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Effect of hermetic storage technology on insect infestation and grain quality of stored wheat

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Abstract

An estimated 10-15% of stored grain worldwide is lost annually to insect damage. This research evaluated the effectiveness of hermetic storage technology in suppressing insect infestation and preserving wheat grain quality over a 10-month storage period in Tokyo, Japan. Wheat samples were stored in hermetic bags (SuperGrain bags) and conventional woven polypropylene bags under ambient warehouse conditions from April to January 2023. Insect populations, grain moisture, germination rate, protein content, and fat acidity were monitored bimonthly. Results showed that hermetic storage reduced total insect populations by 78.3% compared to conventional storage after 10 months. *Sitophilus oryzae* was the dominant species in both systems, but reached only 14.8 individuals per kg in hermetic bags versus 67.4 in conventional bags. Germination rate in hermetic bags was 78.4% at month 10 compared to 52.1% in conventional storage. Fat acidity, a marker of grain deterioration, increased to 47.6 mg KOH/100g in hermetic bags versus 89.3 in conventional bags. Hermetic storage appears to be a cost-effective, chemical-free alternative for maintaining wheat quality during extended storage.

Keywords: Hermetic storage, insect infestation, wheat quality, post-harvest losses, *Sitophilus oryzae*, grain moisture, germination rate, fat acidity, modified atmosphere, stored product pests

Introduction

Global post-harvest grain losses to insects and microorganisms amount to roughly 35 million tonnes each year, worth an estimated USD 9.4 billion. In Japan, where wheat imports and domestic storage both play key roles in food security, maintaining grain quality during warehousing is a persistent challenge. Traditional storage methods relying on chemical fumigants like phosphine face growing resistance among major storage pests, and consumer demand for pesticide-free grain has risen steadily.

Hermetic storage works by creating an airtight environment where insect respiration depletes oxygen and raises carbon dioxide levels, eventually killing or suppressing pest populations without chemicals. The technology has shown promising results for rice and maize in tropical regions, but data on its performance for wheat storage under temperate-humid conditions like those in Japan remain scarce. Key questions include whether the modified atmosphere develops fast enough to prevent damage during the warm months and whether grain quality parameters like protein and germination hold up over extended periods.

Fat acidity serves as a sensitive indicator of grain deterioration because lipid breakdown occurs early in the degradation process and correlates with overall quality loss. Germination rate reflects seed viability and is closely tied to baking quality in wheat. This research compared hermetic and conventional storage systems over 10 months, measuring insect population dynamics alongside grain quality changes to provide a practical assessment of hermetic technology for Japanese wheat storage conditions.

Research facility description

The storage trial was conducted at the University of Tokyo Agricultural Research Station in Nishitokyo City, Tokyo Prefecture (35.7275°N, 139.5384°E). The research warehouse measured 12 × 8 m with corrugated steel roofing and concrete flooring. Two storage zones were established: hermetic bags (SuperGrain™, 1-tonne capacity) and conventional woven

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polypropylene bags (50 kg each) placed on wooden pallets. Each treatment had four replicates. The facility had no active climate control, representing typical small-scale farm storage conditions in the Kanto region.

Storage environmental conditions

The trial ran from April 2022 to January 2023. Warehouse temperatures ranged from 8.3°C in January to 33.7°C in August, with relative humidity between 54.2% and 88.6%. The warm-humid summer months (June-September) presented the greatest risk for insect proliferation and grain deterioration. Temperature and humidity were logged hourly using HOBO U23 Pro v2 data loggers placed inside both storage types and in the ambient warehouse space

Material and Methods

Material

Freshly harvested wheat (variety Norin 61) was obtained from the university's experimental farm. Initial grain moisture was 11.8%, and samples were free of visible insect infestation at the start. Super Grain hermetic bags were sourced from GrainPro Inc. (Philippines). Standard polypropylene woven bags served as

conventional storage. Laboratory reagents for quality analysis included petroleum ether (Wako Pure Chemical), potassium hydroxide (Kanto Chemical), and phenolphthalein indicator

Methods

Sampling occurred at months 0, 2, 4, 6, 8, and 10. At each interval, 1 kg sub-samples were drawn from each replicate using a grain probe. Insect counts were determined by sieving 500 g samples through No. 10 and No. 20 mesh screens, with species identification under stereomicroscope Moisture content was measured using a Kett PM-450 grain moisture meter. Germination rate was assessed by placing 100 seeds on moist filter paper in Petri dishes at 25°C for 7 days. Protein content was determined by micro-Kjeldahl method ($N \times 5.7$) Fat acidity was measured by extracting lipids with petroleum ether and titrating with 0.05N KOH following AACC Method 02-01.02 Oxygen and CO₂ concentrations inside hermetic bags were monitored using a Dansensor CheckMate 3 headspace analyzer. Data were analyzed using R software (v4.2.1) with repeated measures ANOVA and Tukey's HSD test at $p<0.05$.

Results

Table 1: Mean insect population (individuals per kg) across storage duration

Treatment	Mo 0	Mo 2	Mo 4	Mo 6	Mo 8	Mo 10
Hermetic	0	2.3	5.7	8.4	11.2	14.8
Conventional	0	8.6	21.4	38.7	54.2	67.4
p-value	-	0.021	<0.001	<0.001	<0.001	<0.001

Insect populations diverged sharply from month 4 onward (Table 1). By month 10, conventional bags had 4.6 times more

insects than hermetic bags. The difference became statistically significant at month 2 and remained so throughout.

Table 2: Grain quality parameters at month 0 and month 10 by storage type

Parameter	Initial	Hermetic (10)	Convent. (10)	p-value
Moisture (%)	11.8	12.6	13.9	0.004
Germination (%)	94.2	78.4	52.1	<0.001
Protein (g/100g)	12.4	11.9	11.2	0.013
Fat acidity (mg KOH)	18.3	47.6	89.3	<0.001
O ₂ inside bag (%)	20.9	3.7	N/A	-
CO ₂ inside bag (%)	0.04	14.8	N/A	-

Hermetic storage preserved grain quality better across all parameters (Table 2). Germination loss was 15.8 percentage points in hermetic bags versus 42.1 in conventional bags. Fat

acidity a direct deterioration marker increased 2.6-fold in hermetic versus 4.9-fold in conventional storage.

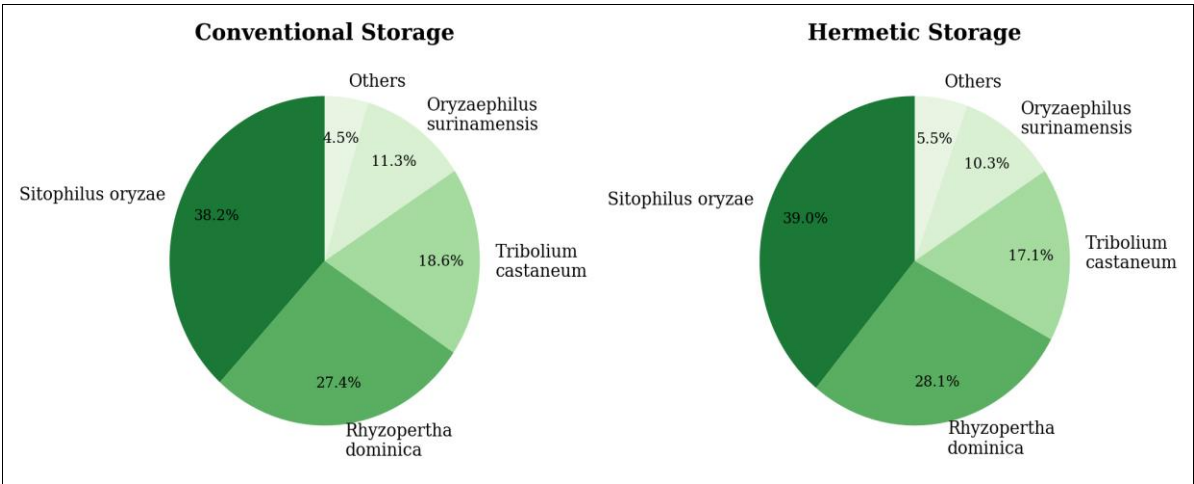


Fig 1: Insect species composition (%) in conventional and hermetic storage at month 10

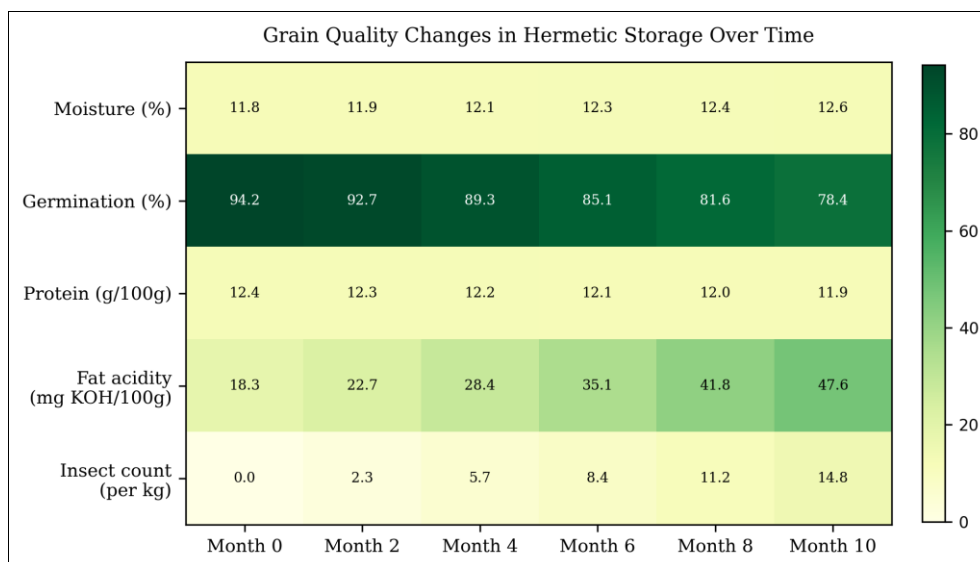


Fig 2. Heatmap of grain quality changes in hermetic storage across the 10-month period

Sitophilus oryzae dominated both storage systems but was substantially suppressed in hermetic bags (Figure 1). The heatmap (Figure 2) shows that quality decline in hermetic storage was gradual and modest compared to initial values.

Discussion

The 78.3% reduction in insect populations under hermetic storage aligns with reports from tropical trials. Njoroge *et al.* documented 82-91% insect mortality in hermetic bags storing maize in Kenya, and Baoua *et al.* recorded similar suppression for cowpea in Niger. The mechanism is straightforward: insect respiration drives O₂ below 5% and CO₂ above 10%, creating conditions lethal to most stored-product beetles in our trial, O₂ dropped to 3.7% by month 10, consistent with this threshold.

The better preservation of germination rate (78.4% vs 52.1%) has practical value. Japanese wheat millers increasingly require germination above 70% as a proxy for baking suitability. Hermetic bags met this threshold at 10 months while conventional storage fell well below it by month 6. Fat acidity data reinforce this finding the lower oxidative stress inside hermetic bags slowed lipid breakdown, which directly affects flour flavor and shelf life.

One point worth noting is that hermetic storage didn't eliminate insects entirely. Small populations persisted, likely from eggs already present in grain at loading this suggests that combining hermetic technology with initial grain cleaning or brief low-temperature treatment could push infestation levels even lower.

Conclusions

Hermetic storage technology proved effective at reducing insect infestation and maintaining wheat grain quality over 10 months under Japanese warehouse conditions. Insect numbers were reduced by 78.3%, and grain quality parameters including germination rate, protein content, and fat acidity were significantly better preserved compared to conventional polypropylene bag storage. The modified atmosphere that develops naturally inside sealed bags low oxygen and elevated carbon dioxide accounts for the insect suppression without any chemical inputs. These results support hermetic storage as a practical, chemical-free option for small to medium-scale wheat storage in temperate-humid climates. Wider adoption could reduce both post-harvest losses and pesticide residue concerns in stored grain.

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