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Original Research Article

Effect of Defatted Rice Bran Addition on Properties of Texturized Soy Protein Products

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ABSTRACT

The objective of this work was to develop low moisture-texturized vegetable protein (LM-TVP) using defatted rice bran (DRB) and soy protein isolate (SPI) as raw materials. The effect of DRB addition on properties of texturized soy protein (TSP) was studied. TSP samples were prepared by blending SPI: DRB at ratio of 45:55, 60:40 and 75:25 (w/w) to produce TSP with 50, 60 and 70% protein, respectively. Then, all samples were extruded using twin screw extruder. Extrusion condition was fixed at 25% of feed moisture, 400 rpm of screw speed and 130 °C of die temperature. Next, properties of TSP50-70 before and after rehydration were characterized. The results showed that the expansion ratio and density of TSP50-70 were in range of 2.03-2.57 and 0.19-0.29 kg/m3, respectively. After rehydration the water absorption capacity, water holding capacity and oil holding capacity of TSP50-70 were in the same range which were 390-430%, 4.62-4.97 g water g-1, 2.9-3.3 g oil g-1, respectively. However, there was a significant difference in texture between TSP50 and TSP70. Decreasing DRB content from 45 (TSP50) to 25% (TSP70) increased springiness from 0.76 to 0.93, cohesiveness from 0.51 to 0.79 and hardness from 0.45 to 1.52 N of TSP samples. Compared to commercial TVP, all studied properties of TSP70 were in acceptable range. Therefore, to add value to DRB the TSP70 (75%SPI and 25%DRB) was proposed in this study to produce TVP with low beany odor.

INTRODUCTION

A growing awareness about healthy and sustainable foods has led to an interest in plant-based meat (Wild et al., 2014). Texturized vegetable protein (TVP) produced by extrusion technology using soy protein and wheat gluten as constituents can produce products that imitate the texture and appearance of meat. Based on moisture content, TVP can be divided into low and high moisture. Low moisture-TVP (LM-TVP) has texture like a sponge, which should be rehydrated before consumption (Zhang et al., 2019). Advantages of LM-TVP are handling, storage and shelf stability (Bakhsh et al., 2021).

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Although soy protein is a plant-based protein with excellent functional properties, it is allergen and has beany odor (Meinlschmidt, Schweiggert-Weisz, and Eisner 2016). In present, the development of TVP using indigenous sources such as chick pea (Anjum, 2011), pea protein (Webb et al. 2020), isolated mung bean protein, isolated peanut protein (Samard et al., 2019) as well as by-products such as black gram by product (Kamani et al., 2021) was studied. Thailand's rice production volume in 2021 was approximately 21.4 million metric tons (Statista, 2022). Rice contains about 7-9%protein. In addition, one of the by-products obtained from rice milling consists of rice bran, which account 10% of paddy rice. After extracting rice oil, the defatted rice bran (DRB) contains 11-17% protein which is a low-cost product used as animal feed (Hunsakul et al., 2021). Therefore, in this study DRB was used as raw material to blend with soy protein isolate (SPI) to produce LM-TVP. Advantages of DRB as TVP components are non-allergen and non beany odor. In addition, DRB contains high methionine which is an essential amino acid in which SPI is low (Fabian and Ju, 2011).

To produce TVP by extrusion, it requires 50-70% protein content to form a fibrous structure. Quality of TVP depends on the extrusion parameters as well as raw material properties (Zhang et al., 2019). Therefore, the objective of this study was to develop TVP using DRB as raw materials to replace SPI which was a common ingredient used to produce commercial TVP.

MATERIALS AND METHODS

Soy protein isolate (SPI) was purchased from PTK Solution and Supplies Limited (Bangkok, Thailand). Commercial defatted rice bran (DRB) was provided by Thai Edible Oil Co., Ltd. (Bangkok, Thailand). Protein content of SPI and DRB was 84.40 and 17.59%, respectively. The commercial texturized vegetable protein (C-TVP) which is soy protein based-product was purchased from Abbra Corporation Limited (Bangkok, Thailand). Its protein and moisture content were approximately 71% and less than 10%, respectively.

In this study, to vary protein of TVP in range of 50-70%, soy protein isolate (SPI) was blended with 25-55% DRB. Then, all samples were extruded using twin screw extruder with 2.5 mm diameter circular die to produce texturized soy protein with 50-70% protein (TSP50-70) products like mined meat. Extrusion condition was fixed at 25% feed moisture, 400 rpm and 130 °C die temperature. Next, properties of TSP samples in terms of expansion ratio, density, water absorption capacity (WAC), water holding capacity (WHC), oil holding capacity (OHC) and texture were measured to compare with commercial soy protein-based TVP (C-TVP).

Table 1. Mixture composition (wt.%) of texturized soy protein (TSP) with different protein contents.

Sample	Composition (wt.%)		Protein content (wt.%)	Extrusion condition			
	SPI	DRB		Moisture content (%)	Screw speed (rpm)	Barrel temperature (°C)	Die temperature (°C)
TSP50	45	55	48	25	400	30/50/70/100/ 130/ 130	130
TSP60	60	40	58				
TSP70	75	25	68				

Sample preparation

The mixture composition and extrusion condition used to prepare the textured soy protein (TSP) with different protein contents are shown in Table 1. The SPI and DRB were blended at ratios of 45:55, 60:40, and 75:25 (w/w). TSP50, TSP60 and TSP70 referred to sample with 50, 60 and 70% protein, respectively. Moisture content of each sample was fixed at 25% (w/w) by adding distilled water. Then, sample was mixed for 5 min using a kneader. (KitchenAid, 5K5SS, Michigan, USA). The sample was packaged in plastic bag and stored at 4 °C for 24 h in a refrigerator (Panasonic, NR-B41MV2, Thailand).

The mixture was extruded using a twin screw extruder with a length to diameter ratio (L/D) of 32 (Chareon tut, Model CTE-D25L32, Samutprakan, Thailand) equipped with circular-shaped die of 2.5 mm diameter. Extrusion condition is shown in Table 1. After extrusion, TSP50-70 was dried at 50 °C for 24 h in a hot air oven (Memmert, UF110, Germany) until its moisture content was less than 8%.

Expansion ratio

Expansion ratio of TPS50-70 was measured using a vernier caliper (Mitutoyo, N15WW, Japan) and was calculated as Equation (1) (Lee et al., 2022).

$$\text{Expantion ratio} = \frac{\text{Diameter of extrudate (cm)}}{\text{Diamter of extruder die (cm)}} \quad (1)$$

Apparent density

TSP50-70 and C-TVP were cut into approximately 1 cm and weighed. Diameter of sample was measured using a vernier caliper (Mitutoyo, N15WW, Japan) to calculate volume of extrudate. The apparent density was calculated as Equation (2).

$$\text{Apparent density (g / cm}^3) = \frac{\text{Mass of extrudate (g)}}{\text{Volume of extrudate (cm}^3)} \quad (2)$$

Water absorption capacity (WAC)

TSP50-70 and C-TVP (~1 cm length) were weighed (W_d) and hydrated in 20 mL of distilled water at 25 °C for 30 min. The residual water was drained after 30 min and the rehydrated samples were weighed (W_h) (Zhou et al., 2021; Lee et al., 2022). WAC was defined as Equation (3).

$$\text{WAC (\%)} = \left(\frac{W_h - W_d}{W_d}\right) \times 100 \quad (3)$$

Water holding capacity (WHC) and oil holding capacity (OHC)

TSP50-70 and C-TVP were ground into a powder using by grinder. Approximately 1 g of the powder was placed in 10 mL of distilled water or rice bran oil and mixed for 30 min at 25 °C. It was centrifuged at 3000 × g for 15 min at 25 °C. Then, the supernatant was discarded and the remaining solids were weighed. WHC/OHC was expressed as the weight of water/oil in grams held by 1 g of powder (Stojceska et al., 2009; Kaleda et al., 2021).

Texture profile analysis

TSP50-70 and C-TVP were cut into approximately 1 cm and then hydrated at 25 °C for 60 min and drained for 30 min. Then, samples were placed horizontally and compressed by a texture analyzer (TA.XT plus, Stable Micro System, UK) using with P/50 probe (Ø 50 mm). The testing condition was set at pre-test speed of 1 mm/s, test speed of 2 mm/s, post-test speed of 5 mm/s, strain of 50%, trigger force of 5 g and time interval between the two compression of 3 s (Lee et al., 2022). Hardness, springiness and cohesiveness values were recorded. These parameters were defined from the texture profile analysis graph. Hardness is defined as the peak force determined during the first compression. Springiness was determined by the ratio of the detected height on the second compression by the original compression. Cohesiveness was calculated using the ratio of the area below during the second compression curve and the area below the original compression curve (Rivera et al., 2021). All determinations were performed in ten replicates for each sample.

Statistical analyses

Statistical analyses were performed using Minitab Statistical Software version 18 (Minitab Inc., State College, Pennsylvania, USA). Tukey's multiple range test was used to analyze the significant difference at $p<0.05$.

RESULTS AND DISCUSSION

To add value of DRB, SPI with 55, 45 and 25%DRB was prepared to produce TSP with 50, 60 and 70%protein, respectively. After extrusion, properties of TSP50-70 in terms of expansion ratio and density were characterized. Then, samples were rehydrated to measure WAC, WHC, OHC and texture.

Expansion ratio and density

Expansion ratio value describes the degree of the puffed extrudate. During the extrusion cooking process, the puffed extrudate occurs the pressure inside the extruder is higher than outside. The water inside the mass of the mixture changes from liquid to vapor state. The mass of the mixture swelled up (Lee et al., 2022). Expansion ratio and density of TSP50-70 and C-TVP are given in Table 2. Expansion ratio of TSP50-70 were in range of 2-2.57. The increase in protein content from 50% to 70% decreased expansion ratio of TSP sample. This may be due to an increase in the protein aggregation in extrudate (Beck et al., 2018; Brishti et al., 2021).

In addition, density of TSP50-70 was in range of 0.19-0.29 kg/m3 which was closed to that of C-TVP which was about 0.3-0.38 kg/m3 (Lee et al., 2022). Increasing density was associated with a decrease in expansion ratio. The protein content has affected the density by obstructing air cells from the large size of protein aggregation, leading to an increase in the density (Mosibo et al. 2020). Figure 1 shows size and number of air cells in TSP50-70 and C-TVP after extrusion. Size and number of air cells of TSP50-70 were quite similar. However, the air cell size of TSP50-70 was smaller than that of C-TVP.

Table 2. Expansion ratio and density of TSP50, TSP60, TSP70 and C-TVP

Sample	Expansion ratio (%)	Density (kg/m^3)
TSP50	2.57 ±0.25^{a}	0.19±0.05^{c}
TSP60	2.33±0.06^{ab}	0.27±0.02^{bc}
TSP70	2.03 ±0.02^{b}	0.29 ±0.02^{b}
C-TVP	-	0.38 ±0.04^{a}

Data are expressed as mean ± standard deviation of two replications. Lowercases (a–c) indicate the significant differences ($P \leq 0.05$)

WAC, WHC and OHC

WAC indicates amount of water that sample can absorb after rehydration of LM-TVP (Farooq and Boye, 2011) which measures the capabilities of TVP products in terms of texture, juiciness and mouthfeel (Brishti et al. 2021). WAC of TSP50-70 was in range of 390-430% as shown in Table 3. This result may be associated with the size and number of air cells in TSP50-70 (Figure 1), resulting in the same volume of water that penetrated into the air cells of samples. WAC of C-TVP was 604% which higher than TSP50-70. This may be attributed to the large air cell size in sample as shown in Figure 1. However, WAC of TSP50-70 was in the same range of TVP in other paper (Lee et al., 2022) which was about 400%.

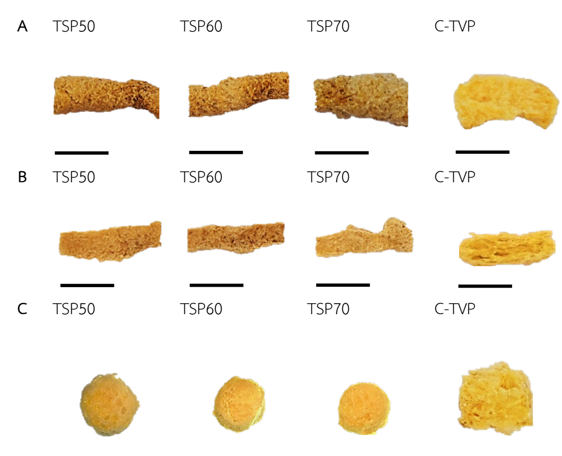

Figure 1. Appearance(A), longitudinal section(B) and cross sectional(C) of TSP50, TSP60 and TSP70 and C-TVP. Scale bar: 10 mm.

WHC is ability of sample to bind water. In addition, OHC is ability of sample to bind lipid which is the important properties to enhance flavor retention and mouthfeel (Asgar et al. 2010; Kyriakopoulou et al., 2021). WHC and OHC of TSP50-70 are shown in Table 3. All samples had the WHC and OHC in the same range which was closed to C-TVP.WHC and OHC of TVP may be associated with the hydrophilic and hydrophobic amino acids content in TVP sample (Kaleda et al., 2021) as soy protein isolate and rice bran protein had 57.6 and 54.9 g /100 g protein for hydrophilic amino acids and 28.2 and 36.7 g /100 g protein for hydrophobic amino acids, respectively (Samard, S., Ryu, G.-H., 2019; Wang et al. 1999). However, the hydrophilic and hydrophobic amino acids content may be slightly changed after extrusion (Lam et al. 2018).

Texture

Texture in terms of hardness, springiness and cohesiveness of TSP50-70 and C-TVP after rehydration was analyzed as shown in Table 4. A significant difference in texture between TSP50 and TSP70 was observed. Decreasing DRB content from 45 (TSP50) to 25% (TSP70) increased springiness from 0.76 to 0.93, cohesiveness from 0.51 to 0.79 and hardness from 0.45 to 1.52 N of TSP samples. An improvement in texture of TSP70 may be because high protein content in sample led to higher protein-protein interaction, resulting in a high hardness and low springiness and cohesiveness of TVP (Shahbazi et al., 2021).

Compared to C-TVP, all values of texture in terms of hardness, springiness and cohesiveness of TVP70 was closed to those of C-TVP measured in this study and in other paper (Lee et al., 2022) which were in the range of 0.73-1.78 N for hardness, 0.95-0.96 for springiness and 0.79-0.82 for cohesiveness. However, texture of TSP 50 especially springiness and cohesiveness were not in the acceptable range compared to C-TVP. Therefore, to add value to DRB the TSP70 (75%SPI and 25%DRB) was proposed in this study to produce TVP with low beany odor as all important studied properties were in acceptable range compared to C-TVP.

Table 3. WAC, WHC and OHC of TSP50, TSP60, TSP70 and C-TVP

Sample	WAC (%)	WHC (g H_2O/ g)	OHC (g Oil/ g)
TSP50	429.47±0.32^b	4.90±0.24^a	2.89±0.09^b
TSP60	427.73±0.15^b	4.62±0.16^a	3.18±0.05^a
TSP70	390.28±0.25^b	4.97±0.09^a	3.30±0.08^a
C-TVP	604.33±0.55^a	4.15±0.09^b	3.27±0.05^a

Data are expressed as mean ± standard deviation of two replications. Lowercases (a–b) indicate the significant differences ($P \leq 0.05$)

Table 4. Texture in terms of hardness, springiness and cohesiveness of TSP50, TSP60, TSP 70 and C-TVP

Sample	Hardness (N)	Springiness	Cohesiveness
TSP50	0.45 ±0.11^c	0.76±0.07^b	0.51±0.03^b
TSP60	0.49 ±0.94^c	0.77 ±0.09^b	0.53±0.03^b
TSP70	1.52±0.94^a	0.93 ±0.05^a	0.79 ±0.04^a
C-TVP	0.71±0.12^{bc}	0.95 ±0.03^a	0.82 ±0.03^a

Data are expressed as mean ± standard deviation of two replications. Lowercases (a–c) indicate the significant differences ($P \leq 0.05$)

CONCLUSIONS

To develop TVP using DRB as raw material, soy protein isolate (SPI) was blended with 25-55% DRB to produce TSP with protein in range of 50-70%. The results showed that physical properties including expansion ratio, density, WAC, WHC and OHC of TSP50-70 were closed and in the same range of C-TVP. However, texture of TSP50 and TSP70 was significantly different. Decreasing DRB content from 45 (TSP50) to 25% (TSP70) improved texture in terms of hardness, springiness and cohesiveness of TSP. Therefore, in this study to add value to DRB, TSP70 (75%SPI and 25% DRB) was proposed to produce TVP as all important studied properties were in acceptable range compared to C-TVP. For future studies, the sensory evaluation should be carried out to determine the effect of rice bran addition on beany flavor of TVP and the acceptance of consumers on texture and overall properties of TVP.

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