# Circular Economy as a New Model for the Exploitation of the Agroindustrial Biomass

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**Abstract.** This paper focuses on a new concept of waste and by-products within the agricultural system, based upon the perspective of circular economy, which directs the agrifood chain and the life style towards a "zero waste" model. This new approach can be achieved through efficient small and industrial scale of bioenergy plants, biorefineries and environmentally friendly process for the production of biomolecules to be employed as active principles in agronomy, cosmetics, foods, feeds and pharmaceutical applications. In particular, the case study of this paper concerns the exploitation of Olea, Cynara and Chestnut tissues and by-products as new source for energy and bioactive antioxidant and antimicrobial compounds (polyphenols) (PCT/IT/2009/09425529 *Olea europaea* L.; PCT/IT/2008/000135 *Cynara scolymus* L., MI2014A000177 *Chestnut*), which will also be assessed in different Italian district. The regional level has been chosen for this analysis because the local approach allows to avoid and/or reduce the economic and environmental cost of the waste transport. The polyphenols market is projected to reach 1 billion dollars by 2020 and 4,790 potential source plants are present in Europe. The recovery of chemicals and the production of energy, should be a continuous process of interaction between high technology and environmental and economic sustainability, making this kind of multifunctional platform highly innovative and consistent with the principles of the circular economy.

***Keywords***: *Circular Economy, Biorefinery, Agroindustrial Residues, Antioxidant polyphenols*

## Introduction

Until now, a linear model of production and consumption has been used so, the new approach of circular economy moving towards a sustainable growth has to be developed. Based upon on this perspective a new concept of waste and by-products within the agricultural system can be suitable implemented. This new approach can be achieved through efficient small and industrial scale of bioenergy plants and biorefineries for the production of biomolecules to be employed as active principles in agronomy, cosmetics, foods, feeds and pharmaceutical applications. In particular, the case study of this paper concerns the exploitation of Olea europea L., Cynara and Chestnut tissues and by-products as new source for energy and bioactive antioxidant and antimicrobial compounds (polyphenols). In this paper a brief assessment of residual biomass from Olea and Cynara has been carried out in the Apulia region. On the basis on the data extraction plant localized in Tuscany and specialized on the generation of bioactive compounds (polyphenols) from the Chestnut tissues and by-products, it hypothesised a multifunctional platform as new source for energy and polyphenols to established in Apulia, a region of the South of Italy, where the two crops considered are the most cultivated in Italy.

## Material and methods

In order to quantify the amount of residues per crop (Cynara and Olea) and region, in particular Apulia, a methodology based on a linear correlation among the main output per year and the reproducibility factor of residues has been used (Paiano & Lagioia, 2016). Data and methods concern the extraction of the fractions from Cynara and Olea by products come from the extraction technology used by the unit operating in Tuscany, carrying out the tannin extraction from the Sweet chestnut fractions, based on new sustainable technologies like a water extraction and membrane separation system. This innovative process uses physical technologies (PCT/IT/2009/09425529 *Olea europaea* L.; PCT/IT/2008/000135 *Cynara scolymus* L., MI2014A000177 *Chestnut*), defined as BAT (Best Available Technology) and recognized from Environmental Protection Agency. The process is based on membrane technologies applied to aqueous extracts obtained by heating in a pneumatic extractor and then purified by filtration: microfiltration (MF) treatment, followed by an ultrafiltration (UF) of the previous permeate, finally concentrate with RO (Reverse Osmosis). The obtained fractions have been analyzed and characterized by chromatographic, spectrophotometric and spectrometric (HPLC-DAD-ESI-MS) methods in order to identify and quantify polyphenolic classes (Romani, Campo and Pinelli, 2012). The two commercial products obtained through this process are a liquid fraction concentrated by nanofiltration, and a dry extract by spray-drying from the liquid commercial fraction.

## Results and discussion

By the assessment of the residues in Apulia region the following figures have been estimated. About Olea, agricultural residues (leafy and bunch prunings) are approximately 695,000 t/y (dry substance, d.s.) and agro-industrial residues (olive oil by products, like pomace) are 260,000 t/y: both of them are equal to over 37% of the Italian total. For Cynara, residues are over 52,000 t/y d.s. considered (30% of the Italian total of Cynara residues). It has to be highlighted that material and energy analysis of the entire chain from residual biomass to the energy and biomolecules production will be carried out in the future research. Through the extractive technologies by membrane separation biophenolic fractions from Olea and Cynara have been produced and each sample have been analyzed by HPLC/DAD/MS quali-quantitative methods. The polyphenols from Olea matrices (olive oil by-products, leaves, stems and olive pulps), are known for the highly antioxidant properties and protective biological and biomedical effects (Brunelleschi et al, 2007; Pampaloni et al, 2014). By the extraction, four PHENOLEA fractions with different biophenol concentrations have been produced: PHENOLEA OH-TYR, obtained from olive oil by-products which contains hydroxytyrosol and derivatives more than 90%; PHENOLEA LEAVES-S from dried olive leaves, containing hydroxytyrosol and derivatives more than 50%, secoiridoids as oleuropein 20-35%, hydroxycinnamic derivatives as verbascoside more than 10%, flavonoids, luteolin and apigenin 7-O-glucosides, 2-7%, and trace amounts of lignans; PHENOLEA LEAVES-F from olive green leaves, with hydroxytyrosol and derivatives more than 20%, secoiridoids 60-70%, hydroxycinnamic derivatives as verbascoside more than 3%, flavonoids, luteolin and apigenin 7-O-glucosides, more than 2%, and lignans about 5%. Finally, PHENOLEA RED is an extract obtained from red olive pulps, containing besides the usual Olea polyphenol classes also anthocyanosides, in particular anthocyanosides evaluated as cyanidin 3-O-rutinoside 15-20%, secoiridoids as oleuropein 60-70 %, flavonoids, luteolin and apigenin 7-O-glucosides 10-15%, and hydroxycinnamic derivatives as verbascoside 3-7%.

As concern Cynara, the following active fractions with different polyphenol concentration have been produced: CYNARA_SOL is a purified concentrate fraction, obtained from artichoke's dry leaf extract (chlorogenic acid is the main polyphenol, with 50% of the total); CYNARA_CUF is an extract obtained by an ultrafiltration (UF) from artichoke's dry leaf (di-caffeoylquinic acids have the most quantity, over 40%); CYNARA_SPRAY, a powder obtained spray-drying the dry leaf aqueous extract, with over 75% of flavonols ; CYNARA_OL_TAN COMPLEX is a mix containing 49% Cynara_Sol, 49% concentrate green leaves extract of Olea and 2% grape seeds extract, characterized by the high presence of procyanidins (over 43%). These solutions and powders, enriched in polyphenols, could be employed to stabilize or enhance products, such as: baked foods, cosmetics and supplements for human health.

After the extraction of bioactive fractions, residues of Cynara and Olea can be used as animal feed, compost or other agricultural or agro industrial products and/or exploited as energy source. These residues, could be suitable in the energy cogeneration and/or anaerobic digestion. In particular lignocellulosic residues from Olea which have a high LHV (Low Heating Value) of 0.429 Tep/t are suitable for the thermochemical process for heat and/or electricity generation and olive pomace with LHV from 0.369 Tep/t to 0.161 Tep/t, according to its moisture content (from 12.50% to 55%) for biogas production. Cynara residues, characterised by a high moisture content (up to 85%), have a LHV of 0.405 Tep/t) usefully could be used for thermochemical processes, as well as for anaerobic digestion. As regards the sweet chestnut tannin extraction plant, it only uses heat produced by the waste biomass of the process (residue of the first extraction step and the residual virgin wood from chipper). These two kinds of residue provide 0.202 Tep/t which is the energy need for the extraction process that by 77.2 tons of virgin biomass produces the dry extract with a 4.7% yield. The polyphenols market is projected to reach 1 billion dollars by 2020 and 4,790 potential source plants are present in Europe. Extraction potential form brewing, malting, cereals and distillery plants exceeds 15.000 tons (Donnelly et al., 2015). The co-products and waste streams is very attractive for their increased value, for Europe Waste Framework Directive is prioritises the reduction and prevention of waste, reuse and recycling.

## Conclusion

The use of residual biomass as a source of bioactive compounds can be also considered as preliminary stage of a closed cycle for the production of energy from waste and exhausted raw material, according to the circular economy concept; indeed these results suggest the possibility of implementing a multifunctional platform, by which the agro industrial chain and the life style towards a "zero waste" model can be suitable developed. Optimizing the productive process, that uses sustainable technologies to obtain standardized and stabilized fractions with higher concentrations of biologically active molecules, will allow to gain new and increasing market shares, because of these biomolecules are suitable for innovative uses in many sectors, like agronomy, textile/dyeing, cosmetics, foods and phytotherapy; besides all of them increasingly demand high value added products, which also are environmentally friendly.

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