Sustainability analysis of new circular strategies for the use of coffee by-products as a new raw material for animal feed

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Introduction

The International Coffee Organization (ICO) reports that European Union countries are the largest coffee consumers worldwide, consuming more than 3 million tons of coffee annually and 53 billion coffee capsules per year. Coffee consumption generates approximately 2 kg of wet Spent Coffee Ground (SCG) from 1 kg of coffee consumed, and approximately 18 g of wet SCG and 3 g of plastics and aluminium waste per coffee capsule. Most of the SCG and coffee capsules are managed as urban solid waste and ends up landfilled or incinerated leading to soil, water, and air pollution.

However, several studies have demonstrated that SCG has high potential as a secondary raw material (1,2). In previous works its potential as secondary feedstuff for animal feed has been demonstrated (2,3,4).

The high moisture content of SCG makes them rapidly biodegradable due to microbial activity, and its handling and processing need to ensure animal feed quality and safety criteria while maintaining its nutritional properties to be used as feed ingredients. Proposed circular scheme include drying processes that are energy-intensive and expensive processes at an industrial level what leaded to analyse low energy consumption drying alternatives, and the use of cheap or renewable energy source to make the entire process more efficient both from the environmental and economic point of view. In this sense, the SCG which comes from coffee capsules is not suitable for animal feeding due to the presence of undesirable substances. Instead, it is proposed to be used as the source of energy for making the drying of SCG more efficient. However, before producing pellets, the organic part of the coffee capsules must be removed from the inorganic part by applying a decapsulation process.

This overall approach allowed us to define a circular economy scheme for the reuse of spent coffee grounds. To ensure the feasibility and suitability of the implementation of this solution a sustainability assessment, taking into account environmental, economic, and social point of view, has been performed.

The present study analyses the sustainability of valorising SCG to obtain an ingredient for animal feed, including the environmental, economic, and social points of view.

Material and methods

A Minimal Functional Processing Unit (MFPU) that would process 15,000 tons per year of SCG was defined as a standard scenario based on the SCG production by HORECA sector at EU level.

The environmental assessment was performed with the standard Life Cycle Assessment (LCA) methodology, which consists in identifying all the inputs and outputs with higher environmental impact and their quantification in a process encompassing the whole value chain. It is regulated by the ISO 14040 and involves four steps, 1) Definition of the Goal and Scope, 2) Life Cycle inventory analysis, 3) Life Cycle Impact Characterisation, and 4) Interpretation. LCA is an iterative technique that allows to increase the level of detail in successive iterations.

The study has evaluated the environmental impacts of different management systems of spent coffee grounds as a coffee by-product: 1) Valorisation to obtain dry feed ingredient for livestock (sheep), and 2) Valorisation to obtain dried hydrolysed feed ingredient for livestock (sheep), and the results were compared with current management options, Landfill and Incineration.

The economical assessment was based on the dimensions for the MFPU. The investment needed to set up a facility, also known as Capital Expenditures (CAPEX), was estimated according to this scenario. Based on this facility, the cost associated to the processing (Operational Expenses or OPEX) were calculated. This allows to evaluate main economic parameters such as Net Present Value (NPV), Internal Return Rate (IRR), Return On Investment (ROI) or the PAYBACK that allows to estimate to profitability of the proposed valorisation route.

The social assessment briefly describes the social impact of the proposed solution in several aspects of the society. The solution was evaluated according to other social benefits such as, creation or maintenance of jobs (direct and indirect), consumer and companies' awareness on environmental protection, contribution to the independence from imported raw materials, or contribution to EU sustainability goals.

Results and discussion

LCA analysis has been based on International reference Life Cycle Data system (ILCD) methodology released by the European Commission, Joint Research Centre in 2012. Sixteen environmental impact categories were assessed for the different scenarios.

The valorisation process (dehydration) is an energy intensive process, which represents a significant impact on the environment (+ 208 kg CO_2 eq.). However, due to the avoidance of oat grain and rapeseed meal cultivation and production (- 936 kg CO_2 eq.), the overall environmental impact obtains a negative value (-728 kg CO_2 eq.). When comparing the obtained environmental impact characterisation results with current management options (landfill and incineration), significant impact reduction results are observed. 1500 or 778 kg of CO_2 eq could be avoided per ton of coffee by-product generated, when choosing this management option instead of landfill or incineration, respectively. The valorisation process (hydrolyzation and dehydration) is also an energy intensive process, which represents a significant impact on the environment (+ 295 kg CO_2 eq.). However, due to the avoidance of oat grain and rapeseed meal cultivation and production (- 754 kg CO_2 eq.), the overall environmental impact obtains a negative value too. When comparing the obtained environmental impact characterisation results with current management options (landfill and incineration), significant impact reduction results are observed. 1230 or 509 kg of CO_2 eq could be avoided per ton of coffee by-product generated, when choosing this management option instead of landfill or incineration, respectively.

From the economic point of view, and MFPU set up in Spain will have an internal return rate of 14,5%, with a return on investment of 11,8% and a payback period of less than 6 years. This clearly states that, within the proposed scenario, the investment is clearly profitable, and the valorisation strategy could lead to an exploitation model and a business plan that could be self-maintained. However, the payback period might deter the participation of investor and public support might be necessary to promote the initiative.

The evaluation of social benefits resulted in different positive impacts such as:

- 10 new direct jobs per MFPU with the implementation of the new business activity of valorisation, with a potential of 3 units in Spain and more than 30 at European level.
- 24 new indirect jobs per MFPU according to the job multiplier factor of primary sector.
- Maintenance of jobs due to the improvement of the competitiveness and sustainability of the coffee sector, animal feed producers' companies and livestock sector.
- An increase of consumer and companies' awareness to sustainability and environmental protection related with waste management and in particular with the spent coffee ground case.
- Contribution to the independence from imported raw materials of animal feed producers and livestock.
- Behavioural changes in the spent coffee ground generators for improving their sustainability.
- Contribution to EU policies, and in particular to the reduction of organic landfilling objectives.

From the sustainability point of view, taking into account its three dimensions, this circular economy scheme has environmental, economic, and social benefits and, whiting the studied scenario, has a very favourable perspective. However, its implementation might need the support of public authorities, with public fundings or benefits, and also the deployment of circular economy strategies and policies that entails the initial reluctances of some actors.

Conclusions

Environmental, economic, and social analysis of the implementation of a valorisation scheme based on the use of spent coffee ground for the production of animal feed ingredients has been proved to be a valid option that would allow to set up a sustainable value chain that will favour not only the coffee value chain, but also the livestock sector and European society. This circular economy scheme will help to reach EU objective to be climate-neutral by 2050, but at the same time might need some public support or promotion.

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