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Intermitency relation in drying and period of storage on industrial quality and the mycotoxins occurrence in corn grains (*Zea mays L.*)

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Abstract

The objective of this work is to evaluate the immediate and latent effects of intermittency relation in grain drying and the storage period on the incidence of defects, fungal and micotoxins occurrence in corn. Corn grain was produced in the Agricultural Center Palma, Research Station of Federal University of Pelotas, South of Brazil. The grain was pre-cleaned in air machine and flat sieves, for removal of strange matters and impurities. The grain drying was accomplished in stationary and intermittent systems. The stationary drying was accomplished with air temperature at 20 ± 5 °C. The intermittent drying was accomplished using a relation of intermittence one for two and one for tree with hot air at 90 ± 5 ºC. The environmental parameters were monitored during drying. Moisture content, defects, ethereal extract, ethereal extract acidity and mycotoxins were analyzed. The intermittent drying is harmful to the grains independently of the intermittence relations. The corn storage with moisture content bellow 13 % avoids generation mycotoxins.

Key words: Corn, Intermitent Drying, Quality.

Introduction

Corn (*Zea mays L.*) is one of the more consumed grains all over the world, used on feeding of the large part of population or as main ingredient in the elaboration of animal feed. In developed countries, the harvest problems, storage and handling of grains (drying, cleaning, movement), constitute object of permanent study to prolong the products shelf life (Puzzi, 2000).

The drying method adopted is important to obtain a product with better quality and to mantain in consumption conditions for a larger time in the storage place. The grains final moisture after the drying is very important to assure a good quality in the storage. The fungus contamination still in the field may cause the mycotoxins occurrence on grains that may be harmful for humans and animals.

The purpose of drying is to remove part of moisture contained in grains. The moisture removal should be conducted until the grain reaches a balance with the humidity of the storage atmosphere and should be done to preserve its appearance and the sanitary and nutritious quality. Stationary drying is characterized by the non movement of the grains during the operation, the contact time between air and grains is long

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and there is a tendency to equilibrate the temperature between them. In intermittent drying the product passes several times through the dryer before completing drying, the grain suffers the heat action during small intervals of time followed by equalization periods, while the mass recirculates and there is no contact with the hot air. The advantage of this system is the product uniformity, but its limitation is the risk of mechanical damage. The objective of this work is study the immediate and latent effects of the intermittence relationship in drying and in storage period on the defects incidence, fungus and mycotoxins occurrence in corn to obtain a final product with more added value (quality) to offer to the producers efficient technologies at low costs.

Materials and methods

The study was accomplished in the in the following units of UFPel: Palma Agricultural Center, Laboratory of Post-harvest and Grain Industrialization of the Agroindustry Science and Technology Department.

Hybrid corn grains AG-303 produced in the Palma Agricultural Center, in the municipal district of Capão do Leão, South Area of the State of Rio Grande do Sul, crop year 2000/ 2001. The grains were harvested manually with 18 % moisture, in stationary machine, cleaned in air machine and flat sieves.

Stationary drying was accomplished at pilot stationary drying silo, with capacity of 250 kg of grains, in layers of 0.50 m of height, and with air flow of 0.2 m min^{-1}. Two air temperatures were used in drying: 20 ± 5 ºC and 50 ± 5 ºC; the first one was in the ambient condition and the last one was achieved with heating in an electric resistance.

The intermittent drying was accomplished in a pilot intermittent dryer, model Vitória, with cylindrical chambers and centered conical base, with the following operational parameters: drying chamber with 90 kg static capacity; equalization chamber with 270 kg static capacity; and total static capacity of 360 kg; Centrifugal fan outflow: 124.16 $m^3 h^{-1}$ of air; Specific outflow of drying: 950 $m^3 h^{-1} m^{-3}$ of air (per cubic meter of grain) and elevator capacity of 752 kg h^{-1}.

The grains were divided in two samples of 270 kg and 360 kg, respectively for the intermittence relationships 1:2 (90 kg of grains in the drying chamber and 180 kg in the equalization chamber), and 1:3 (90 kg of grains in the drying chamber and 270 kg in the equalization chamber. The air parameters psychometrics, like temperature and ambient air relative humidity and the grains mass temperature were monitored hour by hour.

After they were placed in cotton sacks of 40 kg and stored in conventional system by 12 months. The moisture content and the grains quality were analyzed quarterly and the mycotoxins were analyzed at the beginning and in the end of the storage period. The moisture content was analysed by the official method, at 105 ± 3 ºC for 24 h, according to the Rules for Analysis of Seeds (Brasil, 1992). The volumetric weight was determined using it volumetric balance Dalle Molle and an electronic digital balance of 0.01 gr accuracy and expressed in $kg.m^{-3}$. The ether extract was determined by the method described in A.O.A.C. (1997) expressed in percentage of dry matter. The ether extract acidity determination was accomplished according to A.O.A.C. (1997), with the titration of ethereal extract acidity with NaOH and expressed in meq gr oil^{-1}.

The evaluation of defects was accomplished according to official methodology of the Agriculture Ministry (Brasil, 1992), the results were expressed in percentage. The fungus incidence analyses were accomplished as methodology proposed by Neergaard (1977), using the filter paper test or “Blotter-test”, and modified by using three repetitions of sixty seeds by sample. For mycotoxins detection and quantification was adopted the multi-techniques method, described by Rodriguez Amaya (1996).

Drying was conducted until the grains reach 13 % moisture content approximately, characterizing the following conditions: Stationary 1 - Stationary Drying with ambient air, temperature of 20 ± 5 ºC; Stationary 2 - Stationary Drying with hot air at 50 ± 5 ºC; Intermittent 1 - Intermittent

Drying, using intermittence relationship of 1:2 , with air at 90 ± 5 ºC; Intermittent 2 - Intermittent Drying, using intermittence relationship of 1:3, with air at 90 ± 5 ºC.

Results and discussion

Moisture content

Table 1 shows that the moisture content has varied in twelve months of storage. A tendency to reach hygroscopic equilibrium was observed in the grains of the four treatments, mainly in the period between the third and the sixth month of storage.

It can be observed that the grains showed a tendency to increase or to reduce the moisture content in conformity with the environmental conditions of storage (Table 2). During the first three months of storage, the grains in all the treatments absorbed humidity from the ambient air and lost it in the following three months. The lowest moisture content was in January, when the air temperature was high and the air relative humidity was low. There were significant differences among the grains moisture up to the sixth month in the grains dried in the stationary system. Grains dried in the intermittent system were removed from the dryer with less moisture content and reached equilibrium at inferior values than grains dried in a stationary method up to the third month. After that, the grain from all treatments, did not show significant differences in moisture content among them.

Table 1. Moisture content (%) in corn grain, submitted to four treatments and stored in conventional system.

	Storage (Month)				
Drying method	0	3	6	9	12
Stationary 1	13.4 Ab	14.3 Aa	11.5 Ac	12.5 Ab	12.6 Ab
Stationary 2	13.3 Ab	14.0 Aa	12.0 Ac	11.8 Ac	13.0 Ab
Intermittent 1	12.1 Ba	12.4 Ba	11.3 Ab	12.4 Aa	12.5 Aa
Intermittent 2	12.2 Ba	12.4 Ba	11.5 Aa	12.1 Aa	12.2 Aa

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5 ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).

Table 2. Monthly Environmental Parameters during the experimental period.

Month	Average Temperature (ºC)	Average Relative Humidity (%)	Average Precipitation (mm)
01	24.6	82.1	173.1
02	23.7	87.0	170.1
03	19.4	85.8	261.0
04	15.5	89.8	96.0
05	14.8	90.2	208.5
06	13.2	87.2	146.2
07	16.6	86.8	51.4
08	15.7	85.9	229.4
09	19.4	84.0	66.6
10	20.0	78.8	203.8
11	21.2	79.3	124.5
12	23.3	79.9	178.9

Source: Agroclimatologic Station of Pelotas.

In the conventional grains storage system, cotton sacks were used that provides great permeability and allow hydro and thermal changes between grains and storage atmosphere. During the first three months of storage there was a small increase in grain moisture content in all the treatments due to higher air relative humidity and ambient temperature. With the increase of the environmental temperature, mainly in the months of January and February, the grains lost moisture content reaching equilibrium between 11 % and 12 %.

Tables 3 and 4 present the results of the operational parameters observed during the corn drying operation in different methods.

Drying with an intermittence relation of 1:2, took 6 h to reach desired moisture of the grains and when

Table 3. Operational parameters in corn grains drying on the stationary method.

Drying method	Time (h)	T_a (ºC)	RH_a (%)	T_g (ºC)	M_g (%)
Stacionary 1	0	20	82	20	18.0
	3	21	91	20	18.0
	6	22	84	20	17.6
	9	23	80	19	16.8
	45	21	90	19	13.4
Stacionary 2	0	19	75	30	18.0
	1	20	75	29	17.3
	2	20	71	30	16.2
	3	21	71	35	15.5
	4	21	75	36	14.2
	5	21	71	37	13.9
	6	22	71	36	13.3

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively; RH_a - ambient air relative humidity; T_a - ambient temperature; T_g - grains mass temperature; M_g - grains moisture content.

Table 4. Operational parameters in corn grain drying on the intermittent method.

Drying method	Time (h)	T_a (ºC)	RH_a (%)	T_g (ºC)	M_g (%)
Intermittent 1	0	19	81	20	18.0
	1	22	83	32	17.3
	2	24	91	39	17.1
	3	24	91	39	17.1
	4	23	91	40	15.1
	5	24	91	43	14.4
	6	25	91	40	12.1
Intermittent 2	0	12	76	21	18.0
	1	13	76	30	17.8
	2	14	78	33	17.5
	3	15	78	37	17.3
	4	16	78	36	17.1
	5	16	78	38	15.2
	6	17	80	40	14.4
	7	17	80	38	13.1
	8	17	80	41	12.2

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively; RH_a - ambient air relative humidity; T_a - ambient temperature; T_g - grains mass temperature; M_g - grains moisture content.

the intermittence relation was altered to 1:3, due to the increase of the mass of grains in the equalization chamber, drying took 9 h.

Comparing the grains quantity in the intermittence relationship 1:3 and 1:2 it was observed that they have similar yields.

On the other hand stationary drying with ambient air, at 20 ± 5 ºC, took 45 h, while the operation accomplished with air at 50 ± 5 ºC was completed in 6 months.

Volumetric weight

Table 5 shows significant differences in volumetric weight between the treatments after drying and during the whole period of storage.

Grains submitted to drying with intermittence relation 1:2 had smaller volumetric weight in relation to others treatments. This can be explained by a larger movement of the grains in the drier that generated considerable increase of broken grain, harming its quality. The higher values of volumetric weight occurred in the grains dried in the stationary system, in the method that used air without heating. It was also observed that in the stationary drying with ambient air had less alteration the grains volumetric weight. When comparing the results, along the storage period, the volumetric weight diminished significantly from the third month on, in all treatments. The variations were proportionally small due to low moisture of the grain, which had its metabolism reduced in the storage.

Ether extract and its acidity

Tables 6 and 7 shows a decrease in the ether extract content and an increase in the ethereal extract acidity content in all treatments, showing that lipids are grain components strongly susceptible to degradation.

Table 7 shows that in the intermittent drying method the grains acidity index is larger than in the

Table 5. Volumetric weight (kg m^{-3}) in corn grain, submitted to four treatments and stored in conventional system.

	Storage (Month)				
Drying method	0	3	6	9	12
Stationary 1	773.8 Aa	771.0 Aa	765.5 Ab	764.4 Ab	763.4 Ab
Stationary 2	764.6 Ba	761.5 Ba	752.8 Bb	748.4 Bbc	744.4 Bc
Intermittent 1	738.4 Da	735.7 Da	728.72 Db	725.2 Dbc	721.4 Dc
Intermittent 2	754.9 Ca	752.6 Ca	740.8 Cb	737.4 Cbc	730.1 Cc

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5 ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).

Table 6. Ether Extract (%) in corn grain, submitted to four treatments systems and stored in conventional system.

	Storage (Month)				
Drying method	0	3	6	9	12
Stationary 1	7.17 Aa	6.42 Bb	6.39 Ab	6.07 Ab	5.01 Ac
Stationary 2	7.12 Aa	7.17 Aa	6.56 Ab	4.69 Bc	4.51 Ac
Intermittent 1	6.87 Aa	6.18 Bb	5.71 Bab	5.19 Bbc	4.03 Bc
Intermittent 2	7.31 Aa	7.08 Aa	6.03 ABa	5.04 Bb	4.71 Ab

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5 ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).

Table 7. Ether extract acidity (f.f.a. - %) in corn grain, submitted to four treatments and stored in conventional system.

	Storage (Month)				
Drying method	0	3	6	9	12
Stationary 1	0.12 Ab	0.13 Bb	0.14 Bab	0.13 Cb	0.14 Ca
Stationary 2	0.12 Ac	0.14 Ab	0.15 Aa	0.15 ABa	0.16 Ca
Intermittent 1	0.12 Ac	0.11 Cd	0.16 Ab	0.16 Ab	0.24 Aa
Intermittent 2	0.11 Bc	0.11 Cc	0.10 Cc	0.15 Bb	0.20 Ba

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5 ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).

stationary method due to mechanical damage mainly in the grains embryo area, where there was an intensification of lipids oxidations reactions due to the lipoxigenases enzymes action, increasing the amount of ethereal extract acidity.

The greases are substances that consist of a combination of fatty acids with glycerin, and are very unstable when stored in unfavorable conditions to their preservation.

Defects

Table 8 presents the metabolic and no-metabolic defects incidence. The defects increased of metabolic origin during the storage period had significant differences mainly among the drying methods.

The defects of non-metabolic origin did not increase along the storage period, because they are caused mainly by mechanical damages originated in the drying process.

The intermittent drying caused bigger broken grain index increasing significantly the no-metabolic defects incidence. The smaller intermittence relation generated smaller incidence of broken grains due to a little circulation of the grains in the dryer, preserving its physical integrity. The defects incidence increase is normal on grains storage, because the damages caused by insects and fungi are accumulated during the storage period. It was observed, in the first three months of storage, a small reduction in the defects incidence due to a decrease in the occurrence of moldy grains.

Tables 9, 10 and 11 present the results of *Fusarium* spp., *Aspergillus* spp. and *Penicillium* spp. occurrence in hybrid corn grain AG-303 submitted to four treatments and stored in cotton sacks for twelve months.

Table 9 shows that the *Fusarium* occurrence was reduced in all the treatments during the storage period. In the intermittent drying system the contamination was larger immediately after the drying, keeping the same along the storage time due to large amount of broken grains, increasing the grains exposure to the fungus. There was predominance of *Fusarium* in the samples before storage in all the treatments. The results presented in the Table 10 show that, there was not significant difference in the contamination for *Penicillium* in all the treatments.

The fosfine used in the fumigation process in the storage atmosphere can be an important factor to explain the fungus contamination decrease. Hocking and Banks (1991) affirms that the fosfine has the capability to delay the fungus development in stored seeds, when the moisture content is above the value recommended for a safe storage.

It was also verified a low *Aspergillus* spp. and *Penicillium* spp. occurrence, is probably due to species competition for water and nutrients.

The results presented in the Tables 9, 10 and 11 showed that the fungus contamination decrease in all the treatments due to grains low

Table 8. Metabolic and no-metabolic defects in corn grain, submitted to four treatments and stored in conventional system.

Drying method	No-metabolic	Storage (Month) Metabolic defect 0	3	6	9	12
Stationary 1	1.44 C	3.85 Bb	1.27 Cc	3.16 Cb	3.71 Cb	6.32 Ba
Stationary 2	2.22 C	2.82 Cc	1.81 Cd	3.68 Cc	4.75 Bb	6.59 Ba
Intermittent 1	7.70 A	5.59 Ac	6.88 Ab	7.45 Ab	9.13 Aa	9.31 Aa
Intermittent 2	4.68 B	5.02 Ab	4.64 Bb	5.00 Bb	5.59 Bab	6.22 Ba

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).
Metabolic defects: moldy, burned ,woodwarmed and sprouted, several contaminated, germinated; Non metabolic defects: broken grains, strange matters and impurities.

Table 9. Occurrence of *Fusarium* sp. in corn grain, submitted to four treatments and stored in conventional system.

Drying method	Storage (Month) 0	3	6	9	12
Stationary 1	59.5 Ba	48.5 Bb	39.5 Bc	27.5 Bd	19.5 Be
Stationary 2	65.0 Ba	55.2 Bb	43.5 Bc	31.7 Bd	20.0 Be
Intermittent 1	72.0 Aa	63.0 Ab	54.0 Ac	45.0 Ad	36.0 Ae
Intermittent 2	69.0 Aa	60.0 Ab	51.0 Ac	42.8 Ad	33.0 Ae

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5 ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).

Table 10. Occurrence of *Penicillium* sp. in corn grains, submitted to four treatments and stored in conventional system.

Drying method	Month of Storage 0	3	6	9	12
Stationary 1	48.5 Aa	42.6 Ab	36.8 Ac	30.9 Ad	24.0 Ae
Stationary 2	50.0 Aa	42.6 Ab	35.3 Ac	29.9 Ad	20.5 Ae
Intermittent 1	50.5 Aa	45.0 Ab	39.0 Ac	33.5 Ad	25.0 Ae
Intermittent 2	47.5 Aa	41.0 Ab	35.5 Ac	29.0 Ad	21.0 Ae

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5 ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).

Table 11. Occurrence of *Aspergillus* sp. in corn grain, submitted to four treatments and stored in conventional system.

	Month of Storage				
Drying method	0	3	6	9	12
Stationary 1	4.0 Ca	3.1 Cab	2.3 Cab	1.4 Cb	0.5 Cb
Stationary 2	7.0 Ba	6.8 Ba	6.5 Ba	6.3 Ba	6.0 Ba
Intermittent 1	13.5 Aa	12.7 Aab	12.0 Abc	11.2 Ac	10.5 Ac
Intermittent 2	13.0 Aa	12.2 Aab	11.5 Ab	10.7 Abc	10.0 Ac

Stationary 1 and 2 = Stationary drying with ambient air, temperature of 20 ± 5 ºC and at 50 ± 5 ºC, respectively. Intermittent 1 and 2 = Intermittent drying, using intermittence relationship of 1:2 and 1:3, respectively, with air hot at 90 ± 5 ºC. The values accompanied by different small letters on the line and capital letters on the column, differ to 5 % of significance (Tukey Test).

moisture in the storage (Table 1). These results are in agreement with Sauer (1992) that studied the fungus development and the mycotoxins production during the storage and concluded that it can be inhibited with the moisture control of the mass of grain.

Mycotoxins

There was no mycotoxins production in the treatments that were studied, showing that this production is directly associated to the grains moisture content. The corn grains storage with 13 % of moisture content, in sacks with small volumes that make possible the hydro changes in corn grains, disfavors the mycotoxins occurrence in the grains.

With the low contamination of *Aspergillus* spp. the presence of aflatoxins in corn grains, was not detected. The moisture content decrease in drying, probably, did not provide conditions to production of Zearalenona toxin by *Fusarium*.

Conclusion

Evaluating the results obtained using four drying methods on hybrid corn grains of AG-303 quality during the storage period of twelve months, it is possible to conclude that the stationary drying with air without heating provides better grain quality in the storage, but its use is unfersible in unfavorable climatic conditions areas. The use of different drying methods and followed by storage of corn grains with moisture content up to 14,5 % is not propitious to mycotoxins appearance in the grains. The stationary drying system provides better quality to corn grains in comparison with the intermittent system. The increase of intermittence relationship reduces the corn grains damages and keeps its quality on storage.

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