White Paper n.1

# Spent Coffee Grounds

## Beyond the Brew:
## *The Hidden Potential of Spent Coffee Grounds*

CENTER FOR CIRCULAR ECONOMY IN COFFEE

# Executive Summary

The value of coffee goes beyond the beverage. The entire coffee plant contains valuable bioactive compounds and characteristics sought after in a variety of industries. Yet when we brew a cup of coffee, less than 5% of the original coffee cherry remains in our cup. The remaining 95% of the coffee cherry can become either a waste management problem with real environmental implications, or an opportunity to generate new business, improve agricultural productivity, and mitigate climate change.

Spent coffee grounds (SCGs) are the primary solid residue remaining after the brewing of roasted and ground coffee. They represent one of the largest waste streams in the coffee consumption phase, generated daily across industrial, commercial, and domestic contexts. Today, the coffee sector generates 11 million tons of SCGs annually, making it one of the largest food-related waste streams worldwide. When discarded in landfills, SCGs emit more than 700 kg of $CO_2$ equivalent per ton, primarily in the form of methane, a greenhouse gas 25 times more potent than $CO_2$. With coffee consumption rising, the stakes are clear: we must rethink SCGs not as waste, but as a renewable feedstock for sustainable growth.

## The Circular Opportunity

SCGs are rich in cellulose, lignin, lipids, proteins, and antioxidants—compounds that make them valuable across multiple industries. From organic fertilizers and mushroom substrates in agriculture to fiber-rich food ingredients, caffeine-based skincare, biofuels, and even textiles and bioplastics, SCGs offer a pathway to transform waste into wealth. Circular models built around SCG valorization can unlock new income streams for women and youth, addressing structural inequities in the coffee sector while creating jobs and fostering innovation.

## Environmental Gains

Valorizing SCGs delivers measurable climate benefits. Life cycle assessments show that SCG transformation can reduce emissions by up to 76% compared to landfill disposal. When SCGs are used for bioenergy, greenhouse gas emissions can be reduced by up to 50% compared to fossil fuels. Beyond emissions, circular strategies conserve water and resources, helping maintain balance within planetary boundaries, countering coffee's resource intensity. It takes approximately 140 liters of water to produce a single cup of coffee, and the carbon footprint of each cup is estimated at 0.45 kg $CO_2$ equivalent.

## Unlocking the Value of SCGs

SCGs are not merely waste; they represent a significant source of bioactive and structural compounds. Their composition and potential applications are shown in *Table 1*. These compounds make SCGs a versatile feedstock for industries ranging from agriculture to advanced materials.

## Unlocking the Value of SCGs

Despite their potential, SCG valorization faces challenges. The high moisture content of fresh SCG (often exceeding 60%) complicates storage, transportation, and retention of desirable properties, requiring energy-intensive drying or stabilization. Collection logistics remains a major barrier due to the dispersed nature of coffee consumption, where waste generation occurs diffusely across households and cafés rather than centralized facilities. Compositional heterogeneity is another barrier since

| SCG components | Chemicals | Property | Application |
|---|---|---|---|
| Cellulose & Hemicellulose | Sugars | Substrate for fermentation | Bioplastics, textiles, packaging |
| Lignin | Phenolic polymers | Antioxidants, mechanical strength, binding, thermal stability | Cosmetic formulations Bio-based chemicals and energy systems, bioplastics |
| Proteins | Acids | Antioxidant, antimicrobial | Bio-stimulants, nutraceutical, animal feed, food ingredient, soil amendment |
| Lipids | Oleic acids<br>Linoleic acids<br>Palmitic acids<br>Tocopherols | Antioxidant, antiaging | Bio-oils & emulsions for cosmetics |
| Phenols & Bioactive Compounds (including residual caffeine) | Chlorogenic acids<br>Caffeic acids<br>Flavonoids | Antioxidant, anti-inflammatory | Pharmaceutical, nutraceutical, cosmetics |
| Nitrogen Compounds and Minerals | Nitrogen and Minerals including magnesium, potassium, phosphorus, calcium, and iron | Support plant fertility | Agricultural use as soil amendment and biofertilizer, food |

*Table 1 Composition and potential of SCGs*

SCG composition varies depending on coffee species, brewing method, and roasting conditions leading to inconsistencies in functional properties and safety profiles. Such variability complicates the standardization of extraction protocols and quality control for food-grade applications. Finally, regulatory ambiguity further limits progress. These materials occupy a complex regulatory space that intersects waste management, food safety, cosmetic legislation, and renewable energy policy. Lack of harmonized waste classifications, end-of-waste criteria, and clear safety protocols continues to act as a structural barrier to progress. Effective valorization strategies therefore depend not only on technological feasibility but also on the legal re-classification of SCG from “waste” to “secondary raw material” or “by-product” under national and supranational legislation.

# Call to Action

## *Key takeaways box*

- SCGs are generated in three main contexts: industrial, commercial, and domestic.
- Controlled collection and pre-processing to stabilize SCGs is essential in order to prevent contamination from food residues and contaminants, especially in a cafe, restaurant, or mixed waste environment.
- Coffee generates **11 million tons of SCGs annually**, one of the largest food-related waste streams.
- **Landfilling SCGs emits over 700 kg $CO_2$ per ton**, while Life cycle assessments demonstrate that valorization can reduce these emissions by up to 76%.
- **For every kilogram of instant coffee, 2 kg of wet SCGs are produced**, underscoring industrial-scale waste.
- SCGs contain valuable properties including **cellulose, lignin, lipids, proteins, and antioxidants**, enabling applications in agriculture, food, cosmetics, textiles, and energy.
- The lipid component can be recovered as coffee oil, an ingredient of increasing interest in the cosmetic and pharmaceutical industries.
- Residual caffeine in SCGs, though lower than in raw coffee beans, remains valuable for topical products targeting circulation, supporting anti-cellulite and firming cosmetic formulations.
- Circular models create **new income streams for women and youth** in coffee producing countries, promoting equity and inclusion.
- **Moisture content and fragmented collection** remain major logistical challenges.
- **Regulatory ambiguity** and waste classification limits scaling; reclassification is essential particularly for food and cosmetics applications.
- **Local processing hubs and reverse logistics** can cut costs and emissions.
- Financing and IP strategies are critical to **scale circular innovations and attract investment**.

*Unlocking SCG potential requires coordinated action:*

- ***Policy Alignment*** *to harmonize waste classifications and end-of-waste criteria*
- ***Financing and IP Strategies*** *to de-risk investments and support innovation*
- ***Collaboration*** *among coffee producers, innovators, and policymakers to scale circular solutions globally*

***With supportive frameworks and investment in scalable technologies, SCGs can become a cornerstone of the circular bioeconomy — turning coffee waste into a driver of climate resilience, social inclusion, and green innovation.***

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