BAKED FOAMS COMPOSITING OF CASSAVA STARCH, EUCALYPTUS FIBER, AND GLUTEN PROTEIN FOR FOOD PACKAGING

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ABSTRACT The development of baked starch foam has attracted an increasing amount of attention. Native starch has been used to produce starch foam trays. However, starch foam trays exhibit poor mechanical properties and sensitive to water. The combination of cassava starch, gluten protein, and eucalyptus fiber can enhance the performance of cassava starch foam trays. The improvement of cassava starch foam trays blended with gluten protein and eucalyptus fiber at concentrations of 0, 5 and 10% was investigated. All formulations of cassava starch foam were able to form well-shaped trays. The addition of gluten protein and eucalyptus fiber improved the compressive strength, and reduced water and oil absorption of cassava starch foam trays. Although the highest maximal compressive strength (1.74 MPa) was obtained from the formulation containing 10% gluten protein and 10% eucalyptus fiber, water and oil absorption of the cassava starch foam trays was reduced by 43% and 60%, respectively. Moreover, composite cassava starch foam trays blended with 10% gluten protein and 10% eucalyptus fiber were used to pack ready to eat food (fried rice) which it was heated in a microwave (800W) for 120s. Results showed that compressive strength of composite cassava starch foams blended with 10% gluten protein and 10% eucalyptus fiber decreased slightly after microwave heating. The cassava starch foam trays in this study might be an alternative packaging for low water content or low oily foods.

1. INTRODUCTION

Plastic packaging is used extensively of which expanded polystyrene (EPS) is the most common plastic packaging used as single-use packages due to its high strength, low density and low cost (Glenn et al, 2001). Disadvantages of packaging from petroleum-based may require several years to degrade. Therefore, environmentally friendly packaging is of interest to the consumer (Shogren et al., 2002). Biodegradable packaging is an alternative replacement for plastic packaging. One option to replace EPS is a natural polymer such as starch.

Starch has been used to produce starch foam trays because of its low cost, non-toxic, renewable and biodegradable (Yew et al., 2005). Shogren et al. (2002) has shown that shaped starch foams could be produced by baking starch/water batters in hot baking mold. Foams made from native starch are brittle, sensitive to water and require further treatments or additives to improve their strength, flexibility, and water resistance. To overcome these weaknesses, a combination of starch foam with other biopolymers including gluten proteins and eucalyptus fiber would be possible to enhance the performance of starch foam trays.

Gluten proteins are plant proteins which have an ability to interact with the neighboring molecules to form strong cohesive and visco-elastic foam (Zhao et al., 2008). Glutenin and gliadin are major compositions of gluten proteins. These play a role in film formation, strength and elasticity. Eucalyptus fiber has good mechanical properties and is used as a material for the manufacture of low cost packaging. It is used as industrial packaging for products of great volume, due to its low cost and high mechanical resistance to tearing and tension forces (Curvelo et al., 2001; Larotonda et al., 2005).

One interesting point from the combination of cassava starch with eucalyptus fibers and gluten proteins might be the modification and enhance performance of cassava starch foam trays. Therefore, the aim of this study was focused on the use of a baking process to prepare composite trays obtained from cassava starch, eucalyptus fiber and gluten proteins and utilizing composite cassava starch foam trays for containing fried rice in a heating microwave.

2. EXPERIMENT

2.1 Starch Batter Preparation and Baking Process

Starch batter was prepared by adding 100 mL water to 80 g cassava starch. Gluten protein and/or eucalyptus fiber at 0, 5 and 10% (w/w of starch) were mixed. The formulation was homogenized using a blender (8011BU, Waring, USA) at 18,000 rpm for 5 min. Eighty grams of starch batter with additive was poured to the hot baking mold in which its size cavity was 180 mm in length, 105 mm width, and 10 mm in depth. The mold was heated and maintained at 200±5°C for 5 min. Before the properties of foam trays were investigated, they were equilibrated at a temperature of 25±2°C and a relative humidity of 75% using a saturated solution of NaCl in a polyethylene box for 1 week (Soykeabkaew et al., 2004). Properties of cassava starch foam trays were measured and compared with commercial EPS foam trays. The properties of the foam trays were evaluated including, density using the sand volumetric displacement method, compressive strength using textural analyzer (TA Plus, LLOYD Instruments, UK), oil absorption using modified method described by Karnnet et al. (2005) and water absorption using modified method described by Salgado et al. (2008). Moreover, Composite starch foam trays were used as packaging for fried rice and were heated in a microwave (800W) for 120s. Compressive strength and water absorption of the composite cassava starch foam trays was determined.

2.3 Experimental Design for the Optimum Properties of Composite Starch Foam

All experimental data was analyzed using SAS statistical software (SAS Institute, 1990). Duncan's Multiple Range Test ($p \leq 0.05$) was used to detect differences of mean values among foam properties. The optimum physical and mechanical properties of gluten protein combined with eucalyptus fiber of composite cassava starch foam trays was established using response surface methodology (RSM). Values of density, flexural strength, compressive strength, water absorption and oil absorption named as y, were fitted with a second order equation (Eq. 1) of software Statistica version 5.0 (StatSoft, Inc, USA). The independent variables of gluten protein content (G) and eucalyptus fiber content (F) were performed with b_n as the fit constant.

$$y = b_0 + b_1G + b_2G^2 + b_3GF + b_4F + b_5F^2 \qquad (1)$$

3. ANALYSIS

The effect of the addition of gluten protein and eucalyptus fiber on the density of composite cassava starch foam trays was observed using the sand displacement method. The density of composite cassava starch foam trays ranged from 0.183 to 0.429 g/cm^3. Gluten proteins (G) and eucalyptus fiber (F) content were significantly affected by density ($p \leq 0.05$). The polynomial equation (Eq. 2) was fitted to the changes in density with gluten protein and eucalyptus fiber content with $r^2 = 0.945$.

$$\text{Density} = 0.201 + 0.0135G - 0.0001G^2 - 0.00013GF - 0.0046F + 0.00146F^2 \qquad (2)$$

The response surface of gluten proteins and eucalyptus fiber content on density generated by Eq. 2 is shown in Fig. 1a. Results showed that the addition of gluten protein and eucalyptus fiber to the formulation led to an increase in density as compared with the control cassava starch foam. This was probably due to the higher amount of gluten protein and eucalyptus fiber contents, increasing viscosity of cassava starch foam trays, resulting in the difficulty in swelling during foam forming (Zhao et al., 2008, Lee et al., 2009).

Gluten protein content had more effect on density than eucalyptus fiber. The density of cassava starch foam trays blended with 5% gluten protein and 0% eucalyptus fiber was 0.293 g/cm^3, which was higher than 0% gluten protein and 5% eucalyptus fiber (0.225 g/cm^3). This might be explained that the higher gluten protein contents hindered foam expansion. On the other hand, fiber might act as a nucleating agent and might increase the viscosity of starch foam (Bénézet et al., 2012).

Compressive strength is a mechanical property that is important in packing materials. The higher the compression value of the foam, the more loads it can support. Effects of the addition of gluten protein (G) and eucalyptus fiber (F) on the compressive strength were monitored. The polynomial equation (Eq. 3) was fitted with experimental data with $r^2 = 0.866$.

$$\text{Compressive strength} = 1.041 - 0.0587G + 0.0074G^2 - 0.00026GF + 0.0909F - 0.003F^2 \qquad (3)$$

The response surface for the effect of gluten protein combined eucalyptus fiber content on compressive strength was generated by Eq. (3), and is shown in Fig. 1b. It was observed that only the fiber linear term had a significant effect on compression. Gluten protein addition to cassava starch foam decreased compressive strength, but this change was low as the gluten protein concentration increased.

The addition of 10% gluten protein incorporated with 10% eucalyptus fiber to cassava starch foam trays resulted in the highest compressive strength (1.74 MPa). This might be due to their fibrous network formations. The interaction between gluten protein, eucalyptus fiber, and starch matrix was a very good result that was similar to the chemical functional groups (Shogren et al., 2002; Salgado et al., 2008). Moreover, the compressive strength of cassava starch foam trays in this study were 1.15 MPa which their values were closed to EPS foam trays (1.3 MPa).

Cassava starch foams were submerged in distilled water for 30 min and the percentage of water absorption was calculated. Gluten protein (G) and eucalyptus fiber (F) contents were significantly affected the water absorption ($p \leq 0.05$). The polynomial equation (Eq. 4) was fitted to the changes in density with gluten protein and eucalyptus fiber content with $r^2 = 0.910$.

$$\text{Water absorption} = 427.408 + 12.095G - 1.386G^2 - 0.694GF - 1.122F - 0.604F^2 \quad (4)$$

The response surfaces for effects of gluten protein combined eucalyptus fiber content on water absorption of cassava starch foams are displayed in Fig. 1c. The highest water absorption (448%) was observed in cassava starch foam trays because the water molecules attach to H-bonds with OH-groups of starch, weakening them and increasing water absorption (Bénézet et al., 2012). Composite cassava starch foam trays containing 5% and 10% eucalyptus fiber resulted in decreasing water absorption to 380% and 361%, respectively. This might be due to the formation of hydrogen bonds between fiber and starch (Avérous et al., 2001).

When gluten protein was added, the water absorption of cassava starch foam slightly decreased. The lowest water absorption was found in cassava starch foam mixed with 10% gluten protein incorporated with 10% eucalyptus fiber. Previous results suggested that gliadins and glutenin in gluten protein were not soluble in water, resulting in decreasing water absorption (Dangaran et al., 2009). Although gluten protein and eucalyptus fiber could reduce water absorption of cassava starch foam, water absorption of composite cassava starch foam blended with gluten protein and eucalyptus fiber in this study was still higher than EPS foam trays. These results might be explained by the fact that cassava starch and fiber are hygroscopic materials while polystyrene contains long hydrocarbon chains that consist of thousands of styrene monomers (Lee et al., 2009).

The oil absorption of cassava starch foam trays was measured through direct contact with the surface of the foam with palm oil. Effects of gluten protein (G) and eucalyptus fiber (F) on oil absorption were monitored. The polynomial equation (Eq. 5) fitted with the following experimental data with $r^2 = 0.930$.

$$\text{Oil absorption} = 0.0299 - 0.0041G + 0.0002G^2 + 0.0002GF - 0.00306F + 0.00016F^2 \quad (5)$$

Response surfaces for effects of gluten protein combined with eucalyptus fiber on oil absorption of composite cassava starch foam trays are displayed in Fig. 1d. Oil absorption of cassava starch foam decreased with addition of gluten protein and eucalyptus fiber. Composite cassava starch foam trays containing 0% to 10% eucalyptus fiber resulted in a 54% decrease in oil absorption (0.032-0.015 g/m^2), whereas the addition of gluten protein reduced oil absorption up to 66% (0.032-0.013 g/m^2). Moreover, composite cassava starch foam trays combined with 5% gluten protein and 5% eucalyptus fiber could reduce oil absorption to 0.009 g/m^2. This could be from the addition of gluten protein and eucalyptus fiber producing a more dense foam structure, preventing the oil from penetrating into the starch foam (Butkinaree et al., 2008).

Cassava starch foam trays and composite cassava starch foam trays blended with additives were used as packaging for fried rice and heat in a microwave for 120s. Compressive strength of cassava starch foam trays sharply decreased from 1.15 to 0.49 MPa. It might be due to the movements of water and oil in fried rice to the starch foam, weakening them and decreasing the mechanical properties (Mali et al., 2010). Compressive strength of composite CSF blended with 10% eucalyptus fiber and 10% gluten protein slightly decreased from 1.64 to 1.47 MPa, a decrease of approximated 10% by heating with microwave for 120s. It might be due to the addition of protein and eucalyptus fiber producing a more dense outer skin of the foam, preventing water penetrating the starch foam (Schmidt & Laurindo, 2010).

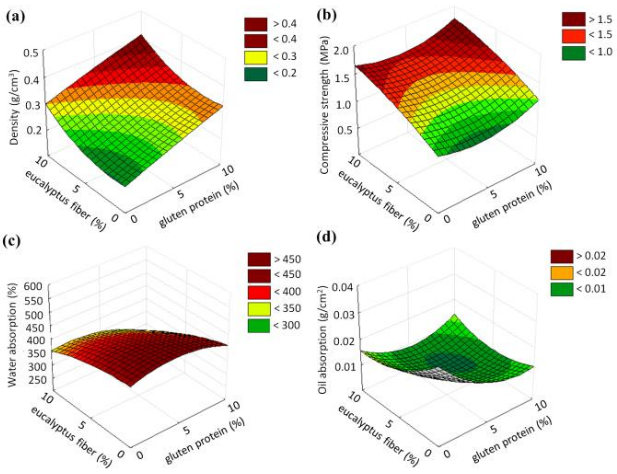

Fig. 1 Response surfaces for the effect of gluten protein combined with eucalyptus fiber on (a) density, (b) compressive strength, (c) water absorption, and (d) oil absorption of composite cassava starch foam trays.

Table 1. Compressive strength of composite cassava starch foam (CSF) trays with additives packed with fried rice, before and after heating in microwave (800W) for 120s.

	Compressive strength (MPa)		Water absorption (%)
	Before	After	
CSF (control)	1.15^b	0.49^d	27.05^a
CSF+10% eucalyptus	1.68^a	1.26^b	8.63^c
CSF+10% gluten	1.14^b	0.91^c	15.83^b
CSF+10% eucalyptus +10% gluten	1.64^a	1.47^a	7.88^c
F-test	**	**	**
C.V.(%)	11.45	9.07	10.95
LSD	0.30	0.18	4.22

a, b, c,... Different superscripts in the same column indicated that means were significantly different ($p \leq 0.05$).

CONCLUSION

This study characterized composite cassava starch foam trays blended with eucalyptus fiber and gluten protein. The addition of gluten protein and eucalyptus fiber led to a significant increase in mechanical properties and a slight decrease in water and oil absorption of cassava starch foam trays. The formulation of cassava starch foam containing 10% gluten protein and 10% eucalyptus fiber exhibited the best properties, including maximal flexural strength, water and oil absorption. Results in this study also showed that composite cassava starch foam trays could be utilized as an alternative to pack fried rice.

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