

Review

Not peer-reviewed version

Life After Brewing—Finding New Purposes for Spent Coffee Grounds: A Review

[Gaja Anna Wachowska](#) and [Magdalena Biesaga](#) *

Posted Date: 24 December 2025

doi: 10.20944/preprints202512.2221.v1

Keywords: spent coffee grounds; natural sorbent; coffee by-products



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a [Creative Commons CC BY 4.0 license](#), which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Review

Life After Brewing—Finding New Purposes for Spent Coffee Grounds: A Review

Gaja Anna Wachowska and Magdalena Biesaga *

Faculty of Chemistry, University of Warsaw, 02-093 Warsaw Poland

* Correspondence: mbiesaga@chem.uw.edu.pl; Tel.: +48225526328

Abstract

Since coffee is the second most important commodity, finding ways to utilize it is crucial. In this review, we briefly discuss the use of spent coffee grounds (SCG) in other sectors of the food industry, as sorbents for preconcentration different chemical compounds, in the beauty industry, in the pharmaceutical industry and future health-related prospects.

Keywords: spent coffee grounds; natural sorbent; coffee by-products

1. Introduction

On the international market, coffee is the second most important commodity after crude oil [1]. Nowadays, the annual coffee sales exceed 10 million tons of unprocessed beans [2]. However, merely 30% of coffee beans' mass undergoes extraction during instant coffee production and ground coffee brewing. The remaining part is known as spent coffee grounds (hereafter referred to as SCG). Despite containing a multitude of versatile compounds, SCG are treated as waste [1]. As a result of processing and consumption, each year approximately 7 million tons of SCG are generated across the globe [3]. It is estimated that half of the coffee waste comes from coffee shops and from instant coffee production, while household consumption is responsible for the remaining part [4].

Waste storage in landfills is currently one of the most frequently applied methods for SCG disposal [5]. This practice poses a great environmental hazard as it leads to the accumulation of organic compounds that have been proven to be ecotoxic in large concentrations. Those compounds include caffeine, polyphenols, and flavonoids [6]. When coffee waste is stored in landfills, the substances can be washed out of SCG by rain and contaminate local groundwaters and other water bodies (ponds, lakes, rivers, etc.) nearby [5]. Those compounds are beneficial for human health; however, at large, and chronic concentrations, they could pose a cytotoxic, ecotoxic, genotoxic, and mutagenic threat to surrounding plants and aquatic and land animals. Besides phenols and polyphenols, SCG are rich in fatty acids, which can be toxic to living organisms in the presence of certain salts or at unsuitable pH values [7]. When leached into the environment, the organic acids and polyphenols present in SCG might affect soil quality, thus impacting crop growth [8]. Those compounds can induce mutagenicity. On top of that, unregulated decomposition of SCG discarded in the landfills might lead to great emissions of greenhouse gases and carbon dioxide, contributing to global warming [9,10].

Incineration is another common way of coffee waste utilization, but considering that SCG are rich in nitrogenous compounds, it poses a great environmental hazard with possible production of nitrogen oxides (NO_x) and ammonia [11].

With the growing concerns for the state of the planet, scientists have been looking for new ways to reuse or dispose of waste, including that made after brewing coffee. Unfortunately, not all of them are safe to apply. SCG have been suggested as a biofuel source; however, the presence of nitrogen and sulfur-containing compounds creates the risk of air pollution [12]. When incorporated into animal feed, coffee waste can be cytotoxic and carcinogenic for the animals. It can cause soil degradation and negatively impact seed growth when used in compost or as a fertilizer [13].

Due to varying extraction rates during the process of coffee brewing, SCG still contain certain amounts of bioactive compounds such as phenolic acids (caffeic, ellagic, gallic, chlorogenic, p-coumaric, tannic, sinapic, p-hydroxybenzoic, feruloylquinic, and proto-catechuic acids) and their esters [14,15], flavonoids (quercetin, catechin, epicatechin, and rutin), alkaloids (caffeine and trigonelline), and diterpenes (cafestol and kahweol) [13,16]. Many of those substances exhibit antioxidant, anti-inflammatory, anticarcinogenic, and antimicrobial properties. [10]. In addition, trigonelline and quinolinic acid are vitamin B3 precursors [17]. As those substances are not fully extracted from coffee beans, it is therefore posited that SCG could be employed in cosmetic, food, and pharmaceutical industries [18].

The solid fraction of SCG is composed of carbohydrates, mainly cellulose, hemicellulose, and lignin [9,19]. Acid, base, or enzymatic hydrolysis of SCG can be performed to re-cover said carbohydrates from the solid residue [20,21]. As a carbon-based waste, the solid phase of SCG makes for an excellent material for the production of adsorbents such as biochar and activated carbon, which can be used to remove diverse pollutants from air or aquatic systems. Activated charcoal is also a popular ingredient in beauty products [22].

Due to their insolubility in water, lipid compounds are mostly retained in coffee waste after coffee brewing. This suggests the potential of SCG as a source of oils for ecological beauty and food products [23]. The oil fraction of SCG is mainly composed of linoleic, palmitic, and oleic acids with traces of stearic and α -linolenic acids [24]. Moreover, with their high content of flavonoids that possess UV-absorbing properties, SCG extracts could find application as ingredients in sunscreens and other cosmetic products aimed to protect skin from sunlight [25].

Many of the techniques applied for reusing SCG or retrieving chemicals from them are relatively low-cost [12]. Coffee oil and retained bioactive compounds can be recovered from SCG through extraction with commonly applied organic solvents (acetonitrile and ethanol for polar, acetone for semi-polar, and n-hexane and chloroform for non-polar substances) [26,27] or a more environmentally friendly supercritical fluid extraction, in cases where the organic solvent would make the extract unsafe to use [28,29].

The purpose of this review is to summarize some of the achievements in SCG reuse in the recent years, with the focus on food, adsorbent, cosmetic, and pharmaceutical applications.

2. Applications in the Food Industry

SCG and their extracts can retain the aroma and flavor of coffee, making the waste a valuable ingredient in the food industry, particularly for beverage production [30–33]. Moreover, SCG is primarily composed of insoluble fiber, making it an excellent source of antioxidant dietary fiber for producing dietary supplements and fiber-rich foods. [34]. Because free glucose is present in insignificant amounts in SCG, the waste has the potential as an ingredient in lower glycaemic foods for people struggling with diabetes or obesity [35–38]. With their high fibre content, SCG addition to food could cause a decrease in starch digestibility; therefore, leading to the increase of resistant starch content, meaning the products would be safer for people at risk of type II diabetes [39,40].

Being rich in phytosterols and tocopherols, with a high unsaturated to saturated fatty acids ratio and a large concentration of an essential fatty acid, which is linoleic acid (about 40-45% of the oil fraction), SCG oil could be incorporated into food as a healthier alternative to commonly utilised fats, like butter or vegetable oils [41,42].

A summary of the various applications in the food sector is presented in Table 1.

Table 1. Applications of SCG in the food industry.

Product Type	Preparation	Results	Ref.
Fermented beverage & distilled spirit	Fermentation of SCG water extract with sucrose, citric acid, and a strain of <i>Saccharomyces cerevisiae</i> .	The fermented beverage had an ethanol content of 12,5%, which increased to 50.5% after distillation. Both products retained coffee aroma, but only the fermented beverage had said flavor	[30]

Distilled spirit	Fermentation of SCG water extract with sucrose, potassium metabisulfite, CaCO ₃ , and a strain of <i>Saccharomyces cerevisiae</i> .	The spirit had an ethanol content of 40%. It was characterized as having a pleasant coffee taste and aroma.	[31]
Coffee-flavored liquor	The SCG ethanol extract was mixed with glucose syrup.	The liquor had an alcohol content of about 21% and was described as having a pleasant coffee smell.	[32]
Flavoring agent in muffins	Dried SCG equated to 10% of the flour mass used for baking	The addition of SCG gave the baked goods a coffee taste, though it also increased bitterness. The texture remained unaffected, while fibre content increased.	[33]
Additive in nutraceutical biscuits	SCG equated to 6% of the flour mass used for baking	The presence of SCG enhanced fibre content but did not impact fat levels, while the protein content decreased.	[34]
Fibre source in biscuits	The dietary fibre was extracted from oven dried SCG by ohmic heating.	SCG addition increased fibre and fat content and enhanced the antioxidant capacity of the biscuits.	[35]
Additive in gluten-free cookies	Oven-dried SCG were incorporated during baking.	Adding SCG increased the fibre content and improved the texture of the baked goods.	[36]
Additive in shortbread	Dried SCG equated to 10% of the flour mass used for baking	Incorporating SCG increased fibre and protein content as well as antioxidant properties, while decreasing calorie and carbohydrate content. Smaller amounts of SCG did not affect the taste of the baked goods.	[37]
Nutritional additive in cookies	SCG equated to 10% of the flour mass used for baking	The cookies had a significantly higher fibre and fat content compared to the control samples. Additionally, they were lower in sodium and higher in potassium.	[38]
Fibre-rich ingredient in bakery products	The SCG were freeze-dried and defatted with n-hexane.	The product had a pleasant coffee flavor, acceptable texture and improved shelf life.	[39]
Ice cream cones	SCG equated to 20% of the flour mass used for baking	The resistant starch content of cones increased, however the addition of SCG negatively impacted the cones' texture.	[40]
Butter substituent in cookies	Lipid fraction was extracted from oven dried SCG using ethanol. The oil was separated after freezing the extract.	The antioxidant properties of the cookies increased. The cookies were deemed acceptable and healthier; however, higher amounts of coffee oil negatively impacted the flavor and the aroma of the baked goods	[41]

3. Applications as Sorbents

SCG-based sorbents demonstrate good adsorption capacities due to their high porosities and large specific surface areas [43]. As carbon biosorbents, they usually exhibit hydrophobic properties, though further activations and modifications can change it, as well as improve their porosities and adsorption capacities [44]. Adsorptive properties of waste-based sorbents can be enhanced with chemical activation, which usually involves acidic or alkaline agents such as phosphoric acid and sodium or potassium hydroxides [45].

Considering the waste's plentiful composition, it is to be expected that the SCG-based sorbents will adsorb diverse pollutants, implying their functional groups such as amine, carbonyl, carboxyl, hydroxyl, and aromatic rings as adsorption sites for bonding [45–47]. Because they are abundant in tannins, which with their polyhydroxy polyphenol functional groups can act as chelating agents, SCG present a potential as sorbents for metal-ions [48–50].

With coffee waste being a lignocellulosic material, adsorption can also occur when lignin units interact with organic compounds through π - π stacking or dipole-dipole force [47]. Waste-based sorbents have been involved in dye removal from water bodies, where the colorful compounds can block sunlight and disrupt natural processes, as well as cause carcinogenicity and mutagenicity in aquatic organisms [51–53]. Biosorbents can also be involved in the remediation of nutrients, such as nitrates and phosphates, that at greater concentrations can cause eutrophication in water systems [54,55].

A summary of the selected applications of SCG as sorbents is presented in Table 2.

Table 2. Applications of SCG sorbents.

Product type	Preparation	Results	Ref.
Biochar for polycyclic aromatic hydrocarbons (PAH) removal from ambient air	SCG underwent pyrolysis at 300 °C	The SCG-based and commercial sorbents had similar adsorption capacities for high molecular weight PAH, but the first one was less efficient with low molecular weight pollutants.	[43]
Biosorbent for CO ₂ capture from flue gas.	Dried SCG were carbonized for 45 min at 700 °C then activated with KOH.	The sorbent exhibited good stability, selectivity, and regenerability. However, its adsorption capacity decreased as the temperature increased.	[44]
Activated carbon for bentazone (herbicide) removal from aqueous solutions.	After pyrolysis at 600 °C coffee waste was chemically activated using ZnCl ₂ , calcined and washed with 0,1 M HCl solution.	The ecotoxicity study was carried out to evaluate the efficiency of adsorption, proving the sorbent's effectiveness.	[46]
Sorbent for remediation of malathion and chlorpyrifos (organophosphate pesticides) from water	Oven dried SCG were rinsed with HCl, NaOH, and water, then dispersed in 50% ethanol solution.	The sorbent was deemed safe and showed comparable adsorption capacities to those of previously tested biowaste-based adsorbents.	[47]
Cd ²⁺ , Cu ²⁺ , and Pb ²⁺ removal from aqueous solutions	Dried SCG were activated with NaOH.	The sorbent exhibited greater adsorption capacity than commercial activated carbon and was efficient for heavy metals remediation in the synthetic multicomponent solution, however its capacity in the presence of other contaminants remains unknown.	[48]
Removal of Cu ²⁺ from aqueous solutions	SCG were dried but did not undergo any further treatment.	The sorbent demonstrated efficiency of over 85% and could be regenerated with HCl solution.	[49]
Sorbent for Cd ²⁺ removal from solutions.	SCG did not undergo any pretreatment.	The FT-IR absorption spectrometry analysis proved that SCG had a higher amount of organic functional groups, with the potential of working as adsorption sites, that the commercial zeolite. It demonstrated a higher adsorption capacity.	[50]
Activated carbon for methylene blue (cationic dye) removal from aquatic solutions	SCG were underwent soft alkaline activation using 1 M NaOH solution and carbonizing at 300 °C.	Adsorption capacity was comparable to that of activated carbon prepared from other bio-sources.	[51]

Sorbent for methylene blue removal from aquatic solutions	SCG were extracted with hot water, activated with 6M HNO ₃ solution and ultrasonicated, then neutralised with NaOH.	Acidic activation generated smaller pores and lead to the increase of carboxyl groups in the sorbent, improving adsorption efficiency.	[52]
Phosphorylated sorbent for methylene blue removal	Dried SCG were activated using a mixture of 85% H ₃ PO ₄ solution and phosphorus pentoxide. The pH was neutralized with 1 M NaOH solution.	Phosphorylation increased the surface area of the sorbent. The presence of anionic groups led to high removal efficiency of the cationic dye.	[53]
Removal of phosphate and nitrate from aquatic solutions.	Dried SCG were activated with 0.04 M Ca(OH) ₂ , then washed with distilled water until pH value reached 7.5.	Modified sorbent had greater porosity than non-treated SCG. The sorbents demonstrated optimal capacity in acidic solutions.	[54]
Phosphate remediation from aqueous systems	Dried SCG were pyrolyzed at 300-550 °C then washed with CH ₂ Cl ₂ to remove PAHs and rinsed with distilled water. Biochar was functionalized with 1 M FeCl ₃ solution.	Adsorption capacity grew as the Fe/biochar mass ratio or pyrolysis temperature increased. Phosphates and other oxyanions demonstrate high affinities towards iron hydroxides.	[55]
Activated carbon for monocarboxylic acids removal from coffee wastewater	Oven dried SCG were mixed with CaCO ₃ and calcinated for 1h at 850 °C, then washed with 2M HCl solution. After rinsing with deionized water until neutral pH, the sorbent was dried again.	The sorbent demonstrated similar adsorption efficiency to that of a commercial one. SCG sorbent showed greater affinity towards the removal of hydrophobic compounds.	[56]

4. Applications in the Beauty Industry

The lipid fraction of SCG, being rich in fatty acids, is suitable for beauty products aiming to boost skin hydration [25]. The abundance of palmitic acid, a saturated fatty acid with emollient properties, in particular makes it suitable for dermatological applications in cosmetic and pharmaceutical products [23]. Unsaturated fatty acids, like linoleic and oleic acids, present in SCG, are often employed in cosmetic products thanks to their beneficial effects to the skin [24]. The linoleic acid is particularly important due to its ability to alleviate melanogenesis, which is the process of melanin production. This makes it a suitable ingredient in products aimed at skin pigmentation issues [57]. Moreover, the natural antioxidants extracted from coffee waste might find applications in anti-ageing beauty products as they protect the skin against oxidative stress [58]. Flavonoids and tocopherols recovered from SCG have the potential as ingredients in cosmetics, especially in sunscreens and other sun protection products, due to their photoprotection activity. Those compounds also have anti-inflammatory and antioxidant properties [25]. In addition to the aforementioned oil extracts, the insoluble part of SCG—e.g., in the form of activated charcoal—can be incorporated into beauty products for exfoliating purposes. Table 3 presents a summary of the chosen applications in the beauty industry.

Table 3. Applications of SCG in the beauty industry.

Product type	Preparation	Results	Ref.
Oil-in-water cream	Oven-dried SCG underwent supercritical CO ₂ extraction. The cream contained purified water, propylene glycol and 10% SCG oil extract.	SCG oil incorporation decreased the pH value of the cream, making it suitable for skin application. The SCG cream was non-irritating to the skin and significantly increased hydration. It had an acceptable texture and application.	[24]

Anti-ageing and skin brightening beauty products	The oil was extracted from oven-dried SCG using n-hexane. The extract underwent complexation using urea and ethanol to obtain SCG oil rich in linoleic acid.	The extract exhibited antimelanogenic properties and decreased UV-induced melanin production. The oil rich in linoleic acid had high cellular antioxidant activity and boosted cellular collagen production.	[57]
Make-up remover	The oil was extracted from SCG using n-hexane.	Makeup remover containing 40% coffee oil was deemed most efficient, with approximately 95% removal efficacy. The remover was approved as safe for the skin.	[59]
Additive in topical formulations	SCG extract was obtained using natural deep eutectic systems with a mixture of proline, glycerol and water.	The extract exhibited high antioxidant activity and showed the ability to protect the skin from oxidative stress. The oil-in-water formulation was safe for use and increased skin hydration.	[60]
Additive to prevent premature photoaging of the skin	The defatted SCG were extracted with 70% ethanol and administered orally to hairless mice.	SCG extract administration in mice inhibited UV-induced photoaging and reduced wrinkle formation.	[61]
Water-in-oil sunscreen	Oven-dried SCG underwent supercritical CO ₂ extraction. The cream contained 35% SCG oil extract.	The product offered good protection against UVB radiation, had satisfactory antioxidant and rheological properties and was safe to use.	[25]
Exfoliating body cream	The cream contained cetyl alcohol, stearic acid, lanolin, water, glycerine, dimethicone, crystal oil, sodium nipagin and 6% dried SCG.	The cream had a high content of polyphenols and antioxidants and demonstrated a satisfactory exfoliating capacity.	[62]
Oil-in-water cosmetic scrub	The scrub contained apricot kernel oil emulsifier, almond oil, castor oil, and 10% dried SCG.	The scrub was deemed skin-friendly and had a natural coffee aroma.	[63]
Anti-ageing face scrub	Dehydrated SCG were carbonized at 450 °C and activated with HCl solution. After washing out the acid, the charcoal was dehydrated again. Besides SCG-based activated charcoal, the scrub contained cetyl alcohol, stearic acid, glycerine, triethanolamine, propylene glycol, methylparaben, propylparaben, and distilled water.	The scrub did not irritate the skin and had a safe pH value. It had a coffee aroma, boosted skin hydration, and reduced the number of pores and wrinkles.	[64]
Liquid bath soaps	Dehydrated SCG were carbonized at 450 °C and activated with HCl solution. After washing out the acid the charcoal was dehydrated again. The bath soap contained cocamidopropyl betaine, sodium lauryl sulphate, and SCG-based activated charcoal.	The soap had a pH value that was safe for skin application and did not cause any irritation.	[65]

5. Potential Applications in the Pharmaceutical Industry and Future Health-Related Prospects

So far, the application of SCG in pharmaceuticals has not been widely studied. However, the waste is abundant in bioactive compounds with many potent health-related purposes, which have been comprehensively evaluated. Coffee oil extracted from SCG is rich in triacylglycerols and unsaponifiables, like diterpenes and tocopherols [66,67]. Those diterpenes, such as cafestol and

kahweol [68], have anti-inflammatory and antioxidant properties. As a plant-derived waste, SCG could also be a valuable source of phytosterols, which are plant sterols with anticancer, anti-inflammatory, hepatoprotective, and LDL cholesterol-lowering properties [42].

Phenolic compounds from coffee waste have been proven potent in preventing neurodegenerative diseases [16]. Chlorogenic acid, one of the main polyphenols in SCG extracts, has antibacterial, antifungal, anti-inflammatory, and hepatoprotective properties, as well as protection against neuronal cell death [8]. Gallic acid has been proven to be antidiabetic and antifungal. Additionally, both acids have anticarcinogenic, antimicrobial and antioxidant effects [69]. Because of those health-promoting properties, SCG extracts have been analysed thoroughly [69–72]. Alongside extract evaluations, several attempts have been made to extract and separate specific bioactive compounds from SCG [68,73–75]. Besides being used as a source of dietary fibre or compounds with antioxidant activity, SCG can also be extracted for polysaccharides possessing immunostimulatory or prebiotic activities [21,76–78]. Galactomannans, the most abundant polysaccharides in SCG, can be used as thickening agents and stabilisers in food. They can also be employed as precursors of manooligosaccharides, which are important in nutraceutical and pharmaceutical industries because of their prebiotic activity and anticarcinogenic, anti-inflammatory, and antioxidant properties [78]. Table 4 presents a summary of the selected applications of SCG in health-related aspects and in the pharmaceutical industry.

Table 4. Applications of SCG in the health-related aspects and in the pharmaceutical industry.

Product Type	Preparation	Results	Ref.
Cafestol and kahweol extract	SCG underwent direct saponification with an ethanol solution of KOH, followed by diethyl ether extraction.	The concentrations of cafestol and kahweol in SCG after saponification were relatively high.	[68]
Tocopherols and phytosterols extract	Oven-dried SCG were extracted with a mixture of chloroform and methanol.	The main phytosterols found in SCG oil were β -sitosterol, stigmasterol, campesterol and Δ^5 -avenesterol, with only traces of cholesterol. Out of the tocopherol isomers, the analysis confirmed the presence of α -tocopherol and β -tocopherol in SCG oil.	[23]
Phytosterols extract	Oven-dried SCG were mixed with HCl solution and ultrasonicated, then saponified using KOH and ethanol. Finally, the samples were extracted with n-hexane.	Four phytosterols were detected: β -sitosterol, stigmasterol, campesterol, and cycloartenol. Total phytosterol content was comparable to that in cereals, making it a valuable source of those compounds.	[42]
Extracts for the treatment of neurodegenerative diseases	Oven-dried SCG were extracted with 50% methanol.	The extracts presented anti-inflammatory and antioxidant activities and reduced the levels of intracellular reactive oxygen species.	[16]
Bioactive extracts	SCG were extracted with a 70% ethanol solution.	The extract showed antifungal bioactivity towards skin infection-related fungi and antiproliferative bioactivity and cytotoxicity against cancer cell lines, indicating the possibility of creating SCG-based treatments for skin infections and cancer.	[69]
Bioactive extracts	SCG were extracted using isopropanol.	The extract exhibited antifungal and anti-mycotoxigenic properties. Therefore, SCG could be employed as an	[70]

		ecological source of natural preservatives for the food industry.	
Antioxidant extract with enzyme-inhibitory properties	SCG were extracted with an ethanol-water solution.	The extract was deemed suitable for use as a food additive due to its high antioxidant activity and good enzyme inhibitory properties. It is also rich in bioactive compounds and can be used in the production of pharmaceuticals.	[71]
Antioxidant additive for shelf-life extension	Antioxidant compounds were extracted from SCG using absolute ethanol.	The addition of SCG extract improved sunflower oil's oxidative stability and shelf-life.	[72]
Caffeine extract	SCG were extracted using a 40% ethanol solution. The extract was purified via liquid-liquid extraction of the alkalized aqueous phase with ethyl acetate.	Caffeine was recovered with a purity of 93.4% through extraction with ethyl acetate.	[73]
Chlorogenic and gallic acids extracts	SCG were defatted with n-hexane and extracted using an 80% acetonitrile solution. Chlorogenic and gallic acids were separated using a three-zone simulated moving bed system.	In the optimized conditions, the relative purity of chlorogenic acid was 99.27% and of gallic acid—98.43%.	[74]
Caffeine and chlorogenic acid extracts	Oven-dried SCG were extracted with water. Caffeine and chlorogenic acid were separated using three-zone simulated moving.	In the optimized conditions, the purities of caffeine and chlorogenic acid were 99.45% and 98.88%, respectively.	[75]
Polysaccharides	Oven-dried SCG were pretreated with NaOH, then underwent supercritical carbon dioxide extraction and enzymatic saccharification.	The obtained polysaccharides enhanced growth and improved the biofilm-forming capacity of the beneficial Bacilli and Lactobacilli strains.	[21]
Oligosaccharides extract	SCG were defatted using n-hexane, then underwent acid-catalyzed extraction using HCl solution.	The extract exhibited prebiotic activity on the strains of Lactobacilli.	[76]
Mannans extract	SCG were extracted using water, imidazole, and sodium hydroxide, then underwent acetylation.	Mannans obtained from SCG exhibited similar immunostimulatory activity to that of commercially available mannans.	[77]
Mannans extract	SCG were pretreated with NaOH. The oligosaccharides were produced enzymatically using an endo-1,4- β -mannanase from the Bacillus subtilis strain.	The manno oligosaccharides showed prebiotic properties, such as growth enhancement of beneficial bacteria with the ability to produce short-chain fatty acids.	[78]

6. Conclusions

Since coffee waste can cause damage to the environment when it is disposed of in landfills and near water bodies, the idea of reusing SCG has been studied thoroughly [79]. After the process of brewing, SCG are left with high content of polysaccharides, polyphenols and oils, which translates to their diverse possible usages [6,80]. Those compounds find application in cosmetic, food, and pharmaceutical industries [1,18]. Additionally, due to the presence of these compounds, coffee waste contains different functional groups that can act as adsorption sites when it is reused as biosorbents [47]. SCG have been tested multiple times as an additive to increase the fibre content of bakery products, with positive results. However, oftentimes consumers reported that with increasing SCG presence, texture, flavor, and odor acceptability of the product decreased, suggesting that the concept still requires some polishing. The plenitude of aromatic rings, hydroxyl, and carbonyl groups [46] makes SCG a desirable material for production of biochar and activated carbon for the removal of

distinct pollutants from both water and air [43,46–48]. Coffee waste contains compounds like flavonoids and tocopherols, which absorb UVB radiation and have anti-inflammatory and antioxidant properties, making SCG desirable ingredients for beauty products [26].

Furthermore, SCG can undergo extraction to isolate caffeine and water-soluble polyphenols with anticarcinogenic, anti-inflammatory, antimutagenic, and antioxidant properties [79], meaning that in the future, the waste could be used as a source of medicine ingredients.

Author Contributions: Conceptualization, G.W. and M.B.; writing—original draft preparation, G.W.; writing—review and editing, M.B.; supervision, M.B.; All authors have read and agreed to the published version of the manuscript.

Funding: Please add: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: This work was supported by the University of Warsaw, Faculty of Chemistry under grant 501-D112-01-1120000 5011000350.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. K. Johnson, Y. Liu & M. Lu (2022), "A Review of Recent Advances in Spent Coffee Grounds Upcycle Technologies and Practices" *Frontiers in Chemical Engineering* 4:838605; DOI:10.3389/fceng.2022.838605.
2. E. S. Rahayu & M. Ferichani (2024), "Export competitiveness of Indonesian coffee in the United States market", *G. A. Innayatuhbah, Scientific Horizons* 27(2): 125-135; DOI:10.48077/scihor2.2024.125.
3. K. M. Yu, O. Y. Chan, Q. Zhang, L. Wang, K.-H. Wong & D. C. W. Tsang (2023), "Upcycling of Spent Tea Leaves and Spent Coffee Grounds into Sustainable 3D-Printing Materials: Natural Plasticization and Low Energy Fabrication", *ACS Sustainable Chemistry & Engineering* 11(16): 6230–6240; DOI:10.1021/acssuschemeng.2c07330.
4. T. M. Mata, A. A. Martins & N. S. Caetano (2018), "Bio-refinery Approach for Spent Coffee Grounds Valorization", *Bioresource Technology* 247: 1077-1084; DOI:10.1016/j.biortech.2017.09.106.
5. K.-T. Lee, Y.-T. Shih, S. Rajendran, Y.-K. Park & W.-H. Chen (2023), "Spent coffee ground torrefaction for waste remediation and valorization", *Environmental Pollution* 324: 121330; DOI:10.1016/j.envpol.2023.121330.
6. R. Cruz, M. M. Cardoso, L. Fernandes, M. Oliveira, E. Mendes, P. Baptista, S. Morais & S. Casal (2012), "Espresso Coffee Residues: A Valuable Source of Unextracted Compounds", *Journal of Agricultural and Food Chemistry* 60(32): 7777-7784; DOI:10.1021/jf3018854.
7. A. S. Fernandes, F. V. C. Mello, S. Thode Filho, R. M. Carpes, J. G. Honório, M. R. C. Marques, I. Felzenszwalb & E. R. A. Ferraz (2017), "Impacts of discarded coffee waste on human and environmental health", *Ecotoxicology and Environmental Safety* 141:30–36; DOI:10.1016/j.ecoenv.2017.03.011.
8. B. Janissen & T. Huynh (2018), "Chemical composition and value-adding applications of coffee industry byproducts: A review", *Resources, Conservation and Recycling* 128:110-117; DOI:10.1016/j.resconrec.2017.10.001.
9. L. Bijla, M. Ibourki, H. A. Bouzid, A. Laknifli & S. Gharby (2022), "Proximate Composition, Antioxidant Activity, Mineral and Lipid Profiling of Spent Coffee Grounds Collected in Morocco Reveal a Great Potential of Valorization", *Waste and Biomass Valorization* 13(3):4495–4510; DOI:10.1007/s12649-022-01808-8.
10. C. Andrade, R. Perestrelo & J. S. Câmara (2022), "Bioactive Compounds and Antioxidant Activity from Spent Coffee Grounds as a Powerful Approach for Its Valorization" *Molecules* 27:7504; DOI:10.3390/molecules27217504.
11. L. I. Austen, T. I. J. Dugmore, A. S. Matharu & G. A. Hurst (2023), "Byproduct Valorization: From Spent Coffee Grounds to Fatty Acid Ethyl Esters", *J. Chem. Educ.* 100:327–335; DOI:10.1021/acs.jchemed.2c00728.

12. T. Jooste, M. P. García-Aparicio, M. Brienzo, W. H. van Zyl & J. F. Görgens (2013), "Enzymatic Hydrolysis of Spent Coffee Ground", *Applied Biochemistry and Biotechnology* 169(8):2248–2262; DOI:10.1007/s12010-013-0134-1.
13. Y.-G. Lee, E.-J. Cho, S. Maskey, D.-T. Nguyen & H.-J. Bae (2023), "Value-Added Products from Coffee Waste: A Review", *Molecules* 28:3562; DOI:10.3390/molecules28083562.
14. J. G. Dórea & T. H. M. da Costa (2005) "Is coffee a functional food?", *British Journal of Nutrition* 93(6): 773–782; DOI:10.1079/BJN20051370.
15. M. Jeszka-Skowron, A. Zgoła-Grześkowiak, Tomasz Grześkowiak (2015), "Analytical methods applied for the characterization and the determination of bioactive compounds in coffee", *European Food Research and Technology* 240(1): 19–31; DOI:10.1007/s00217-014-2356-z.
16. S. Angeloni, M. Freschi, P. Marrazzo, S. Hrelia, D. Beghelli, A. Juan-García, C. Juan, G. Caprioli, G. Sagratini & C. Angeloni (2021), "Antioxidant and Anti-Inflammatory Profiles of Spent Coffee Ground Extracts for the Treatment of Neurodegeneration", *Oxidative Medicine and Cellular Longevity* 6620913; DOI:10.1155/2021/6620913.
17. A. Panusa, A. Zuurro, R. Lavecchia, G. Marrosu & R. Petrucci (2013), "Recovery of Natural Antioxidants from Spent Coffee Grounds", *Journal of Agricultural and Food Chemistry* 61(17): 4162–4168; DOI:10.1021/jf4005719.
18. A. B. Shazly, M. T. Fouad, M. Elaaser, R. S. Sayed & M. Abd El- Aziz (2022), "Probiotic coffee ice cream as an innovative functional dairy food", *Journal of Food Processing and Preservation* 46(3):e17253; DOI:10.1111/jfpp.17253.
19. C. Wongsiridetchai, W. Chiangkham, N. Khlaihiran, T. Sawangwan, P. Wongwathanarat, T. Charoenrat & S. Chantorn (2018), "Alkaline pretreatment of spent coffee grounds for oligosaccharides production by mannanase from *Bacillus* sp. GA2(1)", *Agriculture and Natural Resources* 52(3):222–227; DOI:10.1016/j.anres.2018.09.012.
20. S. I. Mussatto, L. M. Carneiro, J. P. A. Silva, I. C. Roberto & J. A. Teixeira (2011), "A study on chemical constituents and sugars extraction from spent coffee grounds", *Carbohydrate Polymers* 83(2):368–374; DOI:10.1016/j.carbpol.2010.07.063.
21. A. Shaikh-Ibrahim, N. Curci, F. De Lise, O. Sacco, M. Di Fenza, S. Castaldi, R. Istatico, A. Oliveira, J. P. S. Aniceto, C. M. Silva, L. Seuanes Serafim, K. B. R. M. Krogh, M. Moracci & B. Cobucci-Ponzano (2025), "Carbohydrate conversion in spent coffee grounds: pretreatment strategies and novel enzymatic cocktail to produce value-added saccharides and prebiotic mannoooligosaccharides", *Biotechnology for Biofuels and Bioproducts* 18:2; DOI:10.1186/s13068-024-02601-6.
22. G.-W. Hyeon, G. B. Lee & J.-E. Park (2025), "Optimization of Activated Carbon Synthesis from Spent Coffee Grounds for Enhanced Adsorption Performance", *Molecules* 30:2557; DOI:10.3390/molecules30122557.
23. F. Sakouhi, C. Saadi, I. Omrani, S. Boukhchina & R. Rodriguez Solana (2024), "Quality parameters and lipid composition of oil extracted from spent coffee grounds: A promising alternative to vegetable oils used for consumption and cosmetic purposes", *Eur. J. Lipid Sci. Technol.* 126:2300230; DOI:10.1002/ejlt.202300230.
24. H. Ribeiro, J. Marto, S. Raposo, M. Agapito, V. Isaac, B. G. Chiari, P. F. Lisboa, A. Paiva, S. Barreiros & P. Simões (2013), "From coffee industry waste materials to skin-friendly products with improved skin fat levels", *European Journal of Lipid Science and Technology* 115(3):330–336; DOI:10.1002/ejlt.201200239.
25. J. Marto, L. F. Gouveia, B. G. Chiari, A. Paiva, V. Isaac, P. Pinto, P. Simões, A. J. Almeida & H. M. Ribeiro (2016), "The green generation of sunscreens: Using coffee industrial sub-products", *Industrial Crops and Products* 80:93–100, DOI:10.1016/j.indcrop.2015.11.033.
26. J. Bravo, C. Monente, I. Juárez, M. Paz De Peña & C. Cid (2013), "Influence of extraction process on antioxidant capacity of spent coffee", *Food Research International* 50(2):610–616; DOI:10.1016/j.foodres.2011.04.026.
27. K. Pyrzynska (2024), "Useful Extracts from Coffee By-Products: A Brief Review", *Separations* 11:334; DOI:10.3390/separations11120334.
28. R. C. Ribeiro, M. F. S. Mota, R. M. V. Silva, D. C. Silva, F. J. M. Novaes, V. F. da Veiga, Jr., H. R. Bizzo, R. S. S. Teixeira, & C. M. Rezende (2024), "Coffee Oil Extraction Methods: A Review", *Foods* 13:2601; DOI:10.3390/foods13162601.

29. Y.-F. Shang, J.-L. Xu, W.-J. Lee & B.-H. Um (2017), "Antioxidative polyphenolics obtained from spent coffee grounds by pressurized liquid extraction", *South African Journal of Botany* 109:75–80; DOI:10.1016/j.sajb.2016.12.011.
30. L. Wang, X. Yang, Z. Li, X. Lin, X. Hu, S. Liu & C. Li (2021), "Sensory Characteristics of Two Kinds of Alcoholic Beverages Produced with Spent Coffee Grounds Extract Based on Electronic Senses and HS-SPME-GC-MS Analyses", *Fermentation* 7:254; DOI:10.3390/fermentation7040254.
31. A. Sampaio, G. Dragone, M. Vilanova, J. M. Oliveira, J. A. Teixeira & S. I. Mussatto (2013), "Production, chemical characterization, and sensory profile of a novel spirit elaborated from spent coffee ground", *LWT-Food Science and Technology* 54:557-563; DOI:10.1016/j.lwt.2013.05.042.
32. F. Masino, G. Montevecchi, R. Calvini, G. Foca & A. Antonelli (2022), "Sensory evaluation and mixture design assessment of coffee-flavored liquor obtained from spent coffee grounds", *Food Quality and Preference* 96:104427; DOI:10.1016/j.foodqual.2021.104427.
33. S. B. Solberg & S. Ø. Solberg (2025), "Spent coffee grounds as a sustainable coffee flavouring ingredient in muffins", *Explor Foods Foodomics*. 3:101066; DOI:10.37349/eff.2025.101066.
34. H. S. Ali, A. F. Mansour, M. M. Kamil & A. M. S. Hussein (2018), "Formulation of Nutraceutical Biscuits Based on Dried Spent Coffee Grounds", *Int. J. Pharmacol.* 14(4): 584-594; DOI: 10.3923/ijp.2018.584.594.
35. K. Vázquez-Sánchez, N. Martínez-Saez, M. Rebollo-Hernanz, M. D. del Castillo, M. Gaytán-Martínez & R. Campos-Vega (2018), "In vitro health promoting properties of antioxidant dietary fibre extracted from spent coffee (Coffee arabica L.) grounds", *Food Chemistry* 261:253-259; DOI:10.1016/j.foodchem.2018.04.064.
36. J. Oliveira Batista, C. Car Cordeiro, S. J. Klososki, C. M. E. Dos Santos, G. M. Carneiro Leão, T. Colombo Pimentel & M. Rosset (2022), "Spent Coffee Grounds Improve the Nutritional Value and Technological Properties of Gluten-free Cookies", *Journal of Culinary Science & Technology* 12:1-11; DOI:10.1080/15428052.2022.2026266.
37. H. Y. Koay, A. T. Azman, Z. Mohd Zin, K. L. Portman, M. Hasmadi, N. D. Rusli, O. Aidat & M. K. Zainol (2023), "Assessing the impact of spent coffee ground (SCG) concentrations on shortbread: A study of physicochemical attributes and sensory acceptance" *Future Foods* 8:100245; DOI:10.1016/j.fufo.2023.100245.
38. S. Mudalal, K. Sawafta, Z. Ayyad, M. Zaqdah, R. Jaayssa, S. Saidi, B. Rahhal & N. Abu-Khalaf (2025), "Sustainable Cookies Enriched With Spent Coffee Grounds: A Study on Nutritional, Textural, and Sensory Properties", *Journal of Food Processing and Preservation* 1:7439017; DOI:10.1155/jfpp/7439017.
39. C. Papageorgiou, E. Dermesonlouoglou, D. Tsimogiannis & P. Taoukis (2024), "Enrichment of Bakery Products with Antioxidant and Dietary fibre Ingredients Obtained from Spent Coffee Ground", *Appl. Sci.* 14:6863; DOI:10.3390/app14166863.
40. M. López-Silva & D. E. García-Valle (2024), "Ice cream cone fortified with spent coffee ground: Chemical composition, quality and sensory characteristics, and in vitro starch digestibility", *Food Chemistry* 459:140288; DOI:10.1016/j.foodchem.2024.140288.
41. J. Meerasri & R. Sothornvit (2022), "Novel development of coffee oil extracted from spent coffee grounds as a butter substitute in bakery products", *J Food Process Preserv.* 46:e16687; DOI:10.1111/jfpp.16687.
42. F. k. Nzekoue, G. Khamitova, S. Angeloni, A. N. Sempere, J. Tao, F. Maggi, J. Xiao, G. Sagratini, S. Vittori & G. Caprioli (2020), "Spent coffee grounds: A potential commercial source of phytosterols", *Food Chemistry* 325:126836; DOI:10.1016/j.foodchem.2020.126836.
43. W. Tala & S. Chantara (2019), "Use of spent coffee ground biochar as ambient PAHs sorbent and novel extraction method for GC-MS analysis", *Environ Sci Pollut Res Int* 26(13):13025-13040; DOI:10.1007/s11356-019-04473-y.
44. M. Sołtysik, I. Majchrzak-Kucęba & D. Wawrzyńczak (2025), "A Coffee-Based Bioadsorbent for CO₂ Capture from Flue Gas Using VSA: TG-Vacuum Tests", *Energies* 18:3965; DOI:10.3390/en18153965.
45. V. Milanković, T. Tasić, I. A. Pašti & T. Lazarević-Pašti (2024), "Resolving Coffee Waste and Water Pollution—A Study on KOH-Activated Coffee Grounds for Organophosphorus Xenobiotics Remediation", *J. Xenobiot.* 14:1238–1255; DOI:10.3390/jox14030070.

46. da Silva Rocha, L. E. Z. de Moraes, D. Espirito Santo, A. P. Peron, D. C. de Souza, E. Bonae & O. Valarini (2024), "Removal of bentazone using activated carbon from spent coffee grounds", *J Chem Technol Biotechnol* 99(6); DOI:10.1002/jctb.7630.
47. V. Milanković, T. Tasić, M. Pejić, I. Pašti & T. Lazarević-Pašti (2023), "Spent Coffee Grounds as an Adsorbent for Malathion and Chlorpyrifos—Kinetics, Thermodynamics, and Eco-Neurotoxicity", *Foods* 12:2397; DOI:10.3390/foods12122397.
48. N. E. Davila-Guzman, F. J. Cerino-Córdova, M. Loredó-Cancino, J. R. Rangel-Mendez, R. Gómez-González & E. Soto-Regalado (2016), "Studies of Adsorption of Heavy Metals onto Spent Coffee Ground: Equilibrium, Regeneration, and Dynamic Performance in a Fixed-Bed Column", *International Journal of Chemical Engineering* 9413879; DOI:10.1155/2016/9413879.
49. A. Młynarczykowska & M. Orlof-Naturalna (2024), "Biosorption of Copper (II) Ions Using Coffee Grounds—A Case Study", *Sustainability* 16(17):7693; DOI:10.3390/su16177693.
50. M.-S. Kim & J.-G. Kim (2020), "Adsorption Characteristics of Spent Coffee Grounds as an Alternative Adsorbent for Cadmium in Solution", *Environments* 7:24; DOI:10.3390/environments7040024.
51. M. Cuccarese, S. Brutti, A. De Bonis, R. Teghil, F. Di Capua, I. M. Mancini, S. Masi & D. Canianiet (2023), "Sustainable Adsorbent Material Prepared by Soft Alkaline Activation of Spent Coffee Grounds: Characterisation and Adsorption Mechanism of Methylene Blue from Aqueous Solutions", *Sustainability* 15:2454; DOI:10.3390/su15032454.
52. A. M. Araya-Sibaja, T. Quesada-Soto, J. R. Vega-Baudrit, M. Navarro-Hoyos, J. Valverde-Cerdas & L. G. Romero-Esquivel (2025), "Spent Coffee Ground-Based Materials Evaluated by Methylene Blue Removal", *Processes* 13:1592; DOI:10.3390/pr13051592.
53. M. S. Akindolie & H. J. Choi (2022), "Surface modification of spent coffee grounds using phosphoric acid for enhancement of methylene blue adsorption from aqueous solution", *Water Science & Technology* 85(4):1218; DOI:10.2166/wst.2022.021.
54. A. Humayro, H. Harada & K. Naito (2021), "Adsorption of Phosphate and Nitrate Using Modified Spent Coffee Ground and Its Application as an Alternative Nutrient Source for Plant Growth", *Journal of Agricultural Chemistry and Environment* 10:80-90; DOI:10.4236/jacen.2021.101006.
55. A. Torboli, P. Foladori, M. Lu, S. Gialanella & L. Maines (2024), "Spent coffee ground biochar for phosphate adsorption in water: Influence of pyrolysis temperature and iron-coating activation method", *Cleaner Engineering and Technology* 23:100839; DOI:10.1016/j.clet.2024.100839.
56. G. A. Figueroa Campos, J. P. H. Perez, I. Block, S. Tchewonpi Sagu, P. Saravia Celis, A. Taubert & H. M. Rawel (2021), "Preparation of Activated Carbons from Spent Coffee Grounds and Coffee Parchment and Assessment of Their Adsorbent Efficiency", *Processes* 9:1396; DOI:10.3390/pr9081396.
57. M. Kanlayavattanakul, N. Lourith & P. Chaikul (2021), "Valorization of spent coffee grounds as the specialty material for dullness and aging of skin treatments", *Chem. Biol. Technol. Agric.* 8:55; DOI:10.1186/s40538-021-00252-5.
58. R. Rodrigues, M. B. P. Pinto Oliveira & R. Carneiro Alves (2023), "Chlorogenic Acids and Caffeine from Coffee By-Products: A Review on Skincare Applications", *Cosmetics* 10:12.; DOI:10.3390/cosmetics10010012.
59. [59] N. Lourith, K. Xivivadh, P. Boonkong & M. Kanlayavattanakul (2022), "Spent coffee waste: A sustainable source of cleansing agent for a high-performance makeup remover", *Sustainable Chemistry and Pharmacy* 29:100826; DOI:10.1016/j.scp.2022.100826.
60. C. Costa, M. Marques, A. M. Martins, L. Gonçalves, P. Pinto, H. M. Ribeiro, J. Marto & A. Paiva (2025), "Upcycling Spent Coffee Grounds into Bioactive Extracts Using New Natural Deep Eutectic Systems for Sustainable Topical Formulations", *ACS Sustainable Chem. Eng.* 13:1906–1915; DOI:10.1021/acssuschemeng.4c06397.
61. H.-S. Choi, E. D. Park, Y. Park & H. J. Suh (2015), "Spent coffee ground extract suppresses ultraviolet B-induced photoaging in hairless mice", *Journal of Photochemistry & Photobiology, B: Biology* 153:164–172; DOI:10.1016/j.jphotobiol.2015.09.017.

62. S. Delgado-Arias, S. Zapata-Valencia, Y. Cano-Agudelo, J. Osorio-Arias, O. Vega-Castro (2020), "Evaluation of the antioxidant and physical properties of an exfoliating cream developed from coffee grounds", *J Food Process Eng.* 43:e13067; DOI:10.1111/jfpe.13067.
63. W. Szaferski & M. Janczarek (2025), "Preparation of Cosmetic Scrub Bases from Coffee Waste and Eco-Friendly Emulsifiers", *Cosmetics* 12:31; DOI:10.3390/cosmetics12010031.
64. D. S. Ratmelya, J. Reveny & U. Harahap (2022), "Test anti-aging activity in a face scrub preparation that contains coffee-grade active charcoal (*Coffea arabica* L.) with the addition of vitamin E", *ScienceRise: Pharmaceutical Science* 5(39):74–82; DOI:10.15587/2519-4852.2022.265402.
65. H. Maysarah, L. S. Desiyana, S. Nurzuhra & D. N. Illian (2023), "Utilization of Spent Arabica Coffee Grounds as Raw Material for Activated Charcoal in Liquid Bath Soap Formulation", *Pharmaceutical Sciences and Research* 10(1):48-54; DOI:10.7454/psr.v10i1.1282.
66. A. Iriondo-DeHond, F. S. Cornejo, B. Fernandez-Gomez, G. Vera, E. Guisantes-Batan, S. Gomez Alonso, M. I. San Andres, S. Sanchez-Fortun, L. Lopez-Gomez, J. A. Uranga, R. Abalo & M. D. del Castillo (2019), "Bioaccessibility, Metabolism, and Excretion of Lipids Composing Spent Coffee Grounds", *Nutrients* 11:1411; DOI:10.3390/nu11061411.
67. Y. Ren, C. Wang, J. Xu & S. Wang (2019), "Cafestol and Kahweol: A Review on Their Bioactivities and Pharmacological Properties", *International Journal of Molecular Sciences* 20(17): 4238; DOI:10.3390/ijms20174238.
68. F. Acevedo, M. Rubilar, E. Scheuermann, B. Cancino, E. Uquiche, M. Garcés, K. Inostroza & C. Shene (2013), "Spent Coffee Grounds as a Renewable Source of Bioactive Compounds", *Journal of Biobased Materials and Bioenergy* 7:1–9; DOI:10.1166/jbmb.2013.1369.
69. D. Calheiros, M. I. Dias, I. C. F. R. Ferreira, R. C. Calhelha, C. Fernandes, L. Barros & T. Gonçalves (2023), "Antifungal Activity of Spent Coffee Ground Extracts" *Microorganisms* 11:242; DOI:10.3390/microorganisms11020242.
70. A. N. Badr, M. M. El-Attar, H. S. Ali, M. F. Elkhadragey, H. M. Yehia & A. Farouk (2022), "Spent Coffee Grounds Valorization as Bioactive Phenolic Source Acquired Antifungal, Anti-Mycotoxigenic, and Anti-Cytotoxic Activities", *Toxins* 14:109; DOI:10.3390/toxins14020109.
71. G. Zengin, K. I. Sinan, M. F. Mahomoodally, S. Angeloni, A. M. Mustafa, S. Vittori, F. Maggi & G. Caprioli (2020), "Chemical Composition, Antioxidant and Enzyme Inhibitory Properties of Different Extracts Obtained from Spent Coffee Ground and Coffee Silverskin" *Foods* 9:713; DOI:10.3390/foods9060713.
72. L. Bijla, A. Hmitti, A. Fadda, S. Oubannin, J. Gagour, R. Aissa, A. Laknifli, E. H. Sakar & S. Gharby (2024), "Valorization of spent coffee ground as a natural antioxidant and its use for sunflower oil shelf-life extension", *Eur. J. Lipid Sci. Technol.* 126:2300115; DOI:10.1002/ejlt.202300115.
73. A. Vandeponsele, M. Draye, C. Piot & G. Chatel (2021), "Study of Influential Parameters of the Caffeine Extraction from Spent Coffee Grounds: From Brewing Coffee Method to the Waste Treatment Conditions", *Clean Technol.* 3:335–350; DOI:10.3390/cleantechnol3020019.
74. K. Nakkong, P. Tangpromphan & A. Jaree (2021), "The Design of Three-Zone Simulated Moving Bed Process for the Separation of Chlorogenic and Gallic Acids Extracted from Spent Coffee Grounds", *Waste and Biomass Valorization* 12:2389–2405; DOI:10.1007/s12649-020-01160-9.
75. P. Tangpromphan, S. Palitsakun & A. Jaree (2023), "Three-zone simulated moving bed for the separation of chlorogenic acid and caffeine fractions in the liquid extract of spent coffee grounds" *Heliyon* 9:e21340; DOI:10.1016/j.heliyon.2023.e21340.
76. [76] F. Sarghini, F. Marra, A. De Vivo, P. Vitaglione, G. Mauriello, D. Maresca, A. D. Troise & E. Echeverria-Jaramillo (2021), "Acid hydrolysis of spent coffee grounds: effects on possible prebiotic activity of oligosaccharides", *Chem. Biol. Technol. Agric.* 8:67; DOI:10.1186/s40538-021-00262-3.
77. J. Simões, P. Madureira, F. M. Nunes, M. do Rosário Domingues, M. Vilanova & M. A. Coimbra (2009), "Immunostimulatory properties of coffee mannans", *Molecular Nutrition & Food Research* 53(8):1036-1043; DOI:10.1002/mnfr.200800385.
78. M. Magengelele, S. Malgas & B. I. Pletschke (2023), "Bioconversion of spent coffee grounds to prebiotic mannoooligosaccharides– an example of biocatalysis in biorefinery", *RSC Adv.* 13:3773; DOI:10.1039/d2ra07605e.

79. Y. B. Andrade, J. K. Schneider, R. O. Farrapeira, A. N. L. Lucas, I. D. P. da Mota, T. R. Bjerk, L. C. Krause, E. B. Caramão & R. Hynek (2023), "Chromatographic analysis of N-compounds from the pyrolysis of spent coffee grounds", *Separation Science Plus* 6(1):2200057; DOI:10.1002/sscp.202200057.
80. [80] I. Robles, F. Espejel-Ayala, G. Velasco, A. Cárdenas & L. A. Godínez (2022), "A statistical approach to study the valorization process of spent coffee grounds", *Biomass Conversion and Biorefinery* 12(7): 2463–2475; DOI:10.1007/s13399-020-00854-3.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.