Ways to Reuse Spent Coffee Ground: a Brief Overview

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Abstract

Currently, coffee is among the most consumed non-alcoholic beverages in the world. Due to the increased consumer demand for coffee, there is an excessive production of waste arising during this beverage preparation. The accumulated waste from coffee consumption is in literature named spent coffee grounds (SCG). The accumulation of SCG can adversely affect the environment. When significant amounts of SCG are disposed of inlandfills, their anaerobic degradation occurs, which leads to the formation and emissions of greenhouse gases such as methane and carbon dioxide. Furthermore, chemical substances are released into the environment, such as tannins, polyphenols or caffeine, which can affect soil fertility. In order to reduce the undesirable impact on the environment, various repeated methods of this by-product utilization and their application on the market are being studied. The aim of the work was to create an up-to-date overview of the use of SCG invarious branches of industry. The information obtained can be considered usable foundation and base for further research about SCG.

Keywords: *biowaste, landfills, bioplastics, circular economy, recycling*

Introduction

Coffee is one of the most commonly consumed beverages worldwide. The International Coffee Organization reports that at the turn of 2021/2022, there was a global increase in coffee consumption of up to 4.2%, to 175.6 million of 60kg bags (International Coffee Organization, 2023). Based on the data obtained over the years, it can be assumed that there will continue to be a growing demand for this commodity in the upcoming years, resulting in an increase in the amount of by-products coming from the coffee industry. Coffee by-products (mainly SCG – Spent Coffee Grounds), end up in landfills, where their presence adversely affects the environment, meaning that alternative ways of SCG utilization would be highly appreciated (Andrade et al., 2022).

During the coffee grain production and preparation process, several by-products are generated, including skin, pulp, parchment layer, silver membrane and SCG, which makes up the bulk of the coffee waste. SCG could be defined as the fixed residual fraction obtained after coffee preparation (Sousa et al., 2015). SCG composition is quite variable and depends on many factors, for example, the type of coffee, growing conditions, as well as the method of coffee preparation. SCG is primarily composed of polysaccharides, hemicellulose and cellulose, which are present in approximately 50% (Ballesteros et al., 2014; McNutt and He, 2019). A significant amount of the dry matter consists of lignin and proteins, each in about 20%. The main fatty acids found in SCG oil are oleic acid (9%), palmitic acid (36%), and linoleic acid (44%). The amount of oil fraction in SCG varies between 7.90% and 26.40%, while crude fiber content ranges from 19.70% to 22.10%. Furthermore, the micronutrient composition per 100 grams of dry weight includes 882 mg of potassium (K), 220 mg of magnesium (Mg), 153 mg of phosphorus (P), 2.7 mg of manganese (Mn), and 2.5 mg of copper (Cu) (Cruz et al., 2012; Campos-Vega et al., 2015, Kovalcik et al., 2018; Saratale et al., 2020). As for bioactive substances, a significant part of them is extracted in the preparation of coffee. SCG is a good source

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of compounds such as caffeine, epicatechin, catechin, rutin, flavonoids, esters of caffeic and ferulic acids, chlorogenic acid, trans-ferulic acid, and many others. All of the above bioactive compounds perform a number of important biological functions in the body, including antioxidant, antimicrobial, anti-inflammatory, anticarcinogenic, and they can also have a neuroprotective effect (Ramón-Goncalves et al., 2019). The difference between the chemical composition of green coffee, roasted coffee and SCG is shown in Table 1.

At the present time, SCG is an important waste product that has versatile applications in various sectors. It can be used in the production of spirits, fertilizers, insecticides, cosmetics, biofuels, construction products, but also in the nutrition of some animals (Andrade et al., 2022; Singh et al., 2023).

The aim of this article is to create an overview of the use of coffee grounds in industry, from current information available in the literature, which can be applied in further research on this commodity. This paper used selected expert articles available in the following databases: Web of Science, Science Direct and Scopus. Preference was given to recent articles, published within the last decade.

SCG use in the food industry

In recent years, scientific literature has focused on the use of SCG, or its ingredients, in the food production. This is due to the presence of polyphenolics, melanoids and polysaccharides in SCG, which favorably affect the properties of final products (Cavanagh et al., 2023). It has also been noted that after the addition of SCG to food, the amount of mycotoxins is reduced to acceptable levels (Badr et al., 2022).

In their study, Hussein et al. (2019) tested the effect of adding SCG to wheat flour on the chemical and sensory properties of sponge cake. In the preparation of the dough, SCG was used in concentrations of 2%, 4% and 6%. All tested concentrations favorably affected the properties of the product. During baking, there was a decrease in the formation of brown coloration, due to the lower sugar and protein content, compared to the control. Furthermore, the addition of SCG significantly affected the volume, weight, and softness of the dough after baking (Hussein et al. 2019). In another study looking at bakery products, Meerasri and Sothornvit (2022) found that oil extracted from SCG is still a source of compounds that favorably affect the final product. It can be used as a butter substitute in bakery products, up to 20 percent. In the final product, there was an increase in the content of total polyphenols and antioxidants, however, there was a slight decrease in the strength of the biscuits compared to the control (Meerasri and Sothornvit, 2022).

SCG finds further use in the production of fermented alcoholic beverages, which are characterized by a delicate coffee flavor. Wang et al. (2021) focused on the production of an alcoholic beverage using a yeast culture of *Saccharomyces cerevisiae*, specifically strain D254. To ensure the correct course of fermentation, it was necessary to add 20% sucrose to SCG, adjust pH to 4.0 using citric acid, ammonium phosphate in 0.20% was used as a source of nitrogen. After completion of the main fermentation, the post-fermentation phase took place at 15 °C for 30 days (Wang et al., 2021).

In addition to the direct use of SCG in food, this by-product can be used as raw material in the production of biodegradable films. Its heavily represented polysaccharide fraction serves as a precursor in production, while contributing to the improvement of mechanical properties (Batista et al., 2020; Coelho et al., 2021). In the case of the addition of antioxidant or antimicrobial components to the mixture, it is possible to produce so-called active biofilms, which are able to favorably affect the shelf life and safety of packaged food. Biodegradable films are generally produced as alternatives to synthetic packaging materials that adversely affect the environment and animal health (Da Rocha et al., 2018; Dirpan et al., 2023).

SCG use in agriculture

One possible way to recycle SCG is to include it in animal feed. Over the past few years, studies have been conducted on the impact of SCG consumption on animal health.

Bhandarkar et al. (2020), in their study conducted on rats, found that the inclusion of SCG in the diet led to a decrease in total weight and abdominal fat, and decrease in systolic blood pressure. At the same time, there was an improvement in heart, liver and intestinal microbiota function in the subjects observed. With 6 weeks of supplementation, 100 grams of SCG per day, there was no effect observed on the amount of milk produced in dairy goats, but there was an increase in fatty acid content (Carta et al., 2022). Díaz de Otálova et al. (2020) published an article in which they looked at the effect of the addition of several concentrations of SCG to sheep feed parameters, such as the amount of milk produced and its quality, food behavior, digestibility, and short-chain fatty acid content. After 51 days, an addition of 100 g/kg of feed (dry matter) was found to increase milk production, without significant changes in dietary behavior (Díaz de Otálova et al., 2020).

Due to its considerable content of organic compounds, SCG is a suitable source of nutrients for the soil. When using SCG as fertilizer, the advantage is its ability to absorb heavy metals present in the soil and thus prevent their further migration (Campos de Bomfim et al., 2023). In order to avoid potentially toxic reactions with the soil, due to the content of substances such as caffeine and antioxidants, it is advisable to apply farmed earthworms into the soil, which by their activity cause a decrease in the concentration of these substances (Liu and Price, 2011; Hanc et al., 2021).

Hussein et al. (2022) investigated the ability of methanol extract from SCG to act as a bio insecticide against pests typical for green beans, including for the example: *Aphis craccivora*, *Agrotis ipsilon*, *Spodoptera littoralis*, *Bemisia tabaci*, and *Empoasca fabae*. An extract rich in flavonoids and phenolic compounds showed an insecticidal effect, with a mortality rate of 27.5-76% compared to the control samples, prepared without the addition of SCG (Hussein et al., 2022).

Table 1. Chemical profile of green coffee, roasted coffee and SCG (%, dry base).

Coffee type	Carbs	Hemi-cellulose	Lignin	Protein	Oil	Caffeine	Chlorogenic acid	Reference
Green	60	15	2	13	13	1.0-2.0	4.1-7.9	Saud and Salamatu-llah, 2021
Roasted	46-53	5-10	1-3	8.5-12	17.7	0.8-1.4	6.7-9.2	Mussatto et al., 2011
	31-33	-	3.0	10	17	1.1-1.3	1.9-2.5	Farah and Chu, 2012
SCG*	50	45.3	-	13	15	0.5	12	Campos-Vega, 2015
	82	36.7	-	13.6	15.3	0.4	11.5	Janissen and Huyh 2018; Al-Hamamre et al, 2012

*SCG: spent coffee ground

SCG use in the pharmaceutical and cosmetic industry

In the pharmaceutical and cosmetic industries, SCG oil is a valuable ingredient in products, mainly due to its antioxidant, moisturizing and softening properties when applied to the skin. It is reported that already about 10% addition of the oil fraction to the face cream, increases skin hydration and improves its barrier abilities (Ribeiro et al., 2013). Protective properties against UVB radiation have also been described. SCG oil's ability to absorb ultraviolet radiation is attributed to linoleic acid, tocopherols, and waxes (Vidal et al., 2020).

The oil fraction of SCG is composed primarily of triglycerides, approximately 75%, and tocopherols, phosphoglycerides, waxes and sterols are present in 19%, but its composition may vary depending on the coffee variety and oil extraction method (Vidal et al., 2020).

Kanlayavattanakul et al. (2021) in their paper focused on the preparation of linoleic acid-rich SCG oil and its impact on the skin. The authors have confirmed that linoleic acid-rich oil is safe and can be used in the cosmetics industry. Furthermore, it has been found to be able to inhibit the production of melanin in cells and stimulate collagen production. According to authors, it can be assumed that it is a product that is able to brighten the skin and reduce the amount of wrinkles by increasing skin elasticity (Kanlayavattanakul et al., 2021).

Conclusion

SCG accounts for a large proportion of the waste produced daily worldwide. It is the commodity with great potential for use in food or other industries due to the significant content of bioactive compounds and carbohydrates that can enrich existing or new products. At present, many utilization technologies are still in the research phase, especially because the right choice of raw materials and technological processes is essential in the processing of SCG as a waste product. The review briefly summarizes the current possibilities of using SCG, especially aiming to promote the circular economy.

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