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ASSESSMENT AND IMPROVEMENT OF OILSEED STORAGE TECHNOLOGY UNDER THE CONDITIONS OF THE SYRDARYA REGION

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Abstract

Storage of oilseed raw materials is a critical post-harvest operation because moisture content, temperature, aeration, microbial activity, and storage duration collectively determine the rate of quality deterioration. In the present study, an analytical assessment was conducted of the factors affecting the storage of sunflower seeds (*Helianthus annuus* L.) and cottonseed (*Gossypium hirsutum* L.), which are of practical importance to the vegetable oil industry of the Syrdarya Region, Uzbekistan. The findings of the initial study were compared with contemporary published data on moisture content, temperature conditions, storage duration, and quality indicators. In the initial study, an increased risk of quality deterioration was observed at moisture contents above 10–12% for sunflower seeds and above 9–10% for cottonseed, while a temperature range of 5–15 °C was considered rational for slowing biochemical processes. Under favorable storage conditions, the main quality characteristics were reported to remain stable for approximately 6–8 months, whereas under unfavorable conditions, deterioration could occur within 2–3 months. These values should be regarded only as indicative ranges for the conditions investigated. Comparison with current literature confirms the key role of moisture and temperature control, as well as the need to consider relative humidity, aeration, and microbiological risks. An integrated technological scheme is proposed, including lot classification, cleaning, moisture adjustment, cooling, aeration, controlled storage, and periodic laboratory monitoring. The quantitative data presented in Tables 6 and 7 were obtained from published studies and do not represent original measurements by the authors of the present study. The main limitation is the absence of a complete primary dataset from the initial investigation, including detailed information on replication and statistical analysis. Therefore, final validation of the proposed storage conditions requires a specifically designed experiment under the environmental and technological conditions of the Syrdarya Region.

Keywords: sunflower seeds; cottonseed; oilseed crops; storage; moisture content; temperature; relative humidity; acid value; peroxide value; aeration; seed quality; Syrdarya Region

Introduction

Oilseed crops are biologically active raw materials whose quality changes continuously between harvest and processing. Sunflower seeds and cottonseed are of considerable practical importance in Uzbekistan because they are used for the production of vegetable oil and valuable by-products. During storage, seeds continue to respire and exchange moisture with the surrounding environment. The accumulation of heat and moisture within the stored seed mass can intensify respiration, microbial activity, enzymatic reactions, and lipid deterioration, ultimately reducing the technological suitability of the raw material.

Moisture content is one of the principal factors determining the storage stability of oilseed raw materials. According to FAO recommendations for storage under hot climatic conditions, a moisture content of approximately 9% is considered an indicative level for long-term storage of sunflower seeds [6]. Recent studies on cottonseed have demonstrated a pronounced dependence of storage stability on moisture content and storage system. In a 12-month study, samples with higher initial moisture content exhibited substantially greater quality deterioration, whereas storage at lower moisture content under hermetic conditions provided considerably better preservation (Fatima, F., Khalid, E., Afzal, I., et al., 2025).

Temperature acts in interaction with moisture content and environmental conditions. Controlled studies of sunflower seeds have shown that elevated temperature and exposure to light accelerate changes in acid and peroxide values and promote oxidative processes (Xu, W., Yao, J., Yi, Y., Wang, H.-X., Wang, L.-M., 2019). Studies conducted under cyclic variations in temperature and relative humidity have also demonstrated that realistic fluctuations in storage conditions can result in different patterns of changes in moisture content and peroxide value compared with constant storage conditions (Liu, J., Yang, Y., Xu, Z., Wang, Q., Liu, B., Wu, Y., 2022).

Modern approaches to quality control increasingly incorporate rapid, non-destructive technologies. In particular, hyperspectral imaging combined with chemometric analysis has been used to assess the viability and moisture content of sunflower seeds,

whereas Raman microspectroscopy is considered a promising method for the rapid assessment of sunflower seed freshness and viability (Huang, P., Yuan, J., Yang, P., Xiao, F., Zhao, Y., 2024; Ma, J., Yang, L., Gao, W., Chen, J., Li, J., Jin, L., Hou, R., 2024).

The aim of the present study was to analytically assess the principal factors affecting the storage of sunflower seeds and cottonseed, compare the findings of the initial investigation with contemporary scientific evidence, and develop an integrated technological scheme for maintaining the quality of oilseed raw materials under the conditions of the Syrdarya Region, Uzbekistan.

Materials and Methods

The study was based on materials from the initial investigation conducted in the laboratory of the Scientific Center of the Department of Food Technologies at Gulistan State University, together with data obtained from published scientific sources. The objects of the initial investigation were sunflower seeds and cottonseed of practical importance to the vegetable oil industry of the Syrdarya Region, Uzbekistan. The initial study assessed moisture content, temperature, storage duration, organoleptic condition, and physicochemical changes associated with biochemical processes during storage.

The complete primary dataset, information on the number of independent replicates, sample sizes, analytical procedures, and statistical methods were not available in the source materials. Therefore, missing primary data were neither reconstructed nor presented as results of an original experiment in the present study.

For subsequent local validation, independent measurements of moisture content, seed-mass temperature, ambient relative humidity, acid value, peroxide value, oil content, germination/viability, and the degree of fungal contamination should be performed at predetermined sampling intervals.

The moisture-content ranges of 10–12% for sunflower seeds and 9–10% for cottonseed, the temperature range of 5–15 °C, and the reported periods of quality preservation of 6–8 months under favorable conditions and 2–3 months under unfavorable conditions were retained from the initial study.

These values are considered indicative only and should not be interpreted as universally applicable storage standards.

Table 1. *Key Factors Determining the Storage Stability of Oilseed Raw Materials*

Factor	Adverse Change	Underlying Mechanism	Technological Measure
Moisture Content	Increase or Fluctuations	Increased respiration, microbial activity, and hydrolytic processes	Drying and regular moisture monitoring
Temperature	Heat accumulation or temperature increase	Increased respiration and oxidative processes	Cooling and aeration
Relative Humidity	High or fluctuating relative humidity	Moisture exchange and increased risk of fungal growth	Environmental condition control
Impurities and Damaged Seeds	High Content	Localized heating and microbial growth	Cleaning and grading
Storage Duration	Prolonged storage under unfavorable conditions	Cumulative quality deterioration	Periodic quality monitoring

Results and Discussion

The initial study associated moisture contents above 10–12% in sunflower seeds and 9–10% in cottonseed with increased respiration, microbial activity, and a higher risk of self-heating. These findings are generally consistent with international scientific evidence. According to FAO recommendations, a moisture content of approximately 9% is considered an indicative level for the long-term storage of sunflower seeds under hot climatic conditions (De Lucia, M., Assennato, D., 1994). In a recent study of cottonseed, moisture contents of 6, 8, 10, and 12% were evaluated over a 12-month storage period. The results showed that quality deterioration occurred substantially more rapidly at higher moisture contents, whereas storage at 6% moisture under hermetic conditions provided the best preservation among the conditions investigated (Fatima, F., Khalid, E., Afzal, I., et al., 2025). These findings indicate that

moisture content should not be controlled as a single universal threshold, but rather as a range that interacts with temperature, relative humidity, packaging or storage system, and the intended storage duration. For long-term cottonseed storage, the results of recent international studies obtained at lower moisture contents indicate the need for additional local experimental validation before applying the broader 9–10% range identified in the initial study as a zone of increased risk.

Thus, under the conditions of the Syrdarya Region, it is advisable to simultaneously monitor seed moisture content, seed-mass temperature, and ambient relative humidity, because their combined effects determine the stability of the raw material during storage. This approach is consistent with the initial study, in which moisture content was identified as one of the key factors determining the storage stability of oilseed raw materials.

Table 2. *Comparative Interpretation of Moisture-Related Storage Conditions*

Oilseeds	Conditions	Main Outcome	Practical Significance
Sunflower	Long-term storage under hot climatic conditions	Indicative moisture content: $\approx 9\%$	Moisture control is a key condition for maintaining storage stability.

Oilseeds	Conditions	Main Outcome	Practical Significance
Sunflower	Different temperature, light, and relative humidity conditions	The rate of quality deterioration depends on the combined effects of storage conditions.	Moisture and temperature must be controlled.
Cottonseed	Moisture contents of 6, 8, 10, and 12%; 12 months of storage	Higher moisture content accelerated quality deterioration.	Dry and protected storage conditions should be prioritized.
Sunflower kernels	Increase in relative humidity	Higher relative humidity increased the risk of microbial contamination.	It is necessary to control not only seed moisture content but also ambient relative humidity.

Organoleptic assessment can serve as a rapid method for detecting signs of deterioration in the quality of raw materials; however, it should not replace laboratory monitoring. Changes in the odor, color, and overall condition of seeds may indicate the development of undesirable processes, but objective assessment requires additional determination of moisture content, acid value, peroxide value, and other physicochemical parameters.

A recent study of sunflower seed kernels showed that an increase in relative humidity alters the structure of the fungal community and increases the risk of microbial contamination (Liu, J., Yang, Y., Xu, Z., Wang, Q., Liu, B., Wu, Y. 2022). Therefore, during storage, it is necessary to control not only the moisture content of the seeds themselves but also the relative humidity of the air within the storage facility.

In the initial study, a temperature range of 5–15 °C was considered rational, whereas temperatures above 25 °C were considered unfavorable for storage. This conclusion should be regarded as a recommendation applicable to the specific conditions of the study rather than as a universal standard.

Studies on sunflower seed storage have shown that temperature interacts with light exposure and storage duration. Elevated temperature and exposure to light accelerate changes in acid and peroxide values and promote oxidative processes (Xu, W., Yao, J., Yi, Y., Wang, H.-X., Wang, L.-M., 2019).

Temperature and relative humidity fluctuations are also important. Under cyclic changes in these parameters, the dynamics of seed moisture content and peroxide value may differ from those observed under constant storage conditions (Liu, J., Yang, Y., Xu, Z., Wang, Q., Liu, B., Wu, Y., 2022). Therefore, more reliable storage-management principles include preventing heat accumulation within the seed mass and detecting temperature increases at an early stage, rather than relying solely on a nominal average temperature.

Thus, under the storage conditions of the Syrdarya Region, Uzbekistan, continuous monitoring of temperature, seed moisture content, and relative humidity should be ensured for sunflower seeds and cottonseed. When a trend toward increasing temperature is detected, cooling and aeration should be promptly implemented.

Table 3. *Interpretation of Temperature Conditions*

Temperature	Interpretation within the Initial Study	Recommended Technological Measures
5–15 °C	Rational range	Preferred where technically feasible
15–25 °C	Increased intensity of biochemical processes	Enhanced temperature monitoring and aeration
>25 °C	Unfavorable conditions	Cooling, aeration, and quality assessment of the raw material

The initial study showed that under favorable storage conditions, the main quality characteristics were maintained for approximately 6–8 months, whereas under unfavorable conditions, quality deterioration could occur within as little as 2–3 months. However, these periods should not be regarded as guaranteed storage periods or universal shelf-life limits. The duration of safe storage depends on the initial quality of the raw material, as well as on the combined effects of time, temperature, and moisture throughout the entire storage period.

According to the initial study, the main indicators of quality deterioration were the development of a musty odor, darkening of the seeds, reduced germination, decreased oil content, and an increase in acid value. Since quantitative primary data were not

available in the source materials, these indicators are considered in the present study as descriptive observations from the initial investigation rather than statistically validated results of a new experiment.

It should also be considered that during prolonged storage, primary oxidation products, including peroxides and hydroperoxides, may subsequently decompose to form secondary oxidation products. Therefore, a single measurement of peroxide value is insufficient to fully characterize the kinetics of oxidative processes (Xu, W., Yao, J., Yi, Y., Wang, H.-X., Wang, L.-M., 2019). For a more objective assessment of quality dynamics, periodic measurements of acid value and peroxide value should be conducted throughout the entire storage period.

Table 4. Recommended Quality Indicators for Validation of the Results

Indicator	Information Obtained	Priority
Moisture content (%)	Storage stability; risk of microbial activity and increased respiration	Mandatory
Seed-mass temperature (°C)	Risk of heat accumulation and self-heating	Mandatory
Relative humidity (%)	Moisture exchange and risk of fungal growth	Mandatory
Acid value	Degree of hydrolytic deterioration of lipids	Mandatory
Peroxide value	Primary lipid oxidation processes	Mandatory
Oil content (%)	technological oil yield	High
Seed germination / viability	Physiological quality of seeds	High
Fungal contamination	Degree of microbiological quality deterioration	High

Modern instrumental methods can additionally be applied for the rapid assessment of oilseed raw material quality. In particular, hyperspectral imaging has been shown to enable the assessment of viability and moisture content in sunflower seeds, whereas Raman microspectroscopy can be used to differentiate fresh and aged sunflower seeds (Huang, P., Yuan, J., Yang, P., Xiao, F., Zhao, Y., 2024; Ma, J., Yang, L., Gao, W., Chen, J., Li, J., Jin, L., Hou, R., 2024).

It should be emphasized that these methods are proposed only as promising tools for further improvement of the quality-control system and were not used in the initial experiment.

An integrated technological scheme for the storage of oilseed raw materials is proposed. At the initial stage, incoming raw ma-

terials should be classified according to crop type, moisture content, temperature, impurity level, and initial quality.

Following classification, each batch should undergo cleaning and, when necessary, drying to a predetermined target moisture content that has been experimentally validated. Cooling and active aeration should be used to remove accumulated heat and excess moisture.

During storage, individual batches should be stored separately and subjected to periodic monitoring. Monitoring should include assessment of temperature and moisture content, as well as the main quality indicators in accordance with the established monitoring system.

Thus, the proposed technology involves the following sequential operations:

Receiving and classification → Cleaning and grading → Moisture adjustment (drying) → Cooling → Active aeration → Controlled storage → Periodic quality monitoring → Transfer for processing.

The proposed scheme has been developed for the conditions of the Syrdarya Region and

is considered a technological framework requiring subsequent quantitative validation under industrial conditions. In the initial study, this integrated approach was proposed for managing the quality of sunflower seed and cottonseed batches during storage.

Table 5. *Integrated Technological Scheme for Improving the Storage of Oilseed Raw Materials*

Stage	Operation	Critical Control Point	Corrective Action
1.	Receiving and classification	Moisture content, temperature, impurity level	Segregation of batches that do not meet established requirements
2.	Cleaning and grading	Content of impurities and damaged seeds	Additional cleaning
3.	Drying / moisture adjustment	Experimentally validated target moisture content	Continued drying
4.	Cooling	Seed-mass temperature	Intensification of cooling and/or aeration
5.	Active aeration	Temperature response and relative humidity	Adjustment of airflow intensity
6.	Controlled storage	Temperature, moisture content, relative humidity	Corrective measures to eliminate detected deviations
7.	Periodic monitoring	Acid value (AV), peroxide value (PV), oil content, organoleptic indicators	Priority routing of the batch for processing
8.	Transfer for processing	Final raw-material quality	Determination of quality class

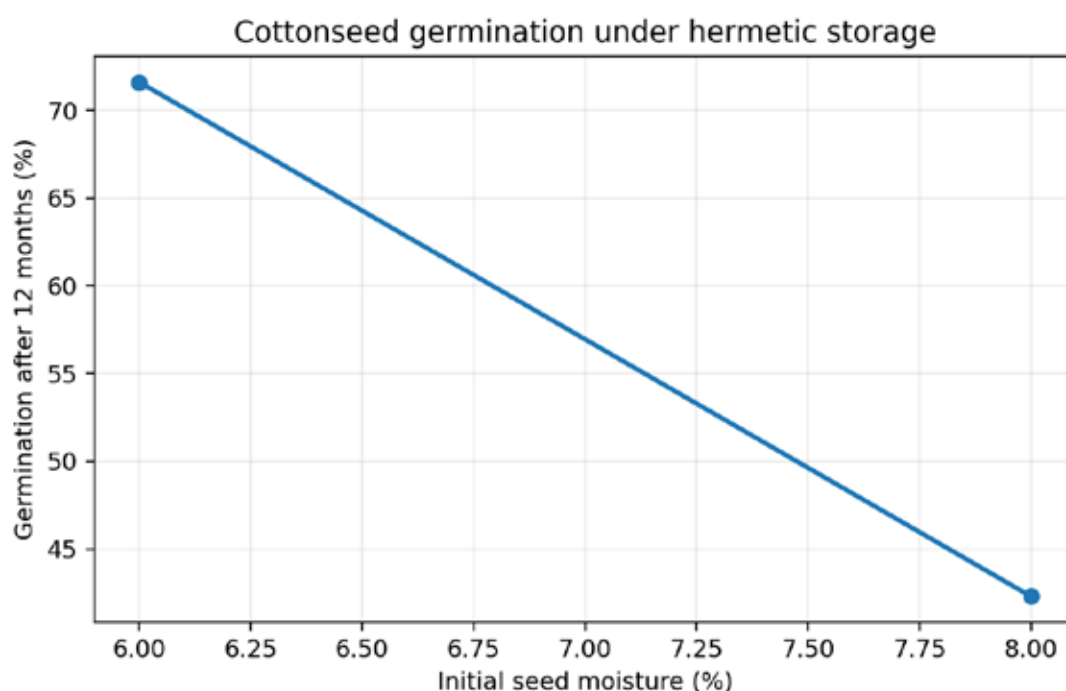
The proposed system considers storage as a dynamic process rather than an operation conducted at a fixed temperature. A sustained increase in temperature or moisture content should serve as a basis for taking corrective action before visible signs of raw-material deterioration appear. This approach enables the timely detection of unfavorable changes in storage conditions and helps prevent further deterioration of seed quality.

To strengthen the quantitative interpretation, without presenting published data as results of the present study conducted in the Syrdarya Region, selected numerical data from two published studies were incorporated. The cottonseed data were obtained from

Fatima et al. (2025), in which cottonseed was stored for 12 months at initial moisture contents of 6, 8, 10, and 12% in hermetic bags. The sunflower seed data were obtained from Premović et al. (2014), in which seeds stored for 0, 6, and 12 months at temperatures below 30 °C under good ventilation were investigated, with acid and peroxide values determined in the seeds and in the cold-pressed oil obtained from them. These data, derived from published literature, are used exclusively for comparative analysis and graphical interpretation; they are not part of the primary experimental dataset of the present study.

Table 6. *Cottonseed Germination after 12 Months of Hermetic Storage, Based on Data from the Published Literature (Fatima et al., 2025)*

Initial Moisture Content (%)	Storage System	Storage Duration (months)	Germination (%)
6	Hermetic bag	12	71,6
8	Hermetic bag	12	42,3
10	Hermetic bag	12	Almost complete loss
12	Hermetic bag	12	Almost complete loss

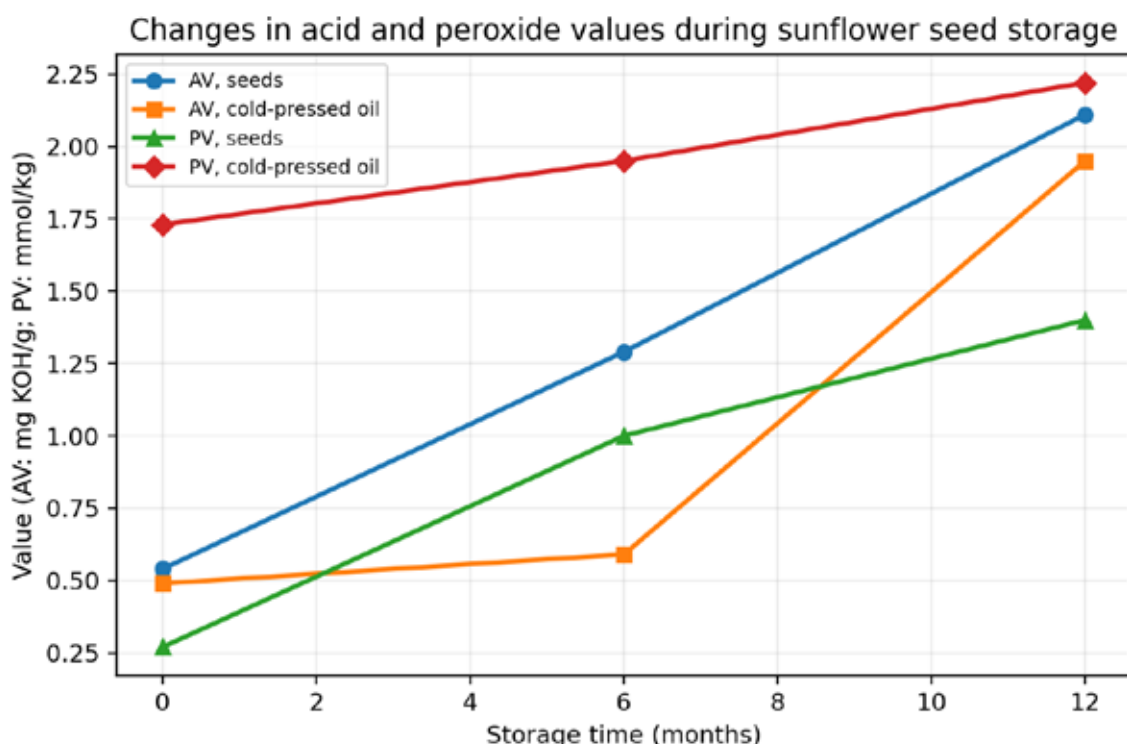
Figure 1. *Relationship between cottonseed germination and initial moisture content after 12 months of hermetic storage, based on published data from Fatima et al. (2025). For moisture contents of 10% and 12%, the source reports an almost complete loss of germination; therefore, no numerical values for these treatments are interpreted in the graph***Table 7.** *Acid and Peroxide Values of Sunflower Seeds and Cold-Pressed Oil during Storage, Based on Data from the Published Literature (Premović et al., 2014)*

Storage Duration (months)	Acid Value, Seeds (mg KOH/g)	Acid Value, Oil (mg KOH/g)	Peroxide Value, Seeds (mmol/kg)	Peroxide Value, Oil (mmol/kg)
0	0,54	0,49	0,27	1,73
6	1,29	0,59	1,00	1,95
12	2,11	1,95	1,40	2,22

Published data on sunflower seeds show a noticeable increase in acid value with increasing storage duration. In oil obtained from fresh seeds, the acid value was 0.49 ± 0.01 mg KOH/g, increasing to 1.95 ± 0.02 mg KOH/g after 12 months of storage. The

peroxide value increased from 1.73 ± 0.02 to 2.22 ± 0.07 mmol/kg. The corresponding values for the seeds also increased, although the magnitude of change varied depending on the parameter evaluated.

Figure 2. Changes in acid value (AV) and peroxide value (PV) during sunflower seed storage based on data from a published literature source. The curves represent published values obtained after 0, 6, and 12 months of storage and do not constitute measurements performed as part of the present study



The practical significance of the study lies in the integration of moisture regulation, cooling, aeration, batch classification, and periodic quality control into a unified storage system adapted to the conditions of the Syrdarya Region for sunflower and cotton seeds. Comparison with recent international studies shows that the quality deterioration mechanisms described in the original study are generally consistent with current scientific understanding; however, the specific quantitative limits require experimental validation under local conditions.

The proposed system can serve as a basis for developing a local technological storage protocol and for conducting a subsequent controlled experiment involving the simultaneous determination of moisture content, seed temperature, relative air humidity, acid value, peroxide value, oil content, and seed viability.

Conclusions

The storage stability of sunflower and cotton seeds is determined by the combined effects of moisture content, temperature, relative air humidity, storage duration, as

well as biological and oxidative processes. In the original study, moisture contents above 10–12% for sunflower seeds and 9–10% for cotton seeds were considered conditions of increased risk, while a temperature range of 5–15 °C was regarded as rational. These values are indicative for the conditions investigated and should not be considered universal regulatory limits.

Recent international studies confirm the critical role of moisture control and demonstrate that elevated temperature, light exposure, and fluctuations in environmental parameters can accelerate seed quality deterioration. The proposed storage system includes batch classification, cleaning, moisture regulation, cooling, active aeration, controlled storage, and periodic laboratory monitoring.

For implementation of this system under the conditions of the Syrdarya Region, quantitative validation under local conditions is required. This should involve repeated measurements of moisture content, temperature, relative air humidity, acid value, peroxide value, oil content, and seed viability, followed by appropriate statistical evaluation of the results.

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