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THE EFFECT OF TEMPERATURE AND HUMIDITY ON MAIZE GRAINS CONSERVATION IN METAL SILOS

Efecto de la temperatura y la humedad en la conservación de granos de maíz en silos metálicos refrigerados

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ABSTRACT. In humid tropical regions, dominated by high temperature and relative humidity, grain and seed conservation is a big challenge. Under these ecological conditions the development of the main factors that cause losses in grain and seed is favored; so ensuring grain storage after harvest has been of great concern. From this a research was carried out in the "Rubén Martínez Villena" town old sugarmill of the same name located in Aguacate Village, Madruga, Mayabeque province, with the aim of studying the behavior of the temperature and humidity relative variables on grain corn in metal silos for storage. The experiment consisted of two containers with corn grains, one with virgin grain and other with processed grain by a dryer, this will give us the possibility to check the efficiency of the drying process for grain stored for a long time. Besides, it gives us a sense of the loss and damage that can occur in a process of long-term storage without prior preparation of the grains. Among the main results of the research in general, it was found that the treated grains of corn were at a lower temperature and relative humidity of the grain, which affected the percentage of damaged grains which decreased when grains were treated through of a pre- storage drying process that had economically impacted because had less losses on money.

Key words: *Zea mays*, storage, grains

RESUMEN. En regiones tropicales húmedas, con predominio de alta temperatura y de humedad relativa, la conservación de granos representa un gran desafío. Bajo estas condiciones ecológicas se favorece el desarrollo de los principales factores que ocasionan las pérdidas en granos y semillas; por lo que garantizar su almacenamiento después de la cosecha, ha sido de gran preocupación. A partir de esto se realizó una investigación en el poblado Rubén Martínez Villena antiguo ingenio azucarero de ese mismo nombre, ubicado en el asentamiento de Aguacate, municipio Madruga en la provincia de Mayabeque, Cuba con el objetivo de estudiar el comportamiento de las variables temperatura y humedad relativa del grano de maíz en silos metálicos durante su almacenamiento. El experimento consistió en dos recipientes con granos de maíz, uno con el grano virgen y el otro con el grano procesado por un secador, lo que permitió comprobar la eficacia del proceso de secado para los granos almacenados por largo tiempo. Además, permitió estimar las pérdidas y daños que pueden ocurrir en un proceso de almacenamiento a largo plazo, sin una previa preparación de los granos. Dentro de los principales resultados de la investigación, se obtuvo que los granos de maíz tratados poseían una menor temperatura y humedad relativa, lo que repercutió en el menor porcentaje de granos dañados al ser tratados previo al almacenamiento, repercutiendo en la menor pérdida en términos financieros en el tratamiento utilizado.

Palabras clave: *Zea mays*, almacenamiento, granos

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INTRODUCTION

Maize (*Zea mays* L.) is one of the main foods in the diet of the Latin American population. Most of the energy and protein consumed in these countries comes from this crop. In Cuba, corn is of great importance and today, the internal needs of that grain is not satisfied with national production, so it is necessary to import large volumes to meet demand (1). Given the importance it represents for food, has set a strategic project for the production of this grain rice to the population until 2015, with the aim of replacing imports of dried corn (2).

Proper storage of basic food grains, essentially depend on the environmental conditions of the plant, the physico-chemical and biological grain properties, the storage period, and the type and characteristics of an open air storage, warehouse or store (3).

In humid tropical regions, dominated by high temperatures and humidity, conservation of grains represents a serious challenge, since under these ecological conditions the development of the main factors that cause losses in grains and seeds is favored; so ensure grain storage after harvest, has been a major concern of farmers as the presence of pests or moisture problems, not only reduce the volume of stored maize, but affects grain quality and therefore it affects the economy by reducing its sales, selling cheaper, having to buy more grain for food or sowing[A] (4).

In some grain moisture it is one of the main factors influencing industrial performance. Grains should be kept clean, dry (13,5 % moisture receipt) without mechanical damage, thus the risk of damage is minimal. For this, it should consider packaging, storage and quality control of grain during this stage (5).

Humidity and temperature are the two variables that affect the activity of grains and organisms living in bulk. At higher temperature and humidity, the greater the microbial activity. Wet grain management is an aspect that is often a problem when harvesting and that problem can be both economic and logistical (6).

A drying system should allow eliminate excessive grain moisture short term and ensure their conservation. Moreover, the power to have a conservation method that achieves secure and maintain grain quality is of great importance, since it guarantees satisfy food supplies to the population and animals for prolonged periods, which has been threatened by increasing human population observed in recent years. For these reasons, it is necessary the development of modern technologies to store large volumes of grain and greater innovation of productive potential[A].

Cuba is not exempt from the current situation and then it needed to increase storage capacities. So it assumed the task of introducing conservation technologies of large volumes of grain for long periods of time. Within these, the refrigerated metal silos (RMS) are completely new. However, the degree of damage that may occur in product quality preserved in them (7) is unknown.

For this reason the Executive Committee of the Council of Ministers of the Republic of Cuba in its agreement No. 3937 of 2006 provides in its second paragraph that the Ministry of Food Industry is the body responsible for directing, executing and controlling among others, production of products derived from flour, so considering that, to ensure the efficient development of this activity as part of the investment process that takes place in the country, have been installed in different entities, refrigerated metallic silos to conserve cereals and legumes. The Silo name Ruben Martinez Villena, was built to store and preserve the grain of corn (yellow) to the state reserve and for human or animal consumption. From the above, charted objective is to study the behavior and economic impact of the main physiological variables associated with the conservation of grains of maize (*Zea mays* L.) in refrigerated metal silos.

MATERIALS AND METHODS

Location of study area

The research was conducted in the town Ruben Martinez Villena (old sugar mill of the same name) belonging to Aguacate town of Madruga municipality, Mayabeque province, located in the 22º 56`9,81 “North Latitude and 82º 2`7 , 49 “west longitude (8).

Vegetal material. Experimental design

For the development of research they were created under laboratory conditions, experimental models that simulated a refrigerated metallic silo (RMS); effected the assembly of two containers of 1 m diameter and 1,5 m high.

For research as plant material was used yellow corn kernels semi-soft type and degree toothed USS No. 2 (9), from USA.

[A] Hidalgo, T. T. M. *Caracterización de la calidad físico-química de los granos de maíz almacenados en los silos metálicos refrigerados de la Empresa Productora de Piensos Balanceados de Cienfuegos*. Tesis de Maestría, Instituto de Ciencia Animal, 2011, La Habana, Cuba, 75 p.

As controls were used 46 kg of corn grains stored in the container 1. It is noted that they were not treated (previous) to storage, simulating the usual practices in the RMS system by Silos and Mills Company in Matanzas[B].

For the case where the grain treatment showed optimum temperatures, they were used 46 kg of corn kernels stored in the container 2, which were dried in an oven for 30 minutes at 40 °C. Following this, the beads were cooled in Cold car for 20 minutes until a temperature of 12 ^{0}C.

Humidity and temperature variable behavioral data of the corn kernel in the development initial stage of experimentation are shown below:

Control: 46 kg of corn kernels, at 19 °C with a humidity (Hg) = 20 %

Treatment: 46 kg of corn kernels, at 12 °C with a humidity (Hg) = 13,5 %

Analysis of grain conservation

After storage of grains (for both control and treatment) assessments were developed for 90 consecutive days in order to assess the state of grain conservation to control conditions and treatment.

Temperature: for the evaluation of this variable, for each container Thermal collectors connected to the wall thereof were used, wherein data from five sensors located inside the silos at a distance proportional to the design set in the RMS to large scale was obtained.

To determine the experimental daily temperature in the control and treatment, the equation developed from FAO and FAOLEX (10) was used:

$$Trecp. = (\Sigma\ [s / n])$$

where:
Trecp- temperature in the container
S- Sensors
N- Number of sensors

Grain relative humidity: for evaluation of this variable, an analysis was conducted in the laboratory, from a daily sampling where 1lb of grain from the middle part of each container (control and treatment) was selected. The sample was measured in a grain moisture meter Gehaka-AGRI G 600, obtaining daily values of this variable.

Percentage of damage: Ways to evaluate the effect of the above variables have on the quality of stored grain, damage percentage was estimated thereof, used for that 1000 grains of the samples collected from the control and treatment. In this sense, they were deposited in nylon bags properly identified and subjected to methods of counting and weighing the following steps:

- Samples on board 1 000 holes so that each hole to retain a grain were spread.
- Each visually grains were reviewed effected a separation into two groups of samples, determining achieving in this regard: grains and damaged grains free of damage.
- In the case of damaged grains and healthy grains, they were weighed by a numbered of Analytical balance (Denver Instrument, max. 600 g d = 0,01 g, Error 0, 001 g) and manually.

The results were recorded separately by using EXCEL, 2009, which allowed calculating the percent damage by the equation:

$$\%\ Damage = [nd\ (ps / ns) / nd\ (ps / ns) + ps] \times 100$$

where:
nd - number of grains damaged
ps- weight of grains healthy
ns- number of healthy grains
pr- weight of recoverable grains

Statistical processing

The data obtained from each evaluation were processed and statistically analyzed. In the case of variables relative grain moisture, temperature and the percentage of damaged grains, a comparison between control and treatment was performed. This comparison was made after an analysis of the confidence interval for the mean (95 %). All statistical analyzes were processed using the statistical package SPSS version 19.0 (11).

Economic valuation

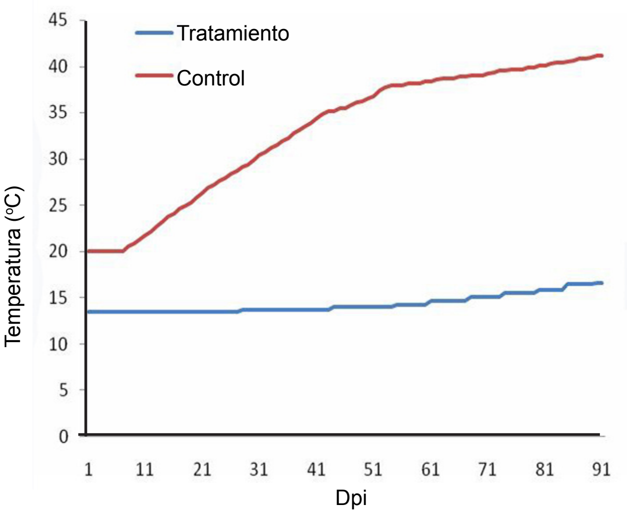
From certain damage percentage to the case of control and the treatment and considering the value of a ton of corn on the international market (12) economic assessment of percentage RMS damage was done.

[B] Jiménez, Lázaro. Jefe de Producción, Empresa Silos y Molinos Matanzas. Comunicación Personal (abril, 2014)

RESULTS AND DISCUSSION

Analysis of the conservation of grain

Upon monitoring the quality of grain storage process of corn in the experiment, a large variation was observed in the behavior of the temperature variable. In this sense, it becomes more marked in the case of control with respect to treatment (Figure 1).

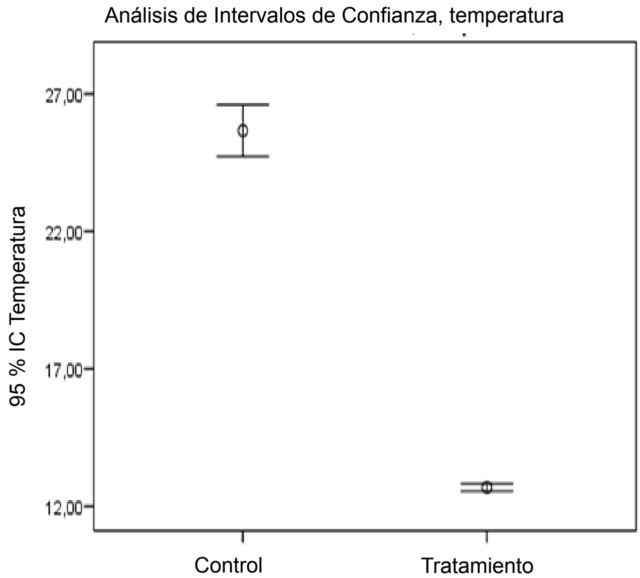


Dpi (days from the start)

Figure 1. Behavior of temperature (°C) during the 90 days of the experiment

This statement is confirmed upon a descriptive analysis of the data (Table I), which shows that in the case of control, the average population showed a temperature of 25 °C (25 ± 0,47 °C), meeting minimum values and the same maximum 19 and 30 °C respectively.

However, in the case of treatment, the mean of the population showed a temperature of 12.7 °C (12,68 ± 0,07 °C), finding minimum and maximum values thereof of 12 and 14,2 °C respectively. In this sense, an analysis of the confidence interval for this variable (Figure 2), significant differences between the control and treatment for the same were observed.



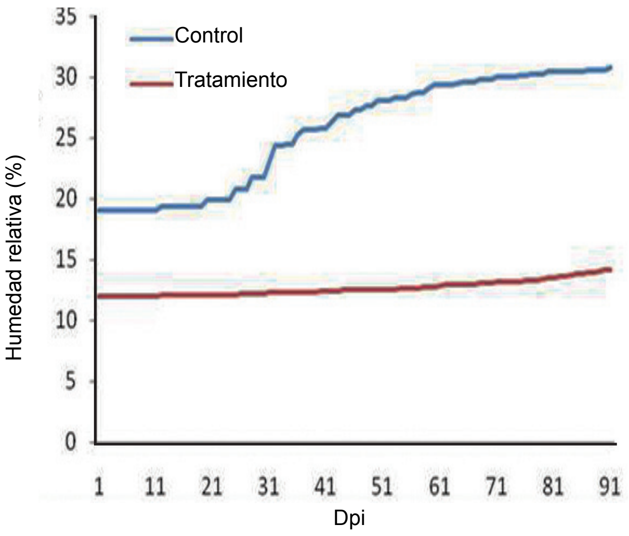
Dpi (days from the start)

Figure 2. Representation of the confidence intervals average 95% for temperature

Similarly, an analysis of the relative humidity of the grain, a large variation was observed in the behavior of this variable becomes more marked in the case of control relative to treatment (Figure 3).

Table I. Descriptive Analysis and Confidence Interval 95 % for temperature

	Treatments			Statistical	Typical error
Temperature	Control	Mean		25,6618	,47282
		Interval of confidence for the mean at 95 %	Inferior limit	24,7223	
			Superior limit	26,6013	
		Minimum		19,00	
		Maximum		30,80	
	Treatment	Mean		12,6844	,06489
		Interval of confidence for the mean at 95 %	Inferior limit	12,5555	
			Superior limit	12,8134	
		Minimum		12,00	
		Maximum		14,20	



Dpi (days from the start)

Figure 3. Behavior grain relative humidity (%) during the 90 days of the experiment

Upon a descriptive analysis of the data (Table II), which shows that in the case of control, the average population showed a relative humidity of grain 33,2 % (33,23 ± 0,73 %), finding minimum and maximum values thereof of 20 and 41,2 % respectively.

However, in the case of treatment, the mean of the population showed a relative humidity of grain of 14,35 % (14,35 ± 0,1 %), finding minimum and maximum values thereof 13,5 and 16, 6 % respectively.

Meanwhile, to make an analysis of the confidence interval for this variable (Figure 4), significant differences between the control and treatment for the same were observed.

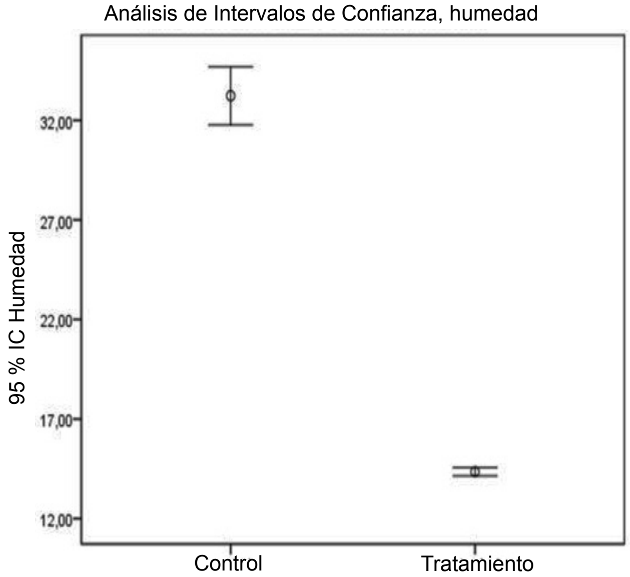


Figure 4. Representation of Confidence Intervals of the average 95 % to grain relative humidity

From the results shown in Figure 4 it can see the importance of treatment applied to the corn kernels before the entrance to the silo. It allows them show a grain moisture between 12 and 14 %, value reported in the literature as the optimal value of conservation of grains for maize (13-15).

Table II. Descriptive analysis and 95% confidence interval for the relative humidity of the grain

	Treatments			Statistical	Typical error
Relative humidity of grain	Control	Mean		33,2344	,73480
		Interval of confidence for the mean at 95 %	Inferior limit	31,7744	
			Superior limit	34,6945	
		Minimum		20,00	
		Maximum		41,20	
	Treatments	Mean		14,3522	,10260
		Interval of confidence for the mean at 95 %	Inferior limit	14,1484	
			Superior limit	14,5561	
		Minimum		13,50	
		Maximum		16,60	

The fact that the grain absorbs oxygen from the air and consume carbohydrate structure, releasing heat; causes a faster breathing since grain is hot and humid, which causes temperature changes cause changes which intensify the variations of the relative humidity of the grain. Thus, the balance of aeration is modified, leading to an increase in the potential for greater grain moisture (16, 17).

Meanwhile, if it is considered that moisture-temperature, relationship is inversely proportional, and that under conditions of RMS this relationship becomes directly due to the increased moisture in the grain mass that occurs in the RMS; this causes an increase in temperature product to the interaction between grains and having little room to breathe. Therefore, heat transfer from grain to grain causes a temperature increase, which in certain conditions induces involvement RMS generally (18, 19).

When the moisture content increases, so does the air gap between stored grains, which contributes to increased resistance of airflow through the grain. In this respect it has been shown that migration of moisture grain prevails[A] (20), thus it requires more time for the water content in the grain begins to stabilize, by the effect of the movement of interstitial air.

When considering the issues raised by other authors (21) the temperature and humidity within a container affect the moisture content of the grains, the importance and the need to have dry grain to the entrance of the silo is confirmed, it which supports the treatment done in this research.

From these approaches, there are several reports in the literature suggest that the more dry beans are to be stored, the lower its rate of deterioration, even when other physical factors are unfavorable C (15, 21).

In this regard, to make a descriptive analysis regarding the number of damaged grains (Table III), which shows that in the case of control, the average population showed an average of 54,85 grains involvement, finding minimum and highs between 31 and 98 damaged grains respectively.

However, in the case of treatment, the mean of the population showed an average of 15,71 grains involvement, finding minimum and maximum values between 7 and 41 damaged grains respectively.

These results are observed markedly to an analysis of the confidence interval (Figure 5), significant differences between the control and treatment, demonstrating the effectiveness of the application of drying prior to storage of the grains in the SMR.

[C] Castillo, A. *Diseño de un silo cilíndrico de fondo plano para almacenamiento de maíz con capacidad de 50 toneladas* [Tesis de Diploma], Universidad Politécnica Saleciana, Sedes Quito, Quito, Ecuador, 2013, p. 85.

Table III.Descriptive analysis and Confidence Interval at 95% for the number of damaged grains

	Treatments			Statistical	Typical error
Number of damaged grains	Control	Mean		54,8556	2,07840
		Interval of confidence for the mean at 95 %	Inferior limit	50,7258	
			Superior limit	58,9853	
		Minimum		31,00	
		Maximum		98,00	
	Treatments	mean		15,7111	1,06120
		Interval of confidence for the mean at 95 %	Inferior limit	13,6025	
			Superior limit	17,8197	
		Minimum		7,00	
		maximum		41,00	

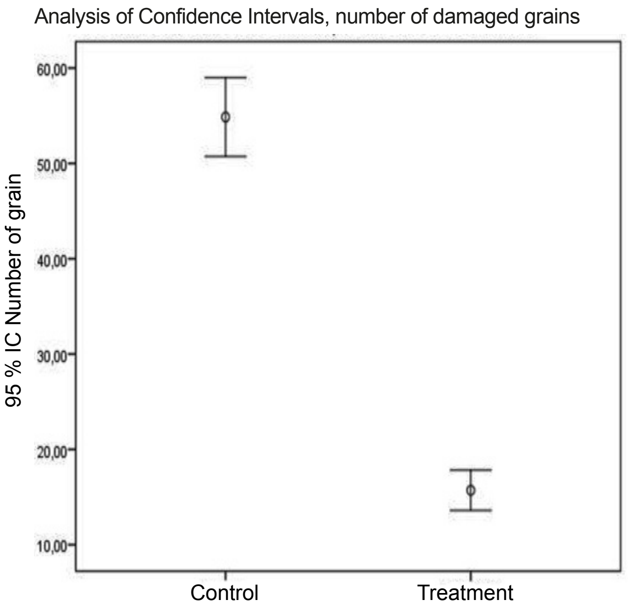


Figure 5. Representation of Confidence of the mean at 95 % for the number of damaged grains

Upon analysis of the percentage of damage (Table IV) it showed that in the case of treatment less damage compared to the control, being in the latter a total number of 4937 damaged grains throughout the sample were reported.

Table IV. Descriptive analysis and confidence interval at 95 % for the number of damaged grains.

	Control	Treatment
Total of damaged grains	4 937	1 414
Percentage of damages	6,50	1,64

Besides, physical levels affectations of grain, due to an increase in the temperature and humidity thereof increase these variables likely leads to damages in grain quality (9).

Corn grain has high-energy content and its oil is rich in unsaturated fatty acids. By losing the grain integrity of the protective cuticle where they are most lipids, these are made available, being exposed to the action of insects, fungi and other pests, which together with the high temperature and humidity, favors the action lipase enzyme, insect and fungus during storage (9).

Economic valuation

In making an economic assessment considering the cost of a ton of corn on the international market ($ 350.00) (22), it was determined from the percentage of damage in experimental models, the percentage of the total damage RMS (Table V).

Table V. Economic valuation and estimation the percentage of damage to the RMS

	Control	Treatment
Percentage of damage total SMR	288,90	72,81
Total loss $ (USD)	101 114.90	25 483,77

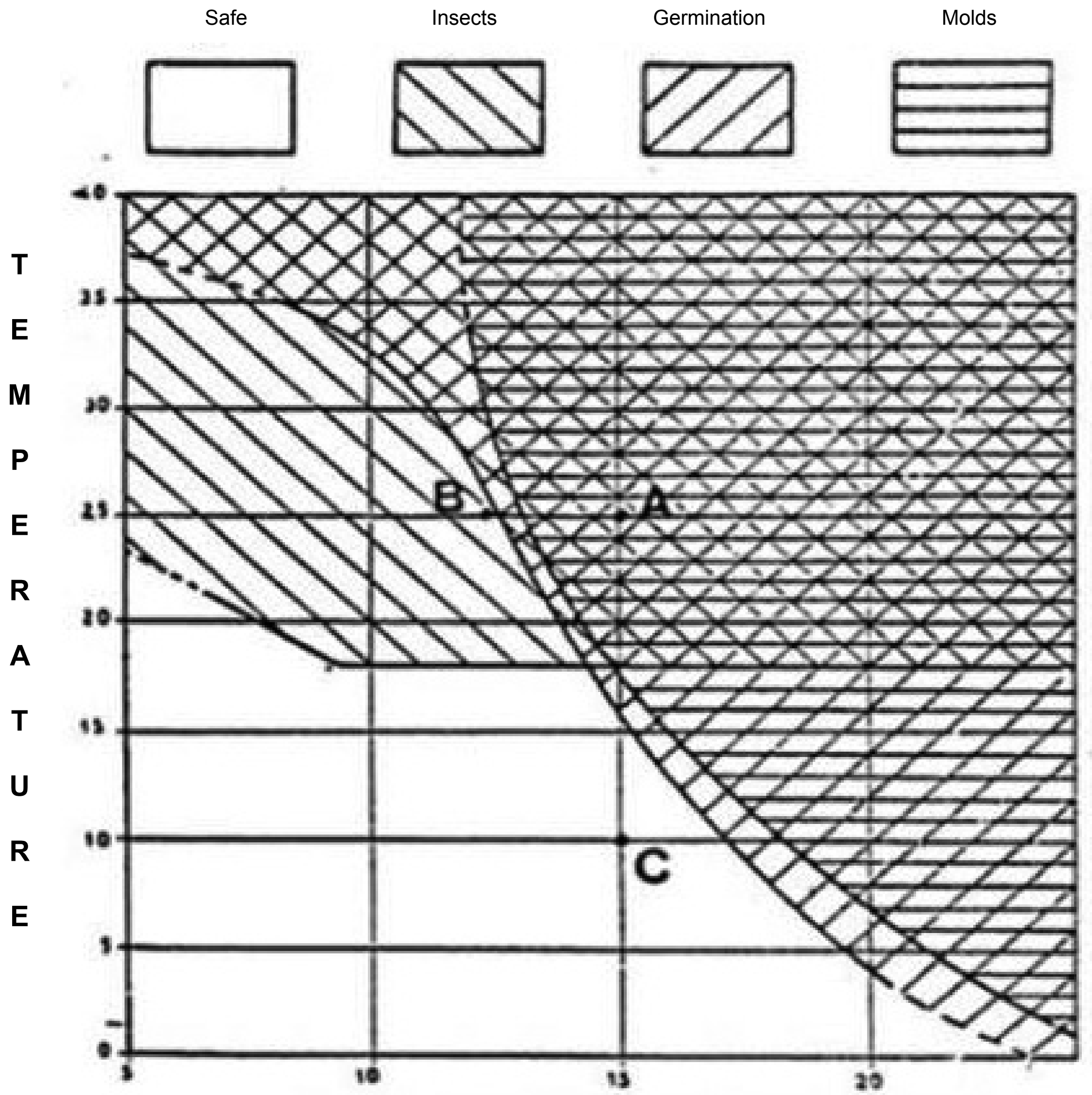
In this sense, from the percentage of damage found for the case of control and treatment, it is found that in a RMS where no pretreatment decreased relative grain moisture and temperature is made, losses will result in 2 101 000 t of $ 114,90; impacting negatively on the country's economy.

These data corroborate with what is proposed in the "Manual Master Procedure for storage service, storage and wholesale marketing of imported grain in the RMS" MINAZ and by Burgess and Burrell, quoted by Hernández (9) (Figure 6), where the permissibility of values recommended for moisture and grain storage temperature is shown. As can be seen, humidity above 24 % results in germination and growth of fungus, which would ruin the loss of part or the total mass of grain stored in RMS.

From the results it is found that, a system of prior to the storage of grain in silos drying can eliminate excessive grain moisture in the short term and ensure the conservation of grains, besides gaining control temperature bulk and Silo uniform cooling.

Therefore, drying produces the main grain processing and postharvest in turn is the procedure requires more attention do not affect the quality of the grains. From the results obtained in this study, confirming the need for a system of reduced moisture prior grain to storage thereof in the RMS as the precooling and during the storage period, as same raises the "Manual of Procedure Master storage service, storage and wholesale marketing of imported grain in the RMS" MINAZ (23).

STORAGE



HUMIDITY OF GRAIN (percentage)

Grain Storage Diagram (Burgess and Burrell)

Source: Burguess y Burrell, cited by Hernández (9)

Figure 6. Permissibility table for storage and storage of grains

For everything mentioned above, the need is reaffirmed with a stable drying temperature prior to the conservation of the grains in the RMS, because this is a system to counterflow (the grain flows down and hot air up). In these systems the temperature reaching grains at the bottom of the silo is approximately equal to the temperature of the drying air, so in some cases (eg wheat) should not be dried at temperatures above 65 °C.

Many of these systems have threads mixers. These have the function of homogenizing the grain moisture inside the silo, but they are most useful when the drying temperature is low (only a few degrees above room temperature). In case of systems, operating at high temperature (40 °C or more) it is best to use forcing threads that go "sweeping" the driest grain silo of bottom layer. In these cases, the system can operate as a dry-aeration, since grain comes out hot (40-60 °C) and must be cooled in another silo.

This is a low-cost technology but it is necessary to consider several aspects, not to fail in the conservation of grains.

The basic principle is to keep the grains dry in a modified atmosphere, with low oxygen and high concentration of carbon dioxide (CO_2). With this control insects and fungi that are the major cause of the increase in temperature of the grains is achieved.

It is also necessary to consider that grains are living organisms and must be healthy, with no mechanical damage and clean, to have greater ability to maintain quality during storage.

It can raise the drying process is able to improve the quality of prolonged storage of grains and improve balance stability within the MRS hygroscopic.

CONCLUSIONS

- ♦ By analyzing the temperature control shows that showed values of 25 °C (25 ± 0,47 °C), unlike the treatment in which the average of the population showed a temperature of 12,7 °C (12,68 ± 0, 07 °C).
- ♦ In analyzing the relative humidity of grain for the case of the control, it is shown that the average population was about 33,2 % (33,23 ± 0,73 %), unlike the treatment, it showed a relative humidity of grain of 14,35 % (14,35 ± 0,1 %)
- ♦ Upon analysis with respect to the percentage of damage of the grains with respect to the control, decreased same treatment was observed, which is associated with less physical and economic loss in the storage process of the kernels.
- ♦ The carried out analyzes reaffirm the importance of pretreating the grains before being stored in the silo.

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