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Development of eggless cakes suitable for lacto-vegetarians using isolated pea proteins

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A B S T R A C T

Cakes are important confectionery and are enjoyed socially within groups. Eggs are important components of cakes, providing emulsification, flavour, colour, and many other properties. However, because of various health concerns and religious beliefs, some consumers cannot enjoy traditional cakes made with eggs. In the current study, isolated pea protein (PPI), xanthan gum (XN), and emulsifier mixtures were investigated to prepare eggless cakes and their roles were determined. The physicochemical properties of the batter and final cake products, the microstructure of the final cakes, and structural properties of starches and glutens at the meso-scale were characterised. The eggless cake recipe containing PPI, 0.1% XN and 1% soy lecithin (SL) was found to be close to the control traditional cakes in terms of specific gravity (1.01 *vs.* 1.03), crumb colour (a^* at 0.09 *vs.* −0.04), and crumb pore properties (average pore area both 0.20 mm^2). Cakes with formulation R4 were most similar to the control cakes with respect to the 1047/1022 relative intensity of the IR spectra of starches (both 0.55) and the nanostructures of glutenins. Therefore, formulation PPI+0.1% XN+ 1% SL was considered as a potential candidate recipe for substituting eggs in cakes.

1. Introduction

Cakes are one of the most widely consumed and enjoyed cereal products, with an ever-increasing global market demand. One of the most important ingredients in cakes is eggs. Eggs have an important function in the foam formation of the batter, as air is incorporated into the batter during the mixing stage and gel setting as the liquid foam (batter) turns into a solid foam (cake) during baking. The unique gel setting property of eggs is essential to provide cakes with their volume, specific texture qualities, colours, and flavours (Kiosseoglou & Paraskevopoulou, 2014). However, besides the prevalence of egg allergy in the paediatric population, the growing trend in lacto-vegetarians, increased rate of heart diseases, high price of eggs, and limited cold chain distribution for certain countries/areas, have increased the demand for eggless cakes.

As a result, many studies have evaluated proteins as potential candidates for egg substitutes, from various sources including soy (Rahmati & Mazaheri Tehrani, 2014), pea (Hoang, 2012) and whey proteins (Ratnayake, Geera, & Rybak, 2012). Currently, however, few have developed an eggless cake that matches cakes made with eggs in terms of their physical properties. This suggested that many egg substitutes are multicomponent, and it would be advisable to consider the application of proteins together with hydrocolloids and emulsifiers to develop egg substitutes. Furthermore, the use of plant proteins and emulsifiers might provide additional nutrients and improve nutrient delivery to the consumers (Mao & Miao, 2015).

Image analysis of the macrostructures of baked products is a relatively simple and quick method to detect the visual differences among crumbs (Turabi, Sumnu, & Sahin, 2010). Currently, no studies have used image analysis of the substitutes of eggs in cakes. Thus, in the present study, image analysis was performed to determine the differences in pore attributes between cakes made with different formulations. In addition, the structures of the major components at

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the molecular level were also investigated for eggless cakes. Fourier transform infrared (FTIR) spectroscopy and atomic force microscopy (AFM) are used widely to study the structural changes of macromolecules in food samples because of their ease of use. FTIR spectroscopy can provide information on molecular interactions, such as bonding, ordering, and secondary structure. (Luo, Lui, Xu, Ionescu, & Petrovic, 2013; Sow & Yang, 2015; Wang, Su, Schulmerich, & Padua, 2013). By contrast, AFM provides more direct visualisation of a molecule's conformation and is suited to characterising macromolecules, including pectin, gelatin, and starch, (An et al., 2011; Chong, Lai, & Yang, 2015; Du, An, Liu, Yang, & Wei, 2014; Feng, Bansal, & Yang, 2016; Feng, Fu, & Yang, 2017; Liu, Tan, Yang, & Wang, 2017; Yang, 2014; Zhang, Chen, Zhang, Lai, & Yang, 2017). Therefore, AFM and FTIR spectroscopy were adopted to access the conformations of the starches and glutens.

The aim of this project was to develop egg substitutes for cakes using pea proteins and plant polysaccharide mixture. The effects of hydrocolloids and emulsifiers on the batter properties and physical properties of eggless cakes were evaluated. Finally, structural analysis at the meso-scale was conducted to better understand the mechanism of action of the effects of the additions to the cake ingredients.

2. Material and methods

2.1. Ingredients

The yellow cake recipe by (Ratnayake et al., 2012), with slight modifications, was used in this study. Table 1 lists the recipes of the control cakes and the eggless cakes with different substitutes, denoted by R1 − R4. Flour was provided by PRIMA RND (Prima Group, Singapore); the rest of the ingredients (sugar, fresh eggs, baking powder, canola oil, and skimmed milk) were obtained from a local supermarket (Fairprice, Singapore). The egg substitute ingredients used were xanthan gum (XN) (Grindstead®) and soy lecithin (SL) (SOLEC®), obtained from Danisco (S) Pte Ltd (Singapore, Singapore); mono and diglycerides (MDG) (Emulpals 110®) from Palsgaard Asia Pacific Pte Ltd (Singapore, Singapore); corn starch from Ingredion Singapore Pte Ltd (Singapore, Singapore); and isolated pea protein (PPI) (80% w.b.) from Shaanxi Fuheng Biotechnology Co. Ltd (Shaanxi, China).

2.2. Preparation of cake batter and baking

The dry ingredients (cake flour and baking powder) were sifted and added into the mixer (KitchenAid, St Joseph, MI, USA) containing the wet ingredients (sugar, milk, eggs and canola oil). The ingredients were first homogenised for 1 min at speed 1 and subsequently mixed at speed 6 for 4 min. Two hundred and 50 g of batter were measured into baking tins and baked in a convection oven (Fabricant Eurfours®, Gommegnies, France) pre-heated at 180 °C for 35 min. The cakes were kept at room temperature to cool for 60 min before performing the analyses.

Table 1
Formulations of control cakes and eggless cakes with different substitutes.

Ingredients	Composition (%)				
	Control	R1	R2	R3	R4
Cake flour	27.88	27.88	27.88	27.88	27.88
Milk	16.73	16.73	16.73	16.73	16.73
Eggs	13.93	–	–	–	–
Baking powder	0.84	0.84	0.84	0.84	0.84
Canola oil	8.36	8.36	8.36	8.36	8.36
Sugar	32.26	32.26	32.26	32.26	32.26
PPI	–	3.48	3.48	3.48	3.48
XN	–	–	0.1	0.1	0.1
MDG	–	–	–	1	–
SL	–	–	–	–	1
Corn starch	–	1.11	1.01	0.01	0.01
Water	–	9.34	9.34	9.34	9.34

*R1: PPI; R2: PPI + 0.1% XN; R3: PPI + 0.1% XN + 1% MDG; R4: PPI + 0.1% XN + 1% SL. PPI − isolated pea protein; XN − xanthan gum; MDG − mono, diglycerides and SL − soy lecithin.

2.3. Physicochemical properties of eggless cakes

2.3.1. Characterisation of the batter

The specific gravity of the batter was measured by filling a cylindrical cup with batter. The mass of the batter was taken relative to the mass of water using the same cup. The specific gravity was calculated using the formula:

$$\text{Specific gravity} = \text{mass of batter/mass of water at } 25\ ^\circ\text{C}$$

A Rapid Viscosity Analyser series 4 (Newport Scientific Pty Ltd., Jessup, MD, USA) was used to measure the batter viscosity, according to Wilderjans, Pareyt, Goesaert, Brijs, and Delcour (2008). The programme Thermocline for windows version 2.4 (Newport Scientific Pty Co., Ltd.) was used to set the parameters for analysis. For the analysis, the temperature profile was based on the internal temperature of the batter during baking. The paddle speed was set at 75 rpm.

2.3.2. Characterisation of the cakes

The volume of the finished product was measured using the Stable Microsystem Volscan profiler 600 (Stable Micro Systems Ltd., Surrey, UK). The specific volume of the cake was determined with the volume and the mass of the final cake using the following formula:

$$Specific\ Volume = \frac{Volume}{Mass}$$

The textural properties of the cakes were measured according to Ratnayake et al. (2012), with some modifications. Cake samples were cut into cubes (20 mm × 20 mm × 20 mm) and the textural properties were determined using a TA-XT2i texture analyser (Stable Micro System Ltd., Surrey, UK) with a 25 mm cylinder probe. A double compression test was performed. For compression testing, the parameters were set accordingly: pre-test speed = 5 mm/s, test speed = 1 mm/s, and post-test speed = 1 mm/s. The compression distance = 10 mm. Firmness and springiness were calculated according to the previous reported methods (Mao et al., 2017; Yang, Wu, Ng, & Wang, 2017).

The moisture content of the samples was measured according to AOAC procedures (Horwitz, 1980), in which 2.0 ± 0.1 g of cake crumbs were dried in an oven (100 °C) for at least 24 h and the weight difference was recorded before and after drying. The colour parameters (CIE L*, a* and b* values) of the cake crumb were measured using a Kinoca Minolta CM-5 spectrophotometer (Konica Minolta Holdings, Inc., Tokyo, Japan). Plastic cling wrap was used as a reference. The overall colour difference, which is denoted by ΔE, was determined using the following formula:

$$\Delta E = \sqrt{\left(L^* - L^*_{ref}\right)^2 + \left(a^* - a^*_{ref}\right)^2 + \left(b^* - b^*_{ref}\right)^2}.$$

2.3.3. Image analysis of cakes

A method similar to that of Hicsasmaz, Yazgan, Bozoglu, and