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Potential of coconut milk and mung bean extract combination as foam stabilizer in non-dairy ice cream

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Abstract

Non-dairy ice cream is one of many food products that are currently developed especially for vegetarians. The use of coconut milk in the manufacture of non-dairy ice cream made from extracts of mung bean *(Vigna radiata)* is expected to increase foam stabilization of ice cream mixture. Coconut milk can serve as fat and protein sources that are needed in the formation of emulsion and stabilization of the foam system that will determine the characteristic of non-dairy ice cream. The aims of this research was to study the potential of a combination of coconut milk and mung bean extract as a foam stabilizer on a non-dairy ice cream mixture. A single factor randomized block design was used and the ratios of mung bean extract : coconut milk (w/w) consisted of four levels, namely P1, P2, P3 and P4, respectively for 90 : 10, 85 : 15, 80 : 20 and 75 : 25. The experiments were carried out with three replications. The viscosity of the mixture was affected by the mixture components such as starch and albumin that are capable of trapping water in gel formation during heating process. Globulin and albumin enveloped the air bubbles and stabilized the emulsion by increasing the foam stability. Combination of mung bean extract and coconut milk in the ratio of 85 : 15 gave the maximum effect on foam stability. This is related to the proportion of the total solids and viscosity that were relatively high compared to the other combinations.

Introduction

Nowadays people are concerned about the health aspects of food choices, for example, some consumers prefer low-fat ice cream products and vegetable-oriented material. Sometimes, mung bean is also used as raw materials of non-dairy ice cream, but scientific studies on the use of mung bean is relatively limited. Some of the issues with non-dairy ice cream are high solids non-fat, low fat content and adequate protein component (Ahsan *et al*., 2015). These conditions affect the texture and sensory properties of non-dairy ice cream that are formed by three main structural components of air bubbles, ice crystals and fat globules.

Characterization of the 16 varieties of mung bean *(Vigna radiata)* produced a wide range of proximate composition protein, 24.26 to 28.50%; crude fiber, 3.21 to 4.18%; fat, 0.57 to 1.86%; ash, 3.64 to 4.24%; water, 7.49 to 8.45%; carbohydrates, 54.25 to 58.69% (Li *et al*., 2010). Mung bean flour is able to stabilize emulsion (37.95%), similar to the rice flour (37.31%), wheat flour (38.38%) and potato starch (41.92%) (Chandra and Samsher, 2013). The capacity of the foam formation from mung bean flour is highest (24.23%) than other flour in the order of 3.52%, 12.92% and 6.84%, respectively for rice flour, wheat and potatoes. At high enough concentrations (18 g/100 mL), mung bean flour can also form gels (Kaushal *et al*., 2012). Mung bean starch (MBS) has the ability to form gel due to a high amylose content (33%) (Keum-Il Jang *et al*., 2009). Mung bean starch can act as stabilizer in the manufacture of ice cream, but the functional properties of some proteins are required for quality ice cream. Globulin and albumin are the main storage proteins in mung bean seeds and make up over 60% and 25% of the total mung bean protein respectively (Tang *et al*., 2014). Studies evaluating the functional properties of mung bean protein isolate (MPI) revealed the water absorption capacity to be 1.03 to 2.78 g/g, foaming capacity as 33.00 to 67.50%, foam stability as 20.00 to 56.00%, and emulsifier activity as 1.77 to 3.30 m2/g (Li *et al*., 2010).

Protein content in coconut milk was reported to be 5-10% dry basis, and based on the solubility properties, 80% of the proteins from coconut endosperm was classified as albumin and globulin (Soler, 2005). Coconut milk has a high surface protein load (7 mg/m^2), of which the major component is cocosin (Tangsuphoom and Coupland, 2009). Some proteins that exist in the liquid phase

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of coconut milk interact with fat globules and act as emulsifiers around its surface (Peamprasart and Chiewchan, 2006). The emulsion formed from the aqueous extract of coconut solid endosperm is relatively unstable because of the large droplet size (Tangsuphoom and Coupland, 2008a). Coconut milk emulsions are negatively charged and not flocculate at pH 6 (Tangsuphoom and Coupland, 2008b). Coconut proteins coagulate at 80.9°C (Tipvarakarnkoon, 2009), but fat droplet aggregation would occur if proteins were denatured by heat. Small oil droplets will interact and coalesence into larger droplets and caused an emulsion destabilization (Raghavendra and Raghavarao, 2010).

During the process of making ice cream, fat globules envelop air bubbles to stabilize the foam. The fat globules will also affect the size of ice crystals. Dispersed small fat globules will inhibit the development of ice crystals into large crystals. Proteins are needed to form a surface layer that surrounds the fat globules during the homogenization operation and during stirring as air bubbles are incorporated. The combination of coconut milk and mung bean extract in a proper proportion will produce expected non-dairy ice cream texture. Therefore, the purpose of this study was to evaluate the potential of combining coconut milk and mung bean extract in a non-dairy ice cream mixture.

Materials and Methods

Materials

Dehulled local mung bean, sugar, coconut, and drinking water were obtained from one supermarket in Surabaya, Indonesia. Chemicals for analysis consisted of distilled water, $K_2S_2O_4$, HgO, H_2SO_4, Zn plate, K_2S, NaOH, HCl, methyl red indicator, n-hexane, and were of analytical grade.

Mung bean extraction

The mungbean was washed and then soaked with water (1: 4) for 8 hr, and drained before milling in hot water (100°C) at a ratio mungbean : water of 1 : 4. Milling was done with blender (Miyako, Japan), and the milled bean suspension was filtered with a cheese cloth.

Manufacture of coconut milk

Coconut milk was prepared according to refers to milk-making pasta of The Indonesian Academy of Science (2000). This involved extracting the milk from coconut without adding water in a food processor.

Table 1. Formulation of the mung bean non-dairy ice cream mixtures

Component	P1	P2	P3	P4
Mung bean extract g)	450	425	400	375
Coconut milk (g)	50	75	100	125
Sucrose (g)	60	60	60	60
Total (g)	560	560	560	560

Preparation of non-dairy ice cream mixture

Mung bean-coconut mixtures, shown in Table 1, were pasteurized at 85°C for 25 sec. The mixtures were homogenized (Ultra-Turrax T25, Janke and Kenkel IKA Labortechnik) after the temperature reached 72°C. The rotation speed of the homogenizer was gradually increased from 8,000 rpm for 2 min, followed by 10,000 rpm for 2 min. The formulation (Table 1) followed a single factor study with a randomized block design at four levels (P1-P4) of the mung bean extract : coconut milk; 90:10; 85:15; 80:20, and 75:25% (w/w). Three replicates of each formulation were prepared and studied.

Experimental design

The single factor study with a randomized block design was applied. The factor was the proportion of mung bean extract : coconut milk (P) consisting of four level of factor, namely P1, P2, P3 and P4, respectively 90: 10; 85: 15; 80: 20 and 75: 25% (w/w). The experiment was carried out with three replications. Analysis of Variance (ANOVA) was performed and differences in mean values were determined using Least Significant Difference (LSD) test at $\alpha = 0.05$ by employing SPSS version 12.

Chemical analysis

Proximate composition of the mung bean extract, and chemical characteristics of the coconut milk and the non-dairy ice cream mixture were determined according to standard procedures (AOAC ,2005).

Physicochemical analysis

Viscosity, foaming capacity and foam stability were the tested physicochemical properties. Viscosity of the homogenized non-dairy ice cream mixtures was determined by viscometer (Brookfield Viscosimeter model LVDVE, USA) at 30 ± 1ºC. Foaming capacity was determined by recording the volumes of the pasteurized mixtures before and after homogenization. The percentage ratio of volume increase to that of the original volume of pasteurized mixture was calculated and expressed as the foaming capacity. The change in volume of foam every 30 minutes until 150 minutes of standing at room temperature was recorded as the foam stability.

Table 2. Composition of mung bean extract and coconut milk

Component	Content ± SD (%)	
	Mung bean extract	coconut milk*)
Water	91.78 ± 0.746	49.58 ± 1.213
Protein	2.41 ± 0.067	4.33 ± 0.548
Fat	0.01 ± 0.004	24.00 ± 0.401
Starch	7.81 ± 0.345	-
Reducing Sugar	0.10 ± 0.008	3.33 ± 0.004
Ash	0.04 ± 0.014	0.55 ± 0.026

*) extraction of coconut milk by food processor without added water

Result and Discussion

Composition of mungbean extract and coconut milk

Table 2 shows the composition of the mung bean extract and coconut milk. Total solid of mung bean extract is 6.07%, while the fat content is 0.01% (wb) or 0.16% (db). Protein from coconut milk is needed in emulsions stabilization and is expected to stabilize the foam system, which will improve the characteristics of non-dairy ice cream. In addition, levels of the protein in coconut milk is higher (4.33%) compared to extracts of mung bean (2.41%).

Physicochemical characteristic of non-dairy ice cream mixture

The water content of the non-dairy ice cream mixture with various proportions of mung bean extracts: coconut milk, as shown in Table 3.The water content of coconut milk (49.58%) was much lower than mung bean extract juice (91.78%). It caused the water content of ice cream mixture to drop significantly with increasing proportion of coconut milk.

Protein can form a gel. Gel formation by protein conformational changes or preceded by partial denaturation of the protein molecules by heat, followed by aggregation of denatured protein molecules gradually to increase the viscosity and form a continuous network. During the preparation of mung bean extracts, heating and pasteurization process carried out at 85-90°C caused protein denaturation. Those temperature was needed to form a stable gel network due to the formation of covalent bond that converts into a thiol group of disulfide bonds and hydrophobic interactions. Intermolecular disulfide bonds increase the stability of the gel matrix (Phillips *et al*., 1994).

Functional properties of proteins in a food product can be influenced by the size, shape, composition and amino acid sequence, charge, hydrophobicity, structure, molecular rigidity in response to environmental conditions (pH, temperature, salt concentration) or interaction with other food components. Some functional properties of proteins in food products depend on the exposure of hydrophobic groups on the molecular surface and its interaction with oil (emulsion), air (foam) or another protein molecule. The residues of hydrophobic amino acids are generally located inside globular protein molecules. If the natural structure of proteins is open due to the stages of food processing, such as homogenization, liquidification and heating, it can be necessary to allow these hydrophobic groups to participate in intermolecular interactions. Flexibility molecular of proteins can be formed by the strength of hydrophobic and electrostatic interactions that maintain internal natural structure, or by the presence of covalent disulfide intramolecular bonds (Alleoni, 2006).

The results of LSD test (α =5%) shown in Table 3, indicated that all treatments resulted in significantly different of viscosities. The viscosity of the mixture formed by the result of the mixture components that are capable of trapping water, such as starch and albumin, thereby reducing the mobility of the water. Prapasuwannakul *et al.* (2014) reported that the viscosity of germinated brown rice ice cream is high because of high starch content. Increasing viscosity with the higher proportion of mung bean extract showed that the viscosity of mixture formula is determined by the high content of the starch in mung bean extract. Too high viscosity of ice cream mixture was undesirable because it allowed low air incorporation in the mixture and lead to low over run.

The data in Table 3 showed the mixture of total solid is higher with increasing proportion of coconut milk, as the total solid of mung bean extract was only 6.07% compared to total solid of coconut milk (50.42%). The addition of coconut milk on mung bean extract improved protein and fat content of the ice cream mixture. Coconut milk protein that has globulin and albumin determined the characteristics of ice cream. Protein enveloped particles and stabilized fat emulsions in homogenized mixture.

Foaming capacity

Foam systems in ice cream mixture play an important role in determining the texture. Product capability in maintaining the texture and structure during and after the freezing process depends on the ability of the dough to trap air. Protein will protect and maintain the air bubbles so that it will improve the texture according to the desired character. Various proteins can be used as an emulsifying agent because its surface properties as a major factor in the expansion of ice cream mixture. Development

Table 3. Water content, viscosity, total solid and foaming capacity of non-dairy ice cream mixture*)

Treatment (mung bean extract : coconut milk)	Water Content (%)	Viscosity (cP)	Total Solid (%)	Foaming Capacity (mL foam/mL total dough)
P1 (90:10)	79[d]	10.212[d]	20[a]	0.85 [b]
P2 (85:15)	77[c]	9.670[c]	22[ab]	0.83 [b]
P3 (80:20)	76[b]	5.670[b]	23[b]	0.76 [a]
P4 (75:25)	73[a]	5.248[a]	25[c]	0.74 [a]

*) For each column, values with different letters are significantly different (α= 5%)

of film formation of proteins associated with the protein's ability to lower the surface tension between air bubbles and solution.

The data in Table 3 showed that foam capacity decreased with increasing proportion of coconut in the mixture. This indicated that the main proteins storage, globulin and albumin were 60% and 25% of the total mung bean protein respectively, were the important materials that have the capacity as the foaming formation. The role of mung bean protein as foam forming also shown in research of Butt and Batool (2010) who found the highest foaming capacity (110 ± 6.78%) of mung bean protein isolates compared to cowpea and pigeon pea. High capacity of foam formation can occur because the protein was dissolved and has sufficient electrostatic repulsion that caused decreasing of protein-protein interactions. A similar case was reported by Chaiseri and Chonhenchob (2005) who studied the effect of chemical reagents on functional properties of mung bean protein product. The low foaming capacity could be due to inadequate electrostatic repulsions, and hence, excessive protein-protein interaction to form aggregates that were detrimental to foam formation.

Foam stability

Foam stability of the non-dairy ice cream mixture as shown in Figure 1 indicated similar pattern of foam stability with a variety of treatments. Decreasing of foam volume during 150 minutes of observation was affected by protein's ability to lower the surface tension between the surface layer of air and water system. Coconut milk proportion affected foam stability because of its fat content.

Mung bean extract used in this research is potentially a good candidate as a stabilizer to foam forming and gel system. Those potential are due to the content of albumin (25% of total protein) in the mung bean, considering that extraction was carried out using water as the solvent at neutral pH.

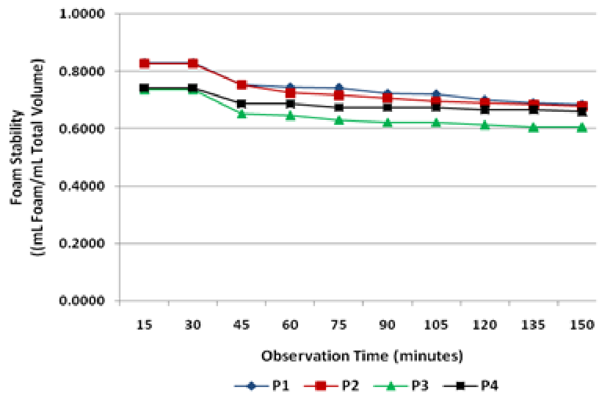

Figure 1. Foam stability of non-dairy ice cream mixture. P1 (mung bean extract:coconut milk=90:10); P2 (mung bean extract:coconut milk=85:15); P3 (mung bean extract:coconut milk=80:20): P4 (mung bean extract:coconut milk=75:25

Conclusion

Mixing mung bean and coconut milk displayed emulsion characteristics that are suitable for non-dairy ice cream. The present study showed that the use of coconut milk with the proportion of 15:85 to mung bean extract has potential foam stabilizer in non-dairy ice cream. The starch content of the mung bean extract was about 8%, and this was thought to be mainly responsible for the increase in the viscosity of the mixtures, although both the albumin of mung bean and coconut milk also contributed to the viscosity by gelation during the heating.

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