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Effects of Storage Methods and Packaging Materials on Viability of Adlai (*Coix lacryma-jobi* L.) Seeds

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ABSTRACT

Adlai was a nutritious and resilient grain that could serve as a staple food source of genetic diversity for sustainable agriculture. However, its seed storage and packaging posed seed viability, quality, and diversity challenges. This study evaluated the effects of different storage methods and packaging materials on Adlai seed characteristics and provided evidence-based recommendations for farmers, seed banks, and policymakers on how to conserve Adlai seeds effectively. The study was laid in a Completely Randomized Design with four treatments (polythene, jute, aluminum foil, and Ziplock bags) and replicated twice. The results indicated that packaging materials significantly affected (P<0.05) seed characteristics such as germination rate, moisture content, and seed weight. The study also revealed a significant (P<0.05) interaction between storage method and packaging materials and suggested optimal combinations for maintaining seed quality. For short-term storage, a Ziplock bag was the best packaging material for Adlai seeds. However, further research was needed to examine the long-term impacts of storage and packaging on Adlai seeds, as this study only covered a one-month storage period.

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RESUMO

Adlai era um grão nutritivo e resistente que poderia servir como fonte alimentar básica de diversidade genética para uma agricultura sustentável. No entanto, o armazenamento e embalagem de sementes representava desafios de viabilidade, qualidade e diversidade das sementes. Este estudo avaliou os efeitos de diferentes métodos de armazenamento e materiais de embalagem nas características das sementes de Adlai e forneceu recomendações baseadas em evidências para agricultores, bancos de sementes e decisores políticos sobre como conservar eficazmente as sementes de Adlai. O estudo foi desenvolvido em delineamento inteiramente randomizado com quatro tratamentos (polietileno, juta, papel alumínio e sacos Ziplock) e replicado duas vezes. Os resultados indicaram que os materiais de embalagem afetaram significativamente (P<0,05) as características das sementes, como taxa de germinação, teor de umidade e peso das sementes. O estudo também revelou uma interação significativa (P<0,05) entre o método de armazenamento e os materiais de embalagem e sugeriu combinações ideais para manter a qualidade das sementes. Para armazenamento de curto prazo, um saco Ziplock foi o melhor material de embalagem para sementes Adlai. No entanto, foram necessárias mais pesquisas para examinar os impactos a longo prazo do armazenamento e embalagem nas sementes de Adlai, uma vez que este estudo cobriu apenas um período de armazenamento de um mês.

Keywords:
Adlai, Materiais de embalagem, Umidade relativa, Viabilidade de sementes, Métodos de armazenamento

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Introduction

Seeds are fundamental units of genetic diversity and represent the potential for plant life continuation and propagation (Finch-Savage & Bassel, 2018). The preservation of seed viability and quality was paramount in ensuring food security, crop diversity, and sustainable agriculture (Kallow et al., 2021). Adlai (Coix lacryma-jobi L.), commonly known as Job's tears, was an underutilized but nutritionally valuable grain that had gained increasing attention due to its adaptability to diverse agroecological conditions and its ability to provide an alternative source of essential nutrients (Weng et al., 2022). Research on the production of Adlai in the Philippines has focused on its site suitability and potential as a wheat flour alternative. Paquit (2022) identified 245,980 ha. in Bukidnon as suitable for Adlai, with a projected increase to 391,872 ha. due to climate change. Some areas of the plantation of Adlai were located in Cordillera and Mindanao (Arcalas, 2022). Andriana (2021) conducted a financial feasibility analysis for small-scale Adlai flour production, finding it a viable alternative to wheat flour. Based on the proximate analysis of Adlai, it had a moisture content of 4.16%, fat (1.56%), protein (11.94%), fiber (0.28%), ash (1.64%), and energy value of 383 kcal/100g (Magpantay et al., 2021). However, the effective storage and packaging of Adlai seeds presented critical challenges, as improper handling could lead to seed deterioration, loss of genetic diversity, and reduced nutritional content (Dela Torre, 2018).

This research aimed to conduct a thorough investigation into the crucial elements of seed storage and packaging for Adlai. The study specifically focused on seed viability and moisture content. Maintaining seed viability and quality was a fundamental aspect of sustainable agriculture as it directly impacted crop production and the preservation of genetic resources (Kansiime et al., 2021; Syed & Rizvi, 2021). Furthermore, moisture content played a fundamental role in seed longevity, and understanding its dynamic relationship with various storage and packaging methods was essential for ensuring the long-term availability of Adlai as a valuable crop (Bakhtavar & Afzal, 2020). The ideal moisture content of Adlai seed for storage in an ambient room temperature is 10% (Reynaldo et al., 2014). The dual significance of Adlai emphasized the importance of this study as both a potential staple food source for communities facing food security challenges and a reservoir of genetic diversity that could contribute to the adaptability of crops to changing environmental conditions (BusinessMirror, 2022; Dela Cruz, n.d.). Adlay, known as Job's Tears, is a staple food due to its nutritional value and potential economic importance (Schaaffhausen, 2008; Weng, 2022). It is a potential alternative to wheat flour, with a high protein and carbohydrate content (Andriana, 2021). Adlay also contains beneficial phytochemicals, such as policosanols and phytosterols, which can help lower cholesterol (Wu, 2007). Its traditional use in Asian medicine further supports its status as a staple food (Weng, 2022).

By systematically evaluating the impact of different storage and packaging methods on seed viability and moisture content, this research intended to provide evidence-based recommendations that could guide farmers, seed banks, and agricultural policymakers in making informed decisions to safeguard Adlai as a valuable crop resource. The findings from this study had the potential to contribute not only to the conservation and utilization of Adlai but also to the broader understanding of seed storage and preservation strategies for other crops in a changing global agricultural landscape.

Materials and Methods

Scope and Limitations of the Study

This study's scope encompassed research conducted at the Department of Agronomy laboratory of Visayas State University in Baybay City, Leyte, Philippines, with coordinates 10°44'48.4"N 124°47'40.8"E. It primarily focused on Adlai seeds sourced from this geographical region, considering the specific agroecological conditions prevalent there. The study's timeline centered on a short-term evaluation, spanning only about one month, during which the impact of various storage and packaging methods on Adlai seed viability and moisture content was assessed. This research provided valuable insights into specific combinations of storage and packaging methods.

Several limitations were inherent in this study. First, the generalizability of the findings might be limited beyond the study's geographical scope and the specific conditions prevailing in the research area. Second, the short-term nature of the study meant that the long-term effects of the evaluated storage and packaging methods on Adlai seeds might still need to be fully understood. Third, this research did not encompass other factors that could influence Adlai seed viability and quality, such as pest infestations, diseases, and environmental variables. Moreover, the sample size used in the study could impact the precision of the results. Seasonal variations in environmental conditions could affect the findings, as they reflected specific seasonal conditions during data collection. Finally, external factors beyond the researchers' control, such as unforeseen events or changes in storage conditions, could impact the study's outcomes. These limitations should be considered when interpreting and applying the study's results.

Research Design

In this study, a factorial Completely Randomized Design was used. One kilogram of dried open-xpollinated variety of Adlai seeds was stored in four different packaging materials (polythene bags, jute bags, aluminum foil, and Ziplock bags) at two different storage methods (room temperature and refrigeration) with two replicates. The seeds were stored for one month. Four sets of seed bags were prepared for each storage material. Two sets were kept at room temperature and the other in the refrigerator at 10°C (50°F).

Data Collection

The parameters that were collected in determining the seed viability of Adlai seed were the 1000 seed weight, germination percentage, moisture content, and seed vigor.

1000 seed weight. The 1000-seed weight was a useful parameter for comparing seed sizes and assessing seed quality. It could also be used to estimate the number of seeds in a given weight, which is valuable information for planting and seeding applications in agriculture. To calculate the 1000 seed weight, they selected 100 seeds from the sample and weighed using a sensitive weighing scale. After that, they calculated the 1000 seed weight using the formula below.

$$\text{1000 Seed Weight} = \frac{\text{Weight of seed in grams}}{\text{Number of seeds in sample}} \times 100 \quad (1)$$

Seed Germination. Germination was evaluated according to the recommended procedures of the Business Diary Philippines (2021). Seeds were soaked in distilled water for eight hours to break their dormancy. After the pre-germination treatment, seeds were placed in a wet tissue paper in a petri dish. Petri dishes were placed at room temperature and monitored to maintain the moisture of the tissue paper, which aided in the germination of the seeds. At the end of the 15th day, the germination percentage was determined as follows:

$$\text{Seed Germination} = \frac{\text{No.of Seed germinated}}{\text{No.of Seeds placed for germination}} \times 100 \quad (2)$$

Seed Moisture Content. The grain moisture analyzer was used to determine the moisture content. The sample scoop was filled with 0.5 gram Adlai seeds, inserted into the device's slot, and pressed to extract the grain moisture content. The measurements were read when the number on the moisture analyzer's screen became stable.

Vigor index determination. The formula proposed by Abdul-Baki and Alderson (1973) was used to determine the seed vigor.

$$\text{Vigor Index} = (\text{Shoot length} + \text{Root length}) \times \text{Germination Percentage} \quad (3)$$

Measurement of temperature and relative humidity of storage environment. The ambient storage room temperature and relative humidity readings were taken at specified times of 8:00 a.m., 12:00 p.m., and 5:00 p.m. to minimize potential variations and microclimate fluctuations. A digital hygrometer was used to take the temperature and relative humidity readings. The device had been placed in the area where the seeds were stored and had waited for a few minutes to stabilize before taking the measurements.

Data Analysis

The data collected in this study was analyzed using the analysis of variance (ANOVA) technique for a two-factor Completely Randomized Design (CRD). The two factors under consideration were Storage Methods (Factor A) and Packaging Materials (Factor B). The statistical analysis was performed using the STAR software.

If significant differences among treatment means were found, a Post-hoc Test using Tukey's Honestly Significant Difference was performed to determine which specific groups or treatments differed significantly from each other. This rigorous statistical approach ensured a thorough understanding of the experimental design, allowing for the identification of significant factors and interactions in the study.

Results and Discussions

Effects of storage methods and packaging materials on 1000-seed weight

Table 1 shows the effects of storage methods and packaging materials on 1000-seed weight. The results showed that the main effect of packaging material was not significant ($P>0.05$), with the Ziplock bag treatment having the highest mean 1000-seed weight (8.5g) and the Polyethylene bag treatment having the lowest mean 1000-seed weight (8.0g). The effect of the storage method was significant ($P<0.05$), with both the Refrigeration and Room temperature treatments having a mean 1000-seed weight of 8. 5g and 8.0g, respectively.

Table 1.

Effects of storage methods and packaging materials on 1000-seed weight (g).

Storage Methods	Packaging materials				Mean
	Polyethylene bag	Jute Bag	Aluminum foil tray	Ziplock bag	
Refrigeration	8.0	8.0	9.0	9.0	8.5^{a}
Room Temperature	8.0	8.5	7.5	8.0	8.0^{b}
Mean	8.0^{b}	8.25^{b}	8.25^{b}	8.5^{a}	

[a,b]Means with the same letter are not significant at the 5% level

However, the interaction between the storage method and packaging material was also significant ($P<0.05$). This meant that the effect of packaging material on 1000-seed weight depended on the storage method (Tabakovic, 2019). The difference in mean 1000-seed weight between the Ziplock bag and Aluminum foil tray treatments was greater at Room temperature (1.0g) than at refrigeration (0.5g). These findings were similar to those of other studies, which had also found that the interaction between storage method and packaging material could have a significant effect on 1000-seed weight (Satasiya *et al.,* 2021; Badawi *et al.,* 2017).

The level of the interaction effect varied between studies. In the study by Yewle *et al.* (2020), the difference in mean 1000-seed weight between the airtight and non-airtight packaging treatments was 1.5g, while in the study by Adjei *et al.* (2022), the difference in mean 1000-seed weight between the polyethylene bag and paper bag treatments was only 0.5g. This might have been due to differences in the species of seed, the storage conditions, or the duration of storage (Bista *et al.,* 2022). The findings of this study suggested that the interaction between storage method and packaging material was an important factor to consider when choosing a storage method and packaging material for seeds. The choice of storage method and packaging material could have a significant effect on seed quality and longevity (Tandoh *et al.,* 2017). In refrigeration storage, it slows seed metabolism, extending viability and preserving germination potential compared to room temperature storage.

Effect of storage methods and packaging materials on seed germination

The data in Table 2 shows the effects of storage methods and packaging materials on seed germination percentage. The results indicated that there was no significant main effect of the storage method on seed germination, as both the Refrigeration and Room temperature treatments had the same mean germination percentage of 93.57% and 96.08%, respectively. This meant that the storage method did not affect the seed germination significantly (P>0.05). Although there was no significant effect, it was evident that packaging materials exhibited a high percentage of seed germination. The Ziplock bag treatment had the highest mean germination percentage of 97.86%, while the Aluminum foil tray treatment had the lowest mean germination percentage of 92.86%.

Table 2.

Effects of storage methods and packaging materials on seed germination (%).

Storage Methods	Packaging materials				Mean
	Polyethylene bag	Jute Bag	Aluminum foil tray	Ziplock bag	
Refrigeration	91.43	91.43	92.86	98.57	93.57[a]
Room Temperature	95.73	98.57	92.86	97.15	96.08[a]
Mean	93.57[b]	95.00[b]	92.85[b]	97.86[a]	

[a,b] *Means with the same letter is not significant at a 5% level*

Moreover, packaging materials had a significant (P<0.05) effect on seed germination. This meant that seed germination depended on the packaging materials used. This finding conformed to the study of Naguib *et al.* (2014). The difference in mean germination percentage between the Ziplock bag and Aluminum foil tray treatments was greater at refrigeration (5.71%) than at Room temperature (4.29%). The result of the study conformed to the study of Azadi & Younesi (2013), which stated that storage method and packaging material were important factors that influenced seed germination. The choice of storage method and packaging material could have a significant impact on seed quality and viability (Arief *et al.,* 2022). These findings suggested that the storage method and packaging material were important factors that influenced seed germination (Nyo *et al.,* 2019).

Fig. 4.

Adlai seeds in germination set up. (a) Seeds were laid in petri dish and placed at room temperature after soaking. (b) Adlai seeds after eight days of germination period

Effects of storage methods and packaging materials on seed moisture content

The data in Table 3 showed the effect of different storage methods and packaging materials on the seed moisture content of the Adlai seeds. Seed moisture content, which was the percentage of water in the seed relative to its dry weight, had an important role in influencing the quality and longevity of stored seeds (Gebeyaw, 2020; Chala, 2017).

Table 3.

Effects of storage methods and packaging materials on seed moisture content (%).

Storage Methods	Packaging materials				Mean
	Polyethylene bag	Jute Bag	Aluminum foil tray	Ziplock bag	
Refrigeration	13.95	15.70	13.40	13.00	14.01[a]
Room Temperature	13.45	15.05	14.55	14.60	14.41[a]
Mean	13.70[b]	15.38[a]	13.97[b]	13.80[b]	

[a,b]*Means with the same letter are not significant at the 5% level*

The interaction between storage methods and packaging materials showed the combined effect on seed moisture content. The mean values from the table revealed that seed moisture content was not significantly (P>0.05) different between storage methods, with values of 14.01% for refrigeration and 14.41% for room temperature. This suggested that the storage method did not strongly influence seed moisture content. On the other hand, significant differences emerged across various packaging materials, with polyethylene bags at 13.70%, jute bags at 15.38%, aluminum foil trays at 13.97%, and ziplock bags at 13.80%. This implied a substantial influence of packaging materials on seed moisture content, with jute bags exhibiting the highest and polyethylene bags having the lowest moisture content (Akinneye, 2015). The permeability of different packaging materials to moisture and their impact on seed respiration explained the observed interaction. Jute bags, being the most permeable, and polyethylene bags, permitted more moisture, contributing to increased seed moisture content, especially at room temperature. Ziplock bags, being the most airtight, reduced seed respiration, further contributing to elevated seed moisture content. At refrigeration temperatures, where lower temperatures slowed down seed respiration, differences in seed moisture content among packaging materials diminished (Tiwari, 2022)

These findings had significant implications for seed storage. When selecting storage methods and packaging materials, careful consideration of their interaction was vital. For room temperature storage, choosing packaging materials with lower permeability, such as aluminum foil trays and Ziplock bags, proved beneficial in maintaining lower seed moisture content. In contrast, refrigeration mitigated the influence of packaging material, making it less critical in achieving and preserving low seed moisture content (Arah et al., 2016). Maintaining recommended seed moisture content ensures both long-term survival and optimal germination potential (Small & Brookes, 2012).

Effects of storage methods and packaging materials on seed vigor

The data shows the effects of different storage methods and packaging materials on seed vigor after one month of storage. Seed vigor is measured as the percentage of seeds that germinate and produce normal seedlings. A seedling was deemed normal if it exhibited a radicle extending more than 1 mm and displayed typical shoot growth (Singkaew et al., 2017). The data suggests that seed vigor is not affected by the choice of storage method or packaging material for one month of storage, as there is no significant difference among the four storage methods (refrigeration, room temperature, polyethylene bag, and ziplock bag) or the four packaging materials (polyethylene bag, jute bag, aluminum foil tray, and ziplock bag).

Table 4.

Effects of storage methods and packaging materials on seed vigor (%)

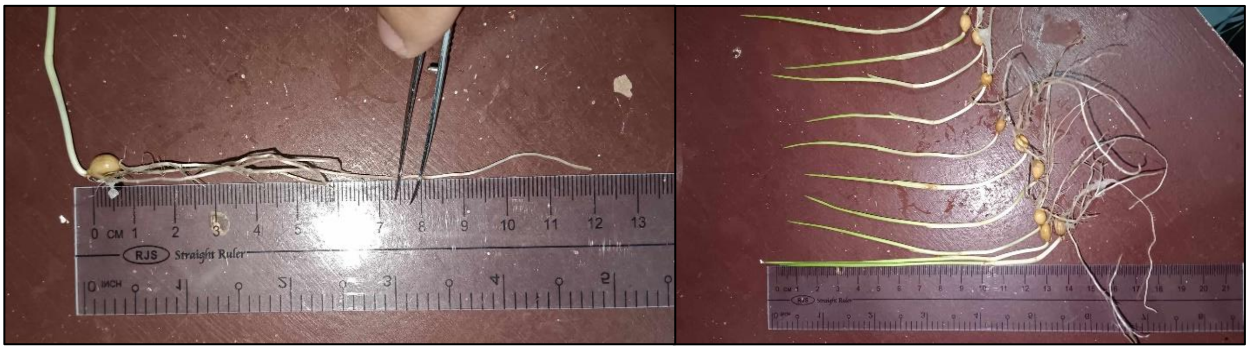
Storage Methods	Packaging materials				Mean
	Polyethylene bag	Jute Bag	Aluminum foil tray	Ziplock bag	
Refrigeration	18.3	18.5	17.0	21.9	18.9[a]
Room Temperature	16.6	17.3	18.2	17.8	17.5[a]
Mean	17.5[a]	17.9[a]	17.6[a]	19.9[a]	

[a]Means with the same letter are not significant at the 5% level

The data also indicates that there is no significant interaction between storage methods and packaging materials on seed vigor, meaning that the effect of one factor does not depend on the level of the other factor. However, this may not be true for more extended storage periods or different environmental conditions. Therefore, it is important to use appropriate and standardized methods to assess seed vigor and to compare the results with other relevant information, such as the warm germination test, the seed purity test, and the field emergence test.

Fig. 2.

Adlai seedlings measurements. (a) root length measurement. (b) shoot length measurement



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

Ambient conditions of storage environments

The relative humidity and temperature varied in the room temperature and refrigeration conditions. The relative humidity was between 73.6% and 79.5%, and the temperature was between 27.3ºC (81.86 ºF) and 28.9ºC (84.02 ºF) in the room temperature condition. The relative humidity was between 55.8% and 61.5%, and the temperature was between 8.7ºC (47.66 ºF) and 11.6ºC (52.88 ºF) in the refrigeration condition. The lowest relative humidity for room temperature was in week 2, and the highest was in week 1. The lowest relative humidity for refrigeration was in week 3, and the highest was in week 2. The lowest temperature for room temperature was in week 1, and the highest was in week 4. The lowest temperature for refrigeration was in week 2, and the highest was in week 1. The temperature in the refrigeration condition exceeded the set 10°C (50 °F) due to a power outage for a whole day.

Table 5.

The temperature and relative humidity of storage environments

Weeks	Room Temperature		Refrigeration	
	Temperature (°C)	Relative Humidity (%)	Temperature (°C)	Relative Humidity (%)
Week 1	27.3	79.5	11.6	59.5
Week 2	27.4	76.3	8.7	61.5
Week 3	27.6	76.8	9.1	55.8
Week 4	28.9	73.6	9.4	57.9

The balance of temperature and relative humidity in seed storage is important for maintaining the quality and viability of seeds. Different seeds have different optimal conditions for storage, but in general, low temperature and low relative humidity are preferred. High temperature and high relative humidity can accelerate the deterioration of seeds, reduce their germination and vigor, and increase the risk of fungal and insect infestation. According to Utah State University (n.d.), a rule of thumb is that the sum of the temperature in degrees F and the % relative humidity should be less than 100 for good seed storage conditions. Smith (1992) suggests that proper storage conditions maintain relative humidity levels between 20% and 40%, giving corresponding seed moisture content between 5% and 8%, depending on the type of seed. Seed storage longevity depends on the seed's moisture content, which influences the seed's metabolic rate and vulnerability to damage (Wawrzyniak et al., 2020). However, seeds with too low moisture content may lose their viability or become dormant. Therefore, seed storage should aim to balance the temperature and relative humidity to achieve the optimal seed moisture content for each seed type.

Conclusion

It was concluded that the type of packaging material had a significant influence on the weight, germination, and moisture of 1000 seeds of an open-pollinated variety of Adlai. Ziplock bags were the best packaging material for all these measures. The storage method also affected germination but not weight or moisture. However, both storage method and packaging material had a combined effect on all the measures, indicating that they should be considered together. The storage conditions also mattered, with cooler temperatures generally preserving seed quality better than warmer ones. The study highlights the importance of choosing the right storage methods and packaging materials to maintain optimal seed quality and viability.

The study suggested that both storage methods and packaging material should be considered when storing Adlai seeds. For short-term storage of Adlai seeds, farmers can utilize Ziplock bags. Further studies should be conducted to determine the long-term effects of storage methods and packaging materials on Adlai seeds. The current study only looked at a one-month storage period. Studying storage for longer periods would help us understand how these factors affect the Adlai seed quality, viability, and other important characteristics over time.

REFERENCES

Abdul-Baki, A. A., & Anderson, J. D. (1973). Vigor determination in soybean seed by multiple criteria. *Crop Science*, *13*(6), pp. 630–633. https://doi.org/10.2135/cropsci1973.0011183x001300060013x

Adjei, E. A., Banful, B. K., Asiedu, E. A., Amoah, R. A., Arthur, M., Yeboah, S., & Asibuo, J. Y. (2022). Interactive effects of moisture content and packaging material on common bean seed yield and yield components. *Journal of Experimental Agriculture International*, pp. 45–55. https://doi.org/10.9734/jeai/2022/v44i630830

Akinneye, J.O., & Aringbangba, R.O. (2015). Effects of Packaging Materials on Proximate, Mineral and Physicochemical Properties of Plantain Chips (*Musa paradisiaca*) in Storage. *Futa Journal of Research in Sciences, 11*, pp. 55–59.

Andriana, Y., Indriati, A., Mayasti, N. K. I., Iwansyah, A. C., Anggara, C. E. W., Litaay, C., & Triyono, A. (2021a). Adlay (Coix lacryma-jobi), a potential source alternative to wheat flour: A financial feasibility analysis for small scale production. *IOP Conference Series. Earth and Environmental Science*, *672*(1), 012032. https://doi.org/10.1088/1755-1315/672/1/012032

Arah, I. K., Ahorbo, G. K., Anku, E. K., Kumah, E. K., & Amaglo, H. (2016). Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review. *Advances in Agriculture*, *2016*, pp. 1–8. https://doi.org/10.1155/2016/6436945

Arcalas, J. Y. (2022, June 21). *Adlai grain in the Philippines*. BusinessMirror. https://businessmirror.com.ph/2022/06/21/adlai-grain-rice-alternatives-philippines/

Arief, R. W., Asnawi, R., Tambunan, R. D., Wardani, N., Mustikawati, D. R., & Mejaya, M. J. (2022). Packaging types as influencing seed quality in some soybean [Glycine max (L.) Merr.] varieties during storage period. *Czech Journal of Food Sciences*, *40*(3), pp. 229–239. https://doi.org/10.17221/119/2021-cjfs

Azadi, M. S., & Younesi, E. (2013). The effects of storage on germination characteristics and enzyme activity of sorghum seeds. *Journal of Stress Physiology & Biochemistry, 9*(4), pp. 289-298. http://www.jspb.ru/issues/2013/N4/JSPB_2013_4_289-298.pdf

Badawi, M.A., Seadh, S. E., Abido, W. A. E., Hasan, & R. M. (2017). Effect of storage treatments on wheat storage. *International Journal of Advanced Research in Biological Sciences (IJARBS)*, *4*(1), pp. 78–91. https://doi.org/10.22192/ijarbs.2017.04.01.009

Bakhtavar, M. A., & Afzal, I. (2020). Seed storage and longevity: Mechanism, types, and management. In *Advances in Seed Production and Management* (pp. 451–468). Springer Singapore.

Bista, M., Ghimire, P., Khanal, D., Khatri, N., & Marasini, S. (2022). Effect of storage materials and duration on quality of rice seed. *Agronomy Journal of Nepal*, pp. 36–44. https://doi.org/10.3126/ajn.v6i1.47926

Business Diary Philippines. (2021, January 19). Adlai production guide. *Business Diary Philippines*. https://businessdiary.com.ph/6443/adlai-production-guide/

BusinessMirror. (2022). Adlai production in the Philippines: Is it a viable alternative for rice in the Philippines? *Adlai Production in the Philippines: Is It a Viable Alternative for Rice in the Philippines? BusinessMirror*. https://businessmirror.com.ph/2022/06/21/adlai-grain-rice-alternatives-philippines/

Chala, M. (2017). Review on Seed Process and Storage Condition in Relation to Seed Moisture and Ecological Factor. *Journal of Natural Sciences Research, 7*, pp. 84–90.

Dela Cruz, R. (n.d.). *Adlay: A healthy, versatile food ingredient*. Gov.Ph. Retrieved September 28, 2023, from https://bar.gov.ph/index.php/media-resources/news-and-events/219-adlay-a-healthy-versatile-food-ingredient

Dela Torre, J.M. (2018). Physicochemical Constituents and Sensory Properties of Adlai (*Coix lachryma jobi*). *Asian Journal of Postharvest and Mechanization, 1*(2), pp. 1-14.

Finch-Savage, W. E., & Bassel, G. W. (2016). Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany*, *67*(3), pp. 567–591. https://doi.org/10.1093/jxb/erv490

Gebeyaw, M. (2020). Review on: Impact of seed storage container on seed quality. *Alliedacademies.org*. Retrieved November 15, 2023, from https://www.alliedacademies.org/articles/review-on-impact-of-seed-storage-container-on-seed-quality.pdf

Gregorio, R.P., Martinez, R.C., & Salarzon, A.L. (2014). Development of Postharvest Technology for Adlai (Study 1. Threshing, Drying and Milling). *Compendium of PHilMech RD&E Abstracts 2012-2017*. pp. 13

Kallow, S., Panis, B., Vu, D. T., Vu, T. D., Paofa, J., Mertens, A., Swennen, R., & Janssens, S. B. (2021). Maximizing genetic representation in seed collections from populations of self and cross-pollinated banana wild relatives. *BMC Plant Biology*, *21*(1). https://doi.org/10.1186/s12870-021-03142-y

Kansiime, M. K., Bundi, M., Nicodemus, J., Ochieng, J., Marandu, D., Njau, S. S., Kessy, R. F., Williams, F., Karanja, D., Tambo, J. A., & Romney, D. (2021). Assessing sustainability factors of farmer seed production: a case of the Good Seed Initiative project in Tanzania. *Agriculture & Food Security*, *10*(1). https://doi.org/10.1186/s40066-021-00289-7

Magpantay, R. L., Jr, Barrion, A. S. A., Dizon, E. I., & Hurtada, W. A. (2021). Influence of heat treatment on the nutrient composition and physicochemical characteristics of Adlai (Coix Lachryma-Jobi L.) and Obatanpa cross Lagkitan (OxL) corn variety (Zea Mays L. 'Los Baños Lagkitan'). *Food Research*, *5*(1), 271–276. https://doi.org/10.26656/fr.2017.5(1).420

Naguib, N., Adly, E. A. I., & Mohamed, N. A. (2011). Effect of Storage Period and Packaging Material on Wheat (*Triticum aestivum* L.) Seed Viability and Quality. *Egypt. J. Agric. Res.*, *89*(4), pp. 1481-1497

Nyo, H. T., Htwe, N. N., & Win, K. K. (2019). Effect of different packaging materials and storage environments on seed quality of sesame (Sesamum indicum L.). *Journal of Biology and Life Science*, *11*(1), pp. 1. https://doi.org/10.5296/jbls.v11i1.15405

Satasiya, R. M., Antala, D. K., Sojitra, M. A., Kothiya, A. V., & Chauhan, P. M. (2021). Effect of packaging on storage behaviour of chickpea grain. *Journal of Pharmacognosy and Phytochemistry, 10*(1), 1575-1584. Retrieved November 15, 2023, from https://www.phytojournal.com/archives/2021/vol10issue1/PartV/9-5-382-330.pdf

Singkaew, J., Miyagawa, S., Wongs-Aree, C., Vichitsoonthonkul, T., Sokaokha, S., & Photchanachai, S. (2017). Season, fruit maturity, and storage affect on the physiological quality of F1 hybrid 'VTM580' tomato seeds and seedlings. *The Horticulture Journal, 86*(1), pp. 121–131. https://doi.org/10.2503/hortj.mi-087

Small, E., & Brookes, B. (2012). Temperature and moisture content for storage maintenance of germination capacity of seeds of industrial hemp, marijuana, and ditchweed forms of*cannabis sativa*. *Journal of Natural Fibers*, *9*(4), pp. 240–255. https://doi.org/10.1080/15440478.2012.737179

Smith, R. D. (1992). Seed storage, temperature and relative humidity. Seed Science Research, 2(2), pp. 113–116. https://doi.org/10.1017/s0960258500001215

Syed, A., & Rizvi, A. (2021). *Maintaining Seed viability and Seed vigour: Important Aspects*. Justagriculture. In. Retrieved September 28, 2023, from https://justagriculture.in/files/newsletter/2021/october/028.pdf

Tabaković, M., Simić, M., Stanisavljević, R., Sečanski, M., Živanović, L., & Štrbanović, R. (2019). Buckwheat seed quality during the five-year storage in various packing materials. *Plant, Soil and Environment, 65*(7), pp. 349–354. https://doi.org/10.17221/237/2019-pse

Tandoh, P., Banful, B., Gaveh, E., & Amponsah, J. (2017). Effects of packaging materials and storage periods on seed quality and longevity dynamics of Pericopsis elata seeds. *Environment Earth and Ecology*, *1*(2), pp. 27–38. https://doi.org/10.24051/eee/76919

Tiwari, R. S., Chandra, K. K., Dubey, S., & Tripathi, S. (2022). Influence of packaging materials and storage conditions on seed germination ability and biochemical changes in some medicinal plants of Indian forests. *Frontiers in Forests and Global Change*, *5*. https://doi.org/10.3389/ffgc.2022.868237

Utah State University. (n.d.). Seed Storage and Handling. Usu.edu. Retrieved November 22, 2023, from https://extension.usu.edu/vegetableguide/production/seed-storage-handling

Wawrzyniak, M. K., Michalak, M., & Chmielarz, P. (2020). Effect of different conditions of storage on seed viability and seedling growth of six European wild fruit woody plants. Annals of Forest Science, 77(2). https://doi.org/10.1007/s13595-020-00963-z

Weng, W. F., Peng, Y., Pan, X., Yan, J., Li, X. D., Liao, Z. Y., Cheng, J. P., Gao, A. J., Yao, X., Ruan, J. J., & Zhou, M. L. (2022). Adlay, an ancient functional plant with nutritional quality, improves human health. *Frontiers in Nutrition*, *9*. https://doi.org/10.3389/fnut.2022.1019375

Yewle, N., Charpe, A. M., Gupta, S., Patil, B., Tushir, S., & Mann, S. (2020). Impact of hermetic packaging on green gram (Vigna radiata) insect and microbial damage under environmental storage condition. *Journal of Entomology and Zoology Studies*, *8*(5), pp. 1883–1887. https://doi.org/10.22271/j.ento.2020.v8.i5z.7766