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Functional coffee substitute prepared from ginger by subcritical water

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ABSTRACT

Functional coffee substitute was prepared from ginger rhizome by subcritical water in a house-made extractor/reactor. The properties and bioactivities of subcritical water extracts of ginger obtained at different temperatures were compared with conventional ginger S/L extracts prepared at atmospheric pressure, in order to define temperature influence of subcritical water treatment on the functional properties. The content of total phenols and flavonoids were compared in obtained extracts. In addition, the extracts were screened for their antioxidant potential by several assays that included different mechanisms encompassing the ability to scavenge hydroxyl, ABTS and DPPH radicals, reducing power, chelating ability and efficiency in the prevention of lipid peroxidation. In prepared ginger-based beverage four macro- and five microelements were quantified in order to define proposed product as a source of essential elements. Sensory properties of prepared ginger-based coffee substitute were compared to common coffee types that included traditional, instant, espresso and American/filter coffees.

1. Introduction

Since ancient times the rhizome of ginger (*Zingiber officinale*) has been used in many traditional medicines, including Ayurveda, Unani, Chinese, Indian, and Arabic in the treatment of different health conditions like flu and cold, migraines, hypertension and headaches [1,2]. Modern science also recognises, explains and confirms its beneficial health effects including antioxidant, antimicrobial and antiviral activity [3–5]. Many studies confirmed its antidiabetic [6], anticancer [7] and anti-inflammatory [8,9] effects, particularly effective in the treatment of prostate inflammation [10], rheumatism and gout [11].

In ginger rhizome more than 50 bioactive compounds have been identified including monoterpenoids and sesquiterpenoids, however its bioactivity is mostly attributed to homologous series of phenols known as gingerols [12]. All gingerols, similarly to capsaicin and piperine, activate vanyloid TRPV1 receptors producing a pungency sensation [13]. Upon dehydration gingerols are converted to shogaols, which are about twice as pungent as gingerols. Upon heating gingerols are converted to zingeron or vanillylacetone, a compound similar to other flavour compounds like eugenol and vanillin building a sweet and spicy flavour [14]. Paradol and curcumin have also been identified in ginger extracts [15].

In the recovery of natural bioactive compounds, the most applied approach is to use solvent extraction or, alternatively, supercritical carbon-dioxide extraction. General intention is to replace organic solvents due to, primarily, safety and environmental considerations. In this respect subcritical water gains significant attention in recent years due to its safe character, excellent solvating properties, competitive selectivity and price. The polarity of water drops substantially by heating producing a solvent with good solvating properties to moderately polar compounds. In addition, heating decreases waters viscosity, density and surface tension contributing to extraction efficiency. Water heated to 300 °C behaves as moderately polar solvents like methanol or acetonitrile [16].

In addition to using subcritical water as an excellent, safe and cheap solvent, it's other applications include decomposition/hydrolysis of waste due to its high chemical reactivity [16,17].

In this work subcritical water was used for preparing a coffee substitute with health benefits and functional properties. According to our knowledge no similar product was reported. Coffee substitutes are mostly prepared from roasted grains and roots, including chicory root and acorn, as well as wheat bran, beechnut, soybean and other plant sources. The mixture of roasted barley, malted barley, chicory, and rye was developed by Nestle and is known under the trade name Nestlé Caro [18]. Polish drink Inka is made of rye, barley, chicory, and sugar

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beet and is being produced since 1971 (http://inka.pl/main-2/). Ersatz coffee is made of roasted rice, roasted buckwheat, and roasted chicory (http://ersatz-coffee.com/gluten-free-caffeine-free/). Coffee substitutes are consumed due to medical or religious reasons. Many people are sensitive to caffeine or tend to reduce or avoid its consumption. On the other hand millions of people enjoy routinely rich coffee flavour, being addicted to this habit. Chrono diet strongly advises the avoidance of coffee due to its effects to increase acidity of bodily fluids [19,20]. Nutritional scheme of chrono diet has helped number of people to regain its balance and reduce their weight, however owing to habits that have been developed over the years and addictive flavour of coffee beverage many people find difficult to give-up this beverage. Commercially available coffee substitutes are caffeine-free, however their taste and flavour are usually notably different of the original coffee beverage. Here we report a new ginger-based functional beverage that simulates coffee and all its sensory properties (flavour, taste, fullness) quite well. According to our knowledge there are no reported ginger-based coffee substitutes. The product was prepared by using home-made subcritical water extractor/reactor. Its functional properties were confirmed by measuring its free-radical scavenging and anti-oxidant properties (DPPH, $OH^{\cdot}$, reducing power), as well as the content of selected micro- and macroelements. In addition, the abilities to prevent lipid-peroxidation and to chelate metal ions were quantified, as well as the content of total phenols and flavonoids. Sensory analysis and consumer acceptability were evaluated by comparing its properties with four conventional coffee types (espresso, traditional, instant, American/filter).

2. Material and methods

2.1. Chemicals and reagents

Folin-Ciocalteu reagent, trichloroacetic acid, 1,1-diphenyl-2-picryl-hydrazyl-hydrate (DPPH), chlorogenic acid, rutin, linoleic acid, sulfuric acid, sodium phosphate, ammonium molybdate, ascorbic acid, gallic acid, butylated hydroxytoluene (BHT), 2-deoxyribose and β-carotene were purchased from Sigma-Aldrich (St. Louis, Missouri, USA). Aluminium chloride hexahydrate, sodium carbonate, sodium acetate trihydrate as well as $ABTS^{\cdot+}$ radical were purchased from Merck (Darmstadt, Germany). Potassium ferricyanide and ferric chloride, were obtained from Zorka (Šabac, Serbia). Etylenediaminetetraacetic acid (EDTA) was purchased from Centrohem (Stara Pazova, Serbia). Tween 80 was purchased from Tedia Company (USA). All other chemicals and reagents were analytical reagent grade.

2.2. Samples

Dry and ground ginger rhizome, as well as ground traditional (Grand kafa), ground American/filter (Intermezzo) andinstant coffee (Nestle Nescafe classic) were purchased at the local retail store. Espresso coffee (Barkafa) was prepared in a usual way at the local bar.

2.3. Subcritical water extraction (SWE)

Subcritical water extraction (SWE) was performed in a house-made subcritical water extractor/reactor previously described by [21]. Used extractor was a batch type, consisting of extraction/reaction vessesel (1.7 L) made of a stainless steel, heating plate and a vibrational platform that provided convective mass transfer during extraction and prevented overheating in contact with a heating plate. Pressurization of the vessel was performed with 99.999% nitrogen (Messer, Germany) in order to prevent oxidation at high temperatures. Extractions were performed during 1 h with double-distilled water in the temperature range from 80 °C to 180 °C at the pressure of 50 bar applying the agitation rate of 3 Hz. In all experiments sample to water ration was 1:10. Obtained extracts were filtrated and stored in the refrigerator until analysis.

For the reference ginger samples were also extracted with water at the atmospheric pressure under mild boiling maintaining the same sample-to-solvent ratio, extraction time and agitation rate. Extracts were filtered and stored in the refrigerator until analysis.

2.4. Spray drying of extracts

Prepared liquid feed (ginger extract) was spray dried using laboratory spray dryer (Mini Spray Dryer-Buchi 190, Buchi, Switzerland). A peristaltic pump was used to pump the feed into the dryer. The process inlet temperature ranged from 150 to 157 °C. Outlet air temperature ranged from 85 to 89 °C. The obtained powder was separated from air by a cyclone. Approximately 3.1% of dry extract was obtained from water ginger extract.

2.5. Preparation of hot beverages

All tested coffee beverages were prepared in a usual way using same bottled water (Aqua Viva, Serbia), maintaining usual way of preparation, as well as coffee-to-water ratio. Traditional coffee was prepared in a typical way by adding 7 g of fine-ground coffee into 100 mL of boiling water, mixing it, and keeping it heated at the heating plate by next 30 s. Traditional way of consumption does not imply phase separation prior use, however in order not to reveal its type prior sensory analysis prepared beverage was filtered. Instant coffee was prepared by dissolving 2.5 g of the product in 100 mL of boiling water. Espresso coffee was prepared in a local bar using 7 g of coffee to prepare 70 mL of ready-to-consume beverage. American/filter coffee was prepared by percolating 500 mL of hot water through 35 g of ground coffee, placed in the filtering compartment of the coffee maker. Ginger-based coffee substitute was prepared by dissolving 1.8 g of spray-dry ginger extracts obtained at 150 °C and 50 bars in 75 mL of hot water. All beverages were served hot to panel members for evaluation.

2.6. Determinations of phenolic and flavonoid compounds

To determine the total phenolics content the Folin-Ciocalteu method [22,23] was used. The reaction mixture was prepared by mixing 0.1 mL of the sample, 7.9 mL of distilled water, 0.5 mL of Folin-Ciocalteu reagent and 1.5 mL of sodium carbonate (20%, w/w). After incubation at room temperature for 1 h, absorbance was measured at 750 nm. The blank was prepared by replacing the samples with distilled water. Triplicate measurements were made for each sample. Chlorogenic acid was used as a calibration standard.

The total flavonoid content was measured according to aluminium chloride colorimetric assay based on the procedure described by Markham [22]. Samples (1 mL) were mixed with 5% $NaNO_2$ solution (0.3 mL). After 5 min aluminiumchoridehexahydrate (10%, 0.3 mL) was added and allowed to stand for further 6 min. Sodium-hydroxide (1 mol/dm^3, 1 mL) was added to the mixture. Immediately, distilled water was properly added to bring the final volume to 10 mL. Blank was prepared using water instead of the samples. The absorbance was measured at 510 nm. Rutin was used as a calibration standard.

2.7. Determination of the antioxidant potential

2.7.1. DPPH radical-scavenging assay

For the DPPH radical-scavenging assay the procedure followed the method of Espin [23] in which the samples express their antioxidant activity by the reduction of purple colored DPPH to the yellow colored diphenylpicrylhydrazine derivatives. The samples were mixed with methanol (96%) and 90 μM DPPH to give final concentrations of 0.01; 0.02; 0.05; 0.1 and 0.2 mg/mL. The mixtures were incubated at room temperature for 60 min, and the absorbance was measured at a wavelength of 515 nm. Methanol was used to set zero of transmittance. All tests were performed in triplicates. The results were expressed as