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SPENT COFFEE GROUND AS A NATURAL SOURCE OF ANTIOXIDANT COMPOUNDS: A MECHANISTIC APPROACH TOWARDS VALORIZATION

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Abstract:

Coffee post-consumption results each year in the production of millions of tons of spent coffee ground (SCG), a waste material currently recognized as a valuable source of various unextracted bioactive compounds, with beneficial properties for human health, among which the antioxidant effect. Several mechanisms have been reported in the literature as underlying the antioxidant effect of phenols and diterpenes, such as: metal chelation, free radical scavenging and neutralization, upregulation of several antioxidant enzymes, and inhibition of pro-oxidant enzymes. With respect to the last effect, a couple of bioactive compounds from SCG have been reported to inhibit monoamine oxidase (MAO), a mitochondrial enzyme with two isoforms, MAO-A and B, in experimental settings (cell lines and animal models) with subsequent neuroprotective effects. While MAO inhibition has demonstrated unequivocal cardiovascular protection in both animal models and *ex vivo* analysed human samples, there are no studies in the literature that addressed the capability SCG compounds to interact with MAO in the cardiovascular tissues. The doctoral study is purported to: i) provide a comprehensive characterization of the SCG bioactive compounds using high-performance liquid chromatography tandem mass spectrometry (HPLC/MS), ii) assess the antioxidant effects of the individual phenolic compounds (chlorogenic and caffeic acids) and diterpenes (cafestol and kahweol), as well as means to enhance their antioxidant properties and iii) investigate the capability of SCG- extracted compounds to modulate *in vitro* the MAO-related oxidative stress in human vascular and cardiac samples harvested from patients with indication of revascularization and cardiac surgery. MAO inhibition could represent a novel mechanism by which SCG compounds exert cardiovascular benefits.

• Introduction

The worldwide rise in obesity ("globesity") has led to a dramatic increase in the prevalence of metabolic syndrome, a cluster of interrelated metabolic abnormalities including central obesity, insulin resistance, hypertension, dyslipidemia, and impaired glucose metabolism. Metabolic syndrome has become a major public health concern due to its strong association with type 2 diabetes mellitus and cardiovascular diseases.

Spent coffee ground (SCG) is the primary solid residue generated after coffee brewing, with millions of tons produced globally each year. Once considered waste, SCG is now recognized as a rich reservoir of bioactive compounds with significant health-promoting potential, including in various experimental models of cardiometabolic diseases.

Monoamine oxidase (MAO) is a mitochondrial enzyme with two isoforms, MAO-A and B, responsible for the constant production of H_2O_2 and whose inhibition has unequivocally demonstrated decreased oxidative stress and subsequent cardiovascular protection in both animal models and *ex vivo* human samples via an antioxidant effect.

• Material and method

Using the PubMed, Web of Science, and Google Scholar databases, a review of the literature addressing the mechanisms underlying the antioxidant effects of SCG compounds was carried out. Peer-reviewed original research and review articles served as the inclusion criteria.

• Results and discussions

SCG contain substantial quantities of phenolic compounds, predominantly chlorogenic acids, which are the primary contributors to the antioxidant activity. Total phenolic content in SCG extracts has been reported to reach up to 217.26 mg GAE/g dry weight under optimized extraction conditions, with strong positive correlations between total phenolic content and DPPH radical scavenging activity [1].

• Results and discussions

SCG extracts effectively reduce ROS production by 21.5-66.4% in macrophages and adipocytes, with chlorogenic acids, protocatechuic acid, and caffeine identified as the main contributors to this antioxidant activity. In human HeLa cells, SCG extracts rich in caffeoylquinic acids and caffeine significantly reduced H_2O_2-induced ROS levels and DNA strand breaks, providing 29-73% protection against oxidative DNA damage [2].

SCG extracts demonstrated multiple antioxidant-related metabolic benefits in cellular models: i) reduced inflammatory markers (TNF-α, IL-6) in macrophages and adipocytes, ii) decreased lipid accumulation in adipocytes by inducing adipocyte browning, iii) modulated insulin receptor signaling pathway phosphorylation, iv) stimulated GLUT-4 translocation increasing glucose uptake, v) inhibited α-glucosidase activity, suggesting anti-diabetic potential, and vi) increased nitric oxide production in endothelial cells in a dose-dependent manner and promote endothelial nitric oxide synthase (eNOS) expression [3].

There are no studies in the literature that addressed the capability SCG compounds to interact with MAO in the cardiovascular tissues. As such, investigation of the capability of SCG- extracted compounds to modulate *in vitro* the MAO-related oxidative stress in human vascular and cardiac samples harvested from patients with indication of cardiac surgery is worth further investigation.

• Conclusions

Spent coffee grounds represent a sustainable, widely available source of bioactive compounds with demonstrated antioxidant and metabolic benefits in preclinical models. However, translation of these findings into validated health claims requires further substantiation through analysis of human samples. The valorization of SCG from environmental waste to functional food ingredient aligns with circular economy principles and offers promising applications in health. MAO inhibition could represent a novel mechanism by which SCG compounds exert cardiovascular benefits.

Selective References: 1. Panusa A, Zuorro A, Lavecchia R, Marrosu G, Petrucci R. Recovery of natural antioxidants from spent coffee grounds. J Agric Food Chem. 2013 May 1;61(17):4162-8. 2. Bravo J, Arbillaga L, de Peña MP, Cid C. Antioxidant and genoprotective effects of spent coffee extracts in human cells. Food Chem Toxicol. 2013 Oct;60:397-403. 3. Jiang R, Hodgson JM, Mas E, Croft KD, Ward NC. Chlorogenic acid improves ex vivo vessel function and protects endothelial cells against HOCl-induced oxidative damage, via increased production of nitric oxide and induction of Hmox-1. J Nutr Biochem. 2016;27:53-60.