Spent coffee ground as second-generation feedstuff for dairy cattle

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Abstract
The EU countries are the most important worldwide coffee consumers with an estimated amount of 2.52 million tons, of which the 8 % corresponds to Spain with 210,000 tons. However, the processing and consumption of coffee and coffee capsules leads to substantial amounts of residues, mainly coffee silver skin and spent coffee grounds (SCG): 1 kg of coffee generates around 2 kg of wet SCG. Around 46 % of this total SCG generation is still being dumped in landfills with the subsequent soil, water and air pollution. So, there is a need of an alternative solution for large SCG volumes currently sent to landfills.
On the other hand, livestock products are projected to increase up to by 70 % by 2050. Many of the ingredients in the diets of EU livestock are sourced from imported raw materials from the Americas: soybeans, etc. This deficit presents already a risk to social, economic and environmental progress in Europe due to the increasing scarcity of global resources. Within this framework, it is necessary the inclusion of biowaste in animal feed that will leads to additional benefits for animal feed sector: availability of environmentally friendly ingredient sources and decrease of dependence on foreign sources.
Within this framework, this study demonstrates that coffee by-products stand as a potential alternative for replacing soy meal in dairy cattle, due to their availability in Europe, their nutritional characteristics and the results obtained in the growing trials with animals.

Keywords: Valorisation; Spent coffee ground; Dairy cattle; Second-generation feedstuff.

Introduction

According to the International Coffee Organization (ICO), the coffee World production in 2017/18 is estimated at 9.5 million tons. The EU countries are the most important worldwide coffee consumers with an estimated amount of 2.52 million tons, of which the 8 % corresponds to Spain with 210,000 tons. The global coffee demand has increased by 33 % between 2000 and 2012 and it is expected to continue to rise due to emerging coffee markets. However, processing and consumption of coffee and coffee capsules leads to substantial amounts of residues, mainly coffee silver skin and Spent Coffee Grounds (SCG) [1]. According to bibliography, 1 kg of coffee generates around 2 kg of wet SCG. Therefore, despite the SCG is already being partially valorised for other applications (fertilizers, energy and high-value applications), around 46 % of the total SCG generation were still being dumped in landfills worldwide in 2014 [2]. Considering that the total wet SCG production in the EU countries is over 5 M tons for 2018, it is estimated that around 2.5 M tons of SCG will be dumped in the EU landfills with the subsequent soil, water and air pollution.
Regarding greenhouse gases emissions, the managing of coffee by products in the European landfills has an estimated impact of 650 million kg CO2 eq./year considering a carbon footprint of 0.26 CO2 eq./kg of SCG [3]. Therefore, due to the limited demand of high-value products, there is a need of an alternative solution for large SCG volumes currently sent to landfills.
On the other hand, many of the ingredients in the diets of EU livestock are sourced from imported raw materials from the Americas: soybeans, etc. This deficit presents already a risk to social, economic and environmental progress in Europe due to the increasing scarcity of global resources. Furthermore, according to FAO, livestock products are projected to increase up to by 70 % by 2050. Within this framework, EU waste framework directive promotes the inclusion of biowaste in animal feed that will leads to additional benefits for animal feed sector: availability of environmentally friendly ingredient sources and decrease of dependence on foreign sources.
Within this framework, the objective of this study was to develop, test and demonstrate an innovative, viable and sustainable solution which increases significantly the coffee by-products recovery at EU level, through their up-grading as animal feed ingredients satisfying the increasing demand of alternative raw materials for animal feed.

Material and methods

The proposed methodology involves testing and evaluating an innovative, viable and sustainable Valorisation scheme to increase significantly the coffee by-products recovery at European level as animal feed ingredient for the dairy producing livestock sector.
The selected geographic area for the case study is the north of Spain (Basque Country and Navarre). This region has been selected due to its representativeness of environmental problem targeted: Spain is the 3rd coffee consumer in EU with 210 thousand tons respectively. In addition, Spain is the 7th most important country in dairy cattle livestock activity with 7.1 million tons of milk delivered to the dairies. Therefore, the results arising from this demonstration trial may be applied in any EU region, since the coffee consumption and dairy cattle are widely distributed across EU. Therefore, the demonstration trial was developed at semi-industrial scale and in a representative EU region to evaluate of technical and economic viability of industrial-scale implementation. It allowed to diminish the potential uncertainties related to the extrapolation of the results to any other EU region.
The study of the different stages in which recovery process is divided involves: 1) a multi-product and inverse logistic collection system for spent coffee ground from HORECA and coffee capsules from Vending machines 2) a materials' separation methodology and/or technology for coffee capsules 3) the suitability of drying technologies for the spent coffee ground processing and stabilization 4) the potential of the new ingredients to increase up to 10 % the milk production and fat content without altering animals' behaviour.
The scale of the demonstration trial involved to collect about 3 tons of spent coffee ground to produce about 1.5 tons of spent coffee ground ingredient. Then, this ingredient was included at 5 % of inclusion to produce about 30 tons of an experimental diet which was tested in 150 heads of dairy cattle for about half a month.

Results and discussion
Obtained results show the feasibility and the appropriateness of the multi-product collection system for centralizing spent coffee ground produced by HORECA sector in a processing plant. The simultaneous collection of used oil and coffee spent ground in HORECA sector is a good option for make profitable the valorisation of coffee spent ground as a new ingredient for animal feed. In addition, the inverse logistic collection system for centralizing coffee capsules in a processing plant is also a very good option. Both collection systems are based in an optimization of a current transport system for the collection coffee by-products.
In addition, the materials' separation methodology for coffee capsules was demonstrated feasible (Figure 1). Firstly, coffee capsules are crushed to extract the spent coffee ground. Then, the crushed material is placed in a vibrating screen sieve (3 mm) to recover the organic part and leaving above plastic and aluminium. Finally, plastic and aluminium are separated according to the Eddy current where metal elements are attracted by a magnetic system.

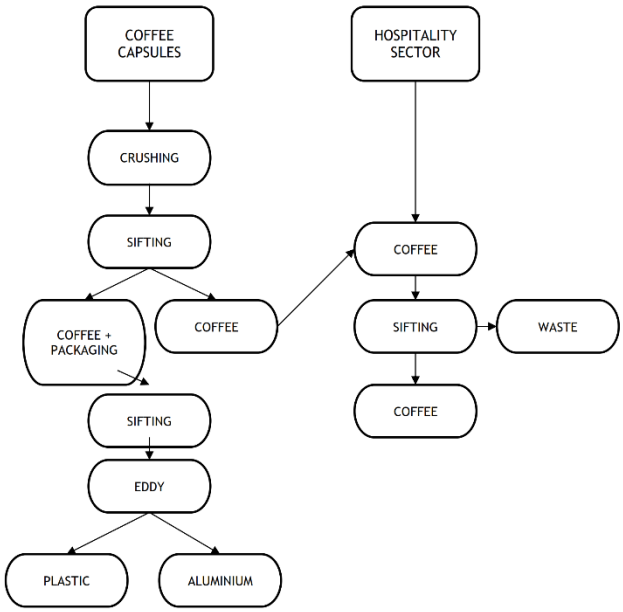

Fig 1 Proposed Flow chart for coffee capsules treatment

The suitability of flash drying technology for the spent coffee ground processing and stabilization (Figure 2) was successful demonstrated and an interesting ingredient for animal feed was obtained.

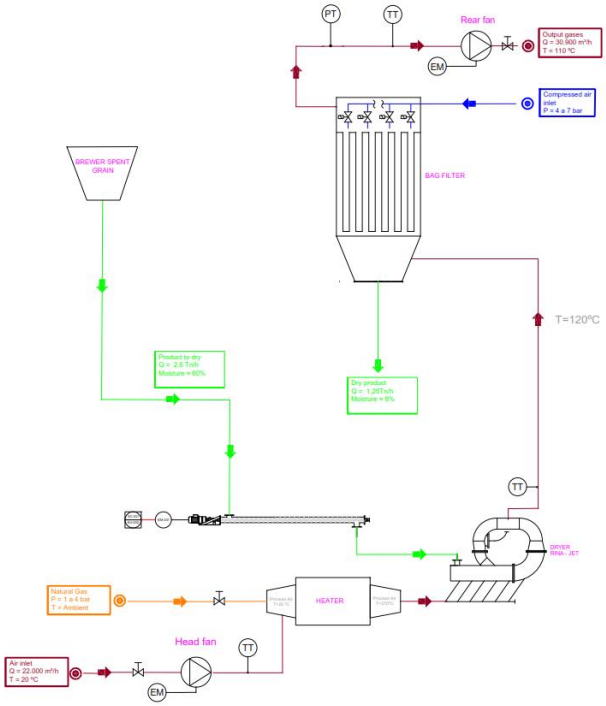

Fig 2 Proposed Flow chart for spent coffee ground drying

Obtained ingredient based on coffee by-products was included in an experimental diet with a 5 % of inclusion level (Table 1):

Table 1 Composition of experimental diet for dairy cattle with 5 % of spent coffee grounds

Raw materials	Protein	Forage Units-milks (UFl)	Starch	Fat	% Inclusion
Barley	11.6	1.09	60.2	2.1	14.92
Durum wheat	16.5	1.17	63.3	2.1	4.48
Corn	9.4	1.22	74.2	4.3	37.90
Rapeseed cake	38	0.96	0	2.6	13.35
Soy cake	47	1.20	0	1.9	18.43
Oil	0	2.73	0	100	1.54
Spent Coffee grounds	13.4	0.16	0	13.55	5.00
Vit-min	0	0.00	0	0	4.38

Finally, the potential of the new ingredient was tested in dairy cattle with the following results: slight increase or maintenance of the milk production and fat content without altering animals' behaviour.

Table 2. Average daily production and milk quality in dairy cattle with 5 % of spent coffee grounds

	Control	5 % of inclusion	EEM[1]	p-valor
Production (L/day)	31.4	31.8	0.61	0.0715
Crude protein (g/kg)	33.5[a]	32.9[b]	0.37	0.0018
Crude fat (g/kg)	39.3	40.0	0.93	0.1345

[1]: Standard error of the mean. Within a row, mean values with different superscripts indicate significant differences ($p < 0.05$).

The scale of the demonstration trial will allow to achieve a transfer readiness level (TRL) of 7, which reduces considerably the techno-economic and environmental risks and facilitates the replicability and/or transferability of the project across EU countries.

Conclusions

In conclusion, coffee by-products stand as a potential alternative for replacing soy meal in dairy cattle, due to their availability in Europe, their nutritional characteristics and the results obtained in the growing trials with animals.
Proposed solution will reduce coffee by-products quantities which are disposed in a landfill through their up-grading as animal feed ingredients. It will contribute to increase the sustainability and competitiveness of coffee producing and consuming sector.
On the other hand, it will also satisfy the highly increasing demand of new raw materials for animal feed production (dairy cattle) through the substitution of around 5 % of current raw materials at case study level by more sustainable ingredients from coffee by-products. It will contribute to increase the sustainability and competitiveness of feed sector by reducing the dependence on current raw materials market.
From the environmental point of view, it will contribute to the sustainability and the social acceptance of the livestock activity and its products. Their availability will contribute to reduce the environmental impact related to animal feed. In addition, it will reduce the environmental pressure and the overexploitation of soil associated to the agricultural activity by reducing necessary soil destined to produce vegetable raw material for animal feed. Finally, although the valorisation of spent coffee ground might also impact over the environment due to the required energy for by-products stabilization, the existing new low-carbon drying technologies and the eco-design concept applied to the construction of new by-products valorisation plants will contribute to reduce the environmental impacts comparing to the current management practices.
Summing up, this solution will increase in the Environmental Efficiency and Competitiveness of coffee value chain by improving the image of environmental protection and sustainable use of resources. In addition, it will increase the Sustainability and Competitiveness of feed producing sector by providing a new sustainable raw material from coffee by-products which satisfies the highly increasing demand of alternative new raw materials. Finally, it will increase of the Sustainability and Social acceptance of the livestock activity by reducing the environmental impact of their activity.

Acknowledge
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