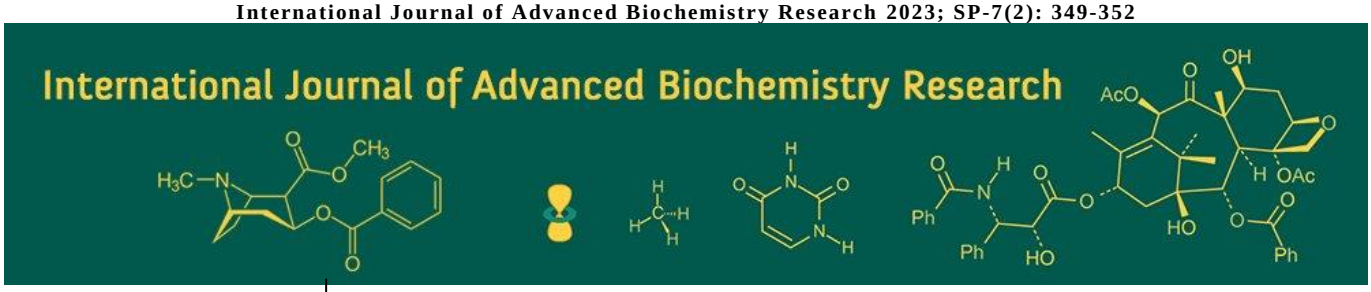

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Comparative study on hermetic and non-hermetic storage of Pearl millet (*Pennisetum glaucum*)

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Abstract
Millets are one of the major cereal grains consumed worldwide, especially in arid and semi-arid areas of Africa and Asia (India and China). Storage is one of the vital post-harvest operations, where the country stores the food commodities in huge capacities for maintaining the buffer stock for future purpose. During long-term storage, Pearl millet (*Pennisetum glaucum*) storage is essential to maintain its quality and prevent spoilage. A comparative study of hermetic and non-hermetic bags on Pearl millet was conducted in four different storage bags *viz.* gunny bags (control), polypropylene bags, *Grainpro* hermetic storage bags, *Proharvest* hermetic storage bags. Hermetic storage of Pearl millet shows that *GrainPro* hermetic bags & *Proharvest* hermetic bags were superior with respect to nutrient retention, no visible mold or pest infestation. It is desirable to use hermetic bags for the storage of millets when it is intended for small scale storage.

Keywords: Germination, CIE color, millet storage

1. Introduction
Millets are one of the oldest human food and believed to be the first domestic cereal grain (Michaelraj & Shanmugam, 2013) [5]. India is the world's largest producer of millet with the production of 11.5 MMT (FAOSTAT, 2020) [3]. Food safety and storage are major concern to the world's population. Storage is one of the vital post-harvest operation, where the country store the food commodities in huge capacities for maintaining the buffer stock for future purpose (Mishra, Prabuthas, & Mishra, 2012) [6]. Storing pearl millet, like storing any grain, can present numerous challenges. Proper storage is important to prevent spoilage, maintain grain quality, and protect it from pests. During long-term storage, proper sorghum storage is essential to maintain its quality and prevent spoilage. By addressing these common storage problems, you can ensure that pearl millet remains in good condition for extended periods. Pearl millet, as reported by Sade (2009) [7], exhibits higher protein (14.01%), fat (5.71%), fiber (2.10%), and ash (2.21%) content compared to major cultivated cereal crops like wheat, rice, and sorghum. Additionally, research by Yadav *et al.* (2014) [8] highlights its greater protein quality, with notable levels of amino acids like tryptophan and threonine. Along with, increased calcium, iron, and zinc content, rendering this crop highly valuable for human consumption.
Commonly it is cultivated in India, Nepal, Sri Lanka, East China and Bangladesh, Kenya, Tanzania etc. Millet storage losses per year can vary depending on the region and storage conditions, but can be as high as 20-30%. This is due to a variety of factors, including pests, diseases, and moisture (FAOSTAT, 2020) [3]. In this research, the impact of internal moisture, germination, temperature and relative humidity on Pearl millet (*Pennisetum glaucum*) will be explored in hermetic and non-hermetic storage.

2. Materials and Methods
2.1 Raw materials and storage bags used
Pearl millet (*Pennisetum glaucum*) used in this experiment were procured from local market of Raipur, Chhattisgarh, India. Pearl millet was cleaned to remove the dirt, dust and chaff materials. *Proharvest* and *GrainPro* hermetic bags was purchased from Universal Enterprises, India and PCI, India, respectively. Gunny bags and polypropylene bags are purchased from local market of Raipur, Chhattisgarh, India.

2.2 Analysis of pearl millet kept in different storage bags

2.2.1 Lab scale storage study

A comparative study of hermetic and non-hermetic bags on Pearl millet was conducted in four different storage bags *viz*. gunny bags (control), polypropylene bags, *Grainpro* hermetic storage bags, *Proharvest* hermetic storage bags. Each bag contains 1 kg of each millet sample. The experiment is triplicated. The samples were subjected under ambient conditions (Temperature 30±4 °C and relative humidity 60±10%) for four months storage study. During storage, temperature and relative humidity values are recorded daily using data logger, at the storage site. The quality parameters *viz*. moisture content and germination were analysed on monthly basis.

2.2.2 Determination of moisture content

Moisture content of pearl millets was determined using standard hot air oven method (AOAC 2006) [1]. Three samples of 5 g each were drawn randomly from each bag that were used for the storage study. Temperature of the hot air oven was set to 110 °C and the sample was kept inside the chamber for 3 hours.

2.2.3 Estimation of weight loss

Grain weight losses is the quantitative loss that occurs due to insect infestation and moisture variation with respect to storage environment. Percent weight change in Pearl millet was calculated by using the equation:

$$Weight\ loss, W\ (\%) = \frac{I - F}{I} \times 100$$

Where, I = initial weight observed before the storage study begins

F = final weight observed after storage study on monthly basis

2.2.4 Estimation of changes in colour

The CIE colour values (L^*, a^*, b^*) of pearl millets were analyzed using Hunter lab colorimeter with D_{25} optical sensor (Hunter Associates Laboratory, Reston, VA). The change in colour was estimated using the equation:

$$Change\ in\ colour\ value, \Delta = \sqrt{(L - \mathrm{l})^2 + (A - \mathrm{a})^2 + (B - \mathrm{b})^2}$$

Where, L = level of lightness, ranging from 0 (black) to +100 (white);

a = -100 (greenness) to +100 (redness) and

b = -100 (blueness) to +100 (yellowness)

Note: All the capital letters (L, A, B) and small letters (l, a, b) used in the equation stands for initial and final values, respectively

2.2.5 Assessment of pest infestation

Stored food commodities are affected by biotic and abiotic factors. Among these, pest infestation is a major issue which leads to contamination making the food unsafe for human consumption (Moses at el., 2015) [9]. Pest infestation in Pearl millet during the storage period was observed visually by removing the grains from bags in tray after opening the stored bags.

2.2.6 Visual mold growth assessment

Visible mold growth gives possibilities of mycotoxin production on the product. High temperature, relative humidity and high pest infested commodities are more prone to mold infestation. The visible mold growths in samples were visually observed by removing the grains in open tray and were also viewed in stand-alone LCD digital microscope (POLY UM038).

2.2.7 Estimation of germination percentage

Germination is one of the important factors to be considered during storage of grains. It is used as an index to test the viability of the grains. For the germination test, Petri dish of 9 cm diameter was taken and Whatman No. 3 filter paper was placed in it. 5.5 ml of distilled water was added into the Petri dish and each petri dish was stacked and covered by using polyethylene bag. This covered Petri dish was then kept in incubator at 25°C for 4 days. Then, polyethylene bag was removed from the incubator and was kept under normal room temperature for 3 days. The germination percentage of seeds were calculated after 7 days by following formula (Chandraprabha and Sharon, 2021) [10].

$$Germination\ (\%) = \frac{Number\ of\ seed\ germinated}{Total\ number\ of\ seeds} \times 100$$

2.2.8 Temperature and relative humidity

Temperature and relative humidity were recorded using HTC easy log data logger model inside the cocoon to observe any changes that result during storage. At the end of the storage period, data on temperature and relative humidity were recorded by transferring the data to the data logger using software and the data were subjected to statistical analysis.

2.3 Statistical analysis

All analysis for the study were performed in triplicates. The difference among the means were tested by one-way ANOVA, at 95% CI (p<0.05), using statistical software SPSS version 25.

3. Results

3.1.1 Moisture content of Pearl millet

Grain moisture content plays an important role, which affects the storage quality. Variation in moisture content of stored Pearl millet in gunny bags, polypropylene bags, *GrainPro* bags and *Proharvest* bags were analysed. Initial average level of moisture content in procured Pearl millet 9.53 ± 0.17% wb. There was no significance difference were found in hermetic storage conditions but there was significance difference were observed in control storage device gunny bag as well as in polypropylene bag. After 120th day of storage of Pearl millet moisture content of pearl millet was analysed 11.15 ± 0.14% in gunny bag, 10.45 ± 0.09% in polypropylene bag, 9.61 ± 0.21% in hermetic storage devices.

Table 1: Difference in moisture content of stored pearl in different packaging material

Pearl millet	Moisture content (%) Mean±SD	
	Initial (0th day)	Final (120th day)
Gunny bags	9.53 ± 0.17	11.15 ± 0.14
Polypropylene bags	9.53 ± 0.17	10.45 ± 0.09
GrainPro hermetic bags	9.53 ± 0.17	9.61 ± 0.20
Proharvest hermetic bags	9.53 ± 0.17	9.61 ± 0.10

3.1.2 Estimation of weight loss of pearl millet

Quantity and quality of stored products should be retained during storage to reduce post-harvest losses. Weight loss in different packaging materials were recorded at the end of the storage period. Gunny bag recorded maximum weight loss in pearl millet (19.11 ± 0.25%) respectively 13.29 ± 0.17% loss in polypropylene bag. Pearl millet stored in *Proharvest* hermetic bags and *GrainPro* hermetic bags recorded less weight loss (0.25 ± 0.03%) respectively.

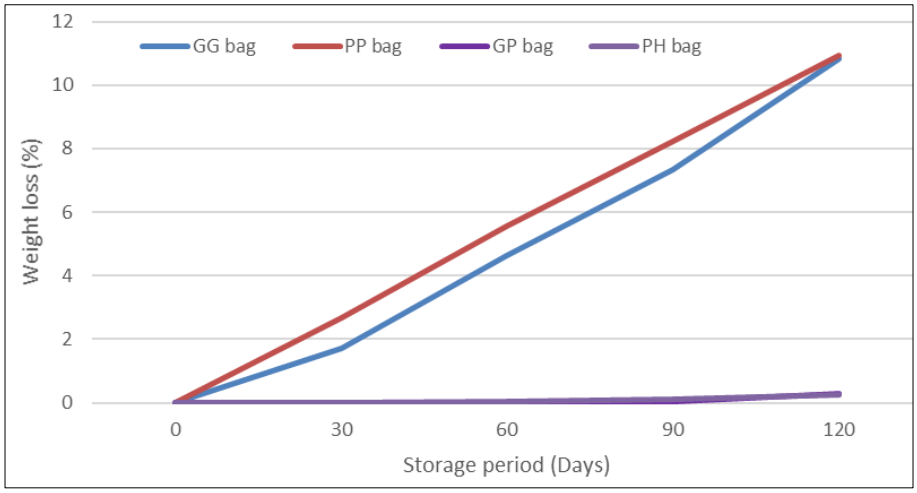

Fig 1: Weight loss of pearl stored in different packaging material under laboratory conditions

3.1.3 Estimation of CIE colour values (L*, a*, b*)

Colour brightness (*L**) and redness value (*a**) of the millet stored in gunny bags, polypropylene bags and hermetic bags does not show much difference in colour values as compared with the initial values. There was a slight increase in yellowness (*b**) of the pearl millet after storage in gunny bags, polypropylene bags, *GrainPro* hermetic bags and *Proharvest* hermetic bags as compared with the initial values. Increase trend in ΔE value in control and hermetic storage might be due to change in (*b**) values.

3.1.4 Assessment of pest infestation

In the present study *T. castaneum* damage in pearl millet were recorded in gunny bags of from 30th day of storage itself. Pearl millet stored in polypropylene bags were infested by *T. castaneum* 60th day of storage. There was no insect infestation in pearl millet stored in hermetic bags till the end of the storage period (120th days).

3.1.5 Determination of visual mold growth

Visible mold growth was observed in pearl millet stored in gunny and polypropylene bags. This could be due to environmental effect, increase in moisture content, water activity and pest infestation in gunny and polypropylene bags there was no visible mold growth observed in pearl millet stored in hermetic bags.

3.1.6 Estimation of germination test

Germination percentage was calculated for pearl millet. The initial and final germination percentage of pearl millets are mentioned below in Table 2.

Pearl millet stored in gunny and polypropylene bags affected the germination drastically and recorded very low germination percentage (17.36, 25.43%). The *GrainPro* and *Proharvest* hermetic bags recorded (92.12 & 93.32%) germination compared to initial germination percentage of 97.33%. Grain pro and *Proharvest* hermetic bags do not show any variation in germination percentage and maintained the same up to 120 days of storage period.

Table 2: Germination percentage of pearl millet stored in different packaging materials (Mean±SD)

Storage bags	Pearl millet Germination (%)	
	Initial	Final
Gunny bags	97.33 ± 2.30	17.33 ± 2.36
Polypropylene bags	97.33 ± 2.30	25.33 ± 2.43
GrainPro hermetic bags	97.33 ± 2.30	92.00 ± 2.12
Proharvest hermetic bags	97.33 ± 2.30	93.33 ± 2.32

3.1.7 Temperature and relative humidity

Temperature and relative humidity were analysed by using the Easy Temperature Humidity software of HTC easy log data logger which was kept in laboratory. The average Temperature 30±4 °C and relative humidity 60±10% was recorded.

3.1.8 Biochemical analysis of stored pearl millet

Proximate analysis consists nutrient profile of pearl millet protein content, fat, fibre, ash was analysed before (0th day) & after (120th day) storage in different packaging devices. Study on storage of pearl millet there was no much changes with respect to nutrient composition of millets stored in packaging in the hermetic bags (*GrainPro* bag and *Proharvest* bag) compared with non-hermetic bags (gunny bag and polypropylene). Slight changes were observed in protein content of the pearl millet stored in gunny and polypropylene bags. This might be due to increase in moisture content and temperature variation.

4. Discussion

Hermetic storage of pearl millet shows that *GrainPro* hermetic bags & *Proharvest* hermetic bags were superior with respect to nutrient retention, no visible mold or pest infestation. It is desirable to use hermetic bags for the storage of millets when it is intended for small scale storage. Insect infestation not only affect the quality and quantity of the food grains, also cause negative impact on human health, viability of the grain, and loss in nutritional value and reduces the commercial value (Kumar *et al*., 2017) [4].

Pearl millet is damaged by a number of insect pests, which leads to quantitative and qualitative losses. The common and affective pest is rice weevil (*Sitophilus oryzae*) in stored pearl millet. Germination is also an important factor vary based on the storage and loss of viability and nutrients in grains like pearl millets were reported due to non-scientific storage practices (Dejene, 2004) [2]. Hermetic storage is a promoting eco-friendly technique the help to increase the shelf life of stored food commodities without compromising the quality. Hermetically stored Food commodities showed better quality retention than conventional storage practices. Hermetic storage can be adopted for long and short term storage for both bulk and small scale storage of food commodities. Hermetic storage of pearl millets were effective in maintaining the quality parameters by avoiding insect and mold growth over four months of storage as compared with conventional gunny bags and polypropylene bags. The quality paramters like weight loss, moistute content, water activity, visible mold growth and pest infestation were increased over storage period in pearl millet stored in gunny bags and polypropylene bags. Whereas no variation in hermetic storage was recorded.

5. Conclusion

Hermetic storage of pearl millet shows that *GrainPro* hermetic bags & *Proharvest* hermetic bags were superior with respect to nutrient retention, no visible mold or pest infestation. It is desirable to use hermetic bags for the storage of millets when it is intended for small scale storage. Farmers and manufacturers are facing huge post-harvest storage losses. Lack of low-cost storage structures with ease of convenience can solve the storage problems effectively. Among the different storage structures, hermetic storage bags are found to be effective. Hermetic storage is a promoting eco-friendly technique the help to increase the shelf life of stored food commodities without compromising the quality. Hermetically stored Food commodities showed better quality retention than conventional storage practices. Hermetic storage can be adopted for long and short term storage for small-scale storage of food commodities. This technique avoids the use of chemical fumigants during storage & avoid pest infestation and storage losses, thus helps in maintaining the quality of the foods. In the present study hermetic storage of millets showed better quality retention by no pest and visible mold growth throughout storage period.

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