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Safe Storage of Corn using different types of Hermetic Bags

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ABSTRACT

The objective of this study was to ascertain the optimal conditions for the secure storage of corn grain and assess the alterations in quality that occur throughout the process of infra-red heating and storage of grain in various types of hermetic bags. The experimental procedures for the infra-red heating process encompassed various durations of exposure time (3, 6, 9, 12, and 15 minutes) as well as four different levels of irradiation intensity, of (0.861, 0.973, 1.093, and 1.161 kW/m^2). A comparative analysis was conducted between several multi-layer hermetic bags, 3 layers, 7 layers, and conventional burlap storage bags. The experimental work utilized freshly harvested yellow corn grain variety Pioneer (3084). The corn samples were acquired from a privately-owned farm located in El-Dakahlia governorate. The results indicated that the application of infra-red pre-heat treatment, specifically at a radiation intensity of 1.161 kW/m^2 and an exposure time of 12 minutes, resulted in a significant decrease in grain moisture content and total microbial count without negative effects on germination percentage. Meanwhile, storing corn grain in hermetic bags 7 layers is recommended for safe storage of corn grain with high quality.

Keywords: Corn, radiation intensity, burlap bags, Hermetic bags, grain quality

INTRODUCTION

Corn, (Zea mays L.), is a significant annual grain crop that belongs to the Ponceau family. According to Sandhu et al. (2007), this crop ranks as the third most prominent globally, following rice and wheat.

Corn, a widely cultivated cereal crop, holds significant historical and contemporary importance due to its popularity, longevity, and versatility in various sectors such as food production, animal feed, and medicinal applications on a global scale. There have been over 3,500 nominations for the utilization of corn products. The inclusion of nutritional values in this context addresses health-related concerns. This substance exhibits analgesic, astringent, anti-allergic, and emollient properties, which make it effective in alleviating skin rashes, sore throat, angina, biliousness, and lithiasis. According to (Huma et al., 2019), this food item is additionally recognized as a valuable provider of vitamins A, B, and E, as well as many essential minerals.

The global yield of corn in 2021 amounted to 1.2 billion metric tons, while Egypt's corn production reached 7.5 million metric tons. The United States of America (USA) is the leading global producer of corn, accounting for around 49.3% of the overall world corn production (Wu et al., 2021).

Corn growers often face challenges when it comes to the secure storage of their grain crop due to the elevated moisture content, often ranging from 22% to 30%, throughout the harvest period. The primary objective of the drying process is to reduce the moisture content in grains to a level that is considered acceptable for storage, typically around 14% (Li et al., 2014).

According to Neethirajan et al. (2010), the postharvest losses of grains represent approximately 25-30%. The extent of these losses is contingent upon various aspects, such as the utilization of manual processing techniques, the presence of storage materials that allow oxygen and moisture to permeate, the susceptibility to pests, the reliance on hand harvesting, and the absence of knowledge regarding appropriate procedures for harvesting and handling (Abass et al., 2014).

In a study conducted by Baoua et al. (2014), it was shown that the use of (now known as PICS – Purdue Improved Crop Storage) bags effectively safeguards corn crops against insect pests. The field trials conducted over a period of 6 months revealed that the utilization of PICS bags did not result in any deterioration of corn quality. A significant reduction in insect pests, up to 98%, can be achieved within a one-month period of storage, resulting in a decrease in both feeding-related damage and weight loss.

The technological approach involves the utilization of hermetically sealed containers to store seeds, effectively mitigating or eliminating gas exchange. The process of aerobic respiration in insects results in the consumption of oxygen (O_2) and the production of carbon dioxide (CO_2), leading to a decrease in available oxygen and an increase in carbon dioxide levels. According to Murdock et al. (2012)the cessation of insect feeding leads to their subsequent mortality.

The primary objective of this study is to mitigate the loss of Egyptian corn grain in terms of both quantity and quality throughout the storage process. The efficacy of the proposed system relies on the effective management of moisture levels, prevention of mold growth, and control of insect infestation in corn before storage. This is achieved through the implementation of controlled infra-red pre-heat treatment, followed by the placement of the heat-treated grain into various types of hermetic bags for storage.

MATERIALS AND METHODS

The current experiment work was conducted in the Laboratory of Food Process Engineering, Agriculture Engineering department of the Faculty of Agriculture Mansoura University. The experimental investigation utilized

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freshly harvested yellow corn grain variety pioneer 3084. The corn samples were collected from a private farm located in El-Dakahlia governorate.The present investigation encompassed three discrete sets of experiments. The initial study investigated the impact of high-temperature short-time heat treatment on the drying and sterilization processes of corn grain. This was achieved by utilizing an infra-red heating rotary drier. The subsequent phase of the study involved the storage of the Pre-treated grain in using several types of hermetic storage bags, to identifying the most suitable bag type for the pilot size storage procedure. The third crucial phase entails the assessment of quality alterations in the heat-treated grain that is stored in different types of hermetic bags.

Infra-red heating unit:

The experimental work employed a rotational infrared heating unit at a practical scale, as established by Matouk et al. (2017). A stationary insulated cylinder surrounds a revolving cylinder within this apparatus. A galvanized iron sheet used to make the rotating cylinder measures 1mm thick, 600mm in diameter and 200mm in length. The rotary cylinder's side cover is equipped with a steel flange measuring 150 mm in diameter. This flange is securely attached to a steel bar, which is supported by a robust ball bearing. The rotary cylinder's ball bearing was attached to the motor by a steel rod, which may be accessed from one side. A 0.5-kiloWatt low-speed electric motor with variable-size rotors supplied power to the rotating cylinder and controlled its rotational speed. Corn grain samples were introduced into the rotatable cylinder by an entrance located on the opposite side, which features a central hole with a diameter of 100 mm. As showed in Fig (1), the heat-treated corn grain is expelled through a part of the cylinder bottom that is designed to be easily detached for practical purposes. In the heating system, a pair of ceramic infrared heaters, each with a power output of 1 kW, were fixed onto two iron blades and subsequently assembled into the middle iron bar of the rotating cylinder, positioned towards the bulk of corn grain. Two screw rods were welded to the iron blades to allow for varying the distance between the heaters and the corn surface. This enabled the heaters to be moved vertically. The temperature of corn grain can be regulated to the desired level by manipulating the radiation output of two heaters through the utilization of an electric circuit equipped with an AC control dimmer.

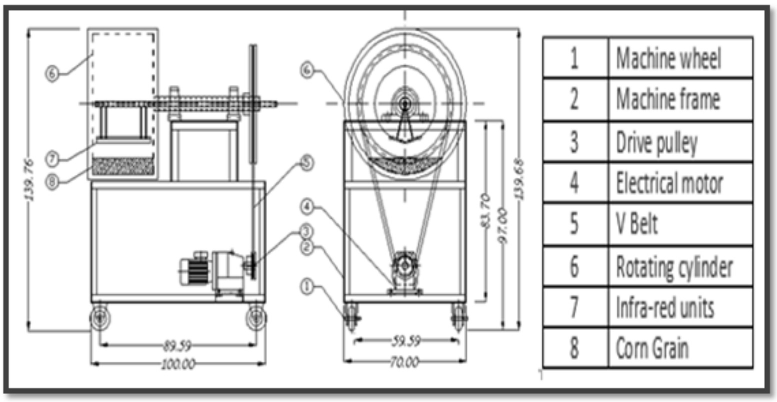


Fig. 1. Schematic diagram for the rotary Infra-red heating unit

Lab infrared heating performance under controlled conditions

The efficacy of the laboratory-scale infrared heating unit was evaluated in order to ascertain the most favorable radiation intensity and duration of exposure for the heat treatment of corn grain. The acquired data provided a suitable basis for operating the pilot-scale heating unit. During the experimentation conducted at the laboratory scale, many heat-treating parameters were considered and analyzed. as showed in table (1).

Table 1. Conditions for testing and optimizing the Infrared heating apparatus

Experimental procedures	Levels of treatments
The initial moisture content of corn	17.66 % (w. b.)
Radiation intensity	0.861, 0.973, 1.093, and 1.161 W/m^2
Grain feed rate	2 kg/ batch
Exposing time	(3, 6, 9, 12, and 15) min.

Corn Storage Experiments

Spesifications of the 3 and 7 layers hermetic films used for developing the storage bags are presented in tables (2) and (3) to describe different groups of films.

Table 2. Specifications of the developed barrier film (type 1) 90 micron (3-layer) by Matouk et al. (2017)

Property		Unit	Method	Value Max.	Value Min.	Value Mean
Average thickness		mμ	DIN	90.9	89.1	90
2 SEGMA thickness tolerance		%	53370	4.5	2.9	3.7
Width		Mm	Internal	422	422	422
Coefficient of Friction	Out/out	----------	ASTM D 1894	0.40	0.36	0.38
	IN/IN			0.20	0.18	0.19
	M/NTR		ISO 8295	--	--	--
Surface tension		CM/Dyn	DNI ISO 8296	--	38	--
Tensile strength at break MD		Mpa	ASTM D882	45.1	36.1	40.5
Tensile strength at break TD		Mpa		38.1	36.7	37.4
Tensile strength at yield MD		Mpa		16.7	14.3	16
Tensile strength at yield TD		Mpa		19.6	18.4	19
Elongation at break MD		%		523.5	447.1	495.1
Elongation at break TD		%		562.4	505.6	534
Elongation at yield MD		%		6.8	5.8	6.3
Elongation at yield TD		%		6.1	7.5	6.8
Oxygen Permeability		Day/m^2/Cc				900≤

Table 3. Specifications of the developed barrier film (type 2) 140 micron (7-layer) by Matouk et al. (2017).

Property		Unit	Method	Value		
				Max.	Min.	Mean
Average thickness		mµ	DIN	143	139	141
2 SEGMA thickness tolerance		%	53370	2.2	2	2.1
Width		Mm	Internal	422	422	422
Coefficient of Friction	Out/out	----------	ASTM D 1894	0.34	0.29	0.32
	IN/IN			0.46	0.41	0.44
	M/NTR		ISO 8295	--	--	--
Surface tension		CM/Dyn	DNI ISO 8296	--	38	--
Tensile strength at breakMD		Mpa	ASTM D882	42	40	41
Tensile strength at break TD		Mpa		38	36	37
Tensile strength at yield MD		Mpa		17	16	16.5
Tensile strength at yield TD		Mpa		575	560	567.5
Elongation at break MD		%		580	555	562.5
Elongation at break TD		%		550	525	537.5
Elongation at yield MD		%		14	13	13.5
Elongation at yield TD		%		14	13	13.5
Oxygen Permeability		Day/m2/Cc				0.1≤
Permeability Water vapor		Day/m2/g				2≤

The films that were produced underwent a transformation process to assume the configuration of bags, possessing a maximum capacity of 10 kilograms per bag. The bags consisting of either 3 or 7 layers, were filled with grain that had undergone heat treatment at the optimal heating settings. Subsequently, these bags were stored within a storage chamber, as depicted in Fig. 2. The control group also utilized burlap sacks for storing grain under the similar condition's. The bags that were subjected to testing were placed on wooden bars within three distinct groups. Two of these groups were representative of different types of plastic films, while the third group represented the conventional method of storage using burlap bags. A type K thermocouple sensors were utilized to measure the temperature within three bags of each stock, representing the top, middle, and bottom positions of the stored grain. The assessment criteria for the developed examined bags encompassed the measurement of carbon dioxide concentration (ppm), grain moisture content (% w. b), fungal colony count (cfu/g), and Insect count (insect/kg) at 30-day intervals for a total storage time of 6 months.

Fig. 2. Tested bags of heat-treated corn grains

Experimental Measurements and Instrumentation

-Determining the moisture content of corn grains

The moisture content of corn grain samples was determined using the conventional air oven method, as outlined in the American Association of Cereal Chemists (AACC, 2000). A total of ten grams of corn grain samples were subjected to a temperature of 105ºC for 24 hours using an electric oven. Subsequently, the samples were stored at room temperature within a desiccator. The dried samples were reweighed using an electronic digital scale, and the moisture content of corn grain was determined on a wet basis using the following equation:

$$Mc_{wb} = [(m_w - m_d) / m_w] \times 100 \text{ ……...[1]}$$

Where

M_{wb}: **Moisture content, %.w.b**

m_w : **Wet mass of grains, g.**

m_d : **Dry mass of grains, g.**

-Surface temperature of the rotating cylinder

The model HT-11 of a remote-type infrared spot thermometer was employed to assess the temperature of the surface of a rotating cylinder.

-Ambient air temperature and relative humidity

The ambient air temperature and relative humidity (RH) of the storage were measured using a temperature – humidity probe coupled to the meter model (T.R-206).

-Bulk temperature of corn grain

The temperature of the heated bulk of corn grain was promptly monitored after each experimental trial. The corn grain that had been discharged was collected within an insulated glass cylinder. A one-point temperature meter model (AW SPERRY DM-8600, Taiwan) was utilized to measure the temperature. The sensing tip of the temperature meter was inserted into the bulk of the corn grain until a stable reading was obtained.

-CO_2 concentration

The concentration of carbon dioxide (CO_2) was measured monthly throughout the storage period using a carbon dioxide sensor (Gas analysis- type VI GAZ "Box 121, France). The probe of the meter was inserted into the bags at different locations and the average of the readings were recorded for each experimental treatment.

-Total microbial count (cfu/g)

The process required 25 g of test material to be deposited in a Seward stomacher bag in London, UK. The homogenization process involved subjecting the material to agitation for a three minutes. This was carried out in a solution consisting of 225 milliliters of sterile saline peptone water

(SPW), which contained 1 gram of peptone and 8.5 grams of sodium chloride. Each sample was serially diluted 10-fold in sterile saline peptone water and used for quantitative microbiological analysis. Then, 1 ml aliquots of the appropriate dilutions were duplicated on agar plates. Over 48 hours at 30°C, bacterial colonies on plate count agar (Merck, 1.05463) were counted to determine the total bacterial count (TBC). Following a pasteurization process conducted at a temperature of 80 °C for a duration of 15 minutes, the enumeration of spore-forming bacteria was carried out using plate count agar (Merck, 1.05463) incubated at a temperature of 30 °C for 48 hours. For five days at 25 °C, Rose Bengal Chloramphenicol Agar (Lab M, 36) treated with chloramphenicol (x009) was used to count fungal colonies. Every plate was studied to discover the typical colony forms and physical characteristics of each culture medium.

-Insect count

A sample of 250 g was taken from each of the storage bag. The grain was sieved through 2 mm mesh sieve (to remove dead and alive insects from the sample taken and to the grain on the sieve) as the method used by Compton and Sherington, (1999). Both alive and dead insect were isolated by using hand lens magnification methods and counted. The counted insects were related to the weight of the sample.

- Germination percentage:

Standard germination tests for control and treated seeds were carried out according to the International Seed Testing Association (ISTA, 2006**)** procedures to evaluate the effect of each treatment on seed germination capacity. 30 seeds were kept in petri-dishes lined on filter paper moistened with distilled water until it was moistened and done in three replications (30 seeds per petri-dishes) and incubated at an electric incubated adjust at the temperature of (25°c) for 5 to 7 days. The germinated seeds were counted visually up on the appearance of radicle and/or plumule and the percentage of germination was calculated as follows:

$$\text{Germination}\,(\%) = \frac{\text{No.of germinated seeds}}{\text{Total No.of seeds soaked in each petri dish}} \times 100 \quad (2)$$

RESULTS AND DISCUSSIONS

- Pre-heat treatment of corn grain using the infra-red rotary dryer

-The change in moisture content of corn grain

The ultimate moisture content of the grain exhibited a gradual decline, ranging from 17.66% to 15.03, 13.7, 11.5, and 9.90% (w. b.), while the radiation intensity levels varied at 0.861, 0.973, 1.093, and 1.161kW/m^2 correspondingly. Typically, with a grain feed rate of two kilograms per batch, the final moisture content varied between 16.6% and 9.90% on a wet basis. Fig. 3 illustrates the relationship between corn grain moisture contents and the duration of the infrared heating operation. The experimental results indicate a direct correlation between the exposure time heating and the reduction in moisture content, given a constant radiation intensity. This phenomenon can be attributed to the corn grain's increased energy absorption over an extended duration, leading to a higher rate of water evaporation. Furthermore, it was evident that corn grain exhibited rapid moisture loss, particularly under conditions of elevated radiation intensity. Nevertheless, as the duration of exposure extended, the rate at which moisture was eliminated steadily diminished, reaching its maximum point during the initial phases of the heating process.

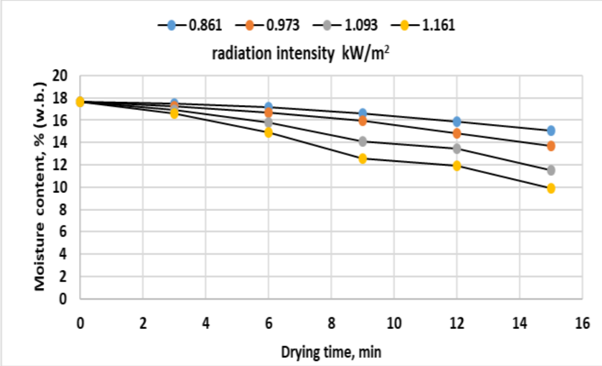


Fig. 3. the variation in moisture content of corn grain to the duration of drying time under varying radiation intensity levels.

-Variation in grain bulk temperature during infrared heating.

The relationship between grain bulk temperature and exposure time of heating is depicted in Fig. 4. The corn bulk temperature exhibited a lower value during the initial phase of heating. Then, it grew steadily as the period of exposure to heat prolonged. This implies that, in the initial phase of heating, there is a significant temperature disparity between the original bulk of the grain and the temperature achieved after infrared heating. As a result, there is an elevated rate of thermal energy transfer from the heat source to the grain, leading to a more rapid rise in the overall temperature of the grain.

The temperature range of heat-treated corn grain samples varied between 28.46 and 49.01 °C at the lowest radiation intensity of 0.0861 kW/m^2. In contrast, it ranged from 57.78 to 117.89 °C under the highest radiation intensity of 1.161 kW/m^2. Typically, the temperature of corn grain bulk exhibited a positive correlation with both the intensity of radiation and the duration of heating.

According to the data presented in Fig. 4, when the grain feed rate was 2 Kg/batch and the highest exposure period was 15 minutes, the final temperature of the grain bulk reached values of approximately 49.01, 78.54, 104.40, and 117.89 °C for the corn grain subjected to radiation intensities of 0.861, 0.973, 1.093, and 1.161 kW/m^2, respectively.

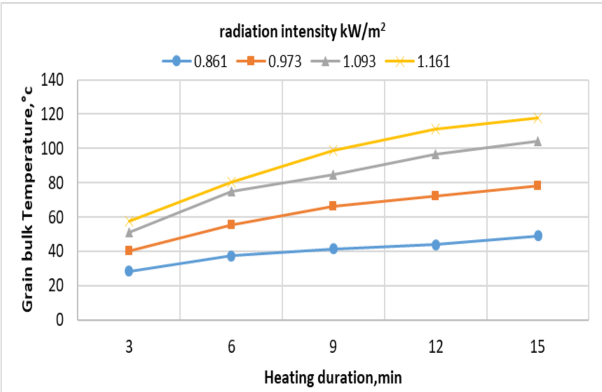


Fig. 4. Effect of different radiation intensity grain bulk temperature.

- Microbial elimination during infrared heating

Fig. 5 illustrates the variations in overall microbial load count (colony-forming units per gram) to radiation intensity across various exposure durations. The results demonstrated that increased levels of radiation intensity had a significant impact on reducing the fungal load in corn grain, with the effectiveness of this reduction being dependent on the duration of exposure .

At the lowest radiation intensity of 0.861 kW / m² and the highest exposure time of 15 min, there was a drop in the overall microbial load count from 39 × 10^2 to 19× 10^2 cfu / g. In contrast, the overall microbial count exhibited a decline from 39× 10^2 to 13× 10^2 cfu / g under the highest radiation dose of 1.161 kW / m² and the highest exposure duration of 15 minutes.

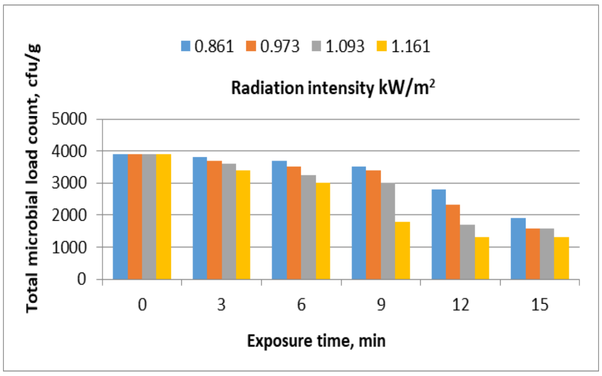


Fig. 5. Influence of radiation dose and exposure duration on the total microbial count of corn.

Influence of infra-red heating on corn germination percentage:

Table (4) displays the variations in grain germination to varying levels of radiation intensity throughout different durations of exposure.

Table 4. Different radiation intensities and heating times affect germination percentage (%).

Exposure	Radiation intensity, kw/m²			
Time, min	0.861	0.973	1.093	1.161
0	96	96	96	96
3	93	92	90	88
6	90	87	86	84
9	88	85	84	83
12	86	84	82	80
15	82	79	74	72

The percentage of germination varied between 96 and 72% based on the level of radiation intensity and duration of exposure. This means that, the pre-heat treatment does not negatively affect the germination of grain and this condition allow the germs to produce the required levels of co_2 inside the bags which play a vital effect on the safe storage process.

Recommendations for scaling up pre-storage heat treatment

Taking into account the alterations in moisture content, fungal count, and other quality variations observed in the grain subjected to heat treatment. It is proposed to utilize a radiation intensity of 1.161 kW/m² and exposure duration of 12 minutes in order to achieve the minimum fungal colony count of 14×10^2 cfu/g, a moisture content of 11.95 % w.b., and a germination percentage of 80%.

-Storage of corn using different types of hermetic bags

-Temperature and relative humidity of the ambient air

Table (5) displays the mean observed values of relative humidity and temperature of ambient air during the duration of the storage operation. According to the data presented in Table 4, the average ambient temperature varied between 21.5 and 31.67 °C, while the relative humidity ranged from 66.4 to 74.1% throughout the storage period.

Table 5. Temperature and humidity changes during storage period.

Storage period (month)	Temperature, °C (T)	Relative humidity % RH
1	21.6	68.0
2	27.2	74.1
3	30.15	70.3
4	31.67	66.4
5	29.75	68.1
6	28.175	70.2

Grain bulk temperature during storage.

The temperature of grain mass within the bags exhibited a discernible trend that closely mirrored the ambient air temperature for the whole duration of storage. As depicted in Fig. 6, there was a reduction in temperature oscillation as the grain depth within each storage bag increased. The average corn bulk temperature for the heat-treated grain was measured to vary from 22.88 to 28.57 °C for the hermetic storage bags with 3 layers, from 22.88 to 22.74 °C for the hermetic storage bags with 7 layers, and from 30.10 to 22.15 °C for the burlap bags (Control). Also, the average corn grain bulk temperature was measured to vary from 21.66 to 21.18, 21.76 to 22.16, and 21.31 to 23.11 °C for the hermetic storage bags consisting of three layers, seven layers, and the burlap bags, respectively, with untreated grain. Typically, the measured temperature of grain bulk can serve as an indicator of the grain's condition, specifically its respiration rate and overall microbial count.

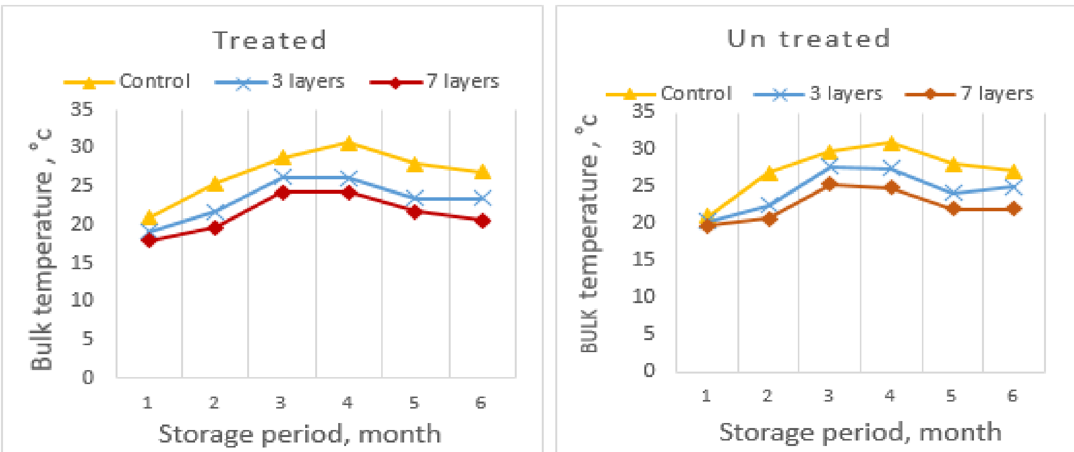


Fig. 6. Grain bulk temperature as related to storage time for the heat-treated grain stored in different types of bags.

- Grain moisture content during storage period.

Several factors, including the initial moisture content, the relative humidity in the storage environment, the presence of insects and microbes, and the respiration rate of the seeds, influence the moisture content of corn during the storage process. Both the respiration rate of seeds and the release of water by insects contribute to changes in moisture content. According to the data presented in Fig. 7, the moisture content of the untreated seeds, which were stored in burlap bags, exhibited a gradual decrease from 11.95 to 10.99% w.b during the initial three months of storage. Subsequently, there was an upward trend, of moisture content which increased to a level of 12.86 % w.b. Toward the conclusion of the storage duration.

Nevertheless, the untreated grain stored in both the three-layer and seven-layer hermetic bags exhibited a marginal rise in moisture content. Specifically, the moisture content rose from 11.95% (wet basis) during the initial first month of the storage period to 12.28 and 12.306 % w.b, respectively. Subsequently, the moisture content began to decline, reaching 10.32 and 12.60% w.b after the storage period. In contrast, the grain subjected to infrared heat treatment and stored in burlap bags (control) exhibited a marginal rise in moisture content after the storage duration. Conversely, the moisture content of the heat-treated corn stored in hermetic bags, specifically those stored in 3-layers and 7-layers, remained relatively consistent with the initial levels.

The experiment revealed that the seeds stored in burlap bags had a higher moisture content when compared to both types of hermetic bags. In general, the untreated seeds exhibited higher levels of bulk temperature and moisture content in comparison to the treated seeds across all types of storage bags. This disparity can be attributed to the respiratory activities of grain, microbes and insects. Simultaneously, the heat-treating procedure resulted in a reduction in the growth rate of microbes, insects, molds, and yeasts. This reduction led to a decrease in respiration rate, as well as lower levels of moisture and temperature in the stored seeds. Simultaneously, the hermetic plastic bags' water seal effectively inhibits moisture absorption from the ambient atmosphere in contrast to the burlap bags, thus safeguarding the stored seeds.

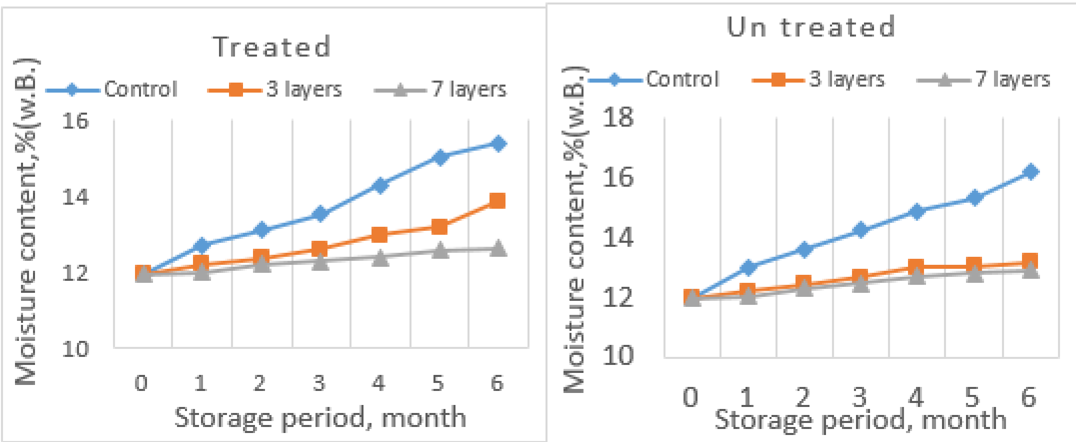


Fig. 7. Grain moisture content as related to storage time for the storage treated and untreated grains in different types of bags.

CO_2 concentration

The process of respiration in the grain ecosystem includes the consumption of oxygen and the subsequent generation of carbon dioxide, heat, and water by various microorganisms such as grains, fungi, and insects. The exchange of gases between the bags is contingent upon the disparity in gas partial pressures and the permeability of the plastic materials. The CO_2 concentration exhibited variability across different plastic materials and grain conditions, as depicted in Fig. 8.

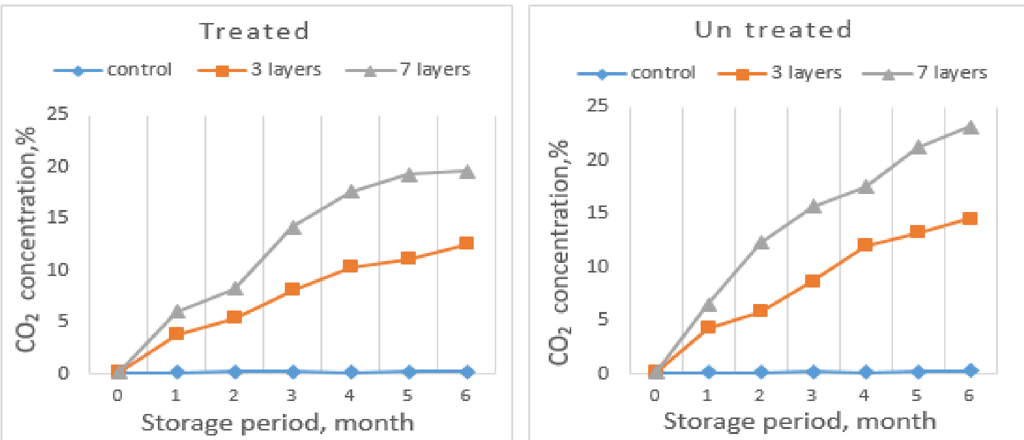


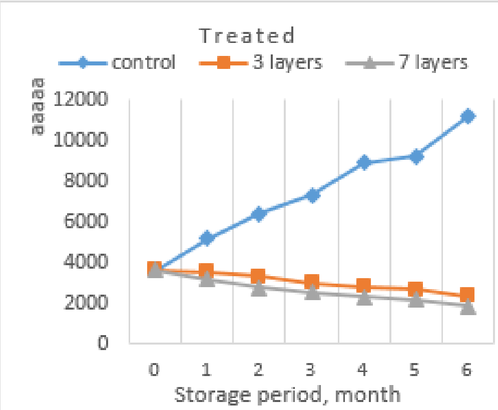
Fig. 8. Carbon dioxide concentration as function to storage period for various types of bags.

The results indicate that the plastic bags with seven layers exhibited the greatest levels of carbon dioxide concentration after heat treatment, with a rise from 0.2% to 20.1%. This was followed by the bags with three layers, which showed a CO_2 level increase from 0.2% to 13.0%. In contrast, the burlap bags exhibited carbon dioxide levels that varied between 0.2% and 0.3% correspondingly. The concentration of carbon dioxide (CO2) exhibited variations based on the specific polymeric material utilized and the condition of the grain. The findings additionally indicate that the untreated grains stored in plastic bags consisting of 7 layers exhibited the greatest concentrations of carbon dioxide, with levels increasing from 0.2% to 22.9%. This was followed by the bags with three layers, which showed a rise in CO_2 levels from 0.2% to 15.1%.

Total microbial count:

The data collected at bag closure indicates that the presence of molds and other bacteria in the grain is influenced by its condition. The inhibition of mold and microbial activity is observed under varying storage conditions in various types of plastic bags, coinciding with a rise in the concentration of CO_2. According to the data presented in Figure (9), the non-treated grain exhibited a final microbial load of approximately 256×10^2, 210×10^2, and 762×10^2 cfu/g when stored in hermetic plastic bags of 3 layers, 7 layers and bulap bags for the duration of the storage period.

This implies that both corn bags of three layers and seven layers, exhibited a very close count of total microbes, during the duration of storage. On the other hand, the heat-treated grain showed a final microbial load of 24×10^2, 19×10^2, and 112×10^2 cfu/g for the corn stored in hermetic bags of three layers, seven layers, and burlap bags, respectively, after the storage period. This implies that both corn bags of three layers and seven layers, exhibited nearly similar total microbial counts and were effective in suppressing fungal development during the storage period. Nevertheless, the heat treatment resulted in reduced microbial burdens.



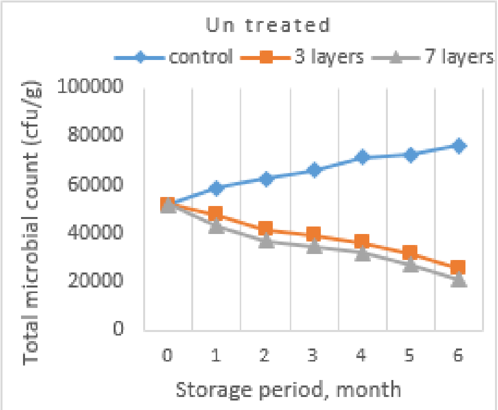


Fig. 9. The relationship between storage period and the total microbial load in various types of bags.

-Insect counts inside the bags.

The occurrence of insects in storage bags is constrained primarily by the fact that the majority of these bags are filled with corn that is directly sourced from the field. Table (6, 7) presents data on the detection of insects in corn grain during the storage process, specifically within various types of bags.

Table 6. Count of insects on heat-treated grain concerning storage time for various types of sacks.

Storage period, month	Burlap	Three layers	Seven layers
0	0	0	0
1	2	0	0
2	4	1(dead)	2(dead)
3	7	0	0
4	12	3(dead)	0
5	17	0	1 (dead)
6	19	2(dead)	0

Table 7. Count of insects on untreated grain in relation to storage time for various types of sacks.

Storage period, month	Burlap	Three layers	Seven layers
0	4	4	4
1	3	5	6
2	8	3	3 (dead)
3	13	4	5 (dead)
4	24	4 (dead)	7 (dead)
5	32	8 (dead)	2 (dead)
6	43	6 (dead)	0

Overall, both types (3 layers) and (7 layers) of storage bags exhibited minimal insect infestation over the entire storage duration without the need for any fumigation measures. Nevertheless, the control bags exhibited a higher rate of insect population, indicating that the utilization of hermetic bags resulted in elevated amounts of carbon dioxide created by grain respiration, which may not be conducive to sustained insect proliferation. Simultaneously, the combined effect of radiation treatment and hermetic sealing serves to inhibit the existence of insects within the stored bags.

CONCLUSION

The obtained results were as following:-

1- A radiation intensity of 1.161 kW/m², an exposure time of 12 minutes, and a grain feed rate of 2 kg per batch are recommended for the Infra-red pre-heat treatment of corn grain.

2- The application of infra-red pre-heat treatment resulted in a significant decrease in the moisture content of the grains, as well as a notable drop in both the total microbial count and insect count during the storage process.

3- The storage of corn grain in 7 layers hermetic bags is recommended for safe storage of corn grain with high quality.

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التخزين الآمن لحبوب الذرة باستخدام انواع مختلفه عبوات بلاستيكية نوعية

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الملخص

أجريت هذه الدراسة لتحديد الظروف المثلى للتخزين الآمن لحبوب الذرة الصفراء صنف (pioneer3084) وتقييم التغييرات في الجودة أثناء المعاملة المبدئية بالأشعة تحت الحمراء وتخزين الحبوب في أنواع مختلفة من العبوات البلاستيكية النوعية. تضمنت المعاملات التجريبية لعملية التسخين بالأشعة تحت الحمراء مستويات مختلفة من أزمنة التعرض 3 ,6 , 9 , 12 , 15 دقيقة،وشدة الإشعاع 0.861 , 0.973 , 1.093 , 1.161 كيلو واط / م ^{2}. تم مقارنة أنواع مختلفة من الأكياس النوعية متعددة الطبقات (3 طبقات - 7 طبقات) بأكياس التخزين التقليدية من الخيش. أظهرت النتائج أن التسخين بالأشعة تحت الحمراء كمعاملة مبدئية للحبوب قبل التخزين ادى الى انخفاضًا ملحوظًا في المحتوى الرطوبى للحبوب، والعدد الكلي للكائنات الحية الدقيقة. تخزين حبوب الذرة في الأكياس النوعية (7 طبقات) موضوع الدراسة الى توفير بيئة قاتلة للحشرات والبكتريا والفطريات. كما أنها لم تؤثر على جودة الذرة. أشارت نتائج هذه الدراسة إلى أنه من أجل الحصول على عدد إجمالي من الكائنات الحية الدقيقة 1400 CFU / g ومحتوى رطوبة 11.95٪ لحبوب الذرة، يوصى بمعالجة الحبوب بالأشعة تحت الحمراء عند شدة الإشعاع 1.161 كيلو واط / م ^{2} ومدة تعرض 12 دقيقة وتخزينها في الأكياس النوعية ذات 7 طبقات وصولا التخزين الآمن للحبوب مع منع نمو الكائنات الحية الدقيقة والحشرات والحفاظ علي جودتها خلال فترة التخزين.