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Review Article

Composition, Phyto-Chemical Properties, Recovery of Bio Active Components and Different Applications Food and Nonfood of the Spent Coffee: A Review

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Abstract

Coffee is the beverage obtained by decoction or infusion of the roasted ground seeds called coffee beans of the homonymous plant and its spent coffee is the main residue from the soluble coffee industry. Spent coffee has polysaccharides which are the main component of spent coffee derived from instant coffee production. Spent coffee contains a significant number of proteins. The caffeine content of spent coffee has often been reported to contain 10% to 15% which is lower than that of coffee beans, and a higher average of 20%. Furthermore, spent coffee has a lipid of 13.9% to 29.2% ether extract, on a dry weight basis, an ash content of 1.6%, which consists of several minerals. The phenolic compounds of spent coffee are the major determinant of antioxidants and the recovery process of the phenolic compounds from the coffee industry by-products and their antioxidant activity. Finally, the presence of bioactive compounds of spent coffee is of great interest for the application of spent coffee as food, cosmetics, and pharmaceutical industries, adding value to the residue generated from instant coffee industrial processing, by making it readily available in large quantities.

Keywords: Spent coffee; Phyto-chemical; Bio-active components; Applications food and nonfood

Introduction

Background

The coffee plant is a special crop that, starting in Ethiopia, is now covered largely in areas of tropical and subtropical cultivation [1]. Coffee belongs to the family Rubiaceae and the tribe Coffee. Currently more than 100 species of the genus Coffee are known with the two varieties *C. arabica* and *C. canephora* being the most economically exploited species. Coffee is one of the most popular and appreciated beverages around the world, being consumed for its stimulating and refreshing properties, which are defined by the green beans composition and changes occurring during the roasting process [2].

Soluble coffee has been reported as a rich source of antioxidants, the consumption of which may prevent diseases caused by oxidative damage [3]. It has a rich source of dietary antioxidants, and this property coupled with the fact that it is one of the world's most popular beverages has led to the understanding that coffee is a major contributor to dietary antioxidant intake [4]. Natural bioactive compounds from coffee industry by-products have been receiving increasing attention, having in view the sustainability of the processes.

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Coffee oil has an emollient property due to the fatty acid composition which can block sunlight harmful to human skin and which has therefore been used in the cosmetic industry [3]. As a consequence of this big market the coffee industry is responsible for generating large quantities of residues among which Spent Coffee Grounds (SCG) [2]. Spent Coffee Ground is the residual material obtained during the treatment of coffee powder with hot water or steam for the instant coffee preparation. Almost 50 % of the worldwide coffee production is processed for soluble coffee preparation, which generates around 6 million tons of Spent Coffee Ground per year [2].

Composition of Spent Coffee

Polysaccharides are the main components of spent coffee derived from instant coffee production (75%). Hemi cellulose 39% and cellulose 12% are the most abundant polysaccharides in spent coffee. The hemicellulose sugars composition in spent coffee is ~37 % mannose, 320% galactose, 24% glucose and 7% arabinose [2].

Some authors have determined the dietary fiber content in spent coffee reporting 43% to 54% total dietary fiber, 47% to 50% insoluble dietary fiber and 6% to 16% soluble dietary fiber. These values differ from those of our experimental assay which found higher amounts of total dietary fiber 82.8% and insoluble dietary fiber 82.3% and lower amounts of soluble dietary fiber 0.43%. Spent coffee grounds also contain protein fat and ash 13.6% to 17.44%, 2.29% and 1.30% to 1.6% respectively.

For minerals potassium is the major component followed by magnesium and phosphorus. Various caffeine concentrations (0.007% to 0.5%) have been reported depending on the caffeine extraction process and spent coffee variety [5].

Polysaccharides

The coffee bean is a rich source of polysaccharides (~50% of the green bean's dry weight) mainly consisting of mannans or galactomannans, type II arabinogalactans and cellulose. However,

most of these polysaccharides remain as insoluble material bound to the spent coffee ground matrix [6,7]. Spent coffee ground is rich in sugars polymerized into cellulose and hemicellulose structures which correspond to almost half (45.3%, w/w, dry weight) of the material.

Spent coffee grounds contain 46.8% mannose, 30.4% galactose, 19% glucose, and 3.8% arabinose with mannans as the major polysaccharides [6,8]. However, further investigation by the same group revealed a lower (2.2-fold) sugar composition for the same spent coffee ground consisting of 21.2% mannose, 13.8% galactose, 8.6% glucose, and 1.7% arabinose.

Proteins

Spent Coffee grounds contain a significant number of proteins (13.6%, w/w). Total coffee nitrogen compounds are relatively stable between species or even during roasting, ranging from 8.5% to 13.6% [8,9], reported that crude protein in espresso coffee residues varies between 12.8% and 16.9%. The mean protein content of spent coffee is 13.6% after soluble coffee preparation [2,6].

Roasted coffee contains on average 3.1% (w/w) protein [10]. The protein content in spent coffee is higher than in the coffee bean due to the concentration of the non-extracted components during instant coffee preparation. The protein content in spent coffee may be overestimated due to the presence of other nitrogen-containing substances (caffeine, trigonelline, free amines, and amino acids) [11].

Amino acids: The essential AAs comprise 42% of the total spent coffee grounds amino acids which are smaller than the 49% described by Lago. Glutamic acid, threonine, aspartic acid, and leucine presented the upper values, unlike data previously reported for spent coffee grounds (glutamic acid, leucine, valine, and isoleucine). Fischer's ratio is the ratio of branched-chain AAs (BCAAs: leucine, valine, isoleucine) to aromatic AAs (AAA: phenylalanine, tyrosine) and plays an important role mainly in liver diseases.

As can be observed (Table 1) a value of (3.39) for the Fischer is obtained which is higher than those described for spent coffee grounds, coffee pulp, and soy meal [8]. Proteins with high BCAA, Fischer's ratio, and low AAAs are sought for the functional foods field to support special requirements in malnourished patients associated with cancers, burns, trauma, and liver failure among others.

Caffeine

Caffeine 1,3,7-trimethyl-xanthine, a purine alkaloid is the quintessential single most popular compound recognized in coffee and coffee products/ingredients. This alkaloid is removed from coffee beans by the decaffeinating process commonly used on the industrial scale. Although the caffeine content in coffee waste is lower than that in coffee beans, a large amount of caffeine remains. Higher caffeine can be extracted from coffee husks or coffee pulp than from spent coffee grounds [12].

Caffeine concentrations ranged from 0.734 mg/mg to 41.3 mg/mg of spent coffee ground extracts obtained by low-pressure extraction (ultrasound and Soxhlet) and Supercritical Fluid CO_2 Extraction (SFE) varying in yield from 9% to 15% [5]. The polar solvent, dichloromethane extracts the most caffeine at low pressure, whereas SFE at high pressure (300 bars) is more efficient both in terms of generating higher caffeine yield and environmental footprint. Caffeine obtained from spent coffee is equivalent to 18% to 48% of those extracted from coffee beans by supercritical CO_2 or 8% to 31% of roasted coffee. Supercritical CO_2 has long been used to decaffeinate coffee beans and therefore can be integrated into processing spent coffee ground. Various caffeine concentrations (0.007% to 0.5%) have been reported depending on the extraction process and spent coffee ground source [5].

Table 1: Amino acids composition (% protein) of spent coffee grounds.

Amino acids	Spent coffee grounds
Alanine (Ala)	2.34 ± 0.71
Arginine (Arg)	0.01 ± 0.01
Aspartic acid (Asp)	5.10 ± 0.71
Cysteine (Cys)	0.15 ± 0.01
Glutamic acid (Glu)	4.13 ± 0.56
Glycine (Gly)	2.68 ± 0.17
Histidine (His)	0.39 ± 0.08
Isoleucine (Ileu)	0.94 ± 0.13
Leucine (Leu)	2.49 ± 0.37
Lysine (Lys)	0.59 ± 0.10
Methionine (Met)a	0.26 ± 0.03
Phenylalanine (Phe)	1.18 ± 0.22
Proline (Pro)	1.63 ± 0.29
Serine (Ser)	0.57 ± 0.10
Threonine (Thr)	4.71 ± 1.01
Tyrosine (Tyr)	0.33 ± 0.09
Valine (Val)	1.69 ± 0.14
Essential AAs (% total)	42.0 ± 1.2
BCAA (Val + Leu + Ile)	5.12 ± 0.6
AAA (Phe + Tyr)	1.51 ± 0.3
Fisher Ratio	3.40 ± 0.3

Results are expressed as mean ± standard deviation (n=3), Essential amino acids.

Lipids

Spent coffee grounds have often been reported to contain 10% to 15 % [13] and sometimes higher average 20% (range 19.9% to 27.8%) lipids or 13.9% to 29.2% ether extract on a dry weight basis [8]. During the brewing process lipids stick to the spent grounds and are filtered off in filter homebrew as well as in instant coffee production.

Lipid yield (7% to 13% dry weight) is low when spent coffee suspended in fresh heptane (1:10 weight ratio) is stirred (3 h) at room temperature [13]. Spent coffee extracted with hexane yields high oil (15.3%), with low acid (3.65%) and saponification (173) values parameters important for Fatty Acid Methyl Ester (FAME) manufacturing (Campos-Vega et al. 2015). The lipid composition is similar to those of boiled or filtered coffee with 875 to 93% triglycerides, 7% to 13% diterpene alcohol esters, 0.2% to 0.9% sterols, and up to 0.8% polar material.

However, the lipid composition of spent coffee ground may vary analogous to those of green coffee oil depending on the source, although generally up to 80% to 90% of the oil will be glycerides, including free fatty acids, with the rest of the lipids containing terpenes, sterols, and tocopherols.

Minerals

Spent coffee also contains an ash content of 1.6%, according to the ICP-AES analysis, consisting of several minerals. Potassium is the maximum rich element, accompanied by phosphorus and magnesium [6,8]. Potassium is as well the predominant mineral in coffee beans, corresponding to 40% of the oxide ash [14]. Most minerals are easily extracted with hot water during instant coffee preparation.

Total mineral (K, P, Ca, Mg, Na, Fe, Cu, and Mn) content of espresso spent coffee differs from 0.82% to 3.52%, verifying mineral escape during espresso coffee preparation although not as exhaustive as with soluble coffee [9]. Potassium is the major mineral of espresso

spent coffee ranges from 3.12 mg/g to 21.88 mg/g (Cruz et al. 2012). The industrial spent coffee contains a lower absolute amount of 3.55 mg/g and relative amounts about 22% of this element. Coffee is viewed as its vital source of Mg, containing about 11% of the spent coffee ground minerals, again higher than those of industrial spent coffee [6].

Phenolic compounds

Phenolic compounds are the major determinant of antioxidant potentials found in high concentrations in plants [15]. Currently interest in plant-derived natural products has grown mainly because synthetic antioxidants suffer from several drawbacks. Spent coffee grounds contain several human health-related compounds, such as phenolics with demonstrated antioxidant, anti-bacterial, antiviral, anti-inflammatory, and anticarcinogenic activities [16]. The recovery of phenolic compounds from the coffee industry by-products and their antioxidant activity has been investigated recently. Phenolic compounds from coffee by-products (spent coffee, coffee pulp, husk, and silver skin) have been extracted using a solvent mixture of isopropanol and water [12]. The coffee by-products contained about 1% to 1.5% total polyphenols with the highest yield for silver skin 25% followed by spent waste 19% and cherry husk 17%when pretreated with vis-co-enzyme. Chloro Genic Acid (CGA) is the major phenolic component once analyzed with high-performance liquid chromatography. Phenolic compounds are mainly found in green coffee beans as Chlorogenic acid up to 12% solids [8].

Phyto-chemical properties of spent coffee

Coffee is known as a valuable source of biologically active phytochemicals such as phenolic compounds and caffeine. The photochemical composition of the spent coffee grounds [17]. Spent coffee ground is the main by-product of the brewing process and a potential source of bioactive compounds, mainly phenolic acids easily extracted with water. The chemical analysis exposed that green coffee is a raw material richer in Chlorogenic acid than roasted one. Knowledge of the total content of phenolic compounds in spent coffee extracts is crucial for their potential use as functional ingredients by the food and pharmaceutical industries.

For comparison, the commercial spent coffee grounds presented lower contents of total phenolics and flavonoids 11.04 mg GAE/g, 1.09 mg CE/g, respectively than spent coffee grounds of 100% Arabica and 100% Robusta extracts [4]. Carotenoids are known to be very efficient physical and chemical quenchers of singlet oxygen ($1O_2$), as well as potent scavengers of other Reactive Oxygen Species (ROS), however in the present study regarding their antioxidant activity, a different correlation was observed, showing an inverse significant correlation, with lycopene and chlorophyll-a increase being strongly associated with a decrease in antioxidant activity (Table 2).

Recovery of Bioactive Components of Spent Coffee

The recovery process of the phenolic compounds from the coffee industry by-products and their antioxidant activity. The coffee by-products (coffee pulp, husk, silver skin, and spent coffee) are obtained from the coffee processing industry [12]. Bioactive compounds are value-added products justifying their isolation from industrial wastes. These residues could be an alternative source for obtaining natural antioxidants, which are considered completely safe in comparison with synthetic antioxidants.

Coffee is one of the copious beverages and worldwide production is over 105 million tons annually. Industrial processing of coffee fruit is done to isolate coffee powder by removing the shell and mucilaginous part from cherries. Coffee is subjected to two methods of processing (washed and unwashed) such as pulping, washing, drying, curing, roasting, and brewing, and during the process various by-products.

Different Applications of Spent Coffee

Spent coffee grounds are the residual material obtained during the treatment of coffee powder with hot water to prepare coffee infusion or steam for the instant coffee preparation. Almost 50% of worldwide coffee production is processed for soluble coffee preparation, generating about 6 million tons of spent coffee per year [6]. On average one ton of green coffee generates about 650 kg of spent coffee and about 2 kg of wet spent coffee is obtained for each kg of soluble coffee produced.

Spent coffee has been proposed as an additive in the production of ceramic bricks, showing acceptable physical and mechanical performance and low thermal conductivity [16]. From an agricultural point of view the possibility of reutilizing spent coffee grounds as an easy and economically feasible soil amendment represents an exciting opportunity to obtain products of high nutritional value [18]. For instance, low amounts of composted spent coffee grounds (up to 15% v/v) produced a relevant increase in essential macro-elements in lettuce, enhancing its quality features.

Food use of spent coffee

Spent coffee from industrial instant coffee is a natural source of antioxidant insoluble dietary fiber, proteins, essential amino acids, and low glycemic sugars [19]. Spent coffee (4% w/w) can be used directly as a food ingredient in solid foods such as biscuits without affecting the conventional food preparation and the final quality of the product. The use of the spent coffee ground as a food ingredient is rich in antioxidant dietary fiber for bakery products. This ingredient could be directly applied in the manufacture of pastry and confectionery foods such as bread, cookies, and breakfast cereals, among others, making it a simple, low-cost alternative.

Spent coffee is used as a novel beverage distilled beverage with a coffee aroma is developed by aqueous extraction of aromatic compounds from spent coffee supplemented with sugar and the production of ethanol [20]. Food preservative addition of spent coffee to meat and other foods is shown to provide antioxidant properties inhibiting lipid oxidation, and also antimicrobial properties reducing pathogenic bacterial growth and, therefore, spoiling of food [21]. Finally roasted beans are ground, and the coffee beverage is prepared at home or processed for soluble/instant coffee leading to the generation of the last coffee by-product, spent coffee grounds [22]. About 2 kg of wet spent coffee is obtained for each kilogram of soluble coffee produced [6].

Nonfood use of spent coffee

Spent coffee ground is used for many applications like Skincare products, Biodiesel, composting and fertilizer, materials for the construction industry. An emulsion containing 35% of oil extracted from spent coffee grounds presented promising characteristics as a sunscreen [17]. This formulation is industrial-scalable and suitable for topical use according to the rheological, mechanical, and safety assessment. Biodiesel is one of the most popular research topics surrounding spent coffee grounds for energy use [23]. It consists of first extracting the oils present in spent coffee grounds and Trans esterifying them into Fatty Acid Methyl Esters (FAME) commonly referred to as biodiesel [24].

Table 2: Photochemical composition and *in vitro* antioxidant activity of the aqueous extracts obtained from three different coffee grounds (100% Arabica, 100% Robusta, and commercial mixture: 80% Arabica+20% Robusta).

Spent coffee grounds			
Photochemical	**Arabica**	**Robusta**	**Commercial mixture**
Phenolics	14.97 ± 0.09[b]	22.56 ± 1.02[a]	11.04 ± 0.17[c]
Flavonoids	2.12 ± 0.04[b]	3.49 ± 0.46[a]	1.09 ± 0.16[c]
Chlorophyll[a]	0.0494 ± 0.002[a]	0.0280 ± 0.001[c]	0.0393 ± 0.002[b]
Chlorophyll[b]	0.0873 ± 0.004[a]	0.0042 ± 0.000[c]	0.0653 ± 0.004[b]
Lycopene	0.0079 ± 0.000[b]	0.0011 ± 0.000[c]	0.0258 ± 0.001[a]

*a, b, c Different letters stand for significant differences ($p<0.01$) in mean value, according to the LSD posthoc test (ANOVA) source from five authors like.

Composting and fertilizer are direct applications of spent coffee grounds to soils that were found to be damaged due to their high C/N ratio, phenol content, and acidity. Positive results have been obtained from studies on the effect of mixing SCGs with other organic wastes in different ratios [25]. Spent coffee grounds are used for the materials used for the construction industry by mixing other waste materials such as recycled glass, bagasse ash or fly ash to produce materials with high compressive strengths, suitable for use as a sub grade material.

Conclusion

Coffee is one of the most popular and consumed beverages in the world. Spent coffee grounds are the residual material obtained during the treatment of coffee powder with hot water to prepare coffee infusion or steam for the instant coffee preparation. However, spent coffee is one of the main coffee residues which, is the solid residues obtained after the preparation of the coffee beverages. Coffee is known as a valuable source of biologically active photo chemicals such as phenolic compounds and caffeine. Moreover, other new valuable properties of the spent coffee are being continuously discovered. The bioactive compounds are value-added products, justifying their isolation from the industrial wastes and these residues certainly could be another source for finding natural antioxidants, which are considered entirely safe in comparison with synthetic antioxidants. In general, nowadays the use of spent coffee increases whether, is as food or as non-food.

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