

Quality evaluation of bean curd utilizing pigeon pea (*Cajanus cajan*) as an alternative to soybeans (*Glycine max*)

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Abstract

The global demand for sustainable and affordable plant-based protein sources is increasing due to rising awareness of health benefits and environmental concerns. Pigeon pea (*Cajanus cajan*), a leguminous crop, presents a potential alternative because of its affordability, resilience, and nutritional profile, which includes proteins, fiber, and bioactive compounds such as anthocyanins and tannins. This study aimed to develop a bean curd using pigeon pea as a partial or complete substitute for soybeans (*Glycine max*), a staple ingredient in plant-based products. Five formulations were prepared: control (0% pigeon pea, 100% soybeans), F1 (25% pigeon pea, 75% soybeans), F2 (50% pigeon pea, 50% soybeans), F3 (75% pigeon pea, 25% soybeans), F4 (100% pigeon pea, 0% soybeans) and evaluated for physical properties, proximate composition, and sensory characteristics. Color analysis revealed a significant reduction in lightness (L^* value) with increasing pigeon pea content, attributed to the presence of natural pigments such as anthocyanins and tannins. The a^* values shifted towards red, while b^* values, representing yellowness, decreased with pigeon pea incorporation. Texture profile analysis indicated that formulations with up to 50% pigeon pea substitution retained texture and taste like the control. However, higher substitution levels of pigeon pea resulted in diminished sensory scores, primarily due to the darker color and stronger beany flavor. These composition profiles established the nutritional variation and potential dietary use of the formulations. Both F1 and F2 were found to be acceptable to consumers and not significantly different from the control. The results indicated that pigeon pea may be used as a partial soybean substitute in bean curd production, offering healthy, low-fat food with acceptable consumer acceptance at levels of moderate substitution.

1. Introduction

In recent years, pea protein has become increasingly popular in the food industry due to concerns arising from animal-based proteins, including higher costs, changing consumer attitudes, and increased greenhouse gas emissions from livestock, affecting ecological systems (Maningat *et al.*, 2021).

Pigeon pea (*Cajanus cajan*), a plant-based protein, is known for its potential to address global protein-energy malnutrition (PEM) worldwide due to its bioactive compounds to treat various diseases (Mathew *et al.*, 2017; Cirunay *et al.*, 2023). These have mostly been

identified as phenolic compounds, whose health benefits involve anti-tumor activity and an ability to lower the risk of cancer (Hertzler *et al.*, 2020), also demonstrate antiviral, anti-inflammatory, antioxidant, hypocholesterolemic, and hypoglycemic activities, which may decrease type 2 diabetes risk (Malik *et al.*, 2016; Ariviani *et al.*, 2021; Gai *et al.*, 2021; A'yuni *et al.*, 2022; Cai *et al.*, 2023).

Aside from being an underutilized tropical legume with great ability to withstand drought, pigeon pea should also be grown as an alternative superfood substitute, such as the already famous soybean (*Glycine*

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max) source, tofu. Tofu is a nutritious, protein-rich food with low fat content compared to meat that can be a staple food and a cheap source of protein in developing countries where PEM is prevalent (Siddiq *et al.*, 2010).

According to Locali-Pereira *et al.* (2023), pigeon pea seeds have 18 to 28 wt % protein (dry basis), with leaves also having high protein content at 19.4 wt %. The amino acid profile of pigeon pea seeds is like soybeans, with 43 wt % essential amino acids like valine, leucine, isoleucine, glutamic acid, phenylalanine, and lysine. Pigeon peas have higher levels of phenylalanine, lysine, and glutamic acid compared to chickpeas.

Pigeon pea locally known as 'kardis' and 'kadyos' as a climate-resilient crop in the Philippines. It is used for various purposes, such as food, feed, fertilizer, and fuel wood, which makes it extremely valuable to smallholder farmers. Its deep-rooting capability and resilience to adverse conditions make it a potential alternative legume crops, which ensure food and nutritional security. Pigeon pea also yields more units of nitrogen per plant biomass than most legumes and can nodulate in a wide range of soil, even if the number of nodules is less (Bernabe, 2021).

Relative to the economic and health benefits of pigeon pea as an alternative plant-based protein, this study was undertaken to formulate a composite bean curd consisting of soybean and pigeon pea. The bean curd formulation was evaluated based on its physical properties, proximate composition, and sensory attributes, using pigeon pea as a partial substitute for soybeans. The findings aimed to enhance the sustainability of plant-based proteins, address consumer protein requirements, and improve bean curd production for both health and economic benefits.

2. Materials and methods

Dried pigeon pea seeds were sourced from Kitchen Happiness VTN Food Products, located on Ipil St., Tabuc, Roxas City, Capiz. Dried soybeans and $\geq 98\%$ calcium sulfate were obtained from the Public Market of Tarlac City.

2.1 Process for making bean curd formulation

The process flow of bean curd production was adapted from Zhang *et al.* (2017) with slight modifications. Dried pigeon pea and soybeans were combined and soaked for 10-12 h at room temperature. After soaking, the beans were drained for 10 min. Ground in a kitchen blender using a 1:7 ratio of beans to distilled water by weight and volume to ensure optimal protein extraction and yield. The mixture was filtered using cheesecloth before cooking. It was boiled at 100°C

for 10 min, then filtered to remove impurities. Coagulation was performed using $\geq 98\%$ calcium sulfate at a concentration of 20% based on the total weight of dried beans. The mixture was left undisturbed in a clean container for 10 min. After coagulation, the bean curd was pressed into a mold for 20 min, then cut and weighed to the desired size before packaging for storage. Five formulations of bean curd were produced, compared to a control with 0% pigeon pea and 100% soybeans. Formula 1 (F1) contained 25% pigeon pea and 75% soybeans. Formula 2 (F2) had an equal ratio of 50% pigeon pea and 50% soybeans. Formula 3 (F3) included 75% pigeon pea and 25% soybeans. Formula 4 (F4) was made with 100% pigeon pea and 0% soybeans.

2.2 Physical properties of the various bean curd formulations

The physical properties, specifically color and texture profile of various bean curd formulations were evaluated using the in-house procedure of the Philippines Department of Science and Technology (DOST), Industrial Technology Development Institute (ITDI) – Food Processing Division (FPD) at the DOST Compound, General Santos Avenue, Bicutan, Taguig City. Color values ($L^*a^*b^*$) were measured in triplicate using a MINOLTA CR-300 Chroma Meter. Texture profile analysis was performed using a Lloyd Texturometer (Model #TA Plus) with 75 mm round compression platens, a test speed of 200 mm/minute, a trigger force of 0.005 kgf, and 50% sample compression.

2.3 Proximate composition analysis

2.3.1. Moisture content

Moisture content was determined by drying the samples at 105°C in a hot air oven (AOAC Official Method 952.08).

2.3.2 Ash

Ash content was determined by gravimetric procedure (AOAC Official Method 930.30).

2.3.3 Crude protein

Crude protein content was determined using the Kjeldahl method (AOAC Official Method 992.23).

2.3.4 Total fat

Total fat content was determined using the acid hydrolysis method (AOAC Official Method 948.15).

2.3.5 Carbohydrates

Carbohydrate content was calculated by difference using the following formula:

Carbohydrates (%) = 100 – (% moisture content + % ash + % protein + % fat)

2.4 Sensory evaluation

All formulations of bean curds were evaluated for consumer acceptability in terms of color, texture, taste, and overall acceptability using a 9-point hedonic scale. The sensory evaluation aimed to assess consumer acceptance of the different formulations. The scale ranged from 9 (extremely liked) to 1 (extremely disliked), with 5 representing a neutral opinion. The evaluation was conducted at the Villa Lucinda Extension Campus of Tarlac State University sensorium. Participated by sixty (60) College of Science students, aged 18 to 22 years, with an equal distribution of 30 males and 30 females.

2.5 Statistical analysis

The data were analyzed using IBM SPSS Statistics version 26 (SPSS Inc., Chicago, USA) with a One-Way Analysis of Variance (ANOVA) at a significance level of $p < 0.05$. Tukey's test was applied to identify significant differences between and among the various formulations of bean curds. Sensory evaluation data were analyzed using Friedman's test, followed by the Wilcoxon test to further determine significant differences between and among samples.

3. Results and discussion

3.1 Physical properties of bean curd

3.1.1 Color

Color analysis in terms of lightness (L^*), redness (a^*), and yellowness (b^*) was done to determine the significant difference between and among formulations in terms of color perceived. Each formulation, together with the control, had the same amount of sample subjected to testing, also reproduced in triplicate to obtain average results. This was to verify the replicability or reproducibility of the different proportions of pigeon pea and soybean curd. Table 1 shows the color analyses (L^* , a^* , b^*) of different proportions of pigeon pea and soybean curd.

The L^* value indicates lightness on a scale from 0 (black) to 100 (white). A decrease in the L^* value, denoting lower lightness, may be attributed to the increased substitution of pigeon pea. The legume contains dark pigments such as anthocyanins and tannins, which have been reported to result in decreased light reflectance. Tannins are usually reported to impact coloration and can suppress light reflection (Price, 1980; Nix *et al.*, 2015). Analysis of the a^* value, representing the red-to-green color axis, exhibited a statistically

Table 1. Color analysis of different proportions of pigeon pea and soybean curd.

Sample	Color score		
	(L)	(a)	(b)
Control (100%SB)	77.56 ± 1.97 ^a	-0.62 ± 0.16 ^a	18.32 ± 0.63 ^a
F1-75% SB 25% PP	71.01 ± 1.68 ^b	1.28 ± 0.15 ^a	6.90 ± 0.35 ^b
F2-50% SB 50% PP	63.70 ± 1.72 ^c	2.99 ± 0.17 ^a	7.69 ± 0.45 ^c
F3-25% SB 75% PP	63.39 ± 2.80 ^d	3.99 ± 0.37 ^b	7.29 ± 0.56 ^{de}
F4-0% SB 100% PP	58.55 ± 0.61 ^e	6.02 ± 0.20 ^c	8.73 ± 0.36 ^c

Values are presented as mean ± SD. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$).



Figure 1. Color and texture profiles of various bean curd formulations.

significantly difference ($p < 0.05$) across all formulations. The control sample (-0.62 ± 0.16) exhibited a negative a^* value, showing greenish color characteristic of soybean curd. With increasing concentrations of pigeon pea, the a^* values significantly shifted towards positive values, reflecting an increase in redness. The recorded a^* values were as follows: F1 (+1.28 ± 0.15), F2 (+2.99 ± 0.17), F3 (+3.99 ± 0.37), and F4 (+6.02 ± 0.20). The increase in redness with higher levels of pigeon pea substitution is due to the natural reddish pigments in pigeon pea becoming more noticeable. This result supports earlier studies that showed how adding legumes can affect the color of plant-based yogurt alternatives and influence consumer acceptance (Boeck *et al.*, 2021). The b^* values, which indicate the yellow-to-blue color range, also showed significant differences among the samples. The control sample (+18.32 ± 0.60) had the highest b^* value, showing a strong yellow color. However, as more pigeon pea was added, the b^* values dropped, indicating a decrease in yellow coloration. While F1 (+6.90 ± 0.35), F2 (+7.69 ± 0.45), and F3 (+7.29 ± 0.56) were not significantly different from each other, showed significant differences compared to the control. Notably, F4 (+8.73 ± 0.36) displayed a slight increase compared to F3, but still maintained a lower b^* value than the control. The observed reduction in yellow coloration with pigeon pea substitution can be attributed to decreased fat content and the presence of darker pigments that mask the yellow component. The results indicated an increase in lightness and yellowness, and a decrease in redness (Sachanarula *et al.*, 2022). This suggests that incorporating pigeon pea affects the color profile of the final product, likely due to its pigment composition, as shown in Figure 1.

3.1.2 Texture profile analysis

Texture profile analysis was conducted to determine significant differences among the formulations in terms of texture. Table 2 shows the mean values for texture parameters of the different proportions of pigeon pea and soybean curd. The parameters measured were hardness, springiness, gumminess, and chewiness. Each formulation, including the control, used the same sample quantity and was evaluated under the same conditions. Hardness, defined as the peak force during the first compression, serves as a key indicator of a product's structural integrity. The mean hardness values for the control (1.225), F1 (1.161), and F2 (1.003) showed no significant difference ($p>0.05$), indicating that up to 50% pigeon pea substitution maintained comparable hardness to the control. However, F3 (0.770) and F4 (0.284) showed significant decreases ($p<0.05$) compared to all other samples. As the proportion of pigeon pea increased, the hardness values decreased. This reduction may be due to differences in protein composition. Soy proteins, rich in globulins, form stronger gel networks, resulting in firmer textures (Zhang *et al.*, 2024). In contrast, pigeon pea proteins produce softer gels due to their weaker gelation properties (Onimawo and Akpojovwo, 2006).

Springiness measures a sample's ability to return to its original shape after compression. The control (0.647) and F1 (0.651) showed no significant difference, indicating that up to 25% of pigeon pea substitution maintained the elasticity. However, F2 (0.593), F3 (0.382), and F4 (0.317) showed significantly reduced springiness ($p<0.05$). The decline may be linked to the limited gel-forming capacity of pigeon pea proteins compared to soy, which forms more elastic matrices (Fernandez *et al.*, 2021).

Gumminess reflects the energy needed to break down a semi-solid food. The control (0.279) and F1 (0.285) showed no significant difference. In contrast, F2 (0.179), F3 (0.076), and F4 (0.036) differed significantly from the control and F1 ($p<0.05$). The decline in gumminess corresponds to a weakening of the curd's internal structure, resulting in a softer and less cohesive

product, as shown in Figure 1.

Chewiness, calculated by multiplying gumminess and springiness, applies to solid foods. The control (1.399) and F1 (1.201) had no significant difference, showing that a 25% substitution preserved desirable textural properties. F3 (0.213) and F4 (0.093) showed significantly lower chewiness, while F2 (0.612) presented intermediate values, differing from other formulations. The decrease in chewiness at higher substitution levels may result from the weaker protein networks of pigeon pea, which lead to a more fragile structure, as shown in Figure 1. Increased levels of pigeon pea reduce gelation capacity compared to other legumes, contributing to a softer texture (Onimawo and Akpojovwo, 2006).

3.2 Proximate composition analyses

The proximate composition results of various formulations of bean curds (mixture of pigeon pea and soybean curd) are presented in Table 3. The parameters analyzed include moisture content, ash, crude protein, total fat, and carbohydrate content.

The control sample (100% soybean curd) had a moisture content of $69.64\pm2.23\%$. In contrast, F3 (75% pigeon pea) and F4 (100% pigeon pea) exhibited significantly higher values at $81.62\pm2.05\%$ and $73.97\pm1.84\%$, respectively ($p>0.05$). Moisture content increased significantly with higher levels of pigeon pea substitution (Sachanarula *et al.*, 2022). This increase can be attributed to the presence of polysaccharides in pigeon peas, which enhance water retention (Sing and Kotwaliwale, 2010). These water-binding properties contribute to higher moisture levels in legume-based food products.

Ash content, which reflects the total mineral content, decreased significantly as the proportion of pigeon pea increased. The control sample showed the highest ash content ($14.37\pm0.53\%$), while F4 recorded the lowest value ($4.26\pm0.11\%$). This reduction is likely due to the lower mineral content per unit weight in certain pigeon pea varieties, compared to soybeans.

Table 2. Texture profile analysis based on mean scores of different proportions of pigeon pea and soybean curd.

Sample	Texture profile analysis (TPA)			
	Hardness (kg)	Springiness index	Gumminess (kgf)	Chewiness (kgf mm)
Control (100%SB)	1.225 ± 0.455^a	0.647 ± 0.040^a	0.279 ± 0.088^a	1.399 ± 0.386^a
F1-75% SB 25% PP	1.161 ± 0.153^a	0.651 ± 0.084^a	0.285 ± 0.047^a	1.201 ± 0.247^a
F2-50% SB 50% PP	1.003 ± 0.407^a	0.593 ± 0.072^b	0.179 ± 0.074^b	0.811 ± 0.347^b
F3-25% SB 75% PP	0.770 ± 0.140^{ab}	0.382 ± 0.061^c	0.076 ± 0.030^c	0.213 ± 0.100^c
F4-0% SB 100% PP	0.284 ± 0.161^b	0.317 ± 0.123^d	0.036 ± 0.020^d	0.093 ± 0.075^c

Values are presented as mean $\pm$ SD. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

Table 3. Proximate analyses mean scores of different proportions of pigeon pea and soybean curd.

Sample	Proximate composition				
	Moisture content	Ash	Crude protein	Total fat	Carbohydrate*
Control (100%SB)	69.64±2.23 ^a	14.37±0.53 ^a	10.46±0.37 ^a	5.16±0.14 ^a	0.37±0.02 ^a
F1-75% SB 25% PP	71.15±3.02 ^a	12.40±0.45 ^b	8.69±0.12 ^b	4.12±0.12 ^b	3.64±0.18 ^b
F2-50% SB 50% PP	72.78±2.14 ^{ac}	10.17±0.32 ^c	9.12±0.14 ^{bc}	2.64±0.08 ^c	5.29 ±0.26 ^c
F3-25% SB 75% PP	81.62±2.05 ^{bc}	6.51±0.18 ^d	8.01±0.10 ^d	3.86±0.11 ^d	*ND ^d
F4-0% SB 100% PP	73.97±1.84 ^{ac}	4.26±0.11 ^e	7.56±0.10 ^{de}	1.77±0.06 ^e	12.44±0.62 ^e

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$).

Crude protein content also declined with increased pigeon pea incorporation. The control sample had 10.46±0.37% protein, while F4 showed a significantly lower value of 7.56±0.10%. However, moderate substitution levels, such as in F2 (50% pigeon pea), maintained a relatively high protein content (9.12±0.14%), indicating its potential as a partial soybean substitute. Legumes, including pigeon pea, are known for being good protein sources (Haji *et al.*, 2024). Additionally, combining legumes or pairing them with cereals can complement amino acid profiles, creating a more balanced and nutritionally complete protein source (Onweluzo and Nnamuchi, 2009).

A significant reduction in fat content was observed with increasing levels of pigeon pea. The control sample had the highest fat content (5.16±0.14%), while F4 recorded the lowest (1.77±0.06%). This trend is observed because soybeans naturally contain higher levels of fat, particularly unsaturated fats, compared to pigeon peas, which have a lower lipid content. The reduction in fat content with greater pigeon pea substitution suggests that such formulations could be suitable as low-fat alternatives for health-conscious consumers.

Carbohydrate content increased significantly with the addition of pigeon pea. The control sample had the lowest carbohydrate content (0.37±0.02%), while F4 exhibited the highest (12.44±0.62%). Pigeon peas are rich in complex carbohydrates, including dietary fiber and resistant starch. They also contain oligosaccharides, essential vitamins, and minerals, making them nutritionally valuable (Khan *et al.*, 2007). The rise in carbohydrate content may also offer functional benefits, such as improved digestive health and enhanced satiety.

3.3 Sensory evaluation of bean curd

Sensory evaluation was conducted using a 9-point hedonic scale to assess the significant difference in consumer acceptability of various bean curd formulations, based on color, texture, taste, and overall acceptability. Bean curd was mixed with miso soup before evaluation. Table 4 presents the sensory evaluation results from sixty panelists.

As shown in Table 4, the sensory evaluation results indicate a significant difference in color perception across the formulations. The control sample (100% soybean curd) received the highest color score (8.77±0.21), described as "liked very much." As the proportion of pigeon pea increased, the color scores significantly declined ($p < 0.05$). F4 (100% pigeon pea) received the lowest score (5.48±0.27), with panelists expressing a neutral preference, described as "neither like nor dislike." This suggests that panelists noticed noticeable differences in the color of the various bean curd formulations.

The color of food and beverages is often strongly associated with consumer expectations of taste, flavor, and texture. This is supported by research showing that visual cues, particularly color, significantly influence consumers' sensory expectations and perceptions. Color serves as a critical sensory cue, shaping expectations about the taste and flavor of food and beverages (Spence, 2015). The darkening effect observed in formulations with higher pigeon pea content can be attributed to the presence of natural pigments in pigeon peas, such as anthocyanins and tannins, which contribute to darker hues. The impact of color changes due to legume incorporation on consumer preference, acceptability, and overall appearance significantly influences consumer perceptions (Carneiro *et al.*, 2022).

Significant differences were also noted in texture scores among the samples. The control sample had the highest texture score (8.77±0.19), while F4 showed the lowest score (5.21±0.33). Texture acceptability declined with higher pigeon pea content, resulting in less favorable feedback from panelists. However, F1 (75% soybean, 25% pigeon pea) maintained a high acceptability (8.23±0.20), suggesting that partial substitution of pigeon pea preserved an acceptable curd texture. The decline in texture acceptability in formulations with higher pigeon pea content can be linked to the compositional differences between pigeon peas and soybeans, particularly in terms of protein and fat content. Hardness and water content can also affect consumer expectations on mouthfeel, texture, and taste

Table 4. Result of the sensory evaluation of bean curd.

Sample	Color attribute*		Texture attribute*		Taste attribute*		General acceptability	
	Mean ¹	Description ²	Mean ¹	Description ²	Mean ¹	Description ²	Mean ¹	Description ²
Control (100% SB)	8.77 ^a	Like very much	8.77 ^a	Like very much	8.27 ^a	Like very much	8.48 ^a	Like very much
F1-75% SB 25% PP	8.38 ^b	Like very much	8.23 ^b	Like very much	8.40 ^a	Like very much	8.18 ^a	Like very much
F2-50% SB 50% PP	6.30 ^d	Like slightly	7.50 ^c	Like Moderately	7.83 ^a	Like Moderately	7.73 ^a	Like Moderately
F3-25% SB 75% PP	7.68 ^c	Like Moderately	6.27 ^d	Like slightly	6.63 ^b	Like slightly	6.92 ^b	Like Moderately
F4-0% SB 100% PP	5.48 ^e	Neither like nor	5.21 ^e	Neither like nor	5.92 ^c	Neither like nor	6.37 ^c	Like slightly

Values are presented as means of sixty (60) determinations. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$).

(Wang *et al.*, 2019).

Taste scores did not show significant differences between the control, F1, and F2, showing that partial replacement of soybeans with pigeon peas did not compromise taste acceptability ($p > 0.05$). F1 recorded a comparable taste score (8.40 ± 0.17) to the control (8.27 ± 0.20). However, taste acceptability significantly declined in F3 (6.63 ± 0.24) and F4 (5.92 ± 0.29), where higher pigeon pea substitution resulted in a stronger beany or earthy flavor. Legumes like pigeon peas are known for their distinct beany taste, often due to volatile compounds such as hexanal and aldehydes, which may not appeal to all consumers. The presence of beany odors due to lipoxygenase (LOX) activity usually limits the overall quality and acceptability of soy-based products (Makinen *et al.*, 2015). Strategies such as flavor masking, soaking, or fermentation can mitigate these undesirable flavors and should be considered in future product development.

Sensory descriptive analysis of food products helps show key attributes for consumer satisfaction and market success (Sirangelo, 2019). General acceptability followed a similar trend to the other sensory parameters. The control sample had the highest acceptability score (8.48 ± 0.18), followed by F1 (8.18 ± 0.22), with no significant difference from the control. This suggests that a 25%-50% pigeon pea substitution is a potential option for maintaining high consumer acceptance. However, formulations with higher pigeon pea content, such as F3 and F4, received significantly lower acceptability scores (6.92 ± 0.25 and 6.37 ± 0.30 , respectively).

The reduction in acceptability for F3 and F4 may be linked to the combined effect of darker color, inferior texture, and stronger beany taste. Future reformulations could explore optimal blending ratios or the addition of flavor enhancers to improve the sensory attributes of higher pigeon pea formulations.

4. Conclusion

The incorporation of pigeon pea into bean curd formulations significantly influenced color, texture

profile analysis, proximate composition, and sensory attributes. Moderate substitution levels (25%–50%) showed favorable texture profile properties and sensory attributes' acceptability, as well as providing nutritional benefits such as higher moisture and carbohydrate content, along with lower fat levels. However, higher substitution levels (75% and 100%) resulted in reduced texture quality, darker color, and a stronger beany flavor, which negatively impacted consumers' acceptability. These findings suggest that the partial substitution of pigeon pea is a promising approach for developing nutritious, low-fat, and acceptable plant-based curd products. This strategy supports the development of diverse and sustainable protein alternatives in food systems.

Conflict of interest

The authors declare no conflict of interest.

References

- A'yuni, N.R.L., Marsono, Y., Marseno, D.W. and Triwitono, P. (2022). Physical characteristics, nutrients, and antinutrient composition of pigeon pea (*Cajanus cajan* (L.) Mill sp.) grown in Indonesia. *Food Research*, 6(2), 53-63. [https://doi.org/10.26656/fr.2017.6\(2\).172](https://doi.org/10.26656/fr.2017.6(2).172)
- Ariviani, S., Hapsari, K.C., Fauza, G., Ishartani, D., Atmaka, W., Khasanah, L.U. and Siswanti. (2021). Evaluation of total phenolic content, antioxidant activity, germination power, and yield of pigeon pea (*Cajanus cajan*) sprouts elicited using various Naalginate levels with different elicitation durations. *Food Research*, 5(S2), 91-97. [https://doi.org/10.26656/fr.2017.5\(S2\).005](https://doi.org/10.26656/fr.2017.5(S2).005)
- AOAC INTERNATIONAL. (2016). Ash of soy protein products (AOAC Official Method 923.03). Official Methods of Analysis of AOAC International. 20th ed., p. 8. Gaithersburg, USA: AOAC INTERNATIONAL.
- AOAC INTERNATIONAL. (2016). Fat (crude) in soy protein products (AOAC Official Method 920.39C).

- Official Methods of Analysis of AOAC International. 20th ed., p. 5. Gaithersburg, USA: AOAC INTERNATIONAL.
- AOAC INTERNATIONAL. (2016). Moisture in soy protein products (AOAC Official Method 925.09). Official Methods of Analysis of AOAC International. 20th ed., p. 3. Gaithersburg, USA: AOAC INTERNATIONAL.
- AOAC INTERNATIONAL. (2016). Protein (crude) in soy protein products (AOAC Official Method 955.04D). Official Methods of Analysis of AOAC International. 20th ed., p. 12. Gaithersburg, USA: AOAC INTERNATIONAL.
- Bernabe, A. (2021). A promising vegetable pigeonpea (*Cajanus cajan* L.) variety released for Ilocos Region, Philippines. *East African Scholars Journal of Agriculture and Life Sciences*, 4(4), 89-95. <https://doi.org/10.36349/easjals.2021.v04i04.002>
- Boeck, T., Sahin, A.W., Zannini, E. and Arendt, E.K. (2021). Nutritional properties and health aspects of pulses and their use in plant-based yogurt alternatives. *Comprehensive Reviews in Food Science and Food Safety*, 20(4), 3858-3880. <https://doi.org/10.1111/1541-4337.12778>
- Cai, Y., Yang, X., Chen, S., Tian, K., Xu, S., Deng, R., Chen, M., Yang, Y. and Liu, T. (2023). Regular consumption of pickled vegetables and fermented bean curd reduces the risk of diabetes: A prospective cohort study. *Frontiers in Public Health*, 11, 1155989. <https://doi.org/10.3389/fpubh.2023.1155989>
- Carneiro, R., Adie, K., Yu, D., Beverly, M., Neill, C., Zhang, B., Kuhar, T., Rideout, S., Reiter, M., Huang, H., O'Keefe, S. and Duncan, S. (2022). Understanding the role of overall appearance and color in consumers' acceptability of Edamame. *Frontiers in Sustainable Food Systems*, 6, 738453. <https://doi.org/10.3389/fsufs.2022.738453>
- Cirunay, A., Sumague, M., Bautista, J. and Mopera, L. (2023). Microbiological, physico-chemical, and sensory quality of yoghurt supplemented with gelatinized pigeon pea (*Cajanus cajan* (L.) Mill sp.) flour. *Food Research*, 7(2), 341-347. [https://doi.org/10.26656/fr.2017.7\(2\).980](https://doi.org/10.26656/fr.2017.7(2).980)
- Fernandez, E.I., Chaves, M.G., Quiroga, A.V. and Avanza, M.V. (2021). Comparative study of structural and physicochemical properties of pigeon pea (*Cajanus cajan* L.) protein isolates and its major protein fractions. *Plant Foods for Human Nutrition*, 76(1), 37-45. <https://doi.org/10.1007/s11130-020-00871-7>
- Gai, Q., Jiao, J., Wang, X., Fu, Y., Lu, Y., Liu, J., Wang, Z.Y. and Xu, X.-J. (2021). Simultaneous quantification of eleven bioactive phenolic compounds in pigeon pea natural resources and in vitro cultures by ultra-high performance liquid chromatography coupled with triple quadrupole mass spectrometry (UPLC-QqQ-MS/MS). *Food Chemistry*, 335, 127602. <https://doi.org/10.1016/j.foodchem.2020.127602>
- Haji, A., Teka, T., Yirga B.T., Negasa Andersa, K., Desalegn Nekera, K., Geleta Abdi, G., Lema Abelti, A. and Makiso Urugo, M. (2024). Nutritional composition, bioactive compounds, food applications, and health benefits of pigeon pea (*Cajanus cajan* L. Mill sp.): a review. *Legume Science*, 6(2), e233. <https://doi.org/10.1002/leg3.233>
- Hertzler, S.R., Lieblein-Boff, J.C., Weiler, M. and Allgeier, C. (2020). Plant proteins: Assessing their nutritional quality and effects on health and physical function. *Nutrients*, 12(12), 3704. <https://doi.org/10.3390/nu12123704>
- Khan, A.R., Alam, S., Ali, S., Bibi, S. and Khalil, I.A. (2007). Dietary Fiber Profile of Food Legumes. *Sarhad Journal of Agriculture*, 23(3), 763-766.
- Locali-Pereira, A.R., Boire, A., Berton-Carabin, C., Taboga, S.R., Solé-Jamault, V. and Nicoletti, V.R. (2023). Pigeon pea, an emerging source of plant-based proteins. *ACS Food Science and Technology*, 3(11), 1777-1799. <https://doi.org/10.1021/acsfoodscitech.3c00268>
- Makinen, O.E., Wanhailinna, V., Zannini, E. and Arendt, E.K. (2015). Foods for special dietary needs: Non-dairy plant-based milk substitutes and fermented dairy-type products. *Critical Reviews in Food Science and Nutrition*, 56(3), 339-349. <https://doi.org/10.1080/10408398.2012.761950>
- Malik, V.S., Li, Y., Tobias, D.K., Pan, A. and Hu, F.B. (2016). Dietary protein intake and risk of type 2 diabetes in US men and women. *American Journal of Epidemiology*, 183(8), 715-728. <https://doi.org/10.1093/aje/kwv268>
- Maningat, C.C., Jeradechachai, T. and Buttshaw, M.R. (2021). Textured wheat and pea proteins for meat alternative applications. *Cereal Chemistry*, 99(1), 37-66. <https://doi.org/10.1002/cche.10503>
- Mathew, D., Lidiya John, P., Manila, T.M. Divyasree, P. and Sandhya Rajan, V.T.K. (2017). Therapeutic molecules for multiple human diseases identified from pigeon pea (*Cajanus cajan* L. Mill sp.) through GC-MS and molecular docking. *Food Science and Human Wellness*, 6(4), 202-216. <https://doi.org/10.1016/j.fshw.2017.09.003>
- Nix, A., Paull, C.A. and Colgrave, M. (2015). The

- flavonoid profile of pigeonpea, *Cajanus cajan*: A review. *SpringerPlus*, 4, 125. <https://doi.org/10.1186/s40064-015-0906-x>
- Onimawo, I. and Akpojovwo, A. (2006). Toasting (Dry heat) and nutrient composition, functional properties and antinutritional factors of pigeon pea (*Cajanus cajan*) flour. *Journal of Food Processing and Preservation*, 30(6), 742-753. <https://doi.org/10.1111/j.1745-4549.2006.00093.x>
- Onweluzo, J. and Nnamuchi, O. (2009). Production and evaluation of porridge-type breakfast products from *Treculia Africana* and sorghum Bicolor flours. *Pakistan Journal of Nutrition*, 8(6), 731-736. <https://doi.org/10.3923/pjn.2009.731.736>
- Price, M.L., Hagerman, A.E. and Butler, L.G. (1980). Tannin content of cowpeas, chickpeas, pigeon peas, and mung beans. *Journal of Agricultural and Food Chemistry*, 28(2), 459-461. <https://doi.org/10.1021/jf60228a047>
- Sachanarula, S., Chantarasinlapin, P. and Adisakwattana, S. (2022). Substituting whole wheat flour with pigeon pea (*Cajanus cajan*) flour in chapati: Effect on nutritional characteristics, color profiles, and in vitro starch and protein digestion. *Foods*, 11(20), 3157. <https://doi.org/10.3390/foods11203157>
- Siddiq, M., Ravi, R., Harte, J. and Dolan, K. (2010). Physical and functional characteristics of selected dry bean (*Phaseolus vulgaris* L.) flours. *LWT - Food Science and Technology*, 43(2), 232-237. <https://doi.org/10.1016/j.lwt.2009.07.009>
- Sing, K. and Kotwaliwale, N. (2010). Effect of moisture content on physico-thermal properties of pigeon pea. *Journal of Food Processing and Preservation*, 34(5), 845-857. <https://doi.org/10.1111/j.1745-4549.2009.00401.x>
- Sirangelo, M.T. (2019). Sensory descriptive evaluation of food products: A review. *Journal of Food Science and Nutrition Research*, 2(4), 354-363. <https://doi.org/10.26502/jfsnr.2642-11000034>
- Spence, C. (2015). On the psychological impact of food colour. *Flavour*, 4, 21. <https://doi.org/10.1186/s13411-015-0031-3>
- Wang, R., Jin, X., Su, S., Lu, Y. and Guo, S. (2019). Soymilk gelation: The determinant roles of incubation time and gelation rate. *Food Hydrocolloids*, 97, 105230. <https://doi.org/10.1016/j.foodhyd.2019.105230>
- Zhang, Q., Wang, C., Li, B., Li, L., Lin, D., Chen, H., Liu, Y., Li, S., Qin, W., Liu, J., Liu, W. and Yang, W. (2017). Research progress in tofu processing: From raw materials to processing conditions. *Critical Reviews in Food Science and Nutrition*, 58(9), 1448-1467. <https://doi.org/10.1080/10408398.2016.1263823>
- Zhang, B., Sun, X., Xia, X., Huang, Y., Zhu, Y., Qu, M., Liu, L., Sun, B. and Zhu, X. (2024). Soy protein isolate gel subjected to freezing treatment: Influence of methylcellulose and sodium hexametaphosphate on gel stability, texture and structure. *Foods*, 13(13), 2117. <https://doi.org/10.3390/foods13132117>