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Effect of packaging materials on post-harvest losses and storage quality of black gram (*Vigna mungo* L.)

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Abstract

Blackgram (*Vigna mungo* L.) is an important pulse crop valued for its high protein content, nutritional quality, and wide use in traditional diets, especially in South Asia. However, its storage is highly prone to quality deterioration due to insect infestation, moisture migration, and microbial growth. Appropriate selection of packaging material plays a vital role in extending shelf life, preserving nutritional quality, and minimizing post-harvest losses. The present study evaluated the influence of different packaging materials namely High Density Polyethylene (HDPE), Jute bags, Low Density Polyethylene (LDPE), Biaxially Oriented Polypropylene (BoPP), and Polyethylene Terephthalate (PET) containers on the storage stability of black gram over 240 days under ambient conditions. Initial grain moisture content was uniform (9.55% w.b), but significant differences emerged during storage. Hermetic packaging (PET and BoPP) effectively maintained stable moisture (9.13% and 9.28%), while HDPE and LDPE showed moderate increases upto 120 days, and jute absorbed the highest moisture (11.67%) at 120 days and then showed a decline trend. Insect infestation and grain damage were completely absent in PET and BoPP, whereas HDPE, LDPE, and particularly jute recorded progressive infestation (up to 224 insects/500 g) and damaged grains (0.74%). Correspondingly, no weight loss was observed in PET and BoPP, while HDPE, LDPE, and jute exhibited 11.93%, 17.06%, and 19.91% losses, respectively. Protein content declined across all treatments, but losses were minimal in PET (22.62%) and BoPP compared to jute (21.82%). Cooking time increased with storage duration, though hermetic packaging minimized the rate of grain hardening relative to conventional materials. These findings confirm that hermetic polymer-based packaging, particularly BoPP and PET, provide superior protection by preserving grain quality, reducing nutrient loss, and preventing insect infestation and physical damage. While PET offers excellent barrier properties, BoPP is more widely preferred in practice due to its cost-effectiveness. Overall, hermetic packaging emerges as the most reliable strategy for minimizing post-harvest losses and ensuring long-term storage quality of black gram.

Keywords: PET, BoPP, HDPE, LDPE, Jute bag storage, Grain storability, Moisture, Post-harvest losses, Storage quality

Introduction

Blackgram (*Vigna mungo* L.), commonly known as urad, is one of the most important pulse crops cultivated in India, valued for its high protein content and its wide use in traditional foods. As the leading producer and consumer, India cultivates blackgram on about 10–13% of the total pulses area, contributing a similar share to national production (Nair *et al.*, 2023)^[6]. During 2021–22, blackgram was cultivated on approximately 4.63 million hectares, producing about 2.78 million tonnes, with an average productivity of 987 kg/ha (Marimuthu *et al.*, 2024)^[5]. However, productivity shows significant regional variability, ranging from below 350 kg/ha in states like Chhattisgarh and Odisha to nearly 900 kg/ha in Bihar and Jharkhand. In 2022–23, the cultivated area decreased slightly to around 3.96 million hectares, with production falling to 1.84 million tonnes for (Vasanthi *et al.*, 2025). Despite its significance, the national average productivity remains below 1.0 t/ha, far lower than the crop's potential, due in large part to susceptibility to pests, diseases, and suboptimal post-harvest management practices.

Pulses are integral to the Indian diet, delivering proteins, carbohydrates, vitamins, and minerals necessary for nutritional security. Among these, blackgram holds a prominent place thanks to its high protein content, digestibility, and use in traditional preparations, especially

among vegetarian populations in developing countries (Jayaramasoundari, 2024; Nair *et al.*, 2023) [3, 6]. Additionally, blackgram enhances soil fertility through biological nitrogen fixation, making it an essential component of sustainable cropping systems (Jayaramasoundari, 2024) [3]. Nonetheless, like other pulses, blackgram is highly vulnerable to both quantitative and qualitative losses during storage, highlighting the need for effective post-harvest management.

A key challenge in blackgram storage is infestation by bruchids (*Callosobruchus* spp.), which cause significant losses in stored pulses damaging grains, causing weight loss, and contaminating produce with insect fragments and frass thus undermining market value and food safety (Kalpna *et al.*, 2022; Bojan *et al.*, 2008) [4, 1]. Packaging material and storage duration critically influence grain quality: packaging regulates moisture and gas exchange, which in turn affects insect attack intensity and overall storability.

Improper packaging accelerates moisture, weight, and protein content changes; increases the percentage of damaged grains; promotes insect population growth; and negatively impacts cooking quality, thereby reducing consumer acceptability and market value. Elevated moisture exacerbates biochemical and microbial activity, leading to both qualitative and quantitative losses including deterioration of germination and rise in free fatty acid value especially at higher storage temperatures and moisture levels. Protein content, a key nutritional trait, can decline significantly with prolonged storage or insect infestation. Cooking quality frequently assessed via cooking time is directly influenced by storage-induced seed changes: for example, in mungbean stored in non-hermetic conditions, cooking time increased by about 40% and grain hardness by about 10%; in contrast, these changes were largely prevented by hermetic storage (Stathas *et al.*, 2023) [14]. Storage conditions and insect damage can alter seed coat permeability and structure, contributing to the development of “hard-to-cook” characteristics that impair cooking behaviour (Prasadi *et al.*, 2023) [12].

Assessing grain storability requires monitoring multiple parameters: moisture content (governs microbial growth and seed deterioration), weight change (reflects dry matter loss), protein content (indicates nutritional stability), percentage of damaged grains, insect infestation, and cooking time (a consumer-relevant quality metric). Considering these aspects, the present study was undertaken to evaluate the suitability of different packaging materials namely HDPE, LDPE, BoPP, jute, and PET for storing blackgram over an eight-month period. The primary objective of this study is to assess changes in moisture content, weight, protein content, damaged grains, insect infestation, and cooking time, in order to identify packaging solutions that reduce storage losses while maintaining nutritional and processing quality.

Materials and Methods

Moisture Content

The moisture content of blackgram grains was determined by the hot air oven method (RDHO 50, REMI, India). A known weight of the sample (5 g) was taken in a pre-weighed moisture dish and kept in a hot air oven maintained at 105±1 °C for 24 hours. After drying, the samples were cooled in a desiccator and weighed (Sharon *et al.*, 2015; Ngoma *et al.*, 2024) [13, 7]. The moisture content was calculated on a wet basis using the following formula:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1 - W_0} \times 100$$

Where:

W_0 = weight of empty dish (g)

W_1 = weight of dish + sample before drying (g)

W_2 = weight of dish + sample after drying (g)

Weight change

A sample of blackgram (100 grains) was taken for each replication. The initial weight of each sample was recorded using a precision balance (Indowsaw, India) with a sensitivity of ±0.01 g. Samples were weighed at predetermined intervals for every 60 days during storage. The weight change was calculated by comparing the sample weight at each interval with its initial weight (Yewle *et al.*, 2022; Chaithanya *et al.*, 2024) [16, 8]. The difference between initial weight and final weight of sample after infestation gives the weight change

$$\text{Weight change (\%)} = \frac{\text{Initial weight of sample} - \text{Final weight of sample}}{\text{Initial weight of sample}} \times 100$$

Protein Content

The Protein content of blackgram grains was estimated by the Kjeldahl method (Ijarotimi & Keshinro, 2013). A known weight of finely ground sample (0.5–1.0 g) was digested with concentrated sulfuric acid using a catalyst mixture until a clear solution was obtained. The digested sample was distilled with 40% NaOH, and the liberated ammonia was collected in a known volume of standard boric acid solution containing mixed indicator. The distillate was titrated against standard 0.1 N HCl to determine the amount of nitrogen present (Parashar *et al.*, 2023) [9]. The crude protein content was calculated by multiplying the nitrogen content with a conversion factor of 6.25.

$$\text{Crude Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

Cooking Time

Whole blackgram (25 seeds) was washed and soaked in distilled water for 8 h at 25±2 °C (seed-to-water ratio 1:10). Soaked grains were drained, transferred to boiling distilled water (seed:water 1:20) and cooked at a gentle boil (96–100°C). At 2-min intervals, 10 randomly chosen grains were removed, briefly cooled in room-temperature water, and tested by finger-press between thumb and forefinger. The cooking time was recorded as the elapsed time when ≥80% of the test grains were easily mashed without a hard core (Perera *et al.*, 2025) [11].

Infestation Assessment

Composite grain samples (approximately 1.0 kg) were drawn from each treatment or packaging lot using a grain trier to collect primary samples from the top, middle, and bottom layers; these were thoroughly mixed to form a composite sample. A working sample of 500 g was obtained by quartering. The 500 g sample was sieved through a stack (with 2.0 mm and 1.0 mm apertures) over a white tray to separate insects and frass. Live and dead insects were then counted and identified under a stereomicroscope (Ngoma *et al.*, 2024; Yewle *et al.*, 2020) [7, 16]. Results were expressed as the number of insects per 500 g (live; dead reported separately). This method follows the seed sampling protocols outlined by the International Rules for Seed

Testing, whereby primary samples are taken from top, middle, and bottom of containers (e.g., using a trier), combined into a composite sample, and then reduced via quartering to obtain a representative working sample.

Damaged grains (% by count)

From each working sample, 100 g of grains was drawn and a subsample of 250 kernels was examined (Patel *et al.*, 2018) ^[10]. Kernels with holes and embryo damage were recorded as damaged.

$$\text{Damaged grain (\%)} = \frac{\text{No. of damaged kernels}}{\text{Total kernels examined}} \times 100$$

Statistical Analysis

All quality parameters were measured in triplicate, and the results are expressed as mean $\pm$ standard deviation. The data were subjected to analysis of variance (ANOVA) using IBM SPSS 25 software. Significant differences among treatment means were identified using Duncan's Multiple Range Test (DMRT) at a 5% probability level ($p < 0.05$).

Results and Discussion

Moisture Content

The initial moisture content of black gram grains across all packaging materials was uniform (9.55%). During storage, slight fluctuations were observed depending on the packaging type. By the end of 240 days, PET and BoPP retained significantly lower moisture (9.13% and 9.28%, respectively), while HDPE and LDPE recorded moderate increases (9.55% and 9.72%). Jute bags showed the highest moisture content (10.08%) (Table 1). These results confirm that hermetic packaging (PET and BOPP) effectively maintained stable grain moisture, whereas jute bags absorbed ambient humidity due to their porous structure. Similar findings were reported in a study by (Sharon *et al.*, 2015) ^[13] who observed that hermetic storage significantly minimized moisture migration in pulses compared to conventional packaging.

Weight change

Weight change corresponded with insect infestation trends (Table 5). No weight loss/change was detected in PET and BoPP, while HDPE (11.93%), LDPE (17.06%), and jute (19.91%) showed progressive grain loss after 240 days. Maximum losses in jute packaging were attributed to both insect feeding and respiration losses under fluctuating moisture. Comparable outcomes were recently reported by (Ngoma *et al.*, 2024) ^[7] who demonstrated through a large-scale meta-analysis that conventional storage bags had 23-fold higher grain weight loss compared to hermetic bags, largely due to insect activity and associated metabolic damage. This study strongly supports the effectiveness of hermetic storage (such as PET and BoPP) in minimizing post-harvest weight loss in stored grains (Ngoma *et al.*, 2024) ^[7].

Protein Content

Protein levels declined progressively with storage duration across all treatments (Table 2). The initial protein content of

25.10% decreased to 22.62% (PET) and 21.82% (jute) after 240 days. The lowest protein degradation was observed in PET and BoPP, while maximum losses occurred in jute packaging. Protein reduction during storage is attributed to biochemical degradation and insect activity. These findings align with (Parashar *et al.*, 2023) ^[9] who reported significant nutrient losses in black gram under non-hermetic storage.

Cooking Time

Cooking time increased steadily during storage in all packaging treatments (Table 3). Initial cooking time (20.43 min) extended to 21.01 min (PET) and 21.41 min (jute) after 240 days. PET and BoPP slowed down the grain hardening process, while LDPE and jute showed a higher increment in cooking time, indicating faster grain hardening. This trend is consistent with the well-documented hard-to-cook (HTC) phenomenon where legumes become increasingly resistant to softening during cooking following storage under fluctuating conditions of temperature and humidity. A study on faba and adzuki (Perera *et al.*, 2025) ^[11] beans demonstrated that grains stored at elevated temperatures (around 40 °C) and high relative humidity (over 80%) developed internal biochemical and structural changes such as protein, starch, and lipid modifications that significantly increased cooking time and reduced digestibility.

Insect Infestation

Insect infestation was absent in PET and BOPP throughout storage (Table 4). HDPE and LDPE recorded low to moderate infestation (up to 11 and 17 insects/500 g, respectively) after 240 days. In contrast, jute packaging exhibited severe infestation, with counts reaching 224 insects/500 g at the end of storage. These results highlight the superior barrier properties of PET and BOPP, which completely prevented insect entry and multiplication. Similar findings were reported by Ngoma *et al.*, 2024 ^[7], who conducted a meta-analysis showing that conventional storage bags had 42-fold more insects and 23-fold more grain weight loss than hermetic bags, confirming the effectiveness of hermetic storage systems in preventing insect infestation.

Damaged Grain

Grain damage followed a pattern similar to infestation (Table 6). PET and BoPP showed no damage, while jute recorded the highest proportion (0.74%) after 240 days, followed by LDPE (0.57%) and HDPE (0.42%). The absence of kernel damage in hermetic packaging highlights their resistance to insect penetration, whereas porous materials such as jute permitted oviposition and larval development. This aligns with findings from (Yewle *et al.*, 2022) ^[16] who studied the performance of various hermetic bags (including PICS, GrainPro, Save Grain, and Eco tact) versus conventional bags (polypropylene and jute) in stored green gram. They reported that insect damage and weight loss increased markedly in polypropylene and jute bags, while grains in hermetic bags showed significantly lower damage and maintained viability throughout storage (Chaithanya *et al.*, 2024) ^[8].

Table 1: Effect of Packaging materials on moisture content of blackgram splits

Days	PET	BOPP	HDPE	LDPE	JUTE
0	9.55±0.04 ^{bp}	9.55±0.04 ^{bp}	9.55±0.04 ^{bp}	9.55±0.04 ^{dp}	9.55±0.04 ^{ep}
60	9.63±0.02 ^{at}	9.74±0.03 ^{as}	9.82±0.02 ^{ar}	10.26±0.03 ^{aq}	10.95±0.03 ^{bp}
120	9.65±0.03 ^{at}	9.75±0.02 ^{as}	9.84±0.03 ^{ar}	10.26±0.04 ^{aq}	11.67±0.02 ^{ap}
180	9.24±0.03 ^{ct}	9.35±0.03 ^{cs}	9.52±0.02 ^{br}	9.83±0.04 ^{bq}	10.37±0.04 ^{cp}
240	9.13±0.03 ^{dt}	9.28±0.03 ^{ds}	9.55±0.04 ^{br}	9.72±0.03 ^{cq}	10.08±0.04 ^{dp}

*PQRST indicates significant difference between different packaging materials at a particular storage period ($p < 0.05$)

*abcde indicates significant difference between different storage days for a particular packaging material ($p < 0.05$)

Table 2: Effect of Packaging materials on protein content blackgram splits

Days	PET	BOPP	HDPE	LDPE	JUTE
0	25.10±0.06 ^{ap}	25.10±0.06 ^{ap}	25.10±0.06 ^{ap}	25.10±0.06 ^{ap}	25.10±0.06 ^{ap}
60	24.88±0.04 ^{bp}	24.70±0.07 ^{bq}	24.49±0.04 ^{br}	24.33±0.05 ^{bs}	24.13±0.06 ^{bt}
120	24.46±0.13 ^{cp}	24.20±0.02 ^{cq}	24.04±0.03 ^{cr}	23.92±0.07 ^{cr}	23.68±0.08 ^{cs}
180	22.87±0.04 ^{dp}	22.66±0.09 ^{dq}	22.32±0.05 ^{dr}	22.10±0.06 ^{ds}	21.88±0.07 ^{dt}
240	22.62±0.05 ^{ep}	22.40±0.06 ^{eq}	22.21±0.04 ^{er}	22.03±0.04 ^{ds}	21.82±0.03 ^{dt}

*PQRST indicates significant difference between different packaging materials at a particular storage period ($p < 0.05$)

*abcde indicates significant difference between different storage days for a particular packaging material ($p < 0.05$)

Table 3: Effect of Packaging materials on cooking time of blackgram splits

Days	PET	BOPP	HDPE	LDPE	JUTE
0	20.43±0.01 ^{dp}	20.43±0.01 ^{dp}	20.43±0.01 ^{ep}	20.43±0.01 ^{ep}	20.43±0.01 ^{ep}
60	20.46±0.01 ^{ct}	20.48±0.01 ^{cs}	20.54±0.01 ^{dr}	20.57±0.01 ^{dq}	21.00±0.01 ^{dp}
120	20.48±0.01 ^{ct}	20.52±0.01 ^{bs}	20.57±0.01 ^{cr}	21.00±0.01 ^{cq}	21.05±0.01 ^{cp}
180	20.52±0.01 ^{bs}	20.52±0.01 ^{bs}	21.00±0.01 ^{br}	21.05±0.01 ^{bq}	21.23±0.01 ^{bp}
240	21.01±0.01 ^{at}	21.03±0.01 ^{as}	21.05±0.01 ^{ar}	21.23±0.01 ^{aq}	21.41±0.01 ^{ap}

*PQRST indicates significant difference between different packaging materials at a particular storage period ($p < 0.05$)

*abcde indicates significant difference between different storage days for a particular packaging material ($p < 0.05$)

Table 4: Effect of Packaging materials on insect infestation of blackgram splits

Days	PET	BOPP	HDPE	LDPE	JUTE
60	-	-	-	1±1.53 ^{dq}	6±1.00 ^{dp}
120	-	-	-	8±1.15 ^{cq}	33±1.53 ^{cp}
180	-	-	8±1.15 ^{br}	13±1.00 ^{bq}	88±0.58 ^{bp}
240	-	-	11±1.53 ^{ar}	17±0.00 ^{aq}	224±1.53 ^{ap}

*PQR indicates significant difference between different packaging materials at a particular storage period ($p < 0.05$)

*abcd indicates significant difference between different storage days for a particular packaging material ($p < 0.05$)

Table 5: Effect of Packaging materials on weight change of blackgram splits

Days	PET	BOPP	HDPE	LDPE	JUTE
60	-	-	-	2.97±0.01 ^{dq}	7.03±0.01 ^{dp}
120	-	-	-	9.54±0.01 ^{cq}	14.06±0.01 ^{cp}
180	-	-	9.54±0.01 ^{br}	15.73±0.02 ^{bq}	17.40±0.01 ^{bp}
240	-	-	11.93±0.01 ^{ar}	17.06±0.00 ^{aq}	19.91±0.01 ^{ap}

*PQR indicates significant difference between different packaging materials at a particular storage period ($p < 0.05$)

*abcd indicates significant difference between different storage days for a particular packaging material ($p < 0.05$)

Table 6: Effect of Packaging materials on damaged grain of blackgram splits

Days	PET	BOPP	HDPE	LDPE	JUTE
60	-	-	-	0.1±0.01 ^{dq}	0.24±0.02 ^{dp}
120	-	-	-	0.15±0.01 ^{cq}	0.45±0.02 ^{cp}
180	-	-	0.07±0.03 ^{br}	0.26±0.01 ^{bq}	0.57±0.02 ^{bp}
240	-	-	0.42±0.02 ^{ar}	0.57±0.01 ^{aq}	0.74±0.03 ^{ap}

*PQR indicates significant difference between different packaging materials at a particular storage period ($p < 0.05$)

*abcd indicates significant difference between different storage days for a particular packaging material ($p < 0.05$)

Conclusions

The study clearly demonstrates that packaging material plays a critical role in preserving the quality of black gram during storage. Among the evaluated materials, PET and BoPP proved to be the most effective, maintaining stable moisture content, minimizing protein degradation, slowing the development of the hard-to-cook phenomenon, and completely preventing insect infestation, weight loss, and

kernel damage over 240 days. HDPE and LDPE provided moderate protection, but still allowed measurable quality deterioration, while jute bags performed the poorest, showing the highest moisture absorption, nutrient loss, insect infestation, and grain damage. Overall, hermetic polymer-based packaging (PET and BoPP) emerges as the most reliable option for long-term storage of black gram, ensuring superior grain quality and post-harvest stability

compared to conventional storage methods. These findings reinforce the importance of adopting improved packaging technologies to reduce post-harvest losses and enhance food security. BoPP is chosen more often than PET because it is more economical.

Credit authorship certificate

S. Mohammad Jeelani: Conceptualization, Investigation, Data curation, Writing – original draft, Software, Data curation.

V. Vasudeva Rao: Validation, Formal analysis, Resources, Data curation, Writing - review and editing.

D. Sandeep Raja: Methodology, Bio-chemical analysis, Data curation, Interpretation of results.

L. Edukondalu: Methodology, Funding acquisition, Writing - review and editing.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

- Bojan V, Madras A, Srinivasan T, Durairaj C, Kumar BV. Damage potential of bruchids in different edible legumes and interspecific competition between two species of *Callosobruchus* spp. (Bruchidae: Coleoptera). J. 2008;95(Dec):400–406. <https://doi.org/10.29321/MAJ.10.200829>
- Ijarotimi SO, Keshinro OO. Determination of nutrient composition and protein quality of potential complementary foods formulated from the combination of fermented popcorn, African locust and Bambara groundnut seed flour. Pol J Food Nutr Sci. 2013;63(3):155–166. <https://doi.org/10.2478/v10222-012-0079-z>
- Jayaramasoundari R. Enhancing productivity and profitability of black gram (*Vigna mungo*) through cluster front line demonstrations. Indian J Agric Res. 2024;58(5):806–810. <https://doi.org/10.18805/IJARE.A-6205>
- Kalpna, Hajam YA, Kumar R. Management of stored grain pest with special reference to *Callosobruchus maculatus*, a major pest of cowpea: a review. Heliyon. 2022;8(1):e08703. <https://doi.org/10.1016/j.heliyon.2021.e08703>
- Marimuthu S, Vanitha C, Surendran U, El-Hendawy S, Mattar MA. Conception of improved black gram (*Vigna mungo* L.) production technology and its propagation among farmers for the development of a sustainable seeds production strategy. Sustainability (Switzerland). 2024;16(11):14750. <https://doi.org/10.3390/su16114750>
- Nair RM, Chaudhari S, Devi N, Shivanna A, Gowda A, Boddepalli VN, Pradhan H, Schafleitner R, Jegadeesan S, Somta P. Genetics, genomics, and breeding of black gram [*Vigna mungo* (L.) Hepper]. Front Plant Sci. 2023;14:1273363. <https://doi.org/10.3389/fpls.2023.1273363>
- Ngoma TN, Monjerezi M, Leslie JF, Mvumi BM, Harvey JJW, Matumba L. Comparative utility of hermetic and conventional grain storage bags for smallholder farmers: a meta-analysis. J Sci Food Agric. 2024;104(2):561–571. <https://doi.org/10.1002/jsfa.12934>
- Chaithanya P, Madhumathi T, Chiranjeevi CH, Krishnam Raju S, Sreenivasulu KN, Srinivas T. Evaluation of hermetic storage bags for the management of pulse beetle, *Callosobruchus maculatus* (Fab.) in chickpea. J Res ANGRAU. 2024;51(4):19–26. <https://doi.org/10.58537/joragrau.2023.51.4.02>
- Parashar A, Sharma Y, Jaiswal V. Effect of phosphorus and sulphur on growth, protein content, yield and economics of black gram (*Vigna mungo* L.). Int J Plant Soil Sci. 2023;35(18):1587–1593. <https://doi.org/10.9734/ijps/2023/v35i183429>
- Patel JV, Antala DK, Dalsaniya AN. Influence of different packaging materials on the seed quality parameters of chickpea. Int J Curr Microbiol App Sci. 2018;7(12):2458–2467.
- Perera D, Jia B, Devkota L, Bhattarai SP, Panozzo J, Dhital S. High temperature and humidity storage alter starch properties of faba (*Vicia faba*) and adzuki beans (*Vigna angularis*) associated with hard-to-cook quality. Carbohydr Polym. 2025;351:123119. <https://doi.org/10.1016/j.carbpol.2024.123119>
- Prasadi VPN, Somaratne GM, Prasantha BDR, Abeyrathne CK, Abhayawardhana PHRM, Wimalasiri KMS. Effect of hermetic storage on the development of hard-to-cook characteristics and nutritional properties of mungbean (*Vigna radiata* (L.) R. Wilczek) and cowpea (*Vigna unguiculata* (L.) Walp.). J Stored Prod Res. 2023;104:102197. <https://doi.org/10.1016/j.jspr.2023.102197>
- Sharon MEM, Abirami CVK, Alagusundaram K, Alice J. Moisture dependent physical properties of black gram. Agric Eng Int CIGR J. 2015;17(1):181–187.
- Stathas IG, Sakellariadis AC, Papadelli M, Kapolos J, Papadimitriou K, Stathas GJ. The effects of insect infestation on stored agricultural products and the quality of food. Foods (Basel). 2023;12(10):2046. <https://doi.org/10.3390/foods12102046>
- Vasanthi R, Karthick V, Nirmala D, Chellamuthu R, Hema B. Evaluating the effectiveness of principal component regression vs multiple linear regression for black gram cultivation in Tamil Nadu. Plant Sci Today. 2025;12(3):1–6. <https://doi.org/10.14719/pst.8036>
- Yewle N, Swain K, Mann S, PN G. Performance of hermetic bags in green gram [*Vigna radiata* (L.) R. Wilczek] storage for managing pulse beetle (*Callosobruchus chinensis*). J Stored Prod Res. 2022;95:101896. <https://doi.org/10.1016/j.jspr.2021.101896>