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Use of spent coffee grounds as food ingredient in bakery products

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ABSTRACT

The present research aimed to evaluate the use of spent coffee grounds (SCG) from instant coffee as a food ingredient and its application in bakery products. Data on physicochemical characterization, thermal stability and food safety of SCG were acquired. Evaluation of feasibility as dietary fibre was also determined. Results showed SCG are natural source of antioxidant insoluble fibre, essential amino acids, low glycaemic sugars, resistant to thermal food processing and digestion process, and totally safe. In the present work, SCG were incorporated in biscuit formulations for the first time. Low-calorie sweeteners and oligofructose were also included in the food formulations. Nutritional quality, chemical (acrylamide, hydroxymethylfurfural and advanced glycation end products) and microbiological safety and sensory tests of the biscuits were carried out. Innovative biscuits were obtained according to consumers' preferences with high nutritional and sensorial quality and potential to reduce the risk of chronic diseases such as obesity and diabetes.

1. Introduction

Spent coffee grounds (SCG) are the most abundant coffee by-product (45%) generated in coffee beverage preparation and instant coffee manufacturing (Murthy & Naidu, 2012b). About 2 kg of wet SCG are obtained from each kg of instant coffee produced, with an annual generation of around 6 million tons worldwide (Mussatto, Machado, Martins, & Teixeira, 2011). To date, several applications have been described for SCG, mainly as biofuels, composts, animal feed, biosorbents and enzymes. Recently, an increase in food and health application is occurring (Del Castillo, Fernandez-Gomez, Martinez-Saez, Iriondo, & Mesa, in press). Previous studies performed by our group indicated the importance of SCG as source of antioxidant dietary fibre (Del Castillo, Martinez-Saez, & Ullate, 2014).

Consumers are concerned about caloric content and glycaemic index (GI) of the food as well as balanced nutrition comprising dietary fibre content. The benefits of low GI diets extend beyond weight loss and have favourable effects on obesity-related diseases such as type 2 diabetes (Esfahani, Wong, Mirrahimi, Villa, & Kendall, 2011). Food industry needs to fulfil the increasing consumer's demand of healthier and tastier foods. The search for healthier and tasty food as for instance bakery products is a necessity in our population. Maillard reaction is the main chemical event occurring during coffee roasting and baking. The reaction affects nutritional quality, safety and sensory value. Maillard reaction products present health promoting (melanoidins) and potential harmful effects (acrylamide, furans and advanced glycation end products) (Tamanna & Mahmood, 2015). The present work aims to evaluate the use of SCG as food ingredient in innovative bakery products with high nutritional and sensorial quality and potential to reduce the risk of chronic diseases such as obesity and diabetes.

2. Materials and methods

2.1. Reagents

Bradford reagent was provided by Bio-Rad Laboratories S.A; α-amylase from human saliva (type IX-A), porcine pepsin from gastric mucosa (3.200–4.500 U/mg protein), pancreatin from porcine pancreas, porcine bile extract, bovine serum albumin (BSA), chlorogenic acid (CGA) (3-CGA), 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid (ABTS)), Folin-Ciocalteu reagent, Nα-Acetyl-L-lysine, ortho-phthalaldehyde (OPA), 1-deoxy-1-morpholinofructose (DMF), nitroblue tetrazolium (NBT), butylated hydroxytoluene and proteinase k from *Pichia pastoris* were from Sigma-Aldrich (St. Louis, MO, USA). Bradford reagent was provided by Bio-Rad Laboratories S.A, glucose kit from Spinreact (Gerona,

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Spain), total dietary fibre kit from Megazyme (International Ireland Ltd) and advanced glycation end products assay kit from Lamider® (México, D.F., México). Buffered peptone water (BPW) from Biocult, plate count agar (PCA) medium from BD Diftco™, brain heart infusion (BHI) agar from BD Bacto™ (New Jersey, USA) and sabouraud dextrose agar (SDA) with chloramphenicol from CONDA (Pronadisa). Water was purified using Milli-Q and Elix system. All other chemicals and reagents were of analytical grade.

2.2. Apparatus

BioTek powerWaveTM XS (BioTek Instruments, U.S.A) and FP-6200 (JASCO, Easton, U.S.A) microplate spectrometers, Agilent G16000A capillary electrophoresis (Agilent, Madrid, Spain), convection oven (Romag S.A, Barcelona, Spain), UN 500 universal oven (Memmert, Germany), Telstar Lyobeta-15 lyophilizer (Telstar, Spain), CertoCLAV A-4050 autoclave (CertoCLAV, Austria), AW Sprint TH-500 water activity system (Novasina, Switzerland), Shimadzu HPLC system (Kyoto, Japan), Agilent 1200 liquid chromatograph coupled to an Agilent Triple Quadrupole MS detector (Agilent Technologies, Palo Alto, CA, USA) and Biochrom 30 Amino Acid Analyzer (Cambridge, UK) were used for analysis. Stomacher® 400 Circulator (Seward, U.K.), horizontal laminar flow bench Mini-H (Telstar, Spain), Nüve EN120 incubator (Nüve, Turkey) and SANYO Mir 154 incubator (SANYO Electric Biomedical Co., Ltd. UK) were also needed for microbiological studies.

2.3. SCG samples

Raw coffee by-product: SCG from industrial soluble coffee production of the Robusta specie were provided by Prosol S.A (Spain) and stored under −20 °C until preparation of the biscuits and microbiological analysis. Information regarding to the thermal stability of SCG dietary fibre was obtained by treating the sample under those conditions used for the baking of biscuits (185 °C, 16 min).

Stabilized SCG: Different drying conditions were applied on raw SCG (40 °C, 70 °C and 100 °C) until constant weight was achieved. Samples were stored at room temperature in dry and fresh place for 24 h, until analyses of their physical properties (moisture loss, moisture content and water activity) and microbiological quality. Energy consumption (kW·h) was calculated for each drying condition by correlation of consumption and operating temperature. Calculation was performed in order to validate the feasibility of the method for its industrial use.

Freeze-dried SCG: The raw material was lyophilized and stored in dry and cool place until analysis of its physico-chemical properties (moisture, water activity, ashes, dietary fibre, proteins, amino acid composition, fat, carbohydrates and antioxidant capacity) and safety by means of the quantification of food processing contaminants (acrylamide and hydroxymethylfurfural).

In vitro oral gastrointestinal digestion was carried out to evaluate the resistance of SCG to digestion process. The freeze-dried SCG were digested as described by Hollebeeck, Borlon, Schneider, Larondelle, and Rogez (2013), with slight modifications. All three stages (salivary, gastric and duodenal) were performed in the same flask covered with aluminium foil. Approximately 1.2 g of SGC were weighed. Conditions were set up as follows: salivary step (pH 6.9, 10 ml, 5 min, 3.9 U α-amylase/ml, aerobic), gastric step (pH 2, 13 ml, 90 min, 71.2 U pepsin/ml, aerobic), and abiotic duodenal step (pH 7, 16 ml, 150 min, 9.2 mg pancreatin and 55.2 mg bile extract/ml, aerobic). The obtained digests were centrifuged and separated in two fractions, supernatant and precipitate. The content of dietary fibre was determined in the precipitate (non-digestible fraction also called colonic fraction). Finally, the soluble fraction was treated to mimic human intestinal reabsorption of bile salts. Cholestyramine resin (10% w/v) previously activated was used as bile acids precipitating agent (Edwards & Slater, 2009) for 1 h at room temperature by mixing with magnetic stirrer. Cholestyramine was removed by centrifugation and gravimetric filtration. The antioxidant capacity and total phenol content of supernatants free of bile salts containing the bioaccesible compounds in the intestinal lumen were analysed. A food control composed by starch, bovine serum albumin and oil was included. Digestion process was carried out in duplicate and the analysis of the samples in triplicate.

Aqueous SCG extracts: An extractable fraction from freeze-dried SCG was obtained with hot water (50 mg/ml) at 100 °C for 10 min as described in the patent WO 2013/004873. Extracts were stored at −20 °C until use. Further chemical analyses (free glucose, antioxidant capacity, total phenolic content, CGA and caffeine) were carried out to gain insight on soluble compounds present in SCG. The analysis of the fraction aimed to assess the interest for extracting other compounds beside dietary fibre from the brewing coffee by-products and to reinforce its value as natural abundant source of antioxidant dietary fibre.

2.4. Biscuits samples

2.4.1. Food ingredients

For the biscuits formulations, all basic ingredients were purchased at specialized and certified food markets. Food grade soy lecithin was provided by Manuel Riesgo S.A. (Spain) and maltitol was supplied by a national food company. The commercial stevia sweetener powder which contained 3% steviol glycosides, was supplied by Gerblé (Spain) and oligofructose powder (ORAFTI®P95) by Beneo-Orafti.

2.4.2. Biscuits formulations

A total of 6 innovative free-sugar biscuits (B1, B2, B3, B4, B5, B6) were formulated as indicated in Table 1. Biscuits were prepared using as basic ingredients wheat flour and sunflower oil. Egg was not incorporated and sucrose was replaced by stevia and/or maltitol as natural hypocaloric sweeteners. SCG were included as antioxidant insoluble dietary fibre. The amount of SCG added to the biscuits ranged 3.5–4.4%, in order to achieve the nutritional claims "source of fibre" (⩾3 g fibre/100 g biscuit) and "high fibre content" (⩾6 g fibre/100 g biscuit). Oligofructose was included as

Table 1
Innovative biscuit formulations: B1 – 100% stevia (ST) and spent coffee grounds (SCG); B2 – 100% ST. oligofructose (OF) and SCG; B3 – 30% ST. 70% maltitol (MT) and SCG; B4 – 30% ST. 70% MT. OF and SCG; B5 – 100% MT and SCG; B6 – 100% MT. OF and SCG.

Ingredients (g)	B1	B2	B3	B4	B5	B6
Wheat flour	61.54	59.37	55.11	55.53	52.83	53.35
Water	21.98	21.20	19.68	18.21	18.87	17.49
Sunflower oil	8.52	8.22	7.63	7.06	7.31	6.78
Baking powder	0.60	0.58	0.54	0.50	0.52	0.48
Salt	0.41	0.39	0.36	0.34	0.35	0.32
Soy lecithin	0.36	0.35	0.32	0.30	0.31	0.29
MT	0.00	0.00	11.81	10.83	16.04	14.87
ST	2.20	2.12	0.60	0.56	0.00	0.00
OF	0.00	3.53	0.00	3.03	0.00	2.91
SCG	4.40	4.24	3.94	3.64	3.77	3.50
Total	100	100	100	100	100	100
Estimated calories (kcal/100 g biscuit)	407	390	346	335	325	316
Estimated fibre content (g fibre/100 g biscuit)	3.6*	7.5†	3.1*	6.4†	3.0*	6.1†

* B1. B3 and B5 might be "source of fibre" (⩾3 g fibre/100 g biscuit).
† B2. B4 and B6 might be "high fibre content" (⩾6 g fibre/100 g biscuit).