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Antioxidative, potentially anti-inflammatory, and antidiabetic properties, as well as oxidative stability and acceptability, of cakes supplemented with elicited basil

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ABSTRACT

The aim of the study was to investigate the effect of addition of basil elicited with jasmonic acid (JA) on the biological properties, oxidative stability, and sensory quality of cakes. Simulated gastrointestinal digestion was used for determination of bioavailability. The antioxidant, anti-inflammatory and antidiabetic potential of fortified cakes were significantly higher than those of the control cakes. The antioxidant activity of the tested cakes was increased after addition of basil, proportionally to the amount of the additive. Additionally, in some cases, better results were obtained using JA-elicited basil instead of the control basil. Basil addition inhibited fat peroxidation in the cakes, measured as the malondialdehyde content. Cakes supplemented with the control and elicited basil were characterized by satisfactory consumer acceptability. Based on the data obtained in the present study, it can be concluded that JA-elicited basil (especially elicited with 100 μM jasmonic acid) can be recommended for food technologists.

1. Introduction

Basil is known to exhibit many pro-health activities, namely anti-allergic, anticancer, antimicrobial, antiseptic, antispasmodic, anti-fungal, antiviral, anti-inflammatory, analgesic, immuno-stimulating, sedative, and antioxidant properties. These properties are attributed to its phytochemical contents of polyphenols or aromatic compounds (Taie, Salama, & Radwan, 2010). As one of the ways to induce production of secondary metabolites by plants, elicitation can improve the pro-health properties of herbs (Baenas, García-Viguera, & Moreno, 2014). Additionally, it has been reported that various elicitors, e.g. chitosan, methyl jasmonate, jasmonic acid, salicylic acid, arachidonic acid and β-aminobutyric acid, can induce the synthesis of secondary metabolites in basil (Alavi-Samani, Kachouei, & Pirbalouti, 2015; Kim, Chen, Wang, & Rajapakse, 2006; Malekpoor, Salimi, & Pirbalouti, 2015; Szymanowska, Złotek, Karaś, & Baraniak, 2015; Złotek, Michalak-Majewska, & Szymanowska, 2016; Złotek, Szymanowska, Karaś, & Świeca, 2016). There are many investigations confirming the positive effects of biotic and abiotic elicitation on the content and biological activity of herbs (Kim et al., 2006; Yin, Fretté, Christensen, & Grevsen, 2012), but there is limited information concerning the bioavailability or feasibility of use of elicited herbs in the food industry. As indicated in a previous study, elicitation can especially contribute to higher phenolic compound content in herbs, which, as some researchers suggest, may be a result of regulation of certain enzymes involved in the biosynthesis of phenolics (Kim et al., 2006; Złotek et al., 2016). It is well known that a diet rich in phenolic compounds can be a preventative factor against degenerative and cardiovascular diseases; therefore, elicited herbs can be a more valuable material for food fortification (González, Fernández, Cuervo, & Lasheras, 2014). Additionally, some phenolic compounds (namely caffeic, chlorogenic, gallic, and rosmarinic acids) possess the ability to inhibit the enzymatic activity of α-glucosidase and α-amylase. α-Amylase and α-glucosidases are enzymes hydrolyzing starch in the human organism; therefore, a sudden rise in blood glucose levels in type 2 diabetes patients takes place due to the action of this enzyme (Oboh, Agunloye, Adefegha, Akinyemi, & Ademiluyi, 2015). Hence, natural sources of compounds inhibiting the carbohydrate-hydrolyzing enzymes (e.g. α-amylase and α-glucosidases) are valuable in the diet because of their potential to contribute to the management of type 2 diabetes (Oboh et al., 2015; Wang et al., 2015). Other secondary metabolites induced after elicitation are essential oil components which possess biological activity, e.g. antioxidative, anti-inflammatory or antimicrobial properties (Beatović et al., 2015; Miguel, 2010).

Our previous study indicated that jasmonic acid, used as an elicitor, positively influenced the content of phenolics and essential oil compounds, as well as some pro-health properties of basil leaves (especially antioxidant and anti-inflammatory activities) (Złotek, Michalak-

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Majewska, et al., 2016; Złotek, Szymanowska, et al., 2016). Based on our laboratory results mentioned above, we decided to use the elicited basil to obtain a new functional product – cakes, enriched with elicited basil and rich in bioactive compounds.

Besides the use of herbs and spices for improvement of the taste of food, there are some other proposals for their use related to their contents of compounds with antioxidant and preservative properties. For this reason, many aromatic plants have been widely used in the food industry as additives in meat, dairy, bakery products and plant oils (Juntachote, Berghofer, Siebenhandl, & Bauer, 2007; Pawar, Gandhi, Purohit, Arora, & Singh, 2014; Saatchi, Kadivar, Soleimanian Zad, & Abaee, 2014). Bakery products, including cakes, are very popular and widely consumed, due to their appeal and special organoleptic characteristics. Due to their high lipid content, cakes are highly susceptible to oxidation. Another problem in the production and storage of this food is the risk of contamination, in particular with mold (Hafez, 2012; Saatchi et al., 2014). Since consumers tend to prefer food products without synthetic additives, preservatives from natural sources, such as herbs and spices, become a good alternative in production of cakes. Another advantage of enrichment of cakes with herbs is the improvement of their bioactivities, including antioxidant and anti-inflammatory properties (Dziki, Różyło, Gawlik-Dziki, & Świeca, 2014).

There are some reports concerning the impact of basil addition on the oxidative stability and sensory quality of cakes (Abou-Zaid, Abdelahafez, & Amer, 2013; Bazrafshan, Shafafizenozian, & Moghimi, 2015), but there is no information about the feasible use of elicited basil in bakery production. Lipid oxidation significantly lowers the nutritional and health value of bakery products but may also have a negative impact on their sensory properties, namely colour, aroma, appearance, and consumer perception of product freshness. The perceived freshness of baked products is considered one of the key determinants of consumer acceptance and choice. Additionally, some new additives can also influence consumer acceptability of bakery products due to changes in the aroma, colour or taste of the product (Chueamchaitrakun, Chompreeda, Haruthaithanasan, & Suwonsichon, 2011; Hafez, 2012; Heenan, Hamid, Dufour, Harvey, & Delahunty, 2009; Przygodzka, Zieliński, Ciesarová, Kukurová, & Lamparski, 2015).

The aim of the present study was to evaluate the impact of addition of basil, elicited with jasmonic acid, on the sensory quality, antioxidative, anti-inflammatory, and antidiabetic properties and oxidative stability of prepared cakes.

2. Material and methods

2.1. Plant materials

Lettuce leaf basil seeds (*Ocimum basilicum* L. cv. *Crispum*) were purchased from Vilmorin Garden Company. The basil was cultivated and elicited with jasmonic acid (1 μM jasmonic acid (JA1) and 100 μM jasmonic acid (JA2)), as described previously (Złotek, Michalak-Majewska, et al., 2016). Afterwards, the herb was dried (in a drying house at 35 °C) and powdered for use in preparation of cakes.

2.2. Preparation of cakes

The cakes were prepared according to Hafez (2012) with some modification. The cakes were baked using 250 g of wheat flour, 100 g of butter, 30 g of egg yolks, 3 g of salt, 40 g of water, and 2 g of baking powder as a basic formula. All ingredients were combined and dough was prepared, which was then cooled at 4 °C (2 h). The dough was cut into 0.5 cm thick discs of 4.5 cm diameter and baked at 180 °C for 15 min in an electric oven. Wheat flour was substituted with the powder of the control and elicited basil at 0% (control), 1%, and 2%. Some of the cakes were stored at room temperature in plastic bags for 14 days (for sensory evaluation and measurement of the degree of lipid peroxidation). The other cakes were dried and used for further analysis.

2.3. Preparation of extracts

2.3.1. Buffer extracts (PBS)

For preparation of the extracts in buffer, powdered samples of dried cakes (1 g) were extracted for 60 min with 20 ml of PBS buffer (phosphate buffered saline, pH 7.4) and then centrifuged at 9000 × *g* for 20 min. Next, the residues were extracted again with 20 ml of PBS buffer. The supernatants were combined and adjusted to a final volume of 50 ml with PBS buffer.

2.3.2. Ethanolic extracts

For preparation of ethanolic extracts, powdered samples of dried cakes (1 g) were extracted for 60 min with 20 ml of 50% (v/v) ethanol and centrifuged at 9000 × *g* for 20 min. Next, the residues were extracted again with 20 ml of 50% ethanol. The supernatants were combined and adjusted to a final volume of 50 ml with 50% ethanol.

2.3.3. In vitro digestion

In vitro digestion was performed as described previously by Gawlik-Dziki, Dziki, Baraniak, and Lin (2009). The powdered samples of dried cakes (1 g) were homogenized in a Stomacher Laboratory Blender for 1 min to simulate mastication in the presence of 5 ml of a simulated saliva solution containing 7 mM NaHCO3, 0.35 mM NaCl (pH 6.75), and α-amylase (E.C. 3.2.1.1., 200 U per ml of enzyme activity). Subsequently, the mixture was stirred for 10 min at 37 °C in darkness. For gastric digestion, the solution was adjusted to pH 2.5 with 1 M HCl and 15 ml of 300 U/ml of pepsin solution (from porcine stomach mucosa, pepsin A, EC 3.4.23.1) in 0.03 M NaCl, pH -1.2, were added. The reaction was carried out for 60 min. at 37 °C. Next, the solution was adjusted to pH 7 with 1 M NaOH and then 15 ml of a mixture of a 0.7% pancreatin solution and a 2.5% bile extract solution were added. The incubation was carried out for 120 min. at 37 °C in darkness. Next, the samples were centrifuged and the supernatants (gastrointestinally digested extracts; GD-extracts) were used for further analysis.

All types of extracts (PBS, ethanolic and GD-extracts) were analyzed to determine phenolic compounds, antioxidant activities, inhibition of lipoxygenase activity, and inhibition of α-glucosidase activity. A Shimadzu UV-1280 spectrophotometer was used for these measurements.

2.4. Analysis of phenolic compounds

2.4.1. Determination of total phenolic compounds (TPC)

The amount of total phenolics was determined using Folin-Ciocalteau reagent (Singleton & Rossi, 1965) and calculated as gallic acid equivalent (GAE) in mg per g of dry weight (DW).

2.4.2. Determination of flavonoid content (TFC)

The total flavonoid content was determined according to the method described by Lamaison and Carnet (1990) and calculated as quercetin equivalent (QE) in μg per g of dry weight (DW).

2.4.3. Determination of phenolic acid content (PAC)

Total phenolic acid estimation was carried out according to the Arnov method (Szaufer-Hajdrych, 2004) and expressed as caffeic acid equivalent (CAE) in μg per g of dry weight (DW).

2.5. Antioxidant activities

The free radical-scavenging activity was measured using 1,1-diphenyl-2-picrylhydrazyl (DPPH) according to Brand-Williams, Cuvelier, and Berset (1995) and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid ($ABTS^{+\cdot}$) according to Re et al. (1999). The antioxidant activity was related to trolox (an analogue of vitamin E) and expressed as μmol of trolox per g of dry weight (DW).

Iron-chelating activity (CHP) and ferric-reducing antioxidant power