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Bio-Waste to Bio-Based

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The high nutritional composition of coffee silverskin makes it an excellent material for bioconversion to functional ingredients, and TEAGASC research is looking at how this might be achieved.

The Earth is projected to hold 9.6 billion people by 2050, consuming approximately 1.6 times the planet's resources and generating a consequent high amount of waste, according to the World Resources Institute. These unsustainable consumption and production patterns exhaust our resources, adversely impacting the climate, and causing air and water pollution, and loss of biodiversity and of fertile soil, among other environmental, social, and economic challenges. In spite of a general awareness that the future focus must be on prevention of waste generation, along with increased preparation for reuse and recycling as proposed under the circular economy concept, there is an urgent need to valorise waste biomass into high-value products and prevent it ending up in landfill, where it contaminates soil and groundwater and generates greenhouse gases (GHGs).

Coffee production and processing generates significant wastes throughout its life cycle stages, and if not treated properly it has critical environmental impacts as it contains caffeine, tannins and polyphenols. At an industrial scale the total quantity of coffee waste biomass generated each year globally is estimated to be around six million tonnes, while in Ireland more than 9,000 tonnes of coffee waste are produced each year, resulting in more than 11 million kg of CO_2 emissions. Most of the coffee waste is currently disposed of in landfills, where it breaks down to produce harmful GHGs, as well as hazardous pathogens and organic leachates that contaminate surface and groundwater courses. This needs to be drastically reduced, according to the EU Waste Framework Directive, 2008. Apart from this detrimental impact on the environment, all along the supply chain, much of the original coffee seed is wasted: research suggests that only about 1% of the seed biomass ends up in the coffee cup after the brewing process. Thus, the opportunity to utilise the majority of the nutrients extracted from soil during the growth stages of the coffee plant is lost. In order to develop a circular economy and the Irish bioeconomy, it is vital to ensure resource efficiency.

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Extraction of phenolic antioxidants

Research projects are currently underway in Teagasc and UCD to develop cleaner and greener pre-treatment technologies for conversion of 'bio-waste' into 'bio-based' products with potential applications in food, feed and biofuel. These projects have the potential to significantly reduce the burden on land use for protein and biofuels, not only in Ireland/Europe but worldwide, along with dramatically improving the conversion efficiencies of current bio-based production technologies. Moreover, these can significantly reduce the ever-increasing environmental problem of waste management and landfill use for waste deposition.

Under the European Union's Horizon 2020 'Waste2Fuels' project, Teagasc researchers are looking at sustainable production of bio-based products from coffee silverskin (CSS) waste. CSS is the major by-product produced during the coffee roasting process, and has started to attract interest in its bioconversion (Procentese *et al.*, 2019). Due to its high nutritional composition (**Table 1**), CSS is being considered as a source of functional ingredients, such as antioxidant compounds

or supplements of soluble dietary fibre. In this work, both simultaneous ultrasound/microwave-assisted (S-UMAE) and sequential ultrasound-microwave assisted aqueous extraction methods (U-MAE and M-UAE) are applied and compared with their individual techniques (UAE alone and MAE alone). The results indicate that S-UMAE showed greater potential and better extraction efficiency for phenolic antioxidants from CSS, compared with UAE, MAE, U-MAE and M-UAE. S-UMAE achieved 25.9 %, 16.7 %, 13.1 % and 12.8 % higher extraction yields than UAE, MAE, U-MAE and M-UAE, respectively. Additionally, the yields of total phenolic content and antioxidant capacity were enhanced significantly by S-UMAE compared to other methods. It was concluded that with the help of novel extraction technology, CSS extraction, with water as solvent, can enhance the extraction performance in a green and sustainable way, and combinations of these extraction technologies could accomplish a balance between extraction efficiency, product quality, consumption of solvent, and production costs in the industry.

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Table 1: Nutritional and mineral composition of coffee silverskin (data expressed as g per 100 g of dry weight).

Coffee silverskin composition (g/100 g)	
Moisture	5.89 ± 0.46
Protein	14.62 ± 0.23
Fat	3.60 ± 0.29
Ash	3.47 ± 0.39
Dietary fibre	64.45 ± 1.63
Insoluble fibre	54.7 ± 0.85
Soluble fibre	9.75 ± 0.78
Carbohydrate	7.97 ± 0.44
Macrominerals	
Calcium (Ca)	1.48 ± 0.05
Potassium (K)	1.21 ± 0.04
Magnesium (Mg)	0.05 ± 0.01
Sodium (Na)	0.05 ± 0.01
Iron (Fe)	0.04 ± 0.01

Commercial perspective

The real benefit of these projects, and their value for primary producers, will not be realised unless there is potential for industrial applications, and this calls for understanding the market for the end product and conducting techno-economic analysis of the procedure, which, when a technology or process is being developed, ensures that market-driven prices can be achieved (Priyadarshini *et al.*, 2018). With its components embedded in research and development of the process, techno-economic analysis and market assessment are invaluable, direction-steering tools. Therefore, the proposed next step in the projects being explored with researchers in TU Dublin, is conducting a costing analysis of the process to quantify the associated life cycle costs and scale-up potential. Market assessment of the end product is also needed, including its current production, manufacturers, product selling prices, product marketing, competing and substitute products, and customer analysis (such as: feed, food ingredient and food supplements manufacturers).

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