***Original Research Article***

**Effect of Packaging on Storage Stability and Insect Infestation in Kodo Millet**

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**Abstract**

In India, one of the main reasons for grain losses during storage is insect infestation. Kodo millet (*Paspalum scrobiculatum* L.) is grown as a cereal in India only, although the wild grass is a widespread tropical weed. Kodo millet is said to be poisonous after rain. This could be due to a fungal infection. The current study examined how insects were stored in various packaging materials and how infestation affected the physical and chemical properties of dehulled kodo millet. Insects and pests that attack kodo millet include the khapra beetle (Trogoderma granarium), rice weevil (Sitophilus oryzae), grain moth (Sitotroga cerealella), and flour beetle (Tribolium castaneum). These pests and mites cause losses in both the quantity and quality of nutrients during the storage period. The current research focused on grain storage tests, quality trait analysis, and post-harvest practices. After being dehulled and ground on a Perfura dehulling and milling machine, raw kodo grains were kept at room temperature during different storage periods (0, 60, 120, and 180 days) in a range of packaging methods (such as vacuum packing, LDPE, HDPE, and gunny bags). The sample materials were properly cleaned, graded, hulled and milled by Perfura, hulling and stored at ambient room temperature for further use in experiments. The products' physical and chemical properties were assessed, together with the relevant insect observations. The maximum number of insects was found (83) in gunny bag storage milled kodo samples at 180 days, while vacuum-packed samples showed a nil number of insects. According to the data collected, samples packed in gunny bags appeared to contain the majority of insects during the six-month period, whereas samples packed in vacuums showed no change. According to the findings, six months of storage was when biophysical qualities changed, not when samples were vacuum-packed. As a result, during the six-month storage at the studies, it was found that the vacuum-packed kodo millet samples showed significant results for all of their quality characteristics. Dehulled kodo millet can be stored for longer by using vacuum packaging since it preserves its physico-chemical composition. In conclusion, millets have potential for protection against age-onset degenerative insect pests. Moisture is another critical factor in the safe storage of food grains. The vacuum-packed kodo millet samples were found to have significant results for all the quality parameters during the six-month storage study. **Keywords**: Kodo millet, Insect pests, , Vacuum packaging, chemical properties, infestation

1. **Introduction**

Kodo millet (*Paspalum scrobiculatum* L.) is one of the minor millets, valued for its rich nutritional profile and is commonly consumed in India. Although many investigations have focused on grain yield and associated traits, and biotic and abiotic stress tolerance in this millet, there are limited reports on recombination breeding efforts as it is constrained by a lack of effective emasculation and crossing technique owing to the small and delicate spikelets, unusual anthesis behaviour, etc (Cheruku et al., 2025).It is grown as a cereal in India only; although the wild grass is a widespread tropical weed. The crop has been grown for at least 3000 years, but we could not find any clear racial differentiation. Wild weeds and cultivated types merged in all the characters studied. Kodo millet is said to be poisonous after rain. This could be due to a fungal infection. Winnowed clear, healthy grain seems to pose no health problems (Hegde & Chandra, 2005).

Due to its intriguing protein and mineral content, Kodo millet is another significant minor millet variety that is very essential in the tribal areas of India (Neelam, Kanchan, & Alka, 2013). It is a crucial crop of the Deccan plateau and is said to have been cultivated in India. Millets are cultivated in an area of 12.45 million hectares, producing 15.53 million Tons with a yield of 1247 kg/ha. It is interesting to note that; India is the topmost producer of Barnyard (99.9%), Finger (53.3%), Kodo (100%), little millet (100%) and pearl millet (44.5%), producing about 12.46 million metric tons from an area of 8.87 million ha (Kumar, Patel, Naik, & Mishra, 2016). Madhya Pradesh, Maharashtra, Uttar Pradesh, Himachal Pradesh, Gujarat, Karnataka, and portions of Tamil Nadu are the principal growing regions. Because of its robust outer shell, which enables it to thrive even in high-drought areas, it is regarded as the toughest millet grain (Sharma, Handa, & Pathania, 2017). The seeds require around five to six months to fully mature (Rachie, 1975), which, when compared to other millet cultivars, generally has the longest agricultural production (FAO, 2001).

Millet grain is abundant in nutrients and health-beneficial phenolic compounds, making it suitable as food and feed. The diverse content of nutrients and phenolic compounds present in finger and pearl millet is a good indicator that the variety of millet available is important when selecting it for use as food or feed. The phenolic properties found in millets comprise phenolic acids, flavonoids, and tannins, which are beneficial to human health (Hassan et al., 2021; Yousaf et al., 2021). Millets contain the bioactive phytochemicals feraxans, lignans, glucan, inulin, resistant starch, sterols, and phenolic compounds (such as ferulic acid, caffeic acid, and quercetin). Studies have revealed that polyphenols have anti-oxidative, anti-carcinogenic, anti-inflammatory, antiviral, and neuroprotective characteristics, all of which have been shown to be beneficial in the treatment and prevention of diseases like cancer, cardiovascular disease, diabetes, high blood pressure, high cholesterol, inflammatory diseases, metabolic syndrome, and Parkinson's disease (Dayakar *et al.,* 2018).

Post-harvest management is an essential part of achieving high-quality grain to meet specific market requirements. Food hygiene regulations apply to stored grain, which must be protected from mould, bacteria, rodent, bird, and insect damage, while pesticide residues must not exceed UK statutory levels (Gooding and Davies, 1997). These standards form the basis of recently introduced quality assurance schemes, combining all facets of grain production from field to store and on to the mill.

1. **MATERIALS AND METHODS**

To conduct the experiment, Kodo millet was procured from the different blocks of Mandla and Dindori district of Madhya Pradesh. The sample materials were properly cleaned, graded, hulled and milled by perfura, hulling and milling machine, then properly packed in gunny bags, LDPE, HDPE, & Vacuumed-pack) and stored at ambient room temperature for further use in experiments.

**Tab.1 Experimental plan of evaluation of kodo millet in different Packaging Materials during the storage period**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S. N.** | **Storage structures** | **Opening secured/tight cover** | **Moisture proof** | **Insect proof** | **O2 proof** | **Storage period (days)** |
|  | **Gunny bag** | Yes | No | No | No | 0,60,120,180 |
|  | **LDPE** | Yes | No | No | No | 0,60,120,180 |
|  | **HDPE** | Yes | No | No | No | 0,60,120,180 |
|  | **Vacuumed-pack** | Yes | Yes | Yes | Yes | 0,60,120,180 |

|  |  |  |
| --- | --- | --- |
| **Fig.-1: Unit operation for grading, Dehulling, milling, and packaging of milled ( kodo millet)** | | |
|  |  |  |
|  |  | |

**2.1 Analytical methods**

**2.1.1 Estimation of moisture content**

The milled kodo sample's moisture content was assessed using the traditional air oven method. The formula that followed has been used to assess the loss of weight and calculate the percentage of moisture AACC (2000).

Moisture content, % (db) = × 100

**2.1.2 Bulk density**

The weight of the seed in the given dimension has been utilized for estimating the bulk density (Bd) of the seed grains (7).

(Bd) =

**2.1.3 True density**

The ratio of grain density to the actual area occupied is known as the actual density (Td). Utilizing the liquid displacement technique, it is determined (7).

Td =

**2.1.4 Porosity**

A ratio of the difference among the grain and bulk densities to the grain density, expressed as a percentage, was used to calculate porosity (7).

Porosity (ε) % = 1 –

**2.1.5 Determination of crude fiber**

The crude fiber was determined by the method as described in AOAC (1984).

Reagents

1. Sulphuric acid 0.255 N

2. Sodium hydroxide 0.313N

**Procedure**

2gm of dry defatted sample was transferred into a 500ml conical flask to which 200 ml of 0.255 N boiling sulphuric acid was added, then it was boiled for 30 minutes, keeping the volume constant by the addition of water at frequent intervals. The mixture was cooled and filtered through a muslin cloth, and the residue was washed with hot water till free from acid. The material was then transferred to the same beaker, and 200ml of boiling 0.313 N NaOH was added. After boiling for 30 minutes, the mixture was cooled and again filtered through muslin cloth. The residue was washed with water till free from alkali, followed by washing with absolute alcohol and ether to remove the moisture and residual fat. It was then transferred to a weighed crucible and kept in the oven at 100 oC for 4-6 hours. The crucible was cooled and weighed. The difference in weight represents the crude fibre content.

Difference in wt. of crucible

Crude fiber (%) = ---------------------------------- × 100

Weight of sample

**2.1.6  Determination of Fat/ Oil**

The fat content of the sample was determined by the procedure as described in AOAC (1984). 5 g of sample was weighed accurately, placed in a thimble and plugged with cotton. The extractor-containing thimble was placed over a pre-weighted extraction flask (A). Fat content was determined by extracting the sample with solvent petroleum ether (AR grade 60-80°c ) for 8 hr. using Soxhlet extraction procedure. After extraction, the excess solvent was distilled off and the residual solvent was removed by heating at 80ºc in the oven for 4-6 hours. The fat content was determined as below:

Crude fat (%) =

**2.1.7. Estimation of protein**

The protein content in the sample was determined by using a conventional micro-Kjeldahl digestion and distillation procedure as given in AOAC (1984).

**Reagents**

1. Catalyst mixture- A mixture of 100 g K2SO4, 20g of CuSO4 and 2.5 g of SiO2.
2. Sodium hydroxide 40%(w/v)
3. Boric acid 2 %( w/v).
4. Concentrated sulphuric acid AR (sp. gr. 1.81)
5. Mixed indicator: 2 parts of 0.2 %( w/v) methyl red and 1 parts 0.2% (w/v) methyl blue in absolute alcohol.
6. Standard sulphuric acid (0.1N)

**2.1.8. Procedure**

The sample (0.2g) was weighed accurately and transferred to a Kjeldahl flask, taking care to see that the material did not stick to the neck of the flask. The catalyst mixture of about 1g and concentrated sulphuric acid (5ml) was added. Then the flask was heated in an inclined position in the digestion chamber for about 4-6 hr. till the liquid became clear (green-blue colour).

**2.1.9. Distillation**

The content in the flask was allowed to cool, and the digested material was transferred quantitatively to a vacuum jacketed flask of micro Kjeldahl distillation apparatus and the ammonia liberated by the addition of 10 ml of 40% NaOH on heating was absorbed in 20 ml of boric acid containing 2-3 drops of mixed indicator in 100ml conical flask. The distilled ammonia was titrated against 0.1N sulphuric acid. The blank was also run in a similar way.

|  |  |  |
| --- | --- | --- |
| N (%) = | Normality of H2SO4 X Volume of 0.1N H2SO4 X 14 | x 100 |
| Weight of sample X 1000 |

Crude protein (%) = N % X 6.25

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**Fig.-2: Effect of insect infestation on different Packaging Materials of milled kodo millet**

**Table- 1: Insect infestation of milled kodo millet in different packaging materials during Storage Period**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Packaging Material** | **Insect Infestation of Milled Kodo During Storage Period** | | | | |
| **0 days** | **30 days** | **60 days** | **90 days** | **180 days** |
| **GB** | 0 | 7 | 18 | 57 | 83 |
| **LDPE** | 0 | 6 | 15 | 27 | 34 |
| **HDPE** | 0 | 0 | 7 | 13 | 18 |
| **VP** | 0 | 0 | 0 | 0 | 0 |
| **Sem+** | 0 | 0.05 | 0.13 | 0.42 | 0.38 |
| **CD @ 5 %** | 0 | 0.16 | 0.40 | 1.27 | 1.23 |

**Fig-3: Insect infestation of milled kodo millet in different packaging materials during Storage Period**

**Table-2: Physico-chemical properties of milled kodo in various packaging materials during storage periods**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Storage Periods** | **Packaging**  **material** | **Kodo (Milled)** | | | | | | |
| **Moisture (%)** | **Protein (%)** | **Fat/Oil (%)** | **Fiber**  **(%)** | **B.D.**  **(g/ml3 )** | **T.D. (g/ml3 )** | **Porosity (%)** |
| **Zero Days** | **GB** | 8.42 | 7.79 | 1.65 | 8.43 | 0.85 | 1.21 | 28.96 |
| **LDPE** | 8.37 | 7.56 | 1.82 | 9.01 | 0.84 | 1.19 | 29.72 |
| **HDPE** | 8.28 | 7.38 | 1.96 | 9.12 | 0.84 | 1.19 | 29.78 |
| **VP** | 7.68 | 8.03 | 1.91 | 9.64 | 0.82 | 1.18 | 29.45 |
| **Sem±** | 0.13 | 0.13 | 0.02 | 0.15 | 0.01 | 0.02 | 0.34 |
| **CD@ 5%** | 0.42 | 0.43 | 0.08 | 0.49 | NS | NS | NS |
| **60**  **Days** | **GB** | 8.84 | 7.88 | 1.45 | 8.71 | 0.85 | 1.19 | 28.95 |
| **LDPE** | 8.79 | 7.47 | 1.62 | 9.08 | 0.85 | 1.21 | 28.96 |
| **HDPE** | 8.46 | 7.81 | 1.86 | 8.93 | 0.84 | 1.17 | 28.46 |
| **VP** | 8.05 | 8.02 | 2.04 | 9.88 | 0.83 | 1.15 | 28.43 |
| **Sem±** | 0.12 | 0.09 | 0.03 | 0.12 | 0.01 | 0.02 | 0.48 |
| **CD@ 5%** | 0.40 | 0.29 | 0.08 | 0.40 | NS | NS | NS |
| **120 Days** | **GB** | 9.34 | 8.16 | 1.21 | 8.43 | 0.86 | 1.16 | 25.86 |
| **LDPE** | 9.27 | 8.54 | 1.14 | 9.01 | 0.84 | 1.14 | 26.31 |
| **HDPE** | 8.54 | 8.44 | 1.88 | 9.12 | 0.84 | 1.13 | 25.66 |
| **VP** | 8.51 | 9.51 | 2.01 | 9.64 | 0.83 | 1.11 | 25.25 |
| **Sem±** | 0.11 | 0.12 | 0.01 | 0.15 | 0.01 | 0.01 | 0.38 |
| **CD@ 5%** | 0.35 | 0.39 | 0.04 | 0.49 | NS | 0.03 | NS |
| **180 Days** | **GB** | 9.86 | 7.75 | 1.11 | 7.88 | 0.86 | 1.14 | 24.86 |
| **LDPE** | 9.24 | 8.74 | 1.32 | 8.71 | 0.85 | 1.13 | 24.94 |
| **HDPE** | 8.66 | 7.89 | 1.78 | 9.64 | 0.85 | 1.13 | 24.88 |
| **VP** | 8.76 | 9.23 | 2.31 | 9.76 | 0.83 | 1.05 | 26.74 |
| **Sem±** | 0.15 | 0.12 | 0.02 | 0.17 | 0.01 | 0.01 | 0.36 |
| **CD@ 5%** | 0.5 | 0.40 | 0.07 | 0.57 | NS | 0.03 | 1.18 |

**3. Results and Discussion**

The present investigation deals with the results obtained for various physical and biochemical properties and insect infestation of dehusked kodo millet, and it also includes the results of experiments conducted to investigate the effect of different packaging materials on the shelf-life of dehusked kodo millet.

**Insect infestation of milled kodo millet during storage periods with various packaging materials**

Table (2) compares the results of the effects of different packaging materials on insect infestation in various milled kodo millets during the storage period.

The insect infestation of milled kodo packed in a gunny bag, LDPE, HDPE, and vacuumed varied from 7-83, 6-43, 7-18, and zero number of insects at 0, 30, 60, 90, and 180 days of storage, respectively (Table 2). The maximum number of insects was found (83) in gunny bag storage milled kodo samples at 180 days, while vacuum-packed samples showed a nil number of insects. The analysis of the variance table indicates that the F-ratio of the model was lower as compared with the table value of 5%% level of significance. There was no significant difference among the different treatments observed for insect infestation of milled kodo.

**Physical properties of milled kodo millet during storage periods with different packaging materials**

**3.1 Bulk density:**

The mean value of milled kodo was compared to the result of the effect of different packaging materials on Bulk Density (g/ml3) packed in various packaging materials and stored for varying storage periods. The Bulk Density of milled kodo packed in Gunny bags, LDPE, HDPE, and vacuumed-packs varied from 0.85-0.82, 0.85-0.83, 0.86-0.83, and 0.86-0.83 at 0, 60, 120, and 180 days of storage, respectively (Table 3). The F-ratio is less than the indicated value at the 5% level of significance, according to the analysis of variance table. Regarding milled kodo, there was no obvious distinction between the various treatments.

**3.2 True density:**

Table (3) compares the results of the effects of different packaging materials on the true density (g/ml3) of various milled kodo millets during storage studies.

The True density of milled kodo packed in gunny bags, LDPE, HDPE, and vacuumed varied from 1.21-1.18, 1.19-1.15, 1.16-1.1, and 14-1.05 at 0, 30, 60, 90, and 180 days of storage, respectively. The maximum True density was found (2.21) in the gunny bag at zero-day storage, while the minimum True density was found (1.05) for the vacuumed-pack at 180-day storage. The analysis of the variance table indicates that the F-ratio of the model was lower as compared with the table value of 5%% level of significance. There was no significant difference among the different treatments observed for the True density of 0, 60, and 60 days stored in GB, LDPE, HDPE, and VP, respectively. Whereas significant effects were found in GB, LDPE, HDPE, and VP at 120 and 180-day storage periods,

**3.3 Porosity:**

The mean value of milled kodo was compared with the result of the effect of different packaging materials on Porosity (%) packed in various packaging materials and stored for different storage periods. The Porosity (%) of milled kodo packed in Gunny bags, LDPE, HDPE, and vacuumed-packs varied from 28.96–29.45, 28.95–28.83, 25.86–25.25, and 24.86–26.74 at 0, 60, 120, and 180 days of storage, respectively (Table 3). The higher value of porosity (%) was observed (31.42) in GB samples at 0 days of storage, while the lower value was found (29.07) at 180 days of storage for VP. The F-ratio is less than the indicated value at the 5% level of significance, observed at 120 and 180 days of storage, according to the analysis of variance table. Regarding the 0, 60, and 90 days of stored milled kodo in different packaging, there was no obvious distinction between the various treatments. A similar finding was observed by Pooran Pragya *et al.* (2018) and Subramanian *et al.* (2007)

**Biochemical properties of milled kodo millet during storage periods with different packaging materials**

**3.4 Moisture**

Table 3 reveals the results of the moisture content of milled kodo in Gunny Bag, LDPE, HDPE, and Vacuumed-pack, which varied from 8.75–8.16, 9.75–8.16, 10.89–8.45, and 12.54–8.77 per cent at 0, 60, 120, and 180 days of storage, respectively. The maximum value was observed in the gunny bag (12.54) at 180 days of storage, whereas the minimum value receded in the vacuumed-pack (8.16) at 0 and 60 days of storage. The analysis of variance table indicates that the F-ratio of the model was higher as compared with the table value of a 5% level of significance. The significant difference among the different treatment combinations has been observed during the storage of milled kodo for various packaging materials and storage periods.

In general, during the storage period, the moisture content varied from 8.16 to 12.54. The ANOVA table indicates that the F-ratio was significant for 0, 60, 120, and 180 days of storage.

**3.5 Protein**

At 0, 60, 120, and 180 days of storage, the protein content of milled kodo in Gunny Bag, LDPE, HDPE, and Vacuumed-pack ranged from 7.79 to 8.03 per cent, 7.88 to 8.02 per cent, 8.16 to 9.51 per cent, and 7.75 to 9.23 per cent, respectively (Table 3). Vacuum-packed samples had a value that was greater after 120 days (9.51); gunny-bag samples showed a lower protein level at 0 and 60 days (7.75). The analysis of variance shows that, at the 5% level of significance, the F-ratio of the model was higher than the table value. The preservation of milled kodo with various packing materials has revealed a notable variation between the various treatment combinations.

On average, the moisture content ranged from 7.75 to 9.51 throughout the storage period. The F-ratio was significant for 0, 60, 120, and 180 days of storage, according to the ANOVA table.

**3.6 Fat**

Table 3 exposes the consequences of the fat content of milled kodo in Gunny Bag, LDPE, HDPE, and Vacuumed-pack, which vary from 1.65–1.19, 1.45-2.04, 1.21-2.01, and 11.11–2.31 per cent at 0, 60, 120, and 180 days of storage, correspondingly. The extreme value was detected in the vacuumed-pack (2.31) at 180 days of storage, whereas the least value receded in the gunny bag (1.11) at 180 days of storage. According to the analysis of the variance table, the model's F-ratio was higher than the table value for a 5% level of significance. A significant difference among the different treatment combinations has been observed during the storage of milled kodo for various packaging materials and storage periods.

**3.7 Crude fibre**

Table (3) indicated the results of the crude fibre content of milled kodo in Gunny Bag, LDPE, HDPE, and Vacuumed-pack, which varied from 8.8-9.98, 8.71-9.88, 8.83-9.64 and 7.88-9.76 per cent at 0, 60, 120, and 180 days of storage, respectively. The highest value was observed in the vacuumed-pack (9.98) at 0 days of storage, whereas the lowest value was observed in the gunny bag sample (7.88) at 180 days of storage. The analysis of variance table indicates that the F-ratio of the model was higher as compared with the table value of a 5% level of significance. A significant difference among the different treatment combinations has been observed during the storage of milled kodo for various packaging materials and storage periods.

**4. Conclusion**

In conclusion, millets have potential for protection against age-onset degenerative insect pests. Moisture is another critical factor in the safe storage of food grains. Grains stored at around 10 per cent moisture content escape the attack of insects. The vacuum-packed kodo millet samples were found to have significant results for all the quality parameters during the six-month storage study. Vacuum packaging storage technology effectively extends the shelf-life of dehulled kodo millet by maintaining its physico-chemical qualities.

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