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Antioxidant capacity and consumer acceptability of herbal egg tofu

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ABSTRACT

A mixture design was used to optimize the herbal egg tofu formulation containing *Polygonum minus*, *Curcuma longa* and *Zingiber officinale*. The effects of the herbs on the total phenolic content (TPC), ferric reducing antioxidant power (FRAP) assay and scavenging activity 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2′-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid (ABTS), texture profile (hardness, springiness, cohesiveness, gumminess and chewiness) and consumer preference on sensory characteristics (appearance, color, aroma, taste, texture and overall acceptability) of the herbal egg tofu were investigated. An increase in *C. longa* content produced egg tofu with significantly higher ($p < 0.05$) TPC and antioxidant activity (FRAP, ABTS and DPPH assay), but a significantly lower score for overall acceptability. An increase in the *P. minus* content significantly ($p < 0.05$) increased the springiness of the egg tofu. The optimum formulation of the egg tofu was determined by overlapping the contour plot related to sensory characteristics (color, taste and overall acceptability) and springiness that formed the region with optimum value. The results showed that the optimum predicted response value for color, taste, overall acceptability and springiness were 4.9, 4.6, 4.8 and 0.96 mm, respectively, which were obtained from a combination of 0.7% *P. minus*, 0.5% *C. longa* and 0.8% *Z. officinale*.

1. Introduction

Herbs and spices have been added to food since ancient times, not only as a flavoring agent, and food preservative, but also as an excellent source of natural antioxidants. Antioxidant activities of herbs and spices have been widely studied (Cousins, Adelberg, Chen, & Rieck, 2007; Hinneburg, Damien Dorman, & Hiltunen, 2006; Kumar, Nayaka, Dharmesh, & Salimath, 2006) and the increasing use of herbs and spices as natural antioxidants in food is attributed to low cost and consumer's concern about the safety of synthetic antioxidants (Suhaj, 2006; Yanishlieva, Marinova, & Pokorný, 2006). The incorporation of herbs and spices in food products, such as meat (Han & Rhee, 2005; Naveena, Muthukumar, Sen, Babji, & Murthy, 2006), fish, yoghurt (Burt, 2004) and dairy products (Viluda-Martos, Ruiz-Navajas, Fernandez-Lopez, & Angel Perez-Alvarez, 2008) has been reported. Authentic Asian cuisine demands the use of many fresh herbs and spices, as well as in the form of extracts and powders. This includes *Polygonum minus*, *Curcuma longa* and *Zingiber officinale*.

P. minus is usually eaten raw or added in cooking. It is known as a medicinal plant with natural antioxidants (Wasman Qader, Abdulla, Chua, & Hamdan, 2012). Phenolic compounds extracted from *P. minus* exhibited antioxidant activities (Huda-Faujan, Noriham, Norrakiah, & Babji, 2007; Maizura, Aminah, & Wan Aida, 2010). In addition, previous research (Huda-Faujan, Noriham, Norrakiah, & Babji, 2009) also showed no significant difference ($p > 0.05$) in the Fe(III) to Fe (II) reducing capacity of *P. minus* extract and butylated hydroxyanisole (BHA), indeed, it was higher compared to butylated hydroxytoluene (BHT). Furthermore, the incorporation of *P. minus* in duck meatballs was proven to reduce the lipid oxidation process (Nurul, Ruzita, & Aronal, 2010).

Z. officinale is widely used in various food and beverages as a flavoring agent and for its health benefits. The pungent properties of *Z. officinale* (gingerols and shogaols) and other compounds, such as polyphenols, ascorbic acid, beta-carotene and flavonoids, have shown antioxidant activities (Aruoma et al., 1997; Ghasemzadeh, Jaafar, & Rahmat, 2010; Stoilova, Krastanov, Stoyanova, Denev, & Gargova, 2007). Murcia et al. (2004) reported that a 5% water extract of *Z. officinale* had almost similar antioxidant activity against lipid peroxidation when compared to BHT.

C. longa is an important spice used in curries as a colorant and

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flavoring agent (Chang, Jong, Huang, Nien, & Changa, 2006). *C. longa* consists of three groups of Curcuminoids including curcumin, demethoxycurcumin, and bisdemethoxycurcumin. Curcumin, which makes up 90% of the curcuminoid content, is a lipohilic polyphenol that is slightly insoluble in water (Wang et al., 1997) and is responsible for the yellow color of *C. longa.* Previous researches (Cousins et al., 2007; Ishita, Kaushik, Uday, & Ranjit, 2004; Sharma, Gescher, & Steward, 2005) found that the antioxidant activity of *C. longa* is due to the polyphenolic compounds, such as curcuminoids, beta-carotene, caffeic acid, eugenol and protocatechuic acid.

Nowadays, egg tofu is becoming popular among Asians. Egg tofu, which is also known as "Japanese tofu", is a savory tofu made from soymilk, fresh egg and coagulating agent. The production of herbal egg tofu by incorporating *P. minus, Z. officinale* and *C. longa* in the egg tofu formulation is expected to enhance the antioxidant properties of egg tofu. By consuming herbal egg tofu, consumers can increase the natural antioxidant intake in their diet. However, the acceptability of the herbal egg tofu depends on the effects of the herbs and spices on the physical, texture and sensory characteristics. Therefore, the aim of this study is to determine the effects of *P. minus, Z. officinale* and *C. longa* on the physical, antioxidant and sensory properties of egg tofu and to optimize the best formulation of herbal egg tofu by using the response surface methodology (RSM).

2. Materials and methods

2.1. Materials

Yellow soybeans (Canada), glucono-delta-lacton (GDL) and corn starch were obtained from Yummy's Bakery Sdn. Bhd. (Selangor, Malaysia). Carrageenan powder was obtained from Omigel Sdn. Bhd. (Sabah, Malaysia), and gum arabic was obtained from Natural Prebiotics Sdn. Bhd. Selangor, Malaysia. Grade A eggs were obtained from Giant hypermarket (Selangor, Malaysia), while fresh *P. minus, Z. officinale* and *C. longa* were purchased from a local market in Selangor. Folin-Ciocalteu's (FC) reagent was obtained from Merck (Darmstadt, Germany). Sodium carbonate, gallic acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,4,6,-Tris (1-pyridyl)-5-triazine (TPTZ) and 2,2′-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid (ABTS) were purchased from Sigma (Steinheim, Germany) and ferrous sulfate was obtained from R&M Chemicals (Essex, UK).

2.2. Experimental design

The response surface methodology (RSM) was applied to determine the experimental design, and the formulations of herbal egg tofu were selected according to the mixture design model "simplex-centroid". In this study, the mixture components comprised three independent variables: *P. minus* (X_1), *C. longa* (X_2) and *Z. officinale* (X_3). The mixture of these three components in egg tofu formulations at different ratios is shown in Table 1. The dependent variables were color (L (lightness), a (red) and b (yellow)), texture profile (hardness, cohesiveness, springiness, firmness and chewiness), total phenolic content (TPC), antioxidant activities (FRAP, ABTS and DPPH assay) and sensory characteristics (color, aroma, taste, texture and overall acceptability).

2.3. Preparation of egg tofu

Soybean seeds were soaked in water, rinsed, ground with water at a bean: water ratio of 1:3 and filtered using muslin cloth. The slurry was cooked at 100 °C for 15 min. Egg tofu was then prepared from a mixture of soymilk and fresh egg (2:1). Firstly, carrageenan (0.12% w/w), gum arabic (0.61% w/w) and corn starch (2.0% w/w) were added to the soymilk and heated to 80 °C with continuous stirring until all the ingredients were completely dissolved. The mixture was then cooled to 40 °C followed by the addition of a filtered fresh whole egg and glucono-delta-lactone (GDL) (0.4% w/w). The mixture was mixed well. This was followed by the addition of *P. minus*, *C. longa* and *Z. officinale* ground beforehand using a blender (*Waring Commercial 240V*, Torrington, CT, USA) into the mixture. The herbal egg tofu was then poured into a plastic container (5.5 cm diameter and 4.0 cm high), and steamed at 90 °C for 20 min. The herbal egg tofu samples were cooled to room temperature and stored at 4 °C prior to analysis.

2.4. Color measurement

The color was measured using a colorimeter Model Minolta R-A70 Spectrophotometer (Japan). The sample was placed in a transparent plastic container and the Hunter values for L^* (lightness), $+a^*$ (red), $-a^*$ (green), $+b^*$ (yellow) and $-b^*$ (blue) were determined for the surface of each sample. The mean value was obtained from three replicates of measurement.

2.5. Texture profile analysis

The texture profile of the samples was determined using a Texture Analyzer (Autograph AGS-J 500N universal testing machine, Shimadzu, Kyoto, Japan) fitted with 30 mm diameter cylinder probe, moving at a rate of 100 mm/min. The penetration depth into the tofu sample (2 cm × 2 cm) was set at 10 mm. Five replicate measurements were done to obtain the mean values for the textural characteristics investigated.

Table 1
Mixture of *Polygonum minus*, *Curcuma longa* and *Zingiber officinale* in egg tofu formulations.

Formulation	Ingredient proportion		
	X_1 *(Polygonum minus)*	X_2 *(Curcuma longa)*	X_3 *(Zingiber officinale)*
Control	0	0	0
1	1	0	0
2	0	1	0
3	0	0	1
4	0.5	0.5	0
5	0.5	0	0.5
6	0	0.5	0.5
7	0.33	0.33	0.33
8	0.67	0.17	0.17
9	0.17	0.67	0.17
10	0.17	0.17	0.67