ผลของการเตรียมก่อนทอดและวิธีการทอดต่อสมบัติด้านเนื้อสัมผัสและประสาทสัมผัสของถั่วทองทอดกรอบ

THE EFFECT OF PRE-FRYING TREATMENTS AND FRYING METHODS ON TEXTURAL AND SENSORY PROPERTIES OF CRISPY FRIED DEHUSKED MUNG BEAN

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***Received:** September 20, 2018; **Revised:** October 26, 2018; **Accepted:** December 27, 2018*

บทคัดย่อ

แม้ว่าถั่วทองทองทอดกรอบเป็นอาหารว่างที่รู้จักกันดีในประเทศไทยและประเทศอื่นๆ ในเอเชีย แต่ยังไม่ค่อยมีข้อมูลด้านคุณภาพและผลกระทบจากสภาวะในกระบวนการผลิต ในการศึกษานี้จึงมีวัตถุประสงค์ในการตรวจสอบผลของการเตรียมวัตถุดิบก่อนการทอดและสภาวะการทอดต่อคุณลักษณะของถั่วทองทอดกรอบ ทำการประเมินคุณภาพถั่วทองทอดกรอบด้าน อัตราการขยายตัว ความแข็ง และการยอมรับทางประสาทสัมผัส (9-Point Hedonic Scale) ทำการทดลองต้มถั่วทองที่อุณหภูมิ 100 องศาเซลเซียส ที่เวลา 1 3 และ 5 นาที ตามลำดับ ผลการทดลองพบว่า ระยะเวลาการต้มส่งผลต่ออัตราการขยายตัวและความแข็งของผลิตภัณฑ์สุดท้ายอย่างมีนัยสำคัญ ($p < 0.05$) แต่การต้มนาน 3 นาที ทำให้ได้ถั่วทองทอดกรอบที่มีคะแนนความชอบโดยรวมสูงที่สุด ($p < 0.05$) จากนั้นทดลองอบแห้งถั่วทองที่มีความชื้นฐานเปียกร้อยละ 56 นำไปอบให้มีความชื้นฐานเปียกร้อยละ 30 40 และ 50 ตามลำดับ ผลการทดลองพบว่า เมื่อความชื้นของถั่วทองก่อนทอดลดลงอัตราการขยายตัวของถั่วทองทอดลดลงและมีความแข็งเพิ่มขึ้นอย่างมีนัยสำคัญ ($p < 0.05$) จากนั้นทำการเปรียบเทียบถั่วทองก่อนทอดที่นำไปบ่มที่อุณหภูมิแตกต่างกัน ได้แก่ ที่อุณหภูมิบรรยากาศ (ประมาณ 35 องศาเซลเซียส) แช่เย็นที่ 4 องศาเซลเซียส และแช่เยือกแข็งที่ -20 องศาเซลเซียส เป็นเวลา 12 ชั่วโมง พบว่าถั่วทองที่ผ่านการต้มแล้วนำไปบ่มที่ -20 องศาเซียลเซียส ก่อนนำไปทอด ให้ลักษณะของถั่วทองทอดที่มีอัตราการขยายตัว และคะแนนความชอบด้านเนื้อสัมผัสที่เพิ่มขึ้น และมีค่าความแข็งที่ลดลงอย่างมีนัยสำคัญ ($p < 0.05$) อย่างไรก็ตาม สภาวะการบ่มไม่มีผลต่อคะแนนความชอบด้านลักษณะปรากฏ สีและคะแนนความชอบโดยรวมอย่างมีนัยสำคัญ ($p > 0.05$) จากนั้นทำการทดลองทอดถั่วทองที่ระดับความดันสุญญากาศต่างๆ (23-43 เซนติเมตรปรอท) และอุณหภูมิต่างๆ (130-145 เซลเซียส) ภายใต้สภาวะแรงขับเนื่องจากความแตกต่างของอุณหภูมิของน้ำมันและจุดเดือดของน้ำที่คงที่ 60 องศาเซลเซียส

เปรียบเทียบกับการทอดในสภาวะบรรยากาศ (76 เซนติเมตรปรอท 160 องศาเซลเซียส) ผลการทดลองแสดงให้เห็นว่าการทอดถั่วทองภายใต้ความดันสุญญากาศที่ความดัน 43 เซนติเมตรปรอท อุณหภูมิ 145 องศาเซลเซียส ทำให้ได้ถั่วทองทอดที่มีอัตราการขยายตัวสูงที่สุด มีค่าความแข็งและค่าวอเตอร์แอคติวิตี้ต่ำที่สุด การประเมินทางประสาทสัมผัสร่วมด้วยการวิเคราะห์ลักษณะโครงสร้างผ่านกล้องจุลทรรศน์อิเล็คตรอนแบบส่องกราดชี้ให้เห็นว่าถั่วทองทอดภายใต้ความดันสุญญากาศ มีคุณลักษณะด้านเนื้อสัมผัสที่ปรับปรุงขึ้นอย่างเห็นได้ชัด รวมทั้งยังได้รับคะแนนความชอบโดยรวมสูงกว่า เมื่อเปรียบเทียบกับถั่วทองที่ทอดภายใต้ความดันบรรยากาศและถั่วทองทอดทางการค้า ($p < 0.05$)

คำสำคัญ: ถั่วทอง อาหารว่าง การทอด สมบัติด้านเนื้อสัมผัส คุณภาพทางประสาทสัมผัส

Abstract

Although fried dehusked mung bean (DM) is a well known nutritious crispy snack in Thailand and other Asian countries, there is rare information regarding its quality and the influence of processing conditions. The objective of this study was therefore to investigate the effect of pre-frying treatments and frying methods on the quality attributes of crispy DM. Expansion ratio, hardness and sensory acceptance (9-point hedonic scale) were quality attributes evaluated for fried DM. Boiling of DM at temperature of 100°C was performed at varied periods of 1, 3 and 5 minutes respectively. The results indicated that boiling periods did not significantly influence on expansion ratio and hardness ($p > 0.05$) of final product but that for 3 minutes gave the highest overall liking score ($p < 0.05$). Subsequently, the boiled DM samples with moisture content of 56%w.b. were dried at temperature of 60°C to obtain varied moisture contents of 30, 40 and 50%w.b., respectively. It was found that as the moisture content of pre-fried DM decreased, it's expansion ratio significantly decreased and hardness significantly increased ($p < 0.05$). Then pre-fried DM aged at various conditions including atmospheric temperature (approx. 35°C), cooling at 4°C and freezing at -20°C for 12 hours were compared. It was found that ageing of cooked DM at -20°C before frying gave significant increase in expansion ratio, textural liking score and significant decrease in hardness of fried DM ($p < 0.05$). Nevertheless, the ageing conditions did not significantly effect on liking scores for appearance, colour and overall liking score ($p > 0.05$). Then the vacuum frying was performed under varied vacuum pressures (23-43 cmHg) and frying temperatures (130-145°C) under equivalent thermal driving force (ETDF) of 60°C and compared with atmospheric condition (76 cmHg, 160°C). The experimental results suggested that frying DM under vacuum pressures of 43 cmHg and temperatures of 145°C gave the highest expansion ratio, the lowest hardness and the lowest water activity (a_w) of the fried DM. Sensory evaluation along with SEM structural analysis indicated dramatically improved textural attributes with significantly higher overall liking score of fried DM under vacuum pressure over atmospheric counterpart and local commercial product ($p < 0.05$).

Keywords: Dehusked Mung Bean, Snack, Frying, Textural Properties, Sensory Properties

Introduction

Mung bean (*Vigna radiate*) is known for a plant seed rich of nutritional components such as protein, carbohydrate, oil, vitamins, minerals and a good source of dietary fiber [1]. Apart from utilization of mungbean as an ingredient in cooking of varieties of foods, fried snack produced from its dehusked form is well known and widely consumed in Thailand and many other Asian countries [2]. An increasing consumers' demand for healthy food products makes snack with nutritional value attractive to many food producers to develop new food product in this category [3]. For most starch based crispy snack, texture is a sensory attribute of uppermost importance for product preference [4]. Nevertheless, there is rare information regarding production and processing parameters associated with the quality attributes, especially texture of crispy fried mung bean product.

Atmospheric deep-fat frying is a conventional method applied for crispy dehusked mung bean available in the market. Vacuum deep-fat frying is an alternative method providing many advantages over conventional method including lower frying temperature, decreasing loss of nutrients, color, flavour, oil uptake and water activity [5-8]. To compare atmospheric and vacuum frying thermal driving force that is the difference between the oil temperature and the boiling point of water or so called equivalent thermal driving force (ETDF) at the working pressure must be kept constant [7-8].

Pre-treatments prior frying is associated to the fried product quality. For material containing starch such as rice, mung bean, etc., gelatinization of starch and moisture content are determining factors for the expansion of fried product [7-10]. Degree of retrogradation of starch induced by low temperature is another factor effecting on characteristics of fried product [11]. Starch retrogradation depends upon the duration of chilled storage. It has been reported recently that the expansion of cracker increased when cooked starch gel was cooled before frying as a result of starch retrogradation [10]. Freezing pretreatment was also found to effect on decreasing hardness of fried carrot snacks as a consequence of rapid evaporation during frying due to ice crystal formation, resulting in a more fragile structure [12].

Objectives

The objective of this study was to investigate the effect of pre-frying treatments (boiling, drying and ageing) and frying methods (Atmospheric and Vacuum) on the quality attributes of crispy dehusked mung bean (DM). Expansion ratio, hardness and sensory acceptance (9-point hedonic scale) were quality attributes evaluated for fried DM.

Methods

Materials for crispy fried dehusked mung bean preparation

Commercial dehusked mung bean (Khao Thong Brand, Thai Food Industry Co., Ltd.) was used for preparation of fried samples. Vegetable oil for frying was palm oil (Morakot brand, Morakot Industry Co., Ltd.) purchased from local supermarket.

Pre-frying process investigation: the effect of boiling period

Dehusked mung bean (DM, 30 g) was cleaned by rinsing with tap water before soaking in water (100 ml) at atmospheric temperature for 120 minutes. Water was then drained, followed by boiling DM sample in 500 ml of water at 100°C for varied periods of 1, 3 and 5 minutes, respectively. After boiling, the DM sample was cooled and ventilated under ambient temperature until the sample reached atmospheric condition. The sample was taken for moisture content determination. To fry the DM sample, palm oil was heated to 160°C under atmospheric pressure and fried for 2 minutes. The fried samples was taken for expansion ratio, hardness and sensory evaluation. The boiling period that provided the highest expansion ratio, the lowest hardness and the highest sensory score was selected for the subsequent experiment.

Pre-frying process investigation: the effect of drying process

DM samples were prepared by following procedure described earlier above with selected boiling time, except before frying, the boiled samples were dried at 60°C in hot air oven at varied times (13, 46 and 78 min) as estimated by drying curve to obtain varied moisture contents of 3 levels (50, 40 and 30%w.b., respectively). Boiled sample (moisture content 56%w.b.) without drying was treated as a control. The fried samples were analyzed for expansion ratio and hardness. Moisture content before frying corresponding to drying time that provided the highest expansion ratio and the lowest hardness was determined for the subsequent experiment.

Pre-frying process investigation: the effect of ageing process

Similarly, DM samples were prepared following procedure described earlier with selected cooking time and suitable moisture content which were then aged under various conditions for 12 hours including atmospheric temperature (approximately 35°C), chilling (4°C) and freezing (-20°C). The samples were then evaluated for expansion ratio and hardness. The ageing condition that provided the highest expansion ratio and the lowest hardness was determined for the subsequent experiment.

The effect of frying methods

The suitable pretreatment was selected according to the prior experimental results for comparison between vacuum frying using locally produced vacuum frying chamber (OFM CO, Ltd., Thailand) and atmospheric frying. The experimental conditions are presented in Table 1 comprising 4 experiments for vacuum frying (1-4) and atmospheric condition (5) as a control. To allow comparison between the frying method, the frying was operated under equivalent thermal driving force (ETDF) of 60°C. The fried samples were evaluated for expansion ratio, hardness and water activity (a_w). The selected vacuum fried sample was subsequently evaluated for sensory acceptance using 9-point hedonic scale and compared with the atmospheric fried sample and a commercial product packed in sealed aluminum bag purchased from local supermarket.

Table 1. Experimental vacuum frying and atmospheric conditions under equivalent thermal driving force (ETDF) of 60°C

Frying conditions	1	2	3	4	5
Pressure (cmHg)	23	29	36	43	76
Oil temperature (°C)	130	135	140	145	160
Water boiling point (°C)	70	75	80	85	100
Frying time (min)	8	7	6	5	2
ETDF (°C)	60	60	60	60	60

Note: 1-4 = vacuum conditions, 5 = atmospheric condition (Control)

Product quality assessments

Expansion ratio of fried DM was measured from relative change in its volume before and after frying. The volume of sample was determined based on sesame replacement. Then volume expansion ratio was calculated from the following equation.

Expansion ratio = Va/Vb

Where Vb = Volume of mungbean seeds before frying

Va = Volume of mungbean seeds after frying

Hardness of sample was measured using Texture Analyzer (TA-TX2i, Stable Micro System CO, Ltd., UK with 5 kg load cell, cylindrical probe (P/50), set at 25 mm return distance, 10 mm/s return speed, 10 g contact force and 70% deformation, placing 5 DM seeds for each measurement.

Water activity (a_w) of ground fried DM sample was measured using bench top water activity meter (Aqualab Series 4TE, Decagon Devices, Inc., Pullman, Washington, USA). Moisture content of each sample was measured following the standard procedure of AOAC (2000).

Sensory evaluation was conducted using 9-point hedonic scale (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely) with 50 untrained panelists. Product attributes evaluated were appearance, color, texture and overall liking.

The microstructure analysis

The microstructure of selected experimental fried DM samples and a commercial product was depicted through Scanning Electron Microscope (SEM, JSM-IT300LV, JEOL Ltd. Japan). Individual fried DM seed was cross-section cut into pieces size of 0.5 mm each. Individual thin piece of fried DM was placed in a sample holder and coated with gold, then transferred to SEM and observed at an accelerating voltage of 10kV with 50x magnification.

Statistical analysis

All statistical data analysis were carried out using SPSS version 18.0 (2009) [13] as a facilitating tool. Whenever means values were compared, 3 replications of each treatment were performed and Duncan's new multiple ranges test was applied following analysis of variance (ANOVA). For sensory data analysis, randomized complete block design was applied with tasting panelists treated as blocks. The statistical significance was determined at 95% confidence ($p < 0.05$).

Results

The effect of boiling period

It was found that increasing boiling period resulted in significant increase in moisture content of boiled DM ($p < 0.05$) (Table 2). However, an increase in moisture content of boiled DM did not significantly effect on expansion ratio and hardness and colour of the fried product ($p > 0.05$). On the other hand, fried DM sample prepared from raw material boiled for 3 minutes received significantly higher liking scores for texture and overall liking ($p < 0.05$). Therefore, boiling DM for 3 minutes was chosen as a fixed condition for a subsequent investigation of drying effect.

The effect of drying process

The drying process was applied to boiled DM before frying in order to prepare samples with varied moisture content before frying. The results are presented in Table 4. It was found that as the moisture content of DM before frying increased, the expansion ratio of fried product significantly increased ($p < 0.05$) but the hardness significantly decreased ($p < 0.05$).

The effect of ageing process

Based on earlier experimental results, boiled DM without drying process was used for investigation of the effect of ageing process which was performed under low temperature at 4 and $-20^{\circ}C$ for 12 hours before frying. The results are presented in Table 5. It was found that ageing the boiled DM under lower temperature, significant increase in expansion ratio with significant decrease in hardness of fried DM product was observed ($p < 0.05$). The fried DM prepared from sample kept under freezing condition ($-20^{\circ}C$) provides the highest expansion ratio with the lowest hardness and consequently used for further investigation on the effect of frying methods.

Table 2. Properties of fried dehusked mungbean (DM) prepared from various boiling period before frying

Boiling periods (min)	Moisture content of DM after boiling (% w.b)	Properties of fried DM	
		Expansion ratio[ns]	Hardness (N)[ns]
1	55.06±0.19[c]	1.64±0.03	1081.73±24.70
3	56.04±0.23[b]	1.66±0.03	1069.44±38.13
5	59.09±0.28[a]	1.69±0.02	1024.05±17.82

Note: The lowercase letters indicate significant differences amongst mean values (±sd) at 95% confidence ($p < 0.05$), ns: non-significant

Table 3. Sensory scores of fried DM obtained from varied boiling periods.

Boiling periods (min)	Sensory liking score (9-point hedonic score)			
	Appearance[ns]	Color[ns]	Texture	Overall
1	6.94±0.89[a]	6.88±0.77[a]	5.98±0.98[bc]	6.10±0.95[bc]
3	7.06±0.93[a]	6.96±0.81[a]	6.82±0.96[a]	6.94±0.79[a]
5	6.89±0.73[a]	6.72±0.83[a]	6.22±1.07[b]	6.48±0.96[b]

Note: The lowercase letters indicate significant differences amongst mean values (±sd) at 95% confidence ($p < 0.05$), ns: non-significant

Table 4. Expansion ratio and hardness of fried DM at varied moisture content before frying.

Moisture content before frying (% w.b.)	Expansion ratio	Hardness (N)
56%	1.66±0.03[a]	1069.02±40.28[d]
50%	1.54±0.02[b]	1199.18±17.07[c]
40%	1.41±0.02[c]	1275.80±31.71[b]
30%	1.21±0.03[d]	1383.19±23.98[a]

Note: The lowercase letters indicate significant differences amongst mean values (±sd) at 95% confidence ($p < 0.05$)

The effect of frying methods

The pre-frying condition was determined according to earlier experimental results and used for investigation of the effect of frying methods comparing atmospheric condition and vacuum counterparts. As demonstrated in Table 6, it was observed that fried DM under vacuum pressure of 43 cmHg provided the highest expansion ratio with the lowest hardness and the lowest aw ($p < 0.05$). Under vacuum pressure, increasing pressure resulted in increasing expansion ratio, decreasing hardness and a_w ($p < 0.05$). Subsequently, the fried DM obtained from 43 cmHg vacuum frying was evaluated by 50 panelists using 9-point hedonic scale and compared with those obtained from atmospheric frying (76 cmHg) and commercial product. The result (Table 7.) indicated that fried DM from vacuum frying received significantly higher overall liking score ($p < 0.05$) as compared to those from experimental atmospheric frying and commercial one. However, all samples were not significantly different in colour liking score ($p > 0.05$) whilst experimental samples had significantly higher liking score for appearance. Liking score for texture of vacuum fried DM was significantly higher than that of commercial product ($p < 0.05$) but not significantly different from that obtained from atmospheric frying ($p > 0.05$).

Table 5. Expansion ratio and hardness of fried DM obtained from different ageing condition for 12 hours.

Ageing condition	Expansion ratio	Hardness (N)
Control (Atmosphere)	1.66 ± 0.03^{c}	1069.02 ± 40.28^{a}
Chilling (4°C)	1.80 ± 0.02^{b}	924.92 ± 27.17^{b}
Freezing (-20°C)	2.03 ± 0.04^{a}	824.84 ± 30.54^{c}

Note: The lowercase letters indicate significant differences amongst mean values (±sd) at 95% confidence ($p < 0.05$)

Table 6. Expansion ratio, hardness and aw of fried DM under varied vacuum pressure and atmospheric pressure.

Vacuum Pressure (cmHg)	Frying temperature (°C)	Expansion ratio	Hardness (N)	Water activity (a_w)
23	130	1.99 ± 0.03^{c}	874.72 ± 56.84^{a}	0.09 ± 0.002^{a}
29	135	2.05 ± 0.03^{b}	759.68 ± 45.37^{bc}	0.08 ± 0.003^{b}
36	140	2.13 ± 0.02^{a}	727.96 ± 26.70^{c}	0.07 ± 0.005^{c}
43	145	2.15 ± 0.01^{a}	644.97 ± 37.89^{d}	0.04 ± 0.003^{d}
76*	160	2.04 ± 0.03^{bc}	824.84 ± 30.54^{ab}	0.21 ± 0.02^{a}

Note: The lowercase letters indicate significant differences amongst mean values (±sd) at 95% confidence ($p < 0.05$)

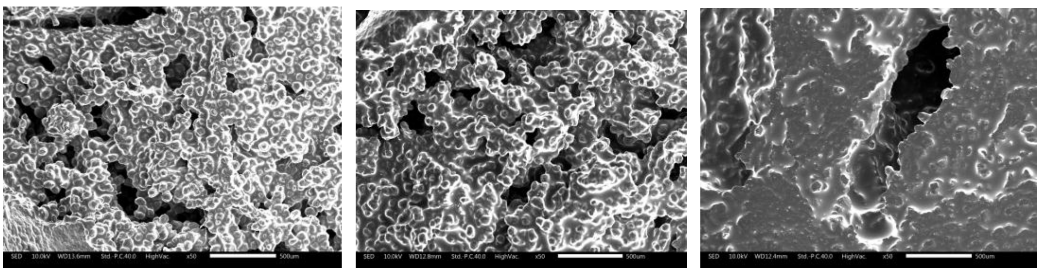
Table 7. Liking scores of fried DM.

Fried DM	Sensory Liking Score			
	Appearance	Colour	Texture	Overall
Commercial	5.98±1.09^{b}	6.68±0.77^{a}	5.90±1.16^{b}	5.52±1.38^{c}
Atmospheric frying (76 cm Hg)	6.68±0.77^{a}	6.82±0.80^{a}	6.30±1.30^{ab}	6.26±1.65^{b}
Vacuum frying (43 cm Hg)	6.46±0.94^{a}	6.72±0.86^{a}	6.61±1.11^{a}	7.10±1.09^{a}

Note: The lowercase letters indicate significant differences amongst mean values (±sd) at 95% confidence ($p < 0.05$)

Microstructure of fried DM

The microstructure of fried DM was observed through SEM. The result was shown in Figure 1. It was found that the DM sample fried under vacuum pressure and atmospheric condition exhibited greater extent of porosity than commercial sample. This result is in agreement with textural and sensory properties previously discussed.



(a) **(b)** **(c)**

Figure 1. Microstructure Of Fried DM (50x Magnification): (A) Atmospheric Frying, (B) Vacuum Frying, (C) Commercial Product.

Conclusions and Discussion

Pre-frying treatments and frying methods effect on characteristics and sensory acceptance of crispy fried DM. The suitable pre-frying conditions include boiling for 3 minutes followed by ageing at $-20^{\circ}C$ for 12 hours before frying. Vacuum frying under pressure of 43 cm Hg provided improved texture and sensory acceptance of fried DM over those from atmospheric frying and commercial product.

It was found that increasing boiling period resulted in significant increase in moisture content of boiled DM. An increase in moisture content of DM was associated with absorbed water and gel setting during the gelatinization of starch influencing the expansion of starch based snacks [9-10]. However, an increase in moisture content of boiled DM did not significant effect on expansion ratio and hardness of the fried product and colour. Thus, the appropriate boiling period of 3 minutes was justified by the highest sensory scores. The drying process was applied in this study to generate varied moisture content of DM samples before frying. It was found that moisture content of DM before frying was positively associated with the expansion ratio but negatively associated with the hardness of fried product. This result could be explained by the effect of vaporization during frying process which induced the expansion of cell structure of frying material under its pressure and left air cells that created the porous structure after the water escaped [9, 14-15]. Therefore, the sample with higher moisture content enables more possibility to create more porosity with great expansion of the fried product. However, when the product expands, its air cell wall becomes thinner and susceptible to collapse with lower force applied [16] indicating increased crispiness of the fried product [8]. Thus, hardness or breaking force is an indicator of crispiness of fried DM. The lower the hardness or breaking force the higher the crispiness. Thus, the more expanded fried product, the higher hardness could be anticipated.

The results indicated that ageing the boiled DM under lower temperatures (4 and -20°C for 12 hours before frying) effected on an increase in expansion ratio with noticeable decrease in hardness of fried DM product. This result could be explained by the retrogradation of starch in DM as induced by low temperature. When retrogradation occurs, starch gel releases water which subsequently evaporated during frying to create more air cells or porosity which produces light and crisp texture of snack [17]. In addition, as the degree of retrogradation increases, the air cell wall created from starch crystallinity in DM during frying becomes stronger which facilitates better porous structure formation and distribution influencing puffing characteristic of fried product [18]. Similar finding was reported by Yuksel; et al. [11] that the addition of stale bread as a result of retrogradation in deep-fried corn chip resulted in decreased hardness of the product. At very low temperature (-20°C), higher degree of retrogradation could be expected. In addition, freezing pretreatment was also found to influence on decreasing hardness of fried snacks as a consequence of rapid evaporation during frying due to ice crystal formation, resulting in a more fragile structure [12].

It was observed that under vacuum condition, pressure was positively related to expansion ratio but inversely associated with hardness and a_w of fried DM. Expansion of fried foods has been previously explained by the concept of rapid increase in molecular volume of water during evaporation [19]. The higher the boiling point at higher vacuum pressure, the larger amount of water becomes trapped within the structure, increasing its expansion capacity during frying by pressure of water vaporization. In addition, the rate of moisture removal was slower under higher vacuum pressure leading to reduced structural degradation and crust formation that might inhibit the escape of water [8] resulting in lower a_w in fried DM under pressure of 43 cmHg. According to sensory evaluation, microstructure and textural properties analysis, an improvement in quality of fried DM was found when suitable pre-treatments and vacuum frying method were applied. The suitable pre-frying treatment and frying condition found in this study could be beneficial to the food manufacturers who expect to improve fried DM quality for differentiated and value-added product.

Nomenclature

a_w	Water Activity
DM	Dehusked Mung Bean
sd	Standard Deviation
SEM	Scanning Electron Microscope
Vb	Volume of Mungbean Seeds Before Frying
Va	Volume of Mungbean Seeds After Frying

References

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