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Potential of flaxseed in the development of omega-3 rice paper with antioxidant activity

Shana J. Cameron [a,b], Farah Hosseinian [a,b,*]

[a] Food Science and Nutrition Program, Chemistry Department, Carleton University, Ottawa, Ontario, Canada K1S 5B6
[b] Institute of Biochemistry, Carleton University, Ottawa, Ontario, Canada K1S 5B6

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ABSTRACT

The objective of this study was to enhance the nutritional quality and antioxidant activity of rice paper by adding ground whole flaxseed to develop omega-3 rice paper (ORP). The amounts of omega-3 and dietary fibre in the ORP were 2.7 g/100 g and 9.1 g/100 g respectively, both of which were absent in the traditional rice paper (TRP). The antioxidant activity of the ORP evaluated by the oxygen radical absorbance capacity (ORAC) (231.7 μmol TE/g) was significantly higher than that of TRP (50.2 μmol TE/g). This correlated well with the results of the DPPH radical scavenging activity. In addition, the total phenolic content of the ORP was much higher than the total phenolic content of the TRP. Sensory analysis indicated that ORP was preferred in all of the tested attributes, particularly in taste and texture. The results suggest that the development of ORP by the addition of flaxseed improved both the nutritional value and the sensory characteristics of rice paper.

1. Introduction

The nutritional properties and health benefits of flaxseed (*Linum usitatissimum*) have gained world-wide attention in research as well as being utilized in the food industry. Studies have indicated that flaxseed provides potential health benefits, such as decreasing the risk of cardiovascular disease (CVD) (Bloedon & Szapary, 2004), diabetes (Haliga et al., 2009), and cancer (Jhala, 2010). Flaxseed is composed of 40–50 g/100 g oil, 23–34 g/100 g protein, 5 g/100 g mucilage, 4 g/100 g ash, and 9–30 mg/g lignan precursors, varying with the cultivar and growth environment (Touré & Xueming, 2010). The health benefits from flaxseed can be credited mainly to its abundance in omega-3 fatty acids, dietary fibre, high quality proteins, and antioxidants such as lignan and other phenolics (Hussain, Anjum, & Alamri, 2011).

Flax has high oil content (41 g/100 g) in its seeds (Bloedon & Szapary, 2004). Flaxseed oil is low in saturated fat (9 g/100 g) and rich in polyunsaturated fat (73 g/100 g) (Bloedon & Szapary, 2004). Approximately 51–55 g/100 g of the total fatty acids in flaxseed oil are Alpha-Linolenic acid (ALA, 18:3, ω-3) (Vijaimohan et al., 2006). The high quantity of this essential omega-3 fatty acid makes flaxseed oil the leading plant source for omega-3 fatty acids. The omega-3 fatty acids play a vital role in improving immunological function (Oomah, 2001), decreasing inflammation (Simopoulos, 2002), and decreasing the risk of CVD (Oomah, 2001).

The abundance of phenolic compounds such as lignan, secoisolariciresinol diglucoside (SDG), and ferulic acid in flaxseed contributes to its well-known antioxidant properties (Kasote, Hegde, & Deshmukh, 2011). The addition of these natural antioxidants from flaxseed may play an important role in the prevention of lipid oxidation of foods to enhance their shelf life (Kasote et al., 2011).

Flaxseed is also rich in soluble and insoluble dietary fibre. Soluble fibre (mucilage) aids in decreasing cholesterol and optimizing blood glucose levels (Hussain et al., 2011). In addition, flaxseed contains all of the essential amino acids that are crucial for the synthesis of proteins that regulate and maintain proper cellular function (Oomah & Mazza, 1993).

Fortification of food with flaxseed is gaining popularity in the development of functional foods. Previous studies have investigated

* Corresponding author. Department of Chemistry, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, Canada K1S 5B6. Tel.: +1 613 520 2600x2048; fax: +1 613 520 3749.
E-mail address: farah_hosseinian@carleton.ca (F. Hosseinian).

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the replacement of wheat flour with ground or whole flaxseed in products such as bread, muffins, cookies, and pancakes (Aliani, Ryland, & Pierce, 2011; Hussain et al., 2011). Bread containing 10–13 g/100 g flaxseed showed an increase in the dietary fibre, protein, ALA, and minerals when compared to regular bread. As well, muffins fortified with 9 g/100 g flaxseed and cookies fortified with 11 g/100 g flaxseed exhibited significant increase in dietary fibre, protein, and ALA in comparison to the common products (Gambus, Mikulec, Gambus, & Pisulewski, 2004).

Rice paper is a common food in Asia, particularly in Vietnam and South East Asia, and is gaining popularity in North America (Nigano et al., 2000). TRP is nutritionally poor since it is made mainly from white rice, which contains mostly starch (Snow & O'Dea, 1981). Brown rice is obtained by removing the hull, leaving the inner bran and germ layers intact. The rice is then polished further to remove the bran and germ layers and produce white rice (Zhang et al., 2011). The white rice is often preferred by consumers for its sensory properties and stability during storage (Gunaratne, Bentota, Cai, Collado, & Corke, 2011). However, white rice is greatly deprived of the B vitamins, dietary fibre, magnesium, trace elements, and phytochemicals that are present in the brown rice (Zhang et al., 2011). Brown rice also has a higher antioxidant level than white rice, containing about three times the quantity of polyphenolics, fourteen times the carotenoids, and six times the α-tocopherol (Choi, Jeong, & Lee, 2007). Thus brown rice is much more nutritious than white rice. The objective of the present study was to enhance the nutritional quality of rice paper by the addition of ground whole flaxseed to develop ORP. Antioxidant activity and sensory attributes were compared between ORP and TRP.

2. Materials and methods

2.1. Materials

The TRP was obtained from a commercial source (Banh Trang My Tho, Vietnam) and was formulated from white rice flour, tapioca, salt, and water. The ground flaxseed, brown rice flour, white rice flour, tapioca, gum arabic powder, and salt were obtained from a commercial source (Bulk Barn, Ottawa, ON). The methanol, acetone, and n-hexane were obtained from Caledon Laboratories Ltd. (Georgetown, ON). Potassium phosphate monobasic, potassium phosphate dibasic, and 2,2′-azobis(2-methylpropionamidine) dihydrochloride (AAPH) were obtained from Acros Organics (Geel, Belgium). Trolox, rutin, Folin-Ciocalteu reagent, ferulic acid, and 2,2-diphenyl-1-picryhydrazyl free radical (DPPH) were obtained from Sigma–Aldrich (Oakville, ON). Fluorescein was obtained from J.T. Baker (Center Valley, PA). Sodium bicarbonate was obtained from Arm and Hammer (Princeton, NJ).

2.2. Sample preparation

ORP was formulated from brown rice flour (36 g/100 g), white rice flour (18 g/100 g), tapioca (33 g/100 g), ground flaxseed (10 g/100 g), gum arabic powder (2 g/100 g), salt (1 g/100 g), and water. The batter was spread thinly on a cloth mold, covered, and steamed for 2–3 min over a water bath that was kept at a controlled temperature of 80 °C. The rice paper sheets were allowed to cool, and then air dried 12–15 h (overnight).

2.3. Extraction

Antioxidants were extracted from ORP and TRP into methanol according to the extraction procedure described by Choi et al. (2007). Briefly, 200 mL of methanol was added to 10 g of ground rice paper and stirred at room temperature for 24 h using a VWR Hotplate/Stirrer. The samples were centrifuged using a Thermo Scientific Sorvall Legend XTR Centrifuge at 2960× g for 20 min at room temperature (23 °C). Insoluble rice paper residue was dried and weighed to determine percent yield. The supernatants were filtered by suction using Fisherbrand P8 filter paper. The filtrate was evaporated using a Heidolph Rotavapor D-91126, and the remainder was dried using a Thermo Scientific nitrogen dryer (Reacti-Vap 1 # TS-18825 Evaporation Unit). Methanol was added to the dried extracts to a concentration of 4 g/L, and the solution was stored at −20 °C.

2.4. Oxygen radical absorbance capacity (ORAC) assay

The ORAC assay was performed according to the methods described previously (Gliwa, Gunenc, Ames, Willmore, & Hosseinian, 2011). The rice paper extracts (4 g/L) were diluted with ORAC buffer (potassium phosphate buffer, pH 7.4) to various concentrations for testing (1, 0.8, 0.67, 0.56, 0.5, and 0.44 g/L). Standard solutions of Trolox were prepared (100, 50, 25, 12.5, and 6.25 μmol/L), rutin control (20 μmol/L), and fluorescein (0.129 μmol/L). A 96 well microplate was prepared containing 120 μL fluorescein solution, and 20 μL of ORAC buffer (blank), Trolox, rutin, or rice paper extract in triplicate. A fluorometric microplate reader was used with an excitation wavelength of 485 nm and an emission wavelength of 528 nm (FLx800 Multi-Detection Microplate Reader with Gen5 software, BioTek Instruments). The plate containing the solutions of fluorescein and ORAC buffer, Trolox, rutin, or extract were incubated at 37 °C for 20 min. 60 μL AAPH (0.16 mol/L) was added to each well in order to generate peroxyl radicals, the plate was shaken for 15 s, and readings were taken every minute for 50 min. The net area under the curve (net AUC) for the rice paper extracts and the equation of the line from the Trolox standard curve were used to calculate the ORAC values for the rice paper extracts and were expressed as μmol Trolox equivalents/gram of extract.

2.5. DPPH radical scavenging activity assay

The DPPH assay was performed as described previously (Li, Hydamaka, Lowry, & Beta, 2009). 60 μmol/L DPPH solution was made in methanol and 3.8 mL was added to 200 μL of the rice paper extract. The absorbance was measured at 515 nm (Cary 50 Bio UV–Visible Spectrophotometer) at 5 min time intervals for 1 h. Methanol was used as the blank and 60 μmol/L DPPH solution was used as the control.

2.6. Total phenolic content assay

The total phenolic content was determined using the Folin–Ciocalteau method as described previously (Li et al., 2009). 200 μL of the extract or ferulic acid standard was combined with 1.9 mL of 10-fold diluted Folin–Coicalteau reagent and 1.9 mL of 60 g/L sodium bicarbonate solution. The absorbance was measured at 725 nm after sitting for 2 h at room temperature (Cary 50 Bio UV–Visible Spectrophotometer). Double distilled water was used as the blank, and the ferulic acid standards (1, 0.5, 0.25, 0.1, and 0.05 g/L) were prepared using methanol. The total phenolic content was expressed in ferulic acid equivalents/100 g of extract.

2.7. Flaxseed oil extraction

Flaxseed oil was extracted from ORP following the conventional extraction method described previously (Zhang et al., 2008). Ground ORP was extracted with n-hexane in a 1/20 w/v ratio (g/mL) for 2 h in a water bath (60 °C). The solution was filtered by suction using