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Effect of Different Percentages of Dried Bean Curd (Yuba) as a Meat Substitute on the Physicochemical and Sensory Properties of Hybrid Chicken Patties

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ABSTRACT

Dried bean curd (DB) is a promising meat substitute because it has a chewy and meaty texture when rehydrated. The objective of this study is to determine the effect of the percentage of DB on the physicochemical and sensory properties of chicken patties. The chicken patties were formulated with five treatments: 100% chicken meat (C100), 75% chicken meat and 25% DB (C75+DB25), 50% chicken meat and 50% DB (C50+DB50), 25% chicken meat and 75% DB (C25+DB75), and 100% DB (DB100). The cooking loss, dimensional shrinkage, color, pH, water holding capacity, emulsion stability, texture, shear force, proximate, sensory, and microstructural properties of different formulations were evaluated. Increasing DB in the formulation significantly reduced total fluid released, fat released, and shrinkage. However, using 100% DB resulted in a poor patty structure after cooking. Among the formulations tested, the C50+DB50 treatment was the most favorable, exhibiting high water holding capacity (65.18%)—which was not statistically different from C100—and the lowest cooking loss (23.77%). This formulation also scored the highest texture (7.48), juiciness (6.80), flavor (7.16), and overall acceptability (7.32) across all samples. Results suggest that DB could be used as a meat substitute without compromising consumer acceptance.

Keywords: chicken patties, flexitarian, hybrid patties, meat emulsion, soy-based meat

INTRODUCTION

Meat is one of the most consumed foods globally due to its pleasant flavor and texture. However, high meat consumption adversely affects ecosystems. The livestock industry significantly contributes to global climate change, and it was estimated that global greenhouse gas emissions from the livestock industry ranged around 12–18% of the total greenhouse gas emissions (Allen and Hof, 2019). Furthermore, meat consumption also strongly correlates with health concerns, including an increased risk of heart disease, diabetes, and pneumonia (Du *et al.,* 2023). Consequently, plant-based sources have increasingly attracted interest for reducing meat consumption by partially substituting meat in meat product formulations.

Meat substitutes, also known as meat alternatives, meat analogs, or imitation meat, are products formulated with plant-based materials to partially or completely replace animal meat while providing some of the functional, nutritional, and sensory characteristics associated with conventional meat products (Ismail *et al.,* 2020). Numerous studies have explored the use of various ingredients as meat substitutes, such as soy and other legumes, mushrooms, and textured vegetable protein, because of their potential to reduce reliance on animal meat while maintaining desirable product characteristics (Kea *et al*., 2025; Kyriakopoulou *et al*., 2021; Wahab *et al*., 2024). Several studies have investigated partially replacing meat with plant-based materials in meat products. Yellow peas, chickpeas, or lentils have been used to partially replace chicken in hybrid burgers, resulting in reduced fat content and improved cooking yield; however, sensory evaluation was not conducted in this study (Chandler and McSweeney, 2022). Soy flakes have also been investigated as a potential meat substitute, with salt adjustment being necessary to achieve saltiness and flavor perceptions comparable to those of beef patties (Chin *et al*., 2024). Similarly, textured protein has shown potential as a meat substitute; however, prior soaking to reduce off-flavors may adversely affect network formation and consequently alter the textural properties of the product (Flores *et al*., 2023). Shiitake

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mushroom as a meat substitute increased the water holding capacity and reduced the cooking loss, indicating potential benefits for cooking characteristics, but patties containing shiitake mushroom were less preferred by consumers than beef patties (Park *et al*., 2023). These findings demonstrate that partially replacing animal meat with plant-based materials could improve some nutritional and technological characteristics, but increasing the replacement percentage may also affect the product's texture and sensory acceptability. Therefore, developing a meat substitute involves a trade-off between the percentage of meat replacement and maintaining favorable structural and sensory characteristics.

Dried bean curd (DB) can imitate chicken meat because it is high in protein (around 16%) (Li *et al*., 2019). When rehydrated, DB has a chewy, meaty texture. Its fibrous structure mimics the muscle fibers in meat, giving it a texture that resembles the sensation of chewing animal proteins. Furthermore, it absorbs flavor effectively, enhancing a dish's overall taste profile. It is made by cooking soy milk until a thin film forms on its top. The thin film is rolled and folded into long, rough tubes, which are then dried. From an environmental perspective, beans have significantly lower greenhouse gas (GHG) emissions and require less land and water than animal-derived products (Semba *et al.,* 2021). These factors make DB a potential meat substitute, but it has been less explored as a partial meat substitute in chicken patties. It was hypothesized that moderate replacement of chicken with DB would provide a more favorable balance between meat reduction, structural properties, and consumer acceptance. This study aimed to evaluate the effects of different percentages of DB substitution on the physicochemical, textural, and sensory properties of chicken patties; and to identify the substitution level that provides the most favorable balance between meat reduction, structural properties, and consumer acceptance.

MATERIALS AND METHOD

Materials

The DB (EverBest, Malaysia; protein: 15%, fat: 75%), chicken breast, salt, sugar, and garlic were obtained from Billion Shopping Centre, Bandar Baru Bangi, Malaysia. Shortening was obtained from Bake With Yen, Bandar Baru Bangi. Sodium tripolyphosphate (STPP) was purchased from CY Online Supply. Chicken breasts were stored in a freezer (-18 °C) before processing. Other ingredients, such as DB, fat (shortening), salt, STPP, sugar, and garlic, were kept at ambient temperature in a dry storage box.

Sample preparation

Sample preparation was performed according to a previous study, with slight modifications to the meat substitution percentage, resulting in a higher meat replacement percentage (Serdaroğlu *et al.,* 2018). Chicken breast (C) was cleaned, cut into smaller pieces, and minced using a meat mincer. The DB was soaked in water at a DB-to-water ratio of 1:4 w/w for 5 min at 80 °C, drained at 25 °C for 30 min, and gently blotted with a paper towel to remove visible excess water. This process was carried out uniformly for all the DB samples. Then the rehydrated DB was mixed with other ingredients (Lee *et al*., 2024). The ingredients of each formulation are given in Table 1. The DB percentage in the formulations was based on rehydrated DB and expressed as the chicken-to-DB ratio within the 75% main protein fraction. For example, C100 contained 75% of chicken in the total formulation. C75+DB25 contained 56.25% of chicken and 18.75% of DB in the total formulation (75% of chicken and 25% of DB in the 75 g of main protein fraction/100 g total ingredients). C50+DB50 contained 37.5% chicken and 37.5% DB in the total formulation (50% chicken and 50% DB in the 75 g of main protein fractions/100 g total ingredients).

Table 1. Formulation of chicken patties and hybrid chicken patties with DB as a meat substitute

Ingredients (%)	C100	C75+DB25	C50+DB50	C25+DB75	DB100
Chicken	75	56.25	37.5	18.75	0
DB	0	18.75	37.5	56.25	75
Fat	15	15	15	15	15
Salt	1.5	1.5	1.5	1.5	1.5
STPP	0.3	0.3	0.3	0.3	0.3
Sugar	1.2	1.2	1.2	1.2	1.2
Garlic	2	2	2	2	2
Ice	5	5	5	5	5
Total	100	100	100	100	100

Note: C= chicken; DB= dried bean curd; STPP= sodium tripolyphosphate; C100= 100% of chicken in the 75 g of main protein fraction/100 g total ingredients; C75+DB25= 75% of chicken and 25% of DB in the 75 g of main protein fraction/100 g total ingredients; C50+DB50= 50% of chicken and 50% of DB in the 75 g of main protein fraction/100 g total ingredients; C25+DB75= 25% of chicken and 75% of DB in the 75 g of main protein fraction/100 g total ingredients; DB100= 100% of DB in the 75 g of main protein fraction/100 g total ingredients

Furthermore, C25+DB75 contained 18.75% chicken and 56.25% DB in the total formulation (25% chicken and 75% DB in the 75 g of main protein fraction/100 g total ingredients). DB100 contained 75% DB in the total formulation.

All ingredients, except fat, were mixed at 1500 rpm in a bowl cutter (CM-21, Mainca, Spain) for 5 min. Subsequently, fat was incorporated and blended for an additional 10 min until a homogeneous mass was obtained. The mixing process was controlled at a temperature below 15 °C using a handheld thermometer (Hanna HI 985091-1, USA). Each mixture weighed 60 g and was molded using a hamburger forming machine (BT10, Omas, Italy) with a diameter of 100 mm. The samples were prepared from three independent batches. The samples were labeled accordingly and kept at -18 °C for two weeks (14 days) before further analysis. For analyses requiring cooked samples, the patties were thawed for 30 min at 25 °C prior to cooking. The cooking process was carried out for 4 min on each side until the internal temperature of the patties reached 73 °C at the geometric center. The griddle (MSM HP-6000, MSM Kitchen Sdn Bhd, Malaysia) was pre-heated until it reached 180 °C prior to cooking to ensure the griddle temperature was uniform for all samples. Because of DB100's fragile structure, this sample could not be processed for further analysis, including sensory evaluation and texture analysis, as firmness was required.

Physicochemical analysis

Emulsion stability

The method for analyzing emulsion stability was adapted from Ismail *et al*. (2021). The sample (15 g) was centrifuged (Kubota 3740, Kubota Corporation, Japan) at 3000 rpm for 15 min at 4 °C. The tubes were submerged in a water bath at 75 °C for 30 min. The tubes were inverted to release the fluids onto the pre-weighed crucibles. The pellet was weighed, and the fluid was oven-dried for 16 h at 105 °C and then weighed. The total fluid released and fat released were calculated using Equation 1, 2, and 3.

$$\text{TEF} = (\text{W of centrifuge tube} + \text{W of sample}) - (\text{W of centrifuge tube} + \text{W of pellet}) \quad (1)$$

$$\text{Total fluid released (\%)} = \frac{\text{TEF}}{\text{W of sample}} \times 100\% \quad (2)$$

$$\text{Fat released (\%)} = \frac{\text{W of crucible} + \text{W of dried supernatant} - \text{W of empty crucible}}{\text{TEF}} \times 100\% \quad (3)$$

W= weight (g); TEF= total expressible fluid (g)

Water holding capacity (WHC)

Water holding capacity was evaluated following a method described by Faridah *et al.* (2023). Briefly, 10 g of sample was combined with 20 mL of distilled water in a centrifuge tube. Then, it was centrifuged at 1500 rpm for 5 min (3740, Kubota Corporation, Japan). The supernatant obtained was weighed. Water holding capacity can be calculated using Equation 4.

$$\text{Water Holding Capacity (\%)} = \frac{\text{WBC-WAC}}{\text{Sample weight (g)}} \times 100\% \quad (4)$$

WBC= Weight of water before centrifuge (g); WAC= Weight of water after centrifuge (g)

pH

The pH value of each sample formulation was measured using a pH meter (Jenway 3505, Essex, UK). The pH meter was calibrated before the analysis. For analysis, 5 g of sample was homogenized with 10 mL of distilled water.

Cooking loss

Cooking loss is the amount of fluid loss during cooking. The measurement was based on the weight difference between patties before and after cooking (Macharáčková *et al.,* 2021). The samples were thawed at ambient temperature. Cooking loss can be calculated using Equation 5.

$$\text{Cooking Loss (\%)} = \frac{\text{W of raw sample (g)} - \text{W of cooked sample (g)}}{\text{W of raw sample (g)}} \times 100\% \quad (5)$$

Dimensional shrinkage

The measurement of dimensional shrinkage aimed to illustrate thickness and diameter changes in patties during cooking. The dimensional shrinkage of the samples was measured using a caliper (Vernier Caliper 531, Carlssoon Technologies Sdn Bhd, Malaysia). The dimensional shrinkage can be calculated using Equation 6 (Cabi *et al.,* 2022).

$$\text{Dimensional Shrinkage (\%)} = \frac{[(\text{RST}-\text{CST})+(\text{RSD}-\text{CSD})]}{[\text{RST}+\text{RSD}]} \times 100\% \quad (6)$$

RST= raw sample thickness (cm); CST= cooked sample thickness (cm); RSD= raw sample diameter (cm); CSD= cooked sample diameter (cm)

Proximate analysis

All patties were examined for moisture, ash, fat, protein, and carbohydrate. The moisture content was calculated by measuring the sample's weight before and after drying for 5 h at 105 °C, following AOAC Official Method 934.01. The samples were burned in a furnace for 4 h at 550 °C, and ash content was determined by weighing the samples before and after incineration, following AOAC Official Method 942.05. The fat content was measured by Soxhlet extraction with petroleum ether, following AOAC Official Method 983.23. Protein was evaluated by the Kjeldahl method, following AOAC Official Method 992.15. The carbohydrate content was measured by the difference method. The analyses were conducted using three independent batches according to AOAC International (2006) methods.

Color

The surface color of samples (both raw and cooked) was measured using a chromameter (CR-410, Konica Minolta Sensing, Inc., Japan) with illuminant D65 and a 10° standard observer as described by Wei *et al.* (2024). Before the color measurement, the chromameter was calibrated using the supplied white standard tiles (L*= 89.17; a*= 0.3174; b*= 0.3340) according to the manufacturer's instructions. The results showed lightness (L*), redness (a*), and yellowness (b*). The L* value indicates the lightness of a color, with the lightest color equal to 100. The a* value refers to the red-to-green color range, where red corresponds to positive values and green to negative values. The b* value refers to the blue-to-yellow color range, where yellow refers to a positive value, while blue refers to a negative value. Color measurements were taken at three randomly selected locations on the surface of patties, and the mean value was used for statistical analysis.

Texture profile analysis (TPA)

The texture profile of the samples was examined using a Texture Analyzer (TA-XT2i, Stable Micro Systems, UK) (Wahab *et al*., 2024) with slight modifications. The cooked samples were cut (L: 3 cm, D: 3 cm) and compressed to 75% of their original height for the first and second compression using a P/75 probe with a 75 mm diameter and a 30 kg load. A 75% compression level was selected to provide sufficient deformation for characterization of the textural properties of the beef patties and was consistently applied to all samples. The pre-test, test, and post-test speeds were set at 1.00 mm/s, 1.50 mm/s, and 1.50 mm/s, respectively. The interval time between compressions was set to 5 s.

Warner-Bratzler shear force

The shear force was determined using a Texture Analyzer with a 25 kg load. A sample 3 cm long × 2 cm in diameter was cut using a 1 mm-thick Warner-Bratzler shear blade at a speed of 1.5 mm/s with a 100% cutting percentage (Ismail *et al*., 2021).

Sensory evaluation

Sensory evaluation was conducted by recruiting 50 untrained assessors (10 male and 40 female students and staff, aged 18–35 years) from the Faculty of Food Science and Technology, Universiti Putra Malaysia, through poster information and personal invitation. Individuals with known food allergies or intolerances to any ingredients used in the samples were excluded from the session. Before participation, all assessors received an information sheet explaining the purpose and procedures of the sensory evaluation, the food samples, potential risks, and their rights as participants. The assessors were also informed that they could withdraw from the session at any time. The sensory evaluation was conducted using a hedonic test in accordance with international standards on a 9-point scale (1= dislike extremely to 9= like extremely). The sensory evaluation was performed in individual cabins with white lighting and was held in one session for all assessors for all samples evaluated. The color, aroma, texture, juiciness, flavor, and overall acceptability of patties were evaluated (Lee and Han, 2024; Wahab *et al*., 2024). The samples were served using random three-digit sample codes in a randomized serving order to minimize bias. Each sample was served in 20 g portions (30 °C) to each assessor. Mineral water was provided as a palate cleanser.

Microstructure

The microstructure of hybrid chicken patties was observed under scanning electron microscopy (SEM) (JSM-IT100 InTouchScope, Jeol Ltd, Malaysia). The cooked patties (10×10 mm) were examined at 250× magnification (Basri *et al.,* 2024). The sample was fixed with 0.1 mol/L phosphate buffer (pH 7.0) containing 2.5% glutaraldehyde at 4 °C for 24 h and dehydrated in increasing concentrations of ethanol (50, 70, 90, 95, and three times with 100%) for 10 min per solution. The samples were freeze-dried in acetone, cooled in liquid nitrogen, mounted on stubs using double-sided carbon conductivity tape, and sputter-coated with gold for 3 min using an automated sputter coater. One independent sample from each treatment was prepared and observed for micro-structure analysis. Three representative fields of view (n= 3) were examined for each sample, and the most representative micrographs were selected for qualitative comparison.

Statistical analysis

All the samples were prepared from three independent batches. Physicochemical analyses were performed using *n*= 3 independent samples or batches for each treatment. The experimental unit was the individual assessor, with each assessor evaluating four formulations (DB100 was not evaluated). Sensory evaluation was conducted by *n*= 50 independent assessors, each of whom evaluated all four formulations, with sensory attributes as a fixed effect and assessor as a block or random effect. One-way analysis of variance (ANOVA), followed by Tukey's test, was used to determine significant differences at the 95% confidence level ($p<0.05$) and for pairwise comparisons while controlling for multiple comparisons (sensory evaluation). Minitab Statistical Software version 22 was used to analyze the data obtained, which were displayed as mean±standard deviation.

RESULTS AND DISCUSSION

Emulsion stability (ES), water holding capacity (WHC), pH value, cooking loss, and dimensional shrinkage of hybrid chicken patties

Table 2 presents the results for ES, WHC, pH, cooking loss, and dimensional shrinkage. Emulsion stability was expressed as total fluid released (TFR) and fat released (FR). The results show notable differences in TFR and FR between the samples ($p<0.05$). C100 had the highest TFR (19.10±1.36%) and FR (2.75±0.44%) among all samples ($p<0.05$). As the percentage of DB increased, TFR and FR decreased, with C25+DB75 having the lowest TFR (1.08±0.72) and FR (0.13±0.083) ($p<0.05$). It shows that C25+DB75 produced the most stable emulsion among the samples. Emulsion stability is influenced by the structural characteristics of the interfacial layer between the two phases in the emulsion system. The use of DB, which is originally composed of soybean protein, can act as an emulsifier through several mechanisms, such as reduction of interfacial tension and electrostatic repulsion (Xiao *et al.,* 2025). However, emulsion stability in WHC relies on a different physical mechanism, resulting in different outcomes. The ability of the chicken patty system to hold water refers to the strength of the network to entrap water under some mechanical treatment. C100 exhibited the highest WHC (71.45±2.01%) among all samples, while C25+DB75 was the lowest (37.06±5.76%). Myofibrils from chicken meat are the primary site of water binding in meat (Xiong, 2005). Hence, 100% chicken showed the strongest water-binding properties. DB is prepared by heating soymilk and then drying. Drying may weaken the protein network structure, leading to fluid loss after centrifugation (Bi *et al*., 2024). Thus, the WHC of the sample with DB was lower than that of C100; however, among all DB-added samples, C50+DB50 exhibited the WHC closest to C100 ($p>0.05$).

The pH values of uncooked hybrid patties ranged from 6.01 to 6.70. These values are higher than those of a hybrid chicken patty with mushroom, which had a pH of 5.53 (Wahab *et al*., 2024). As the DB percentage increased, the pH of uncooked hybrid patties increased significantly ($p<0.05$). Plant-based protein ingredients can commonly raise pH. A similar trend was also reported from hybrid patties with black-jelly mushrooms (Wahab *et al.,* 2024). After cooking, the pH values of hybrid patties altered in a distinct trend, with DB100 having the highest pH ($p<0.05$). This indicates that total replacement of meat with DB resulted in a higher pH.

Cooking loss refers to the loss of moisture and fat from the sample during cooking. C100 exhibited the highest cooking loss of 31.49±1.69%, while C50+DB50 showed the lowest cooking loss of 23.77±2.16% ($p<0.05$). The lower cooking loss indicates the patties' ability to retain their components during heating. Furthermore, it affects patty tenderness and juiciness when consumed. The more fluid (water and fat) released from the system, the drier the patties would be. Interestingly, a higher percentage of DB in C25+DB75 resulted in higher cooking loss, indicating that DB utilization at a certain level was not sufficient to retain fluid during cooking. This was also reported in a previous study of chicken patty with oyster mushroom (Wan Rosli *et al.,* 2011).

Table 2. The emulsion stability, water holding capacity, pH, cooking loss, and dimensional shrinkage of chicken patties and hybrid chicken patties with DB as a meat substitute

Sample	Emulsion Stability		Water Holding Capacity (%)	pH		Cooking Loss (%)	Dimensional Shrinkage (%)
	Total Fluid Released (%)	Fat Released (%)		Before Cooking	After Cooking		
C100	19.10±1.36^{a}	2.75±0.44^{a}	71.45±2.01^{a}	6.01±0.096^{c}	6.42±0.08^{ab}	31.49±1.69^{a}	17.76±0.3^{a}
C75+DB25	14.17±4.29^{a}	2.57±1.32^{a}	61.47±12.74^{ab}	6.13±0.10^{bc}	6.34±0.14^{ab}	28.27±2.14^{ab}	14.33±2.4^{a}
C50+DB50	7.38±0.78^{b}	1.53±0.68^{ab}	65.18±13.51^{a}	6.23±0.064^{bc}	6.27±0.04^{b}	23.77±2.16^{b}	8.54±2.2^{b}
C25+DB75	1.08±0.72^{b}	0.13±0.083^{b}	37.06±5.76^{b}	6.37±0.035^{b}	6.35±0.025^{ab}	30.05±3.33^{ab}	5.62±1.9^{b}
DB100	2.74±3.02^{b}	0.48±0.44^{b}	52.82±11.47^{ab}	6.70±0.18^{a}	6.59±0.14^{a}	ND	ND

Note: Values are presented as mean±standard deviation. Values with different superscripts within the same column are significantly different ($p<0.05$). C100 (100% C); C75+DB25 (25% DB); C50+DB50 (50% DB); C25+DB75 (75% DB); DB100 (100% DB) where C= chicken; DB= dried bean curd; ND= no data

Based on the results, C100 showed the greatest shrinkage (17.76±0.3) among all samples (p<0.05), indicating the system's poor ability to retain its components and shape. At the same time, C25+DB75 showed the lowest shrinkage percentage (5.62±1.9) (p<0.05). These results show that chicken patties exhibited the greatest fluid loss, followed by hybrid chicken patties. The heating led to protein denaturation in chicken meat, which in turn caused shrinkage and the association of protein filaments, leading to fluid expulsion. In contrast, protein from DB was already denatured during its own processing; hence, the polymeric network is stronger and more resistant to shrinkage (Vu *et al.,* 2022).

Although DB100 could not retain a coherent patty structure after cooking and was fragile, it was subjected to the same thermal treatment as the other formulations. The resulting heat-treated material was used for ES, WHC, and pH. When DB100 disintegrated during cooking, it may not have been possible to reliably determine the mass and dimensions of the original patty, nor those of the recovered cooked patty.

Proximate composition of hybrid chicken patties

The proximate composition of hybrid chicken patties is shown in Table 3. There was no significant difference among samples for fat and protein content (p>0.05). A higher percentage of DB in the formulation significantly reduced the moisture content of hybrid chicken patties (p<0.05). However, there was no significant difference between C100 and C75+DB25. Chicken meat has a considerably high moisture content at around 75%, which contributes to the high moisture content of C100 (Ming-min and Ismail-Fitry, 2023). C100 exhibited the highest ash content (2.69%), while DB100 had the lowest (1.95%). This result showed that chicken meat had a higher ash content than DB. Chicken breast consists of around 1.12% ash (Benamirouche *et al.,* 2020), while DB has around 0.8% ash. C100 exhibited the lowest carbohydrate content of 1.25%, while DB100 exhibited the highest carbohydrate content of 13.38% (p<0.05). Higher DB percentages increased the carbohydrate content of hybrid chicken patties. DB contained approximately 12% carbohydrates (Chen *et al.,* 2009). Although DB100 did not retain a coherent patty structure after cooking, it underwent the same thermal treatments as the other formulations. The resulting heat-treated material was used for proximate analysis.

Color of hybrid chicken patties

Table 4 shows the color of hybrid chicken patties, while Figure 1 shows the picture of raw and cooked hybrid chicken patties. No significant differences were observed among all raw patties based on L* (lightness), a* (redness), and b* (yellowness) values (p>0.05). Interestingly, although DB has a yellow color, the yellowness of patties with DB was not significantly influenced (p>0.05).

After cooking, the L* value decreased for all samples compared to raw patties. Furthermore, after cooking, DB100 had the lowest L* value among all samples, 51.51±5.35 (p<0.05). Whereas other hybrid patties, C75+DB25, C50+DB50, and C25+DB75, had no significant differences from each other for L* values (p>0.05). Using 100% DB in the formulation resulted in a darker patty. Incorporating DB into the patties also significantly increased the a* value, with DB100 reaching the highest a* value (7.60) among all samples (p<0.05). All hybrid patties had significantly higher a* values than the control chicken patties (p<0.05).

Table 3. Proximate composition of chicken patties and hybrid chicken patties with DB as a meat substitute

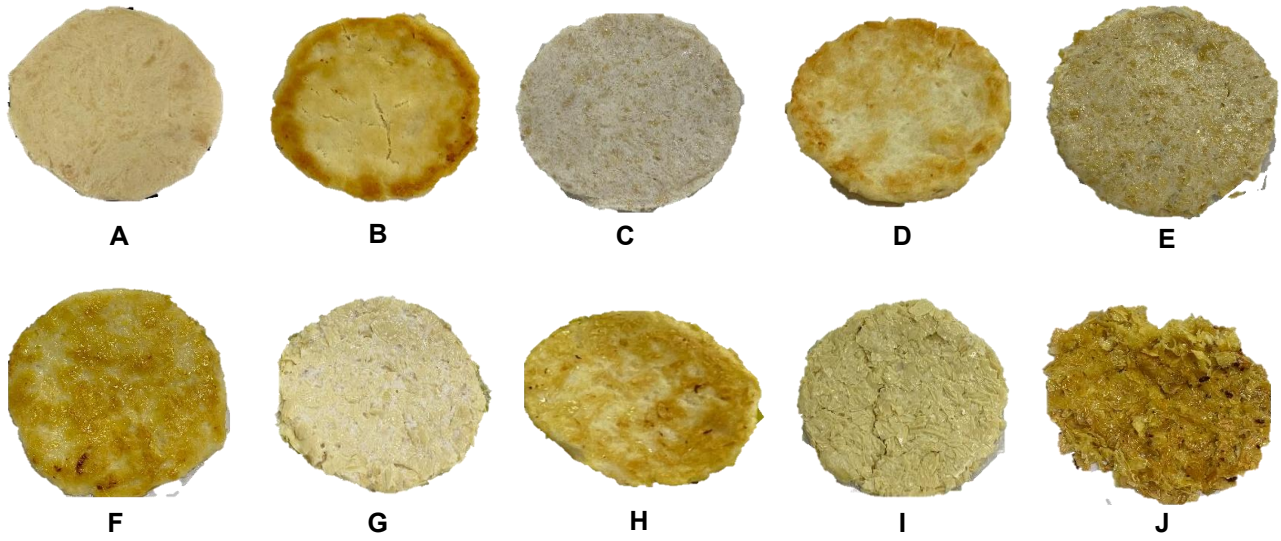
Sample	Fat (%)	Protein (%)	Moisture (%)	Ash (%)	Carbohydrate (%)
C100	12.75±2.09^{a}	20.74±0.90^{a}	62.56±0.19^{a}	2.69±0.06^{a}	1.25±1.36^{c}
C75+DB25	12.21±1.89^{a}	18.81±1.06^{a}	62.75±0.62^{a}	2.45±0.05^{ab}	3.78±1.88^{bc}
C50+DB50	11.09±1.10^{a}	18.69±2.35^{a}	60.42±0.17^{b}	2.39±0.05^{ab}	7.41±1.78^{b}
C25+DB75	14.93±0.77^{a}	19.62±1.30^{a}	56.93±0.96^{c}	2.24±0.08^{bc}	6.28±2.79^{bc}
DB100	12.38±0.77^{a}	22.04±0.66^{a}	50.25±0.59^{d}	1.95±0.30^{c}	13.38±1.17^{a}

Note: Values are presented as mean±standard deviation. Values with different superscripts within the same column are significantly different (p<0.05). C100 (100% C); C75+DB25 (25% DB); C50+DB50 (50% DB); C25+DB75 (75% DB); DB100 (100% DB), where C= chicken; DB= dried bean curd

Table 4. The color measurement (L*, a*, b*) of chicken patties and hybrid chicken patties with DB as a meat substitute

Sample	Before Cooking			After Cooking		
	L*	a*	b*	L*	a*	b*
C100	79.50±3.89^{a}	2.67±0.94^{a}	16.91±0.80^{a}	73.57±1.01^{a}	1.82±0.59^{c}	13.42±1.20^{b}
C75+DB25	78.44±2.28^{a}	2.13±0.94^{a}	18.01±0.52^{a}	73.73±1.88^{a}	1.84±0.44^{bc}	12.76±2.12^{b}
C50+DB50	77.44±1.13^{a}	2.07±0.34^{a}	18.25±0.39^{a}	69.15±2.67^{a}	3.57±0.57^{bc}	14.31±1.79^{b}
C25+DB75	79.28±3.31^{a}	1.87±0.70^{a}	19.37±1.09^{a}	73.73±1.88^{a}	3.87±0.38^{b}	15.01±1.36^{b}
DB100	75.14±5.61^{a}	2.10±1.14^{a}	19.65±3.56^{a}	51.51±5.35^{b}	7.60±1.37^{a}	27.70±3.98^{a}

Note: Values are presented as mean±standard deviation. Values with different superscripts within the same column are significantly different (p<0.05). C100 (100% C); C75+DB25 (25% DB); C50+DB50 (50% DB); C25+DB75 (75% DB); DB100 (100% DB) where C= chicken; DB= dried bean curd; L*= lightness; a*= redness; b*= yellowness



Note: A= raw with 100% chicken; B= cooked with 100% chicken; C= raw with 25% DB; D= cooked with 25% DB; E= raw with 50% DB; F= cooked with 50% DB; G= raw with 75% DB; H= cooked with 75% DB; I= raw with 100% DB; J= cooked with 100% DB

Figure 1. Visual of uncooked and cooked chicken patties and hybrid chicken patties

Similar results were also observed for b*, with DB100 showing the highest b* value (27.70±3.98) among all samples (p<0.05). The yellowness, b*, may be related to the intrinsic yellowish color of DB, which could contribute to the overall yellowness of the patties. Although DB100 did not retain a coherent patty structure after cooking, DB100 also underwent the same thermal treatment as the other formulations. The resulting heat-treated sample was used for color measurements.

Texture profile and Warner-Bratzler shear force of hybrid chicken patties

Table 5 presents the results of the texture profile and Warner-Bratzler shear force analysis. No significant differences were observed between all samples for hardness, cohesiveness, chewiness, gumminess, and shear force (p>0.05). However, cohesiveness, gumminess, and chewiness increased with DB addition. For DB100, no texture data were obtained due to its poor structure. DB100 underwent the prescribed cooking but did not form a structurally intact cooked patty. Texture profile analysis requires a specimen with sufficient structural integrity and standardized dimensions.

As the DB percentage increased in hybrid patty formulations, springiness increased significantly (p<0.05), and C25+DB75 showed the springiest texture compared to the other patties (0.83). This result aligns with a previous study that investigated beef patties with modified pea protein as an extender (Shen *et al*., 2022). Springiness reflects the patties' capacity to recover their original size or shape after compression (Ming-min and Ismail-Fitry, 2023).

A higher springiness value indicates a greater ability of the patties to bounce back (Souppez *et al*., 2025). This indicates that partially substituting chicken meat with DB could improve patty structure. The resilience value of patties also increased from 0.24 to 0.35 as DB increased in the formulation (p<0.05). These hybrid chicken patties showed higher resilience than the hybrid meat batters with plant protein from various legumes (Lin and Barbut, 2024). Thus, using DB enhances the texture properties of patties.

Sensory evaluation of hybrid chicken patties

The results of the sensory evaluation of hybrid chicken patties are presented in Table 6. The color, aroma, texture, juiciness, flavor, and overall acceptability were examined. Significant differences were observed among the samples for color, texture, juiciness, flavor, and overall acceptability (p<0.05), except for aroma. Overall, C50+DB50 had the highest scores for aroma, texture, juiciness, and flavor, as reflected in the overall acceptability score. Interestingly, C100 had the lowest score for color, texture, and juiciness. However, C25+DB75 received the lowest overall acceptability score. For DB100, no data were obtained because the sample was fragile and not acceptable for assessor evaluation; thus, it was excluded before sensory evaluation. DB100 exhibited poor structural integrity and was fragile. This may be associated with the absence of a meat-protein matrix and limited cohesion in bean curd structures. The results show that C50+DB50 is the most preferred patty.

Microstructure of hybrid chicken patties

The microstructure of hybrid chicken patties is shown in Figure 2. As shown, C100 exhibited a coarse structure with some pores. In contrast, no pores were observed in DB100. DB100 also showed thread-like, compact, and dense structures. Thread-like structures were also observed in C50+DB50 and C25+DB75, but in lower quantities than in DB100; while no threads were observed in C100.

The compact and dense structure of DB100 contributes to low fluid and fat release. A previous study of chicken meat emulsion also reported that fewer and smaller pores resulted in good emulsion stability, which was determined as low fluid loss (Faridah *et al.,* 2023). Although larger pores are often associated with lower structural integrity and higher fluid loss, pore size alone does not necessarily determine emulsion stability.

Table 5. The texture profile analysis (TPA) and shear force of chicken patties and hybrid chicken patties with DB as a meat substitute

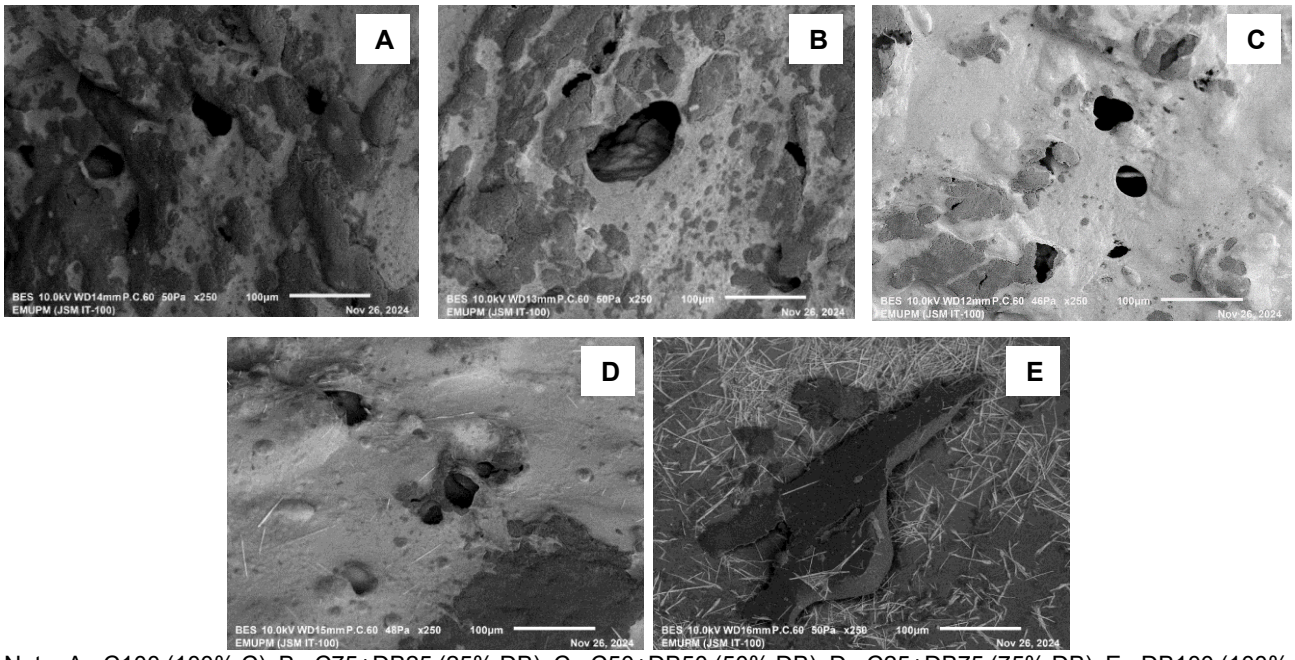
Sample	Hardness (g)	Springiness	Cohesive-ness (J/J)	Gumminess (g)	Chewiness (g.mm)	Resilience (J/J)	Shear Force (N)
C100	31355±4266^{a}	0.66±0.061^{b}	0.58±0.013^{a}	18068±2776^{a}	12043±2868^{a}	0.24±0.01^{b}	10.78±2.52^{a}
C75+DB25	33261±4819^{a}	0.74±0.045^{ab}	0.60±0.031^{a}	20192±3857^{a}	15008±3335^{a}	0.27±0.04^{ab}	9.92±3.00^{a}
C50+DB50	33810±2627^{a}	0.81±0.024^{ab}	0.62±0.038^{a}	21079±2939^{a}	17129±2841^{a}	0.31±0.04^{ab}	9.94±1.17^{a}
C25+DB75	33763±4196^{a}	0.83±0.10^{a}	0.65±0.036^{a}	22163±3705^{a}	18718±5069^{a}	0.35±0.04^{a}	11.06±1.73^{a}
DB100	ND	ND	ND	ND	ND	ND	ND

Note: Values are presented as mean±standard deviation. Values with different superscripts within the same column are significantly different (p<0.05). C100 (100% C); C75+DB25 (25% DB); C50+DB50 (50% DB); C25+DB75 (75% DB); DB100 (100% DB) where C= chicken; DB= dried bean curd; ND= no data

Table 6. The sensory evaluation of chicken patties and hybrid chicken patties with DB as a meat substitute

Sample	Color	Aroma	Texture	Juiciness	Flavor	Overall acceptability
C100	6.44±1.62^{b}	6.84±1.38^{a}	6.00±1.71^{b}	5.52±1.88^{b}	6.10±1.59^{b}	6.40±1.41^{b}
C75+DB25	7.02±1.15^{ab}	6.98±1.35^{a}	6.42±1.51^{b}	5.56±1.66^{b}	6.36±1.43^{ab}	6.58±1.23^{b}
C50+DB50	7.28±1.43^{a}	7.14±1.40^{a}	7.48±1.27^{a}	6.80±1.49^{a}	7.16±1.28^{a}	7.32±1.08^{a}
C25+DB75	7.52±1.15^{a}	6.76±1.49^{a}	6.22±1.73^{b}	5.56±1.64^{b}	5.64±1.87^{b}	6.18±1.52^{b}
DB100	ND	ND	ND	ND	ND	ND

Note: Values are presented as mean±standard deviation. Values with different superscripts within the same column are significantly different (p<0.05). C100 (100% C); C75+DB25 (25% DB); C50+DB50 (50% DB); C25+DB75 (75% DB); DB100 (100% DB) where C= chicken; DB= dried bean curd; ND= no data



Note: A= C100 (100% C); B= C75+DB25 (25% DB); C= C50+DB50 (50% DB); D= C25+DB75 (75% DB); E= DB100 (100% DB) where C= chicken; DB= dried bean curd

Figure 2. The microstructure images of chicken patties and hybrid chicken patties (250× magnification

Sample C25+DB75 exhibited larger pores, but it also showed high emulsion stability, suggesting that emulsion stability was influenced by factors beyond the presence and size of pores, such as protein-protein interactions, interfacial stabilization, and the ability of the protein network to immobilize water and fat.

CONCLUSION

The inclusion of DB in the chicken patties as a meat substitute is promising. In conclusion, formulation C50+DB50 exhibited the highest overall acceptance (7.32) and the lowest cooking loss (23.77%) among all tested samples. Despite the total fluid released and WHC reported, C50+DB50 showed lower fluid loss than C100 and comparable WHC, making it a better quality product than C100. The results suggest that DB could be used as a meat alternative.

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REFERENCES

Allen, A. M., & Hof, A. R. (2019). Paying the price for the meat we eat. *Environmental Science and Policy*, *97*, 90–94. https://doi.org/10.1016/j.envsci.2019.04.010

AOAC International. (2006). Ash Determination (AOAC Official Method 942.05). *Official Methods of Analysis* (17th ed.). Gaithersburg, USA: AOAC International

AOAC International. (2006). Crude Protein Meat and Meat Products Including Pet Foods (AOAC Official Method 992.15). *Official Methods of Analysis* (17th ed.). Gaithersburg, USA: AOAC International

AOAC International. (2006). Moisture (M) (AOAC Official Method 934.01). *Official Methods of Analysis* (17th ed.). Gaithersburg, USA: AOAC International

AOAC International. (2006). Total Fat Foods (AOAC Official Method 983.23). *Official Methods of Analysis* (17th ed.). Gaithersburg, USA: AOAC International

Basri, N., Ming, F., Ishamri, I., & Ismail-Fitry, M. R. (2024). Comparison of patties produced using meat from various animal species with black-eyed peas as the partial meat substitute. *Malaysian Journal of Analytical Science*, *28*(4), 812–827.

Benamirouche, K., Baazize-Ammi, D., Hezil, N., Djezzar, R., & Niar, A. (2020). Effect of probiotics and Yucca schidigera extract supplementation on broiler meat quality. *Acta Scientiarum*, *42*, 1–9. https://doi.org/10.4025/actascianimsci.v42i1.48006

Bi, J., Zhang, J., Chen, Z., Li, Y., Obadi, M., Liu, W., Qin, R., Zhang, L., & He, H. (2024). Quality variation analysis and rehydration kinetics modeling of yuba subjecting to three different drying process. *Food Chemistry: X*, *24*, 101987. https://doi.org/10.1016/j.fochx.2024.101987

Cabi, A., Saricoban, C., & Unal, K. (2022). The effect of dried peach leaves powders with different methods on lipid oxidation, textural and sensory properties of patties. *Selcuk Journal of Agriculture and Food Sciences*, *36*(1), 114–119. https://doi.org/10.15316/SJAFS.2022.016

Chandler, S. L., & McSweeney, M. B. (2022). Characterizing the properties of hybrid meat burgers made with pulses and chicken. *International Journal of Gastronomy and Food Science*, *27*, 100492. https://doi.org/10.1016/j.ijgfs.2022.100492

Chen, Y., Yamaguchi, S., & Ono, T. (2009). Mechanism of the chemical composition changes of yuba prepared by a laboratory processing method. *Journal of Agricultural and Food Chemistry*, *57*, 3831–3836. https://doi.org/10.1021/jf8035269

Chin, S. W., Baier, S. K., Stokes, J. R., & Smyth, H. E. (2024). Evaluating the sensory properties of hybrid (meat and plant-based) burger patties. *Journal of Texture Studies, 55,* 1–15. https://doi.org/10.1111/jtxs.12819

Du, Q., Tu, M., Liu, J., Ding, Y., Zeng, X., & Pan, D. (2023). Plant-based meat analogs and fat substitutes, structuring technology and protein digestion: A review. *Food Research International*, *170*, 112959. https://doi.org/10.1016/j.foodres.2023.112959

Faridah, M. R., Yusoff, M. M., Rozzamri, A., Zunairah, W., Ibadullah, W., & Ismail-Fitry, M. R. (2023). Effect of palm-based shortenings of various melting ranges as animal fat replacers on the physicochemical properties and emulsion stability of chicken meat emulsion. *Foods*, *12*, 597. https://doi.org/10.3390/ foods12030597

Flores, M., Hernán, A., Salvador, A., & Belloch, C. (2023). Influence of soaking and solvent extraction for deodorization of texturized pea

protein isolate on the formulation and properties of hybrid meat patties. *Journal of the Science of Food and Agriculture, 103*(6), 2806-2814. https://doi.org/10.1002/jsfa.12453

Ismail, I., Hwang, Y., & Joo, S. (2020). Meat analog as future food: A review. *Journal of Animal Science and Technology*, *62*(2), 111–120. https://doi.org/10.5187/jast.2020.62.2.111

Ismail, N. A., Bakar, J., Sazili, A. Q., & Ismail-Fitry, M. R. (2021). Effect of different levels of fat, sodium chloride, and sodium tripolyphosphate on the physicochemical and microstructure properties of Jamnapari goat meat emulsion modelling system. *International Food Research Journal*, *28*(5), 916–925. https://doi.org/10.47836/ifrj.28.5.04

Kea, T., Hun, S., & Rahman, A. (2025). Plant-based burger patties : effect of chickpea and textured vegetable protein concentrations on their properties and in vitro digestibility. *Applied Food Research*, *5*, 101270. https://doi.org/10.1016/j.afres.2025.101270

Kyriakopoulou, K., Keppler, J. K., & van der Goot, A. J. (2021). Functionality of ingredients and additives in plant-based meat analogues. *Foods*, *10*, 600. https://doi.org/10.3390/ foods10030600

Lee, G., Jung, M., Kim, B., & Jun, J. (2024). Effects of sodium alginate on the physical properties and storage stability of freeze-dried tofu coagulated with crab shell extract. *Foods*, *13*, 74. https://doi.org/10.3390/foods13010074

Lee, J., & Han, J. (2024). Exploring the potential of bacterial cellulose paste as a fat replacer for low-fat plant-based hamburger patties. *Food Research International*, *176*, 113832. https://doi.org/10.1016/j.foodres.2023.113832

Li, L., Sun, M., Sun, J., Kong, H., Zhong, W., & Wang, H. (2019). The effect of dried beancurd on bone mineral density in postmenopausal Chinese women: A 2-year randomized controlled. *Calcified Tissue International*, *105*, 573–581. https://doi.org/10.1007/s00223-019-00604-2

Lin, W., & Barbut, S. (2024). Hybrid meat batter system: Effects of plant proteins (pea, brown rice, faba bean) and concentrations (3−12%) on texture, microstructure, rheology, water binding, and color. *Poultry Science*, *103*, 103822. https://doi.org/10.1016/j.psj.2024.103822

Macharáčková, B., Bogdanovičová, K., Ježek, F., Bednář, J., Haruštiaková, D., & Kameník, J. (2021). Cooking loss in retail beef cuts:vThe effect of muscle type, sex, ageing, pH, salt and cooking method. *Meat Science*, *171*, 108270. https://doi.org/10.1016/j.meatsci.2020.108270

Ming-Min, W., & Ismail-Fitry, M. R. (2023). Physicochemical, rheological and microstructural properties of chicken meat emulsion with the addition of Chinese yam (*Dioscorea polystachya*) and arrowroot (*Maranta arundinacea*) as meat substitutes. *Future Foods*, *7*, 100221. https://doi.org/10.1016/j.fufo.2023.100221

Park, G., Oh, S., Park, S., Kim, Y., Park, Y., Kim, Y., Lee, J., Lee, H., & Choi, J. (2023). Physicochemical characteristics and storage stability of hybrid beef patty using shiitake mushroom (*Lentinus edodes*). *Journal of Food Quality*, *2023*, 7239709. https://doi.org/10.1155/2023/7239709

Semba, R. D., Ramsing, R., Rahman, N., Kraemer, K., & Bloem, M. W. (2021). Legumes as a sustainable source of protein in human diets. *Global Food Security*, *28*, 100520. https://doi.org/10.1016/j.gfs.2021.100520

Serdaroğlu, M., Kavuşan, H. S., İpek, G., & Öztürk, B. (2018). Evaluation of the quality of beef patties formulated with dried pumpkin pulp and seed. *Korean Journal for Food Science of Animal Resources*, *38*(1), 1–13. https://doi.org/10.5851/kosfa.2018.38.1.001

Shen, Y., Hong, S., Du, Z., Chao, M., Quinn, T. O., & Li, Y. (2022). Effect of adding modified pea protein as functional extender on the physical and sensory properties of beef patties. *LWT - Food Science and Technology*, *154*, 1–8. https://doi.org/10.1016/j.lwt.2021.112774

Souppez, J. R. G., Dages, B. A. S., Pavar, G. S., Fabian, J., Thomas, J. M., & Theodosiou, E. (2025). Mechanical properties and texture profile analysis of beef burgers and plant-based analogues. *Journal of Food Engineering*, *385*, 112259. https://doi.org/10.1016/j.jfoodeng.2024.112259

Vu, G., Zhou, H., & McClements, D. J. (2022). Impact of cooking method on properties of beef and plant-based burgers: Appearance, texture, thermal properties, and shrinkage. *Journal of Agriculture and Food Research*, *9*, 100355. https://doi.org/10.1016/j.jafr.2022.100355

Wahab, N. Q. A., Pangestika, L. M. W., & Ismail-Fitry, M. R. (2024). Partial incorporation of black jelly mushroom (*Auricularia polytricha*) as a plant-based ingredient in the production of hybrid patties using meat from different species. *International Journal of Food Science and Technology*, *59*(11), 8786–8795. https://doi.org/10.1111/ijfs.17516

Wan Rosli, W., Solihah, M., Aishah, N., Nik

Fakuruddin, N., & Mohsin, S. S. (2011). Colour, textural properties, cooking characteristics and fibre content of chicken patty added with oyster mushroom (*Pleurotus sajor-caju*). *International Food Research Journal*, *18*, 621–627.

Wei, A. S., Brishti, F. H., Sani, M. S. A., Ishamri, I., Sarbon, N. M., & Ismail-Fitry, M. R. (2024). Methylcellulose replacement with different enzymatically treated plant fibres as a binder in the production of plant-based meat patties. *LWT - Food Science and Technology*, *201*, 116231. https://doi.org/10.1016/j.lwt.2024.116231

Xiao, T., Ma, X., Hu, H., Xiang, F., Zhang, X., Zheng, Y., & Dong, H. (2025). Advances in emulsion stability : A review on mechanisms, role of emulsifiers, and applications in food. *Food Chemistry: X*, *29*, 102792. https://doi.org/10.1016/j.fochx.2025.102792

Xiong, Y. L. (2005). Role of myofibrillar proteins in water-binding in brine-enhanced meats. *Food Research International*, *38*, 281–287. https://doi.org/10.1016/j.foodres.2004.03.013