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Gagan Dip
College of Dairy Science and Food Technology, Raipur, Chhattisgarh, India

Nikita Sharma
College of Dairy Science and Food Technology, Raipur, Chhattisgarh, India

Corresponding Author:
Gagan Dip
College of Dairy Science and Food Technology, Raipur, Chhattisgarh, India

Physiochemical study on storage of little millet (*Panicum miliare*) in hermetic storage

Gagan Dip and Nikita Sharma

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Abstract
Storage plays critical role as post-harvest operation, where nations maintain substantial capacities for storing food commodities to ensure availability of buffer stocks for future needs. It is crucial to ensure the quality and prevent spoilage of little millet during prolonged storage, as this preservation process is integral to maintaining the long-term feasibility of these grains as valuable food resources. A comprehensive physiochemical study was conducted on the bulk scale storage of little millet (*Panicum miliare*) employing hermetic storage methods. Then 50 kg of little millets were packed in 60 kg capacity bags. The hermetic structure was placed under ambient condition (temperature 30 ± 7 °C and relative humidity 60 ± 10%) for 120 days of storage. The hermetic bags were sealed with an airtight zipper. Quality parameters were analysed before and after 120 days of storage. In the context of hermetic storage for little millet, the application of *GrainPro* hermetic bags and *postharvest* hermetic bags proved to be superior in terms of maintaining nutrient content and ensuring the absence of visible mold or pest infestation. Therefore, using hermetic bags is recommended for bulk-scale little millet storage with better retention of quality characteristics.

Keywords: Germination, storage study, gas concentration

1. Introduction
Millets are among the early known human food sources and are considered to be the first cereal grain cultivated for domestic use (Michaelraj & Shanmugam, 2013) [13]. With a millet production of 11.5 million metric tons, India holds the title of the world's primary millet producer (FAO, 2020) [5]. Ensuring food safety and proper storage are significant global priorities. Storage represents a critical post-harvest activity, where nations store food commodities on a large scale to maintain buffer reserves for future needs (Mishra, Prabuthas, & Mishra, 2012) [14]. Scientifically known as *Panicum miliare*, Little Millet is recognized as one of the minor millet types well known for its advantageous nutritional composition, boasting significant quantities of crude fiber (7.7 g) and fat (4.7 g) per 100 grams, in addition to significant levels of phosphorus (220 mg) and iron (9.3 mg) per 100 grams (Mannuramath *et al*., 2015) [12]. Little millet's low glycemic index is mainly attributed to its high dietary fiber content. A recent study on this millet has confirmed its hypoglycemic effect, which is largely due to its higher dietary fiber content (Itagi *et al*., 2013) [8]. Storing little millet, like any other grain, comes with its share of challenges. It is crucial to ensure proper storage practices to prevent spoilage, maintain grain quality, and protect it from pests. Maintaining the quality and preventing spoilage is vital during the extended storage of little millet. Addressing these typical storage issues is essential to ensure the long-term preservation of little millet in good condition. Among the various species of this millet cultivated for food use. Each year, storage losses for little millet can fluctuate based on regional and storage conditions, with potential losses ranging from 20% to 30%. These losses are attributed to a range of factors, including pests, diseases, and moisture levels (FAO, 2020) [5]. In this research, the impact of internal moisture, germination, temperature and relative humidity on little millet will be explored in hermetic storage.

2. Materials and Methods
2.1 Raw materials and storage bags used
Little millet (*Panicum miliare*) used in this experiment were procured from local market of Chhattisgarh, India. Little 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 Bulk scale storage study
Gunny bags (control), polypropylene bags, *Grainpro* hermetic storage bags, *Proharvest* hermetic storage bags of 50 kg capacity each was used in this study. Little millets were filled in triplicates in these storage bags. The bags were placed inside cacoon™ structure and properly sealed with airtight zipper. The study was conducted under ambient condition (temperature 30±7 °C and relative humidity 60±10%) for 120 days of storage.

2.3 Determination of moisture content
The moisture content of little millet was measured through the established hot air oven technique, following the AOAC (2006) [1] standards. In this process, three random samples, each weighing 5 grams, were extracted from the bags utilized in the storage study. The hot air oven's temperature was adjusted to 110 °C, and the samples were placed within the chamber for a duration of 3 hours.

2.4 Estimation of water activity
The water activity (aw) of little millet was assessed utilizing a water activity meter, specifically the Aqua lab 4TE. This equipment operates by accurately determining the dew point temperature of the sample, achieved by directing an infrared beam onto a small mirror. The sample was positioned in a disposable cup and inserted into the water activity meter. Upon sealing the chamber and conducting the analysis, the resulting values were digitally displayed and afterward documented.

2.5 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 (Golebiowska, 1969) [7]. Percent weight change in little 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

2.6 Assessment of pest infestation
Food commodities in storage are susceptible to both living organisms (biotic) and non-living environmental influences (abiotic). Among these factors, pest infestation poses a significant concern, resulting in contamination that renders the food unsuitable for human consumption, as noted by (Moses, Jayas, and Alagusundaram 2015) [17]. To monitor pest infestation in stored little millet, the grains were visually inspected during the storage period by removing them from bags and placing them in trays after opening the storage containers.

2.7 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).

2.8 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 (Pomeranz, 1982) [15]. 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 (Sharon *et al*., 2015) [17].

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

2.9 Temperature and relative humidity
Temperature and relative humidity were recorded using HTC easy log data logger model inside the hermetic bag 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.

2.10 Gas concentration measurement in GrainPro cacoon™ bag
Gas concentration is one of the most important parameters of hermetic storage. Hermetic mechanism works on the basis of increase in CO_2 concentration and decrease in O_2 concentration during storage. O_2 & CO_2 concentration inside the *GrainPro* hermetic bag was measured using PBI Dansensor Check Point-1 portable handheld gas analyser. In hermetic sealed cacoon there was a space to measure gas concentration, where the needle probe of the gas analyser was inserted. The relative percentage of carbon dioxide and oxygen were recorded.

2.11 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 and Discussion
3.1 Moisture content
Moisture content of the little millet was analysed before (0^{th} day) and after (120^{th} day) storage in GrainPro hermetic bag. Proper packaging and storage conditions help in maintaining the optimum moisture content of the produce and to reduce moisture migration from outside environment (Divekar & Sharma, 2016; Dunno *et al*., 2016) [3, 4]. There was no significant difference in moisture content of little millet stored in any packaging materials in gunny bag, polypropylene bag, *GrainPro* hermetic bag and *Proharvest* hermetic bag.

3.2 Water activity
Water activity in little millet remains almost same in gunny, polypropylene bag, *GrainPro* hermetic bag and *Proharvest*

hermetic bag storage. Hermetic bags helps in maintaining the water activity levels in little millet during storage. Hermetic storage helps to maintain product quality regardless of stored environmental condition (Jonfia-Essien, Varro, & Villers, 2010) [9].

3.3 Visible mold growth in little millet stored in hermetic bags

Little millet stored in hermetic bags, showed no visible mold growth. During hermetic storage the mold growth hindered by modified atmosphere created within the bags due to increase in CO_2 concentration and decrease in O_2 concentration inside the hermetic bags.

3.4 Pest infestation in stored little millet

Pest infestation is the major problem during storage and handling of food commodities. Proper storage conditions are required for the safe storage of little millet. Millets stored in hermetic bags showed no insect and pest infestation during the four month of storage period.

3.5 Germination percentage and weight loss

Germination test and weight loss were analysed before (0^{th} day) and after (120^{th} day) storage in hermetic bags. Before and after, all millet samples of little millet were germinated during hermetic storage. As well as there was no significance difference were analyzed after 120^{th} day of storage.

3.6 Temperature and relative humidity of stored little millet

Temperature and relative humidity the important parameter that affects storage (Lane & Woloshuk, 2017) [11]. Temperature and relative humidity affect the stored food commodity by causing biochemical changes. Temperature and relative humidity were analysed by using the Easy Temperature Humidity software of HTC easy log data logger which was kept inside the hermetic bag. There was no effect of temperature and relative humidity on the quality of the little millet during the four months of storage.

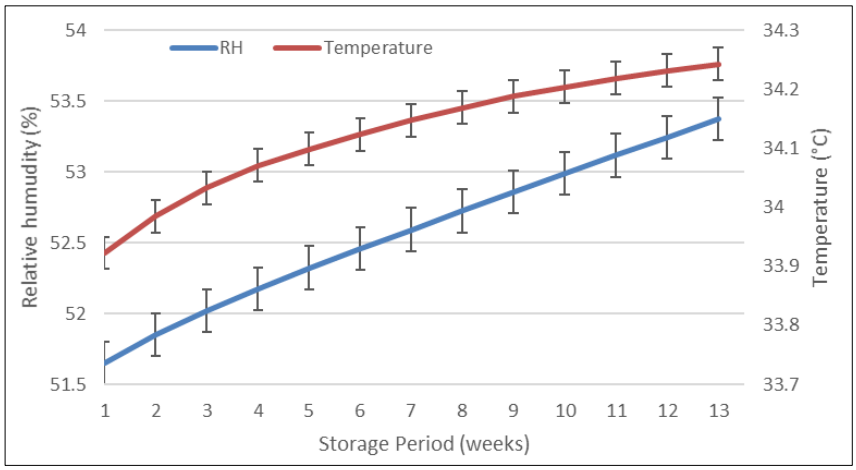

Fig. 1: Fluctuation in RH and temperature during cacoon^{TM} storage of little millet

3.7 Gas concentration in little millet stored in hermetic bags

Gas concentration is one of the most important parameters of hermetic storage. Hermetic mechanism works on the basis of increase in CO_2 concentration and decrease in O_2 concentration during storage. Little millet was stored in hermetic bags, which was completely sealed with the help of zipper for maintaining hermetic technology. Concentration of O_2 decreased with increase in storage period and CO_2 concentration was increased. Increased CO_2 concentration results in anoxia and death of stored pests. The concentration of gas inside hermetic bags was monitored and measured using PBI Dansensor CheckPoint-1 portable gas analyser. The change in gas concentration is shown in below figure 2.

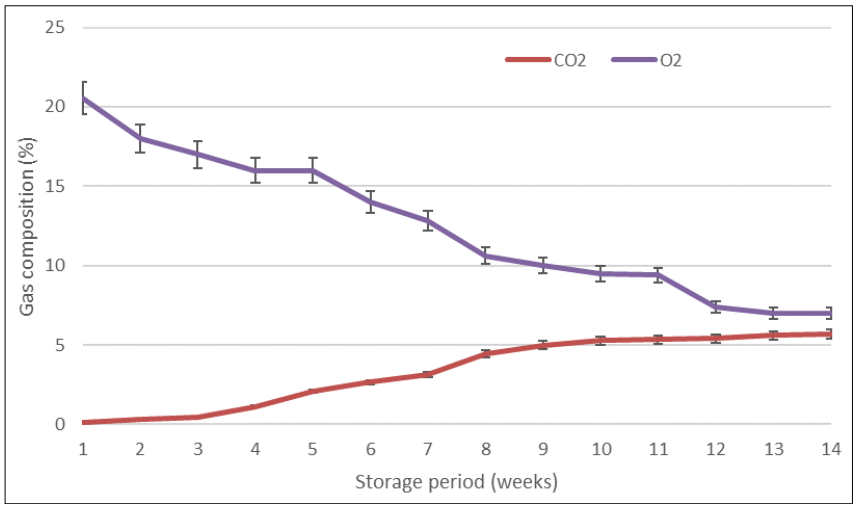

Fig. 2: Changes in gas concentration during bulk scale storage study of little millet

3.8 Proximate analysis of little millet stored in hermetic bags

Little millet stored in hermetic bags were subjected to proximate analysis (protein content, fat content, fibre content and ash content) using AOAC method (AOAC, 2006) [1]. Results shows that, there was no significant change in the nutritional profile of stored little millet in the hermetic bags. The composition of little millet no significant changes during storage. The protein content was 8.63 ± 0.05% to 8.44 ± 0.14%, while fat content was from 4.60 ± 0.10% to 4.52 ± 0.17%. Fiber content also shown no significant difference, going from 6.62 ± 0.09% to 6.46 ± 0.13%, while ash content was from 3.55 ± 0.16% to 3.64 ± 0.18%.

Studies shows that, storage affects the nutritional quality of the stored food commodities (Rehman, 2011) [16]. There was slight change in protein content of maize in non-hermetic bags but there was no significant change in nutritional quality of the maize stored under hermetic storage conditions (García-Lara *et al*., 2020) [6].

4. Discussion

Hermetic storage of little millet shows that *GrainPro* hermetic bags & *Proharvest* hermetic bags were superior with respect to nutrient retention, no visible mold or pest infestation. 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) [10] bulk storage in hermetic bags is desirable. Inside the hermetic bags, if gunny (or) polypropylene bags are used no pest infestation (or) visible mold growth & loss in nutrients were reported. The grains used must be free from pest infestation & should be stored with desirable moisture content. Cooperatives & farmers producer's organization can make use of hermetic bags for long term storage of millets. Little millet is damaged by a number of insect pests, which leads to quantitative and qualitative losses. Germination is also an important factor vary based on the storage and loss of viability and nutrients in grains like little millet was reported due to non-scientific storage practices (Dejene, 2004) [2]. Hermetic storage is a promoting eco-friendly technique the help to increse 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 little millet 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 no significant variation over storage period in little millet no variation in hermetic storage was recorded.

5. Conclusion

Hermetic storage of little 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 bulk 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 both bulk and 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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