never worked together before;*
- *improve the environmental performance and efficiency in terms of the bio-refinery process costs compared to the current state of the art;*
- *demonstrate an integrated process with more than 40% of the raw material enhanced in high value-added products;*

- *evaluate new products 2-5 times higher than the current for the raw material applications, leading to a significantly higher total enhancement of agricultural crops, thus contributing to development and rural employment;*
- *meet a clear market demand by providing final products with an overall better sustainability score than their fossil-based counterparts;*
- *contribute to the disposal of waste and reduce the EU's dependence on fossil fuels, while creating new growth and new jobs.*

www, agrimax-project.eu

3.3.1. BIO-BASED PRODUCTS FROM AGRICULTURAL WASTE: A SPECIFIC CASE THE ESSENTIAL OILS

Essential oil is a sub-product from agricultural production with high added value and is part of a very complex market, depending on different industries:

- Chemical (as high added value components).
- Organic agriculture (plant protection and field disinfection).
- Cosmetic.
- Hygiene and cleaning industry.
- Medical, naturopathy, homeopathy.

It is easy to see that the chemical industry can easily dominate such application fields, asking for bio-based raw materials as an alternative to the oil extraction industry, also following the growing demand for “clean” and renewable components.

We consider an essential information and data source as the Zion Research 2014 report on Essential Oils (Orange, Corn Mint, Eucalyptus, Citronella, Pepper Mint, Lemon, Clover Leaf, Lime, Spearmint) Market for Medical, Food & Beverage Spa & Relaxation, Cleaning & Home, and Other Applications: Global Industry Perspective, Comprehensive Analysis and Forecast, 2014 – 2020”.

The global market demand for essential oils is estimated at around 5.50 billion dollars in 2014, expected to reach 9.80 billion in 2020, with an annual growth rate of 9% until 2020.

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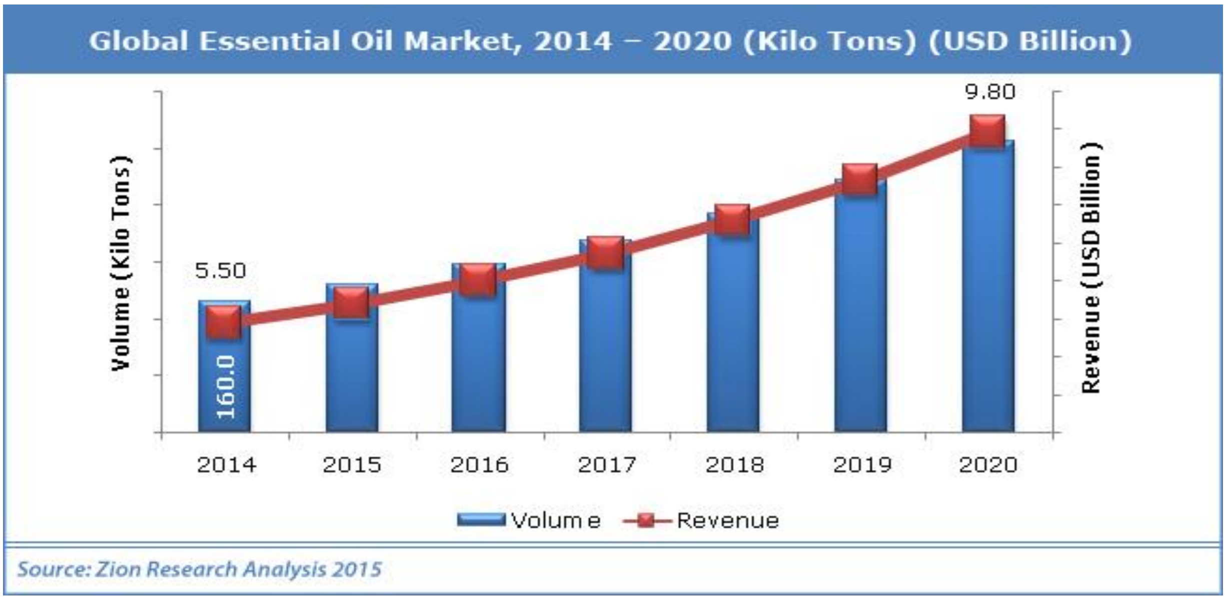

Uses - They are generally extracted by distillation, often using steam. They are used in perfumes, cosmetics, soaps and other products, to flavour foods and beverages, for incense and cleaning products for the house. Among the various uses (medical, food & beverage, spa and relaxation, cleaning and domestic and others) food and beverages prevail with over 30% of total turnover; strong growth is expected for the sector. Spa & relax is another important market segment.

Markets - Europe dominates the global market for essential oils in terms of volumes and revenues. The growing demand is driven by natural cosmetics and beauty products, medicines and nutraceuticals thanks to the strong demand coming from a population that is aging in countries such as Germany, the United Kingdom and France. Rapid growth is expected in the Asia-Pacific area. North America was the second largest market for essential oils.

3.4. A NEW VISION OF THE AGRICULTURAL JOB: FROM AGRICULTURE TO RURAL BUSINESS START UP OR BUSINESS CONTINUITY

The traditional agriculture is more and more involved in new technologies, innovation processes, new product creation.

The main challenge, now, is the economic sustainability of the agricultural activities, just following the main principles of the business sector.

The business model approach

The main concept is to support organized farmer groups mainstream business thinking among their members and to move away from running operations that are dependent on government or donor

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contributions. The approach supports farmer organizations define how they do business with their customers based on a better understanding of buyers' needs, so that they can begin to prioritize activities and guide smallholder members in responding to those requirements. Also supported is the strategic prioritization of activities that contribute to more effective business relationships between smallholder supplier groups and small, medium or large agribusinesses. The inclusive element of the concept applied addresses the development constraints and concerns of linking commodity dependent smallholders through farmer organizations to markets. The methodology includes a diagnostic appraisal to understand how business is or is not being carried out and focus group meetings to identify the success factors that are critical for improving commercial ties between farmer organizations and buyers. The identification of the critical success factors guides the farmer organizations, with the support of local service providers, in the prioritization of activities. Strategic actions can subsequently be financed by the actors themselves, donors, projects or with government funding. As described below, the approach supports farmer organizations improve the aspects of their business related to (i) strategic business management of operations, (ii) better business to business coordination between farmer groups and immediate buyers and, (iii) responding to customer and value chain needs and priorities.

Managing a business strategically	• Training in business and financial management and marketing Appraise and address logistical constraints • Training in bulk buying and marketing • Identify low cost institutional innovations that improve delivery times • Reduce waste and protect the environment from harmful production and processing activities • Identify potential sources of credit and support loan applications • Mapping exercises and workshops to understand the product flow
Business to business coordination	• Appraise and address sources of uncertainty for a buyer, for instance related to reliability of supply, product quality. • Facilitating the implementation of contractual arrangements (formal and informal) • Information exchange mechanisms that improve transparency • Facilitated business meetings to identify bottlenecks and better understand the role of each actor • Strategic and operational management planning to enhance the supply of the product through the chain

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Responding to customer needs	• Synchronize product delivery and logistics to suit customer demands • Implement grading systems and control mechanisms for product quality and safety • Disseminate information on customer requirements o Market appraisal and surveys to understand consumer needs and demands • Training in good agriculture practices and post-harvest handling • Training in standards and certification processes

3.5. NEW EU FUNDING OPPORTUNITIES FOR SMES[6] OPERATING IN THE FIELD OF CIRCULAR ECONOMY WITH FOCUS ON WASTE MANAGEMENT.

Circular Economy has acquired an important role in facing the new challenges that have emerged in the last years in relation to sustainable growth and resource and waste management. So far, there have been many European Programmes that have already financed projects focused on waste management. That is the case of **Interreg Mediterranean**, that has supported projects in renewable energy that include waste management and biomass[7], or **Horizon 2020**, that includes "waste" in the focus areas of "Climate action environment, resource efficiency and raw materials Challenge" and has supported different EU initiatives in this field[8], or even **Erasmus+**, which has referred to waste management in the eligibility criteria for the Sector Skill Alliances for implementing a new strategic approach to sectorial cooperation on skills[9].

In the framework of cross-border cooperation, **ENI CBC MED Programme 2014-2020** has funded projects which address circular economy from the point of view of waste, such as *CEOMED*, that is focused on organic fraction of Municipal waste, or *CLIMA* that looks forward to reduce waste in order to boost economies[10], **ENI CBC Italy-Tunisia** has also funded projects focused on waste, as is the case of *MED Dé.Co.U.Plages* for the prevention and reuse of marine biological residues and plastic waste[11].

Considering its importance, the European Union has included Circular Economy as one of the key points in different programs for the new Budget 2021-2027.

[6] Small and Medium Enterprises
[7] Interreg Mediterranean Renewable Energy**,** Comopse, Forbioenergy.
[8] EUROPEAN COMMISSION, Horizon 2020, **"**Waste: a resource to recylce, reuse and recover raw materials"
[9] EUROPEAN COMMISSION, "Erasmus+. Programme Guide", 2018, p. 148,149
[10] ENI CBC MED Cooperation Across Borders in the Mediterranean
[11] PROGRAMME IEV DE COOPERATION TRANSFRONTALIERE ITALIE TUNISIE 2014-2020, "Avis public n. 1/ 2017 pour les projets standards. Liste des projets admis au financement", p.6

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The new **InvestEU Programme** will support four different policy areas among which is Sustainable Infrastructure, which will finance projects in circular economy[12]. In the case of the new **LIFE Programme**, not only Karmenu Vella, Commissioner of Environment, Maritime Affairs and Fisheries, has stressed the importance of speeding up the transition to the circular economy[13], but also the programme will include a sub-programme that will support actions focused on the objects of transition to a circular economy and improving the quality of life[14]. The new proposal for the **European Maritime Fisheries Fund** will include stronger synergies with other EU policies which includes fighting against climate change and implementing the European strategy for plastics in a circular economy[15].

Finally, as far as Regional Development and EU Cohesion policies are concerned, the **Interreg Programme** will continue working to remove cross border obstacles and support interregional innovation projects, which includes giving more support to build pan-European clusters in sectors such as circular economy[16].

3.6. BENCHMARKING BEST PRACTICES, THE AGRO-START UP CONCEPT

Following EU-STARTUPS.COM, these are the 10 best agro-startups in 2018

InFarm: Berlin-based InFarm has developed a vertical indoor farming system that can be implemented in supermarkets, restaurants, local distribution warehouses, or even schools – allowing businesses to grow their own fresh produce on site to deliver to customers. InFarm controls the farms remotely using IoT, Big Data, and cloud analytics. Founded in 2012, that startup is already opening indoor farms in 1,000 locations in Germany, and expanding in other European markets, while planning to launch in North America in 2019.

Peas & Love: Launched in 2017, this French urban farming startup rents out gardening parcels for only €8.99/month. The best part? You don't have to maintain it yourself – the garden parcels are maintained by an on-site community farmer. Peas & Love offers a selection of over 60 fruits and vegetables to grow in your community garden and use in your meals for a healthier diet. The

[12] EUROPEAN COMISSION, "EU BUDGET FOR THE FUTURE. InvestEU: What will it finance?", 6 June 2018, p.1
[13] EUROPEAN COMMISSION,"EU BUDGET FOR THE FUTURE. The new life programme: Investing more in environment and climate action", 1 June 2018, p.1
[14] EUROPEAN COMMISSION,"EU BUDGET FOR THE FUTURE. The new life programme: Investing more in environment and climate action", 1 June 2018, p.2
[15] EUROPEAN COMMISSION,"*EU BUDGET FOR THE FUTURE. The European Maritime and Fisheries Fund*", June 2018, p.2
[16] EUROPEAN COMMISSION,"*EU BUDGET FOR THE FUTURE. Regional Development and Cohesion. Regional Development and Cohesion beyond 2020: the new framework at a glance*", 29 May 2018, p.3

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startup's app will alert you to the harvest plan and schedule of your vegetable farm, and the upcoming urban farming events that are hosted by the startup.

WeFarm: An agritech startup based in London, WeFarm is a digital peer-to-peer network that aims to serve small farmers, of which there are over 500 million in the world, the majority of which live on less than $1/day. Founded in 2015, WeFarm gives farmers access to advice and solutions from other farmers to solve daily challenges. Small scale farmers can use the network to receive crowdsourced answers to their farming questions, such as, "How can I prevent my tomatoes from getting diseases?" or "Why isn't my farm producing more maize?". Users don't need a smartphone, but 90% of small farmers now have access to a mobile phone and can ask their questions via SMS. So far, 1.2 million farmers have registered with the platform, asking 2.2 million questions with 4.8 million responses, providing them with advice and knowledge that has helped them to increase their incomes and start micro-businesses.

Agroptima: Founded in 2014, this Barcelona-based startup allows farmers to manage their farms from their phones. Using its app, farmers can track jobs, fields, products, workers, and machinery. The app records daily farm operations such as sowing, fertilising, and harvesting, and farmers can access all of the data on its web-based platform. Agroptima's software also provides farmers with personalised reports based on this data. The startup currently has 1,700 paying customers.

Ignitia: Founded in 2015, this Swedish startup provides accurate, hyper-local weather forecasts to small farmers in tropical climates. Rain in the tropics doesn't follow the same pattern as weather in temperate regions – storms appear rapidly and are more unpredictable, making traditional global weather forecasts undependable for tropical farmers. However, Ignitia's forecasts are 84% accurate – twice as accurate as global models. Ignitia's precise forecasting allows local, tropical farmers to increase yields and profits. Farmers don't need a smartphone – forecasts are delivered by SMS, and pay using their phone credit.

Phytoponics: Land and soil are becoming increasingly scarce as the population increases and clearing land for agriculture has led to deforestation on a mass scale, contributing significantly to climate change. Hydroponics allows farms to grow crops without soil or the need for arable land, instead placing the roots of the plants in a nutrient-rich solution. Founded in 2016 and based in the UK, Phytoponics has developed a commercial-scale hydroponic growing system called Hydrosac, which is cheaper and easier to install than traditional hydroponic systems. Employed on a large scale, hydroponics provides an innovative solution to address world hunger and sustainability. The startup's CEO, Adam Dixon, says that his vision is that using hydroponics, we'll only have to use 10% of land for agriculture in 2050.

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Connecterra: This startup uses an intelligent dairy farmer assistant to apply IoT to food, in what it calls the "Internet of Food". Its app, Ida, monitors cow behaviour and activity, and allows farmers to detect health issues in livestock to improve dairy farming and milk production. Ida measures each cow's eating behaviour and milk yield, helping farmers to identify which cows are most productive and why. Using this data, farmers can make better decisions regarding fertility, breading, milk yield, and heat detection.

VisualNAcert: This Spanish startup uses technology including sensors, drones, satellite imagery, geolocation, and Big Data to help farmers manage all aspects of their farms in an all-in-one platform. Farmers can use the platform to create work orders and control costs and stock, track their crop cycles and plan harvests, and register the activities performed on each plot. Founded in 2014, VisualNAcert (or "VISUAL") also provides farmers with valuable information, including reports with advanced agro-climatic data for each crop and crop growing cycle, and monitors the temperature and humidity of the air and soil using sensors.

Vitibot: If there's anything France is famous for, it's wine. This startup from France's champagne region has developed a solar-powered robot, Bakus, to maintain vineyards. Founded in 2016, Vitibot's robot can perform all of the groundwork in vineyards and is capable of working for up to 10 hours at a time.

Ecorobotix: Founded in 2011, Swiss startup Ecorobotix has created a smart weeding solution; an autonomous machine that can efficiently detect and destroy weeds among row crops. Powered by solar energy, the robot can work for 12 hours without recharging, and can be remotely controlled using a smartphone. Ecorobotix's solution allows farmers to use 90% less herbicide, improving yields for farmers.

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ANNEX 1: PETITGRAIN ESSENTIAL OIL

Emanuela D'Agostino

Founder of Pura Vita, Center for the Diffusion of the Naturopathic Lifestyle and the Uses of Medicinal Plants, Polizzi Generosa (PA), Italy

The essential oil extracted from the leaves of the Citrus plants is called Petitgrain (Fr.: "little grain") and it gains its name from the fact that it used to be extracted from the unripe small green fruits of the plant.

Its main regions of production are Paraguay and France, with the former's product being of higher odour tenacity. The oil has a greenish woody orange smell that is widely used in perfumery and found in colognes.

Historically, Petitgrain essential oil has been used for cleaning purposes and it has been used internally to support healthy immune system and nervous system function. It has been used extensively in perfumery since the 18th century. It is also a common fragrance in soaps, cosmetics, and detergents; and it is a flavoring agent in foods (candy and other sweets) and beverages (both alcoholic and non-alcoholic). Emerging scientific evidence provides support for these traditional and other uses.

Petitgrain is a versatile essential oil to keep on hand. There are no known contraindications of this oil, although any oil should be skin-tested before using, especially on individuals with sensitive skin.

There are many benefits attributed to petitgrain. Some of the following might be helpful at home: as an antidepressant oil, you can use petitgrain as a mood stabilizer and antidepressant, to calm anxiety, ease despair and grief symptoms, reduce stress, help with focus and concentration, fight exhaustion and fatigue, and more. Petitgrain is also an anti-inflammatory and antispasmodic, which makes it excellent in creams, massage oils, and gels for muscle aches and pains.

According to a research study produced in Evidence-based Complementary and Alternative Medicine (eCAM) in 2017, there are a number of dermatological applications for petitgrain essential oil as listed in aromatherapy literature:

Acne

Antiseptic

Bacterial infections

Balances sebum in greasy and oily skin

Helps with blemishes

Hyperhidrosis

Pimples

Pressure sores

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Sensitive skin

Toner

Tonic

Wounds

The research also states that the oil shows efficacy against:

Skin problems associated with gram-negative pathogens

Candida albicans

C. albicans, Staphylococcus aureus, and Pseudomonas aeruginosa when combined with lavender (Lavandula angustifolia).

In a study from 2008 published in the Journal of Clinical Biochemistry and Nutrition, petitgrain from France showed 100% scavenging activity against singlet oxygen at 0.1%, 0.4–2%. At 0.2% concentration, the scavenging efficacy was 92%. Singlet oxygen (1O2) is a reactive oxygen species (ROS) and is a highly active form. When produced on the skin after exposure to ultraviolet rays, it starts attacking cells.

CHEMICAL COMPOSITION

Oil	Binominal name	Plant	Distilled parts	Components
Petitgrain bigarade	*Citrus ×aurantium* subsp. *amara*	Bitter orange	leaves, (twigs, branches)	Linalyl acetate(45%), Linalool(20%), β-Pinene(<10%), α-Terpineol(6%), Geranyl acetate(<5%), cis-β-Ocimene(<5%)
Petitgrain mandarin	*Citrus reticulata*	Mandarin orange	leaves, (twigs, branches)	Methyl anthranilate(50%), γ-Terpinene(15%), Limonene(5%), p-Cymene(3%)
Petitgrain citronnier	*Citrus limon*	Lemon	leaves, (twigs, branches)	Limonene, Citral,Geranyl acetate, β-caryophyllene

PLANT'S CONDITIONS GUIDELINES

In harvesting, collecting and transporting phases there are some important conditions that it needs to be respected.

1) The citrus leaves used in distilling production should be absolutely not damaged by pests, diseases or physiological disorders as well as contaminated with pesticides or chemicals. The leaves used in

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distilling production usually should be in their best conditions and in the appropriate time of the year (harvesting time).

2) If the pruning time doesn't correspond with the harvesting time (in general before flower's blooming for leaves) it's not suggested at all to use the material obtained in distilling processes, because the extraction could be unproductive and all the process could reveal itself as unsustainable.
3) The leaves should be distilled immediately after collected (fresh).
4) All containers used at harvest should be kept clean and free from contamination by previously harvest plant's or other foreign matters.

For the WHO (World Health Organization) guidelines of GACP (Hood Agriculture and Collective Practices) plants used for therapeutics/ aromatics/ foods should be harvested during the optimal season or time period to ensure the production of finished herbal products of the best possible quality.

The harvest time depends on the plant and on the part of it to be used and is the time in which the plant reaches its best concentration of biologically active constituents or "biological properties" and organoleptics. This concentration varies with the stage of plant growth and development as well as seasons and weather conditions. For what concern leaves, harvest time in general is before flower's blooming.

Leaves should be harvested under the best possible weather conditions, avoiding dew, Rain or exceptionally high humidity. If the harvesting occurs in wet conditions, the harvested material should be transported immediately to an indoor drying facility to expedite drying so as to prevent any possible deleterious effects due to increased moisture levels which promote microbial fermentation and mold.

The contact of the plant with soil should be avoided to the extent possible so as to minimize the microbial load.

Raw plant materials should be inspected and sorted prior to primary processing.

The inspection may include:

- Visual inspection for cross contamination by other untargeted plants or part of biologically its
- Visual inspection for foreign matters
- Organoleptic evaluation, such as appearance, damage, size, color, odor and possibly taste.

SOURCES: www.apps.who.int

LEAF DISTILLATION SYSTEMS

The essential oils are biosynthesized substances by plants. They contain all the properties of the plants and more, what is called "the Essence of the plant". That's why ancient people used to call It Just "essences" or "aromatics essences" for their properties of preserving the essential characteristics of the distilled plant. It

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was After 1400 A.C. that people started to call them "essential oils", not because they have some chemical affinities with vegetal oils, but just because like them they float on the water's surface.

The part used for the distilling process (in which essential oils are contained) are flowers, green crops, leaves, roots and barks especially from some particular plants called "essential plants" for the characteristics of containing high percentage of essential oils.

Essential oil's main characteristics are:

- Oil-free products
- Intensely aromatic
- Highly aggressive on skin and mucous membrane
- Highly volatiles
- Insoluble in water, low soluble in vinegar and soluble in alcohol, oils, data and waxes
- They can be damaged by air and light exposures (oxidation)

The beast distillation system for essential oils and aromatic waters is low pressure steam extraction because It preserves the active principles and the organoleptic properties of the plant, avoiding the complete extraction.

SOURCES:

Julia Lawless, The Encyclopaedia of essential oils, Great Britain 1992

Valerie Ann Worwood, The fragrant pharmacy, London 1990

ECOCITRIC DISTILLATION SYSTEM

Fresh citrus leaves once inspected are introduced in the distiller, well pushed in the way to create a big solid bed…

…and extracting the steam essence contained in some “drops” located into the specific part of the plant (in this case into the leaves). The steam breaks the drops and the essential oil comes out in a highly volatile form.

This steam travel to the condenser where it is condensed and cooled creating a liquid mixture composed by water and essential oil. This liquid emulsion is separated…[…] with traces of essential oils (in the proportion of 1/2 %) called hydrolats or aromatic waters.

Aromatic waters are clear aqueous solution saturated with volatile oils or other aromatic or volatile substances eg. camphor. Their odours and taste are of those of the drugs or volatile substances from which they are prepared. In fact, the hydrolats contain the water-soluble fraction of the volatile component of the

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aromatic plants, and since the molecules that dissolve well in the water are those especially rich in oxygenated compounds, the hydrolats will be particularly rich in alcohols and carboxylic acids, weak acids which are absent from essential oils, while hydrocarbons, molecules composed solely of carbon and hydrogen and therefore not soluble in water, will only be in essential oil. The aromatic water will be so the more aromatic and charged the more the plant contains oxygenated compounds, while it will be rather poor in aroma when the plant contains almost only hydrocarbons.

In general, the percentage of essential oil present in aromatic water permit it to be preserved by molds but hydrolat production varies greatly from one country to another and from one distillation plant to another. In larger, commercial distillation plants, the material is usually distilled in a closed and controlled environment and therefore it is difficult for the hydrolats to be contaminated. But when the plant is small and in the open, hydrolats can easily be contaminated due to poor hygienic conditions of the plant or due to contact with the atmosphere. Unlike EOs, which are a substrate extremely refractory for the growth of bacterial or fungal colonies, hydrolats, being mainly water with a small amount of volatile compounds, are almost ideal substrates. Of course, a contaminated hydrolat can be safely restored by the bottling process if it is preceded by pasteurization or micro-filtration.

It is hard to think of hydrolats toxicity, since they are highly diluted derivatives of plants which are mostly permitted for free consumption; to reach a toxic dose it would be necessary to drink several liters of the substance.

There are not many scientific data supporting the hydrolats activity. According to various authors, the carboxylic acids present in hydrolats are very calming elements and are ideal for treating the skin, as they preserve its acidity. Also, the presence of a fraction of mono- and sesquiterpene alcohols is interesting for possible hydrolats applications when it is necessary to act with great delicacy with antiseptic and anti-inflammatory agents. Some hydrolats can be very useful in a limited range of problems, especially dermatologic ones. They can be cosmetic agents used to control excessive sebum production or to reduce acne inflammation. Some are ideal for eye injuries and inflammation of the conjunctiva and are, from this point of view, better than infusions because most of the plant particles are eliminated.

Given the absence of toxicity, it is possible to use them in place of the essential oils in the nebulizers in order to scent the air of a room without running the risk of exaggerating with the doses, and with the added bonus of nebulizing also water, useful in case of very dry air or respiratory problems. They can also be used as a simple and uncomplicated scent method or as refreshed sprays. In the last few years, aromatic waters have come back to the forefront of fashion in the field of aromatization of foods and beverages. Always due to their lack of toxicity and the delicacy of aroma, they are ideal to spice at the last minute on the dishes before serving them or as delicate marinade. In the cocktail range they can be replaced with the aqueous phase, added to increase the aromatic profile without altering the flavor.

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RECORDING CONDITIONS

The distilling conditions should be recorded as well as other data concerning collective conditions and characteristics of the grown place.

It would be appropriate if the producers collect data in schedules dedicated to each part of the process (watch schedules attached below).

An accurate estimate of the process should be done just by recording conditions, essential to determine the quality of the finished product.

Once obtained an optimal finished product would be appropriate to reproduce the best as possible all the conditions that determined it (same place, approx. same period of the year, same weather, collective techniques, conditions of the plant, distilling conditions…).

1. COLLECTIVE CONDITIONS:

- Latin name of the plant: …………………..

- Date: …………….

- Place: ……………………..

- Weather: ………………

- Conditions of the plant (age, pathogens if present, cultivar, cultivation techniques)

- Collective techniques: ……………………………….

- Weight in kilos: …………………………….

- Other: …………………..

2. PLACE'S CONDITIONS:

- Geographic coordinates: ………………….

- Altitude above sea level: ………………………..

- Exposure of the land: …………………………..

- Composition of the soil: …………………………..

- Water supply: ……………………………………

- Climate conditions during all the year: ………………………….

- Other: ………………………………..

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3. DISTILLING CONDITIONS:

- Distillation system: ……………….

- Date: ………………..

- Altitude above sea level: ……………………..

- Amount of vegetal material for each distillation: ………………..

- Time of starting: ……………………….

- Time of stopping: …………………….

- Amount of aromatic water in liters: ………………..

- Amount of essential oil in liters: ……………………..

- Other: ………………………..

4. HYDROLATE'S CHARACTERISTICS

- Amount in liters: ……

- Percentage: ……….

- Look & Texture (color, density, viscosity…): ………

- Other organoleptic tests (smell, feel, taste, flavor…): ……

- Chemical tests (quality control, composition, active principles, purity…): ……

- Handling, packaging & storage: …………………

5. ESSENTIAL OIL'S CHARACTERISTICS

- Amount in liters: ……

- Percentage: ……….

- Look & Texture (color, density, viscosity…): ………

- Other organoleptic tests (smell, feel, taste, flavor…): ……

- Chemical tests (quality control, composition, active principles, purity…): ……

- Handling, packaging & storage: …………………

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HANDLING, PACKAGING & STORAGE

Other considerations include packaging, storage and handling. Distilling products should be handled with care because if not trained for internal/external use they should be highly aggressive to skin and mucous tissues. Moreover, chemical degradation can occur with exposure to heat, light or oxygen.

Essential oils from citrus products are especially prone to oxidation that can quickly alter their chemistry.

Distilling products must be packaged in tightly closed, darkened glass containers and stored in a cool place to ensure high and lasting quality.

QUALITY IN ESSENTIAL OILS

Quality should be the most important aspect in distilling products. Nowadays it should be a priority to replace low quality distilling products with a high-quality offer on marketplace, in a perspective of an environmental and human care. In this perspective there are increasingly growing the health conditions related to the increased use of medications, processed foods and skin care products containing synthetics or low-quality ingredients, like skin and stomach affection or asthma.

In parallel there is a growing demand for pure, unadulterated essential oils that possess the optimum ratio of natural constituents, especially for therapeutic use in aromatherapy.

Essential oils however are distilled and used not only in holistic aromatherapy, but are also distilled for using in the personal fragrancing, home fragrancing, cosmetic and in the food/beverage/flavoring industry.

Until now in these industries where purchasers of essential oils use them for mass production, there is far less need for pure essential oils and far greater need for consistent, standardized essential oils that do not change from lot to lot.

This standardization process however is not ideal for aromatherapy work as the resulting oil is no longer an unadulterated distillation or extraction and may contain added isolates or may have important constituents removed.

What affects the quality of essential oils?

The aroma and the exact percentage of each natural constituent contained in a particular pure unadulterated essential oil can depending on a variety of factors:

- Quality of the soil the botanical is grown in
- Amount of rainfall during the year
- Temperature/climate
- Altitude

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- Harvesting/Collective practices
- Storage prior to distillation
- Time between harvest and distillation
- Part of the plant distilled
- Distillation system
- Source of water used for the process
- Storage conditions

TESTS FOR QUALITY AND PURITY

Distillers often test their oils to compare them with previous distillations. This helps them assess quality between harvest and distillation.

Several quantifiable tests exist that allow scientists, producers, suppliers and end users to be able to test their oils to determine quality and help to ascertain if an oil is pure, like GAS CHROMATOGRAPHY AND MASS SPECTROMETRY (GC-MS). This test can help to verify that the constituents contained within an essential oil sample are representative of what that particular essential oil should contain.

Unusual levels of particular constituents in the tested oil can flag that the oil is inferior quality or has been adulterated.

SOURCES: www.aromaweb.com

ESSENTIAL OILS AND SUSTAINABILITY

When it comes to protect the environment, sustainability is another key consideration in purchasing essential oils. Due to a variety of factors, large amounts of product in its best conditions are needed to produce oils and a number of plants used to create essential oils are increasingly overharvested.

While many manufacturers make it a priority to use sustainably harvested plant material, some companies may source their ingredients in a manner that seriously threatens natural resources. If we're not careful, essential oil use could potentially become one of the largest modern sources of environmental damage.

Being an environmentally and productively responsible company is fundamental in a sustainability perspective, for the benefit of the earth and of all the living beings, including human's health.

In this perspective the best practice should be obtaining less well priced high-quality products from a small amount of pure and clean plant's material than a cheaper low-quality product obtained from a big poor plant material amount.

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