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Microstructure, physicochemical properties of precooked- kidney bean (Phaseolus vulgaris L.), mung bean (Vigna radiata L.) and job's tear (Coix lachryma – jobi L.) on heat moisture and freezing treatments

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Abstract

Kidney bean, mung bean and job's tear were precooked by subjected to moisture heating and freezing treatments based on 3 steps, i.e. soaking and steaming with variable times (soaking at 4, 5, 6 and 7 hours and steaming at 10, 15, 20 and 30 minutes), freezing with variable times (1, 2 and 3 hours) for constant temperature at -30°C and drying at 60 °C (kidney bean and mung bean) and 90 °C (job's tear). Increasing level of soaking and steaming conditions gave higher level of moisture content inducing soft texture and breaking on outer sheet of beans. Longer freezing and drying times gave disorder beans in terms of % breaking and overall appearance. The changes of each bean after precooked were investigated using scanning electron microscope (SEM), cooking time and % water uptake. SEM image showed that precooking treatment induced changes in the starch granules of beans, with the microstructure becoming more honeycomb-like structure in job's tear, shrinkage area on the surface and cluster granule in kidney bean and uncompleted gelatinization in mung bean. % water uptake of precooked kidney bean, mung bean and job's tear were increased with reducing the cooking times 61%, 30% and 56% respectively.

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Keywords: precook; mung bean; kidney bean; job's tear; freezing

1. Introduction

Cereal grain contains macronutrients as a major source of protein carbohydrate and fat. In some developing country (Thailand), consumers consume cereal grains, e.g., mung bean, job's tear and kidney bean, etc. The consumer supposes these cereal grains as food supplements taken orally that contain of protein, vitamin B and energy that are intended to supplement from one's consuming. FAO forecasted the world cereal production in

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2012 standing at 2,419 million tons with increasing 3.2 percent from 2011[1]. However, one major problem in the cereal industry is taking long time for cooking. As this matter of fact, it consequently consumes too much energy, loses unnecessary economic and is difficult to control the final product quality. Several researches showed how to eliminate these problems by treating staple carbohydrate source as rice to be instant or quick-cooking rice basing on gelatinization, cracking and porosity properties happening in the products [2-5]. Whereas there are limited research worked, up to date, on the precook cereal especially in staple cereal grain in South East Asia, i.e., kidney bean, mung bean and job's tear, most of them worked on the effect of pretreatment methods, e.g., cooking temperature and time, heat moisture treatment etc. on physicochemical changing of cereal starch but not rely on bean [6-10]. The objective of this study was to evaluate the effect of moisture heating in combination with freezing treatment on microstructure, moisture content, cooking time, overall appearance, % water uptake and % breaking of precooked kidney bean (*Phaseolus vulgaris* L.), mung bean (*Vigna radiata* L.) and job's tear (*Coix lachryma – jobi* L.). This study presented comprehensively the basic understanding of the changes in starch granule and some physical properties following pretreatment by moist – heating cooperated with freezing condition. The outcomes of this research would be absolutely applied to cereal industry focusing instant or quick-cooking cereal.

2. Materials and Methods

2.1 Materials

Kidney bean (*Phaseolus vulgaris* L.), mung bean (*Vigna radiata* L.) and job's tear (*Coix lachryma – jobi* L.) were obtained from Choomsin Food Industrial Co., LTD. (Nontaburi, Thailand) with an initial moisture content 8 -10 % (wet basis) for mung bean and job's tear and 12 - 13%(wet basis) for kidney bean. They were packed in foil-laminate bags under the vacuum condition and then kept at ambient temperature

2.2 Precooked treatments of beans

2.2.1 Soaking and steaming

Each bean was soaked in water at ambient temperature with a ratio of bean to water of 1:3. The soaking time was varied by 2 levels (kidney bean for 5 and 6 hrs, mung bean for 4 and 5 hrs. and job's tear for 6 and 7 hrs.) until the final moisture content reached to 30% (wet basis), followed by steaming at 20 and 30 minutes (kidney bean and job's tear), 10 and 15 minutes (mung bean) until the moisture content of bean was over 60% (wet basis). The moisture content of the sample was determined by drying in hot air oven at 105 ± 1 ^{o}C according to [11]. The suitable soaking and steaming methods were selected to further study in sense of freezing and drying steps.

2.2.2 Freezing and drying

The freezing method was monitored by air blast (air blast freezer, March Cool Industry, Thailand) at -30 ^{o}C under varying conditions of the periods at 1, 2 and 3 hours. After, the drying step with hot air oven (Binder model FD115, Germany) , then, performed at 60 ^{o}C for kidney bean and mung bean, and 90 ^{o}C for job's tear until the beans reached the final moisture content of 12% (wet basis).

2.3 Percentage of breaking, percentage of water uptake and cooking time

2.3.1 Percentage of breaking

Percentage of breaking was determined by weighing the total precooked and defected precooked beans. The defected precooked beans were selected by using 80% obviously cracked beans. Percentage of breaking was calculated as follows:

$$\text{Percentage of breaking} = \frac{\text{weight of defected precooked beans (g)}}{\text{total precooked beans weight (g)}} \times 100$$

2.3.2 Percentage of water uptake and cooking time

Percentage of water uptake was determined according to [12] application. The methodology was determined using the ratio of boiling water to bean of 1:30 for kidney bean, 1:10 for mung bean and 1:20 for job's tear, boiled until beans were cooked (recorded cooking time). Drain the excess water for 5 minutes, and then weigh them. The percentage of water uptake was calculated as weight of bean before and after cooking:

$$\text{Percentage of water uptake} = \frac{\text{weight of cooked beans (g)} - \text{weight of uncooked beans (g)}}{\text{weight of uncooked beans (g)}} \times 100$$

Cooked beans were noticed by using visual evaluation (no hard spot and white colour inside the beans) in parallel with texture analysis (Stable Micro System model TA XE plus) in term of hardness value in order to eliminate the error of time and control the optimum cooked bean. The hardness values were constantly fixed at 29,802 ± 3981 for kidney bean, 27,348 ± 3,223 for mung bean and 26,195 ± 1,471 for job's tear.

2.4 Scanning electron micrograph (SEM)

SEMs of bean samples were investigated by Cam scan model MX-2000 (England). The samples were prepared by partially breaking beans using mortar and pestle, and then coated them with gold. The samples were examined at 15 kV to view the sample in three dimensions including surface features of starch granules.

2.5 Statistical analysis

The experiments were carried out using completely randomized design. The measurements were performed in three repetitions. The results were statistically analyzed by SPSS version 11 for the Analysis of Variance (ANOVA). The test of mean comparison according to Duncan's new multiple range tests was applied with a significant level of 0.05.

3. Results and Discussion

3.1 Soaking and steaming

The effect of soaking and steaming on moisture content and overall appearance of beans are presented in Table 1. The bean samples that were treated with different soaking and steaming times exhibited different moisture content and overall appearance. The moisture content of bean was increased with increase in soaking and steaming periods. Logically, this is due to water penetrates longer time from surrounding into inner beans and gelatinization happening during the heat treatments [13]. The heating starch granules in excess water leads to granules swelling and amylose diffuse out of the granule. Longer heating period, starch gelatinization increased urging in total disruption of granules [6,8], responsible the textural properties giving softer texture and breaking on outer sheet of bean.

Table 1. Moisture content and overall appearance of beans after soaking and steaming conditions

Soaking (hours)	Steaming (minutes)	Moisture content (%wet basis)	Overall appearance (visual evaluation)
Kidney bean			
5	20	$47.00^{c}\pm 0.11$	Hard, not properly cooking
	30	$48.00^{c}\pm 0.10$	Completely cooking
6	20	$51.44^{b}\pm 0.15$	Over cooking, soft and broken grain
	30	$55.00^{a}\pm 0.10$	Over cooking, soft and broken grain
Mung bean			
4	10	$30.55^{b}\pm 0.14$	Completely cooking
	15	$31.44^{b}\pm 0.12$	Over cooking, soft and broken grain
5	10	$33.44^{a}\pm 0.10$	Over cooking, soft and broken grain
	15	$33.89^{a}\pm 0.11$	Over cooking, soft and broken grain
Job's tear			
6	20	$32.89^{c}\pm 0.12$	Hard, not properly for cooking
	30	$33.89^{c}\pm 0.10$	Completely cooking
7	20	$36.89^{b}\pm 0.11$	Over cooking, soft and broken grain
	30	$40.22^{a}\pm 0.10$	Over cooking, soft and broken grain

Values in the same column with different superscripts $^{(a, b, c)}$ mean the values are significantly different ($p\leq 0.05$)

3.2 Freezing and drying

The freezing and drying step affected the beans quality in terms of percentage of breaking (Table 2) and overall appearance including bean morpholo1gy (Figure 2). Longer freezing time lead to be greater in percentage of breaking and inferior overall appearance, i.e., color changing and cracking on the surface (data not shown), which might be owned to the porosity and ice crystal started up during slow freeze. Generally, slow freezing indicated large ice crystals, whereas rapid freezing promoted the formation of small ice crystals [14]. During the drying step the water was removed out of food by the driving force of water [15], playing a key role connect to percentage of breaking or cracking on the surface of bean (SEM figures). In case of processed job's tear, it promoted higher in percentage of breaking. This might be caused from the native grain that has no outer skin different from kidney bean and mung bean which have impervious shells.

Table 2. Percentage of breaking of beans after freezing and drying process

bean	Optimum treatments of soaking and steaming	Freezing time (hours)	Drying time (min)	%breaking
Kidney bean	5 hrs, 30 min	1	300	$16.10^{c}\pm 0.12$
		2	370	$31.23^{b}\pm 0.10$
		3	600	$39.50^{a}\pm 0.11$
Mung bean	4 hrs, 10 min	1	200	$16.12^{c}\pm 0.15$
		2	280	$60.66^{b}\pm 0.16$
		3	330	$77.10^{a}\pm 0.14$
Job's tear	6 hrs, 30 min	1	210	$60.00^{c}\pm 0.10$
		2	250	$68.00^{b}\pm 0.11$
		3	310	$70.00^{a}\pm 0.11$

Values in the same column with different superscripts $^{(a, b, c)}$ mean the values are significantly different ($p\leq 0.05$)

3.3 Scanning electron micrographs, cooking time and percentage of water uptake

Cooking time, percentage of water uptake and microscopy are depicted in Fig. 1 and 2. The results provided the clear view of changes in beans and starch granules. Herewith, precooked treatment induced different changes in each bean by the gelatinization during heating and freezing effects. Job's tear pattern can be seen more honeycomb-like structure on surface and porosity in inner bean. The formation of a honeycomb-like network occurred concomitantly with starch gelatinization remaining surface starch after some gelatinization starch leached out the bean [16]. SEMs morphology also presented in parallel with kidney bean which can be viewed as cracking on surface but shrinkage area and cluster group of starch granules in inner bean. This pattern was owing to gelatinization during heating and growing ice crystal during freezing step [10, 17]. The SEM pattern of mung bean was become greater cracking on surface, shrinkage and gelatinization than those in other beans. In the other hand, percentage of water uptake of precooked kidney bean, mung bean and job's tear was increased and reduced the cooking times 61%, 30% and 56%, respectively. The cracking in the surface and many small holes or porosity structure in beans probably permit the penetration of water into the interior of bean during cooking. The porosity and cracking phenomena may be caused by ice crystal growth during freezing step [10, 17].

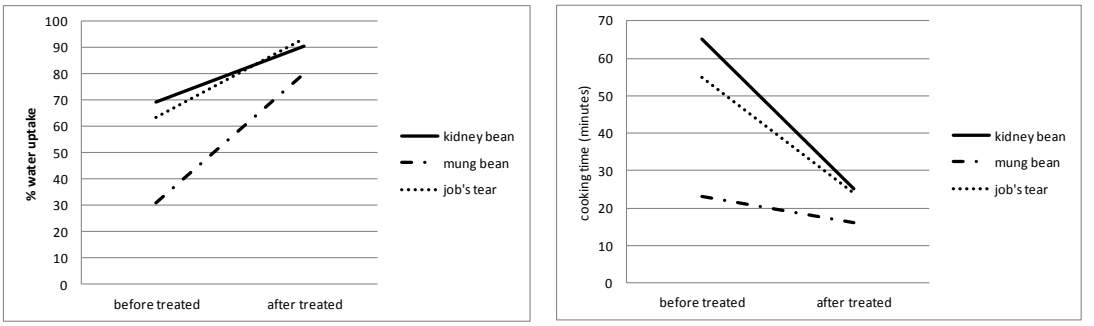
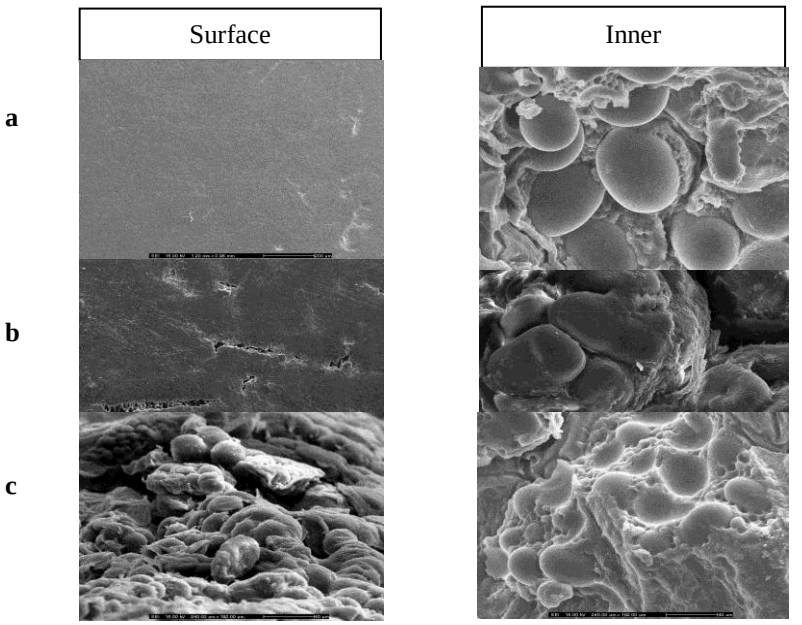


Fig. 1. Percentage of water uptake and cooking time of beans before and after treated under optimum moisture heating in combination of freezing. The optimum treatments of beans were followed by soaking, steaming and freezing steps, i.e., kidney bean was performed at 6 hrs, 30 min and 1 hr, respectively, mung bean was performed at 5 hrs, 30 min and 1 hr, respectively, while job's tear was performed at 4 hrs, 10 min and 1 hr



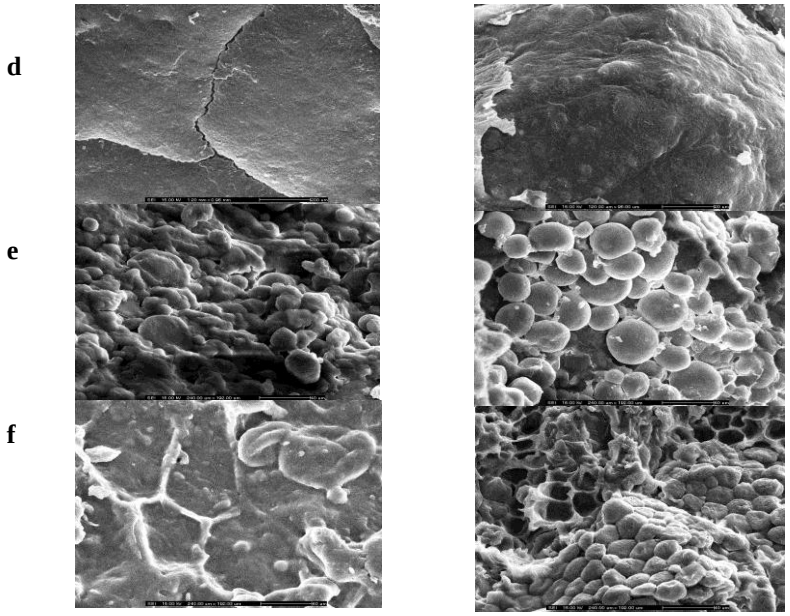


Fig. 2. Scanning electron micrographs of beans before and after optimum treated with moisture heating in combination of freezing (x 500), (a) kidney bean before treated; (b) kidney bean after treated; (c) mung bean before treated; (d) mung bean after treated; (e) job's tear before treated; (f) job's tear after treated

4. Conclusions

Moisture content, overall appearance, percentage of breaking, percentage of water uptake cooking time and bean structure (SEMS) were influenced by action of moisture heating and freezing treatments. The soaking and steaming induced the moisture content causing starch gelatinization. Additional the freezing and drying steps connected to the porosity, cracking and percentage of breaking, these corresponded to the observed morphological by SEMs. The precooked bean dealing in this study enhanced percentage of water uptake and eliminated cooking time in kidney bean, mung bean and job's tear for 61%, 30% and 56%, respectively, so that the cereal industrial applicable in sense of quick-cooking cereal.

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