Valorization of spent coffee grounds - tannin recovery

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Spent coffee grounds (SCG) are a lignocellulosic biowaste, with interesting composition, including valuable compounds such as antioxidants, tannins, cellulose, lipids. The best combination of the different parameters allowed us to recover 25.6 mg of tannins from 40 g of SCG, making it the best yield. The corresponding test conditions were: SCG collected from cafeteria with a moisture content of 53%, extracted using ethanol as the solvent, at a solid to liquid ratio of 40 g: 50 ml, at a temperature of 50 ºC, for 1 hour of contact time. With this rate of recovery of tannins from SCG, if only 50% of the SCG produced in Portugal were collected, it would be possible to recover around 16,040 kg/year of tannins.

Keywords: Biowaste valorization, Spent coffee grounds, Circular economy, Tannins

1. Introduction

The high coffee consumption in the world makes spent coffee grounds (SCG) one of the most abundant kind of waste in the world (Narita and Inouye, 2014). This residue presents an extremely high contamination potential due to the toxic compounds that constitute it (tannins, caffeine, polyphenols, etc.) (Dattatraya Saratale *et al* 2020).

The disposal of these compounds, many times made in uncontrolled conditions, represents a big and dangerous risk to the environment. In an attempt to develop a potential solution to fight this problem, while extending the life of coffee within a circular economy framework, this work aimed to evaluate the potential for valorization of spent coffee grounds, namely through tannins recovery. Thus, in this work it was optimized the extraction conditions of tannins in samples from different origins (SCG from espresso capsules, SCG from restaurants and cafeterias – standard SCG, etc.), testing processes for the recovery of tannins and their conversion to tannase. Subsequently, it was optimized the process for tannins recovery from the SCG.

2. Materials and methods

2.1. Experimental conditions for tannin extraction

In the first phase of this work, the varied parameters for tannins extraction were the following: type of sample (standard SCG, SCG from capsules), type of solvent (acetone, methanol, ethanol and water), extraction temperature (50 °C and TA (21-23 °C)), wet or dried SCG, for 1 h of extraction time. In a second phase, in addition to the conditions mentioned above, it was tested 2 h extraction time, extraction of a SCG sample with 53% moisture content, and an extraction with 2 contacts of 1 h contact time each.

2.2. Tannin quantification

Tannin quantification was performed as follows: 1.58 ml of water, 0.1 ml of Folin reagent, 20 µl of extract sample were inserted in a test tube, stirred to homogenize and let stand for 5 minutes. Then, 0.3 ml of sodium carbonate at 20% were added to the test tube and incubated at 45 ºC for 30 minutes. A blue colour developed after incubation of the samples. After incubation, the absorbance (ABS) was read in a UV-Vis specttopometer (Shimadzu UV-160 A), at 765 nm (λ= 765 nm). A calibration curve for galic acid (ABS = 0.0156 Ct + 0.0028) was used to determine the tannins concentration (Ct, µg/ml) and the amount of tannins recovered (Tr, µg) was calculated using tannin concentration and the volume of supernatant from the extraction step (Vf, ml) (Tr = Ct × Vf).

3. Results and discussion

The results show that extraction of SCG with a moisture content of 53%, using ethanol as a solvent at a solid to liquid ratio of 40 g: 50 mL, in two consecutive contacts of 1 h each, at a temperature of 50 °C yield the higher recovery of tannins of 0.044% (Fig. 1.), which is within the range of values reported in the literature of 0.02-0.45%. Thus, in the first contact, 17.7 mg of tannins were extracted at a temperature of 50 ºC, and in the second contact additional 7.9 mg could be recovered, giving a total of 26.6 mg of extracted tannins. For the room temperature assay, a total of 15.0 mg of tannins was recovered.

Moisture in SCG facilitates the penetration of the solvent into the sample, allowing to increase the yield from the total contact time; however, the disadvantage for large-scale application, is the need for larger reactors due to the moisture content of the SCG that increases its volume, which entails higher energy consumption and higher initial investment. Using the SCG as collected (with moisture) reduces the energy consumption for drying, but makes it more important to increase the frequency of SCG collection and transportation to the processing facility as moisture favours development of fungi and moulds.

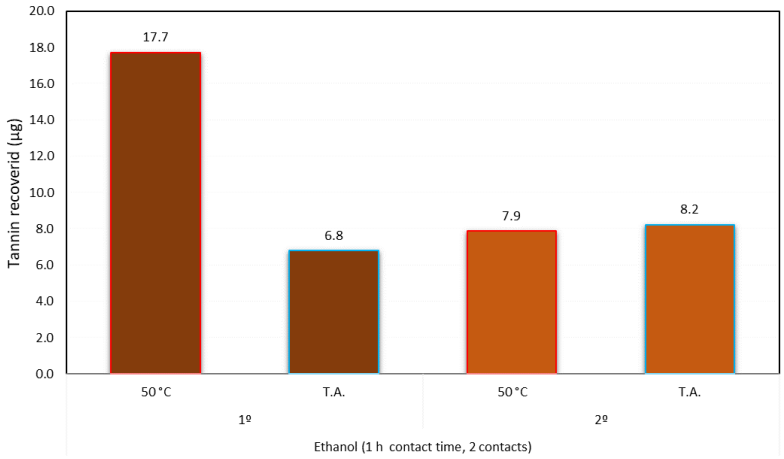

Fig.1. Results of extraction of tannins using a sample of wet spent coffee grounds (53% moisture) using two 1 h contacts.

Comparing the results obtained in the present work with those in the literature for other feedstock, such as cashews with tannin extraction yield between 0.35 - 0.72 %, cassava 0.62 - 1.11 % and acacia wood 2.77 % (Battestin *et al* 2004), it is evident that SCG yield lower amount of tannins; however, the amount of SCG available is much higher than that of other raw materials, representing a waste with high need to obtain a new end of life.

Considering the amount of SCG produced in Portugal (only SCG produced in cafeterias), with an average of 4.4 kg of coffee consumed per person per year and with a population of 10,297.1 thousand inhabitants and considering that only 80% of the coffee is consumed in the cafeterias, 36,247.8 tons/year of SCG are produced, if the SCG has 53% moisture, the residue must correspond to 68,388.3 tons/year. It can be estimated that it would be possible to extract and recover about 16,040 kg of tannins annually. For this purpose, it would be necessary to collect the SCG and send it to tannin extraction units, which would use the ethanol solvent, at a temperature of 50 °C, with a moisture content of 53% and two extraction steps with contact time of 1 hour each.

4. Conclusions

The best combination of the different parameters allowed us to recover 25.6 mg of tannins from 40 g of SCG, making it the best yield. The corresponding test conditions were: SCG collected from cafeteria with a moisture content of 53%, extracted using ethanol as the solvent, at a solid to liquid ratio of 40 g: 50 ml, at a temperature of 50 ºC, with two consecutive contacts of 1 hour contact time each.

The fact that the residue is wet facilitates the penetration of the solvent into the sample, allowing higher efficiency to be obtained from the total contact time; however, it presents the disadvantage for large-scale application, with the need for larger volume extractors, due to the moisture content of the SCG, which entails higher energy costs and a greater initial investment. On the other hand, it has the advantage of not having to spend energy to remove the moisture from the wet SCG waste, being necessary the daily collection of commercial SCG for its use, since storing wet SCG, fungus and moulds will develop. The success of this process can inspire the establishment and development of an industry that uses a residual feedstock, leading to the creation of several jobs and valuable products, contributing to the promotion of Circular Bio-Economy and the valorization of bio-waste.

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References

Battestin, V., Matsuda, K.L., Macedo, A.G. (2004) Fontes e aplicações de taninos e tanases em alimentos. Alimentos e Nutrição, Araraquara, 15(1), 63-72. (in Portuguese).

Dattatraya Saratale, G., Bhosale, R., Shobana, S., Banu, J. R., Pugazhendhi, A., Mahmoud, E., Sirohi, R., Kant Bhatia, S., Atabani, A. E., Mulone, V., Yoon, J. J., Seung Shin, H., & Kumar, G. (2020). A review on valorization of spent coffee grounds (SCG) towards biopolymers and biocatalysts production. Bioresource Technology 314, 123800. https://doi.org/10.1016/j.biortech.2020.123800

Narita, Y., & Inouye, K. (2014). Review on utilization and composition of coffee silverskin. Food Research International, 61, 16–22. https://doi.org/10.1016/j.foodres.2014.01.023