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Effect of stationary and intermittent drying on latent damages in rice grains stored

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Abstract

The objective of the present work was to verify the immediate and latent effects in long-fine rice grains qualitative parameters, submitted to 2 drying conditions: 1) stationary system with air at 30 ± 5 ºC; 2) intermittent system with growing air temperature at 70-90-110 ± 5 ºC. Besides the qualitative grains parameters, consumption of energy was also evaluated during the drying. Immediately after drying the grains were stored for 160 days, and analyzed in the beginning and at 80 and at 160 days of storage. It was concluded that: 1) stationary and intermittent methods are appropriate for drying rice; 2) demand of energy, for movement of the grains and air, in the intermittent dryer, is larger than requested for drying in a stationary method; 3) stationary drying with slighted heated air results in larger percentage of whole grains than in the intermittent method; 4) the longer the storage period the greater is the increase of the incidence of metabolic defects, independently of the grains drying method.

Key words: stationary drying, intermittent drying, grains stored.

Introduction

Rice (*Oryza sativa* L.) is, among the other cereals, the most important consumed for majority of the world-wide population. Brazil, that is the bigger producer of South America and one of the ten greater of the world, produces rice in two systems: irrigated and dry land. The south states, where predominate irrigated system produce more than 50 % of national rice (IRGA, 2006; FAO, 2005).

Due to the fact that is a seasonal product and of constant consumption over the years, the domain of drying technologies and storage is essential for better use.

The problems found rough rice drying are similar to the ones of other cereals, but rice demands more controlled operation, in reason of it susceptibility for breakings during and after drying. During rice drying, it can have a considerable loss, for its characteristics drying method (continuous, intermittent, stationary), thermal handling of the air drying, and for the controls of the operation and the equipment (Elias, 2002; Canepelle et al., 1992).

The most used process for rice drying is the intermittent where the main characteristic is the

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discontinued contact of air in the grains in movement. Grains that are sensible to thermal shocks, as rice grains, when submitted to variation of warm air and air in room temperature, have increases of fissures and, or breaks, intensifying the content of broken grains and reducing its conservation during storage, due to occurrence of physical, chemical and biochemical damages (Abud-Arquila, 2000).

The yield of entire grains is the main parameter of immediate effect to be considered in the commercial evaluation of rice, for quality and price determination of the product. Among other factors, the methods and the conditions of drying process, which the product is submitted, affects directly the processing, intervening, mainly, in the percentage of entire grains, being responsible for latent damages, as the incidence of defects during storage. Some studies have been carried to evaluate the influence of drying and storage in industrial performance of rice grains, however these studies are still insufficient (Barbosa et al., 2005; Fagundes et al., 2005; Bonazzi et al., 1997; Steffe et al., 1979).

This work aimed to verify the immediate and latent effect in qualitative parameters of long-fine rice class grains, submitted to three drying conditions, as well as the energy consumption during drying.

Material and methods

Were used rough rice grains of irrigated culture, of long-fine class, produced in the south region of Brazil, pre-cleaned and with harvest moisture, acquired from regional industry. Grains were submitted to stationary and intermittent drying methods in two treatments:

T1 - stationary drying with air temperature of 30 ± 5 ºC;

T2 - intermittent drying with increasing temperatures of air drying of 70-90-110 ± 5 ºC.

The stationary drying was carried through a pilot stationary silo-drier with the following characteristics: a) bottom in perforated plain plate; b) air insufflation through centrifugal ventilators with outflow of 196 m^3 of air h^{-1}; c) specific outflow drying = 1,155 m^3 of air $h^{-1}.m^3$ of grain; d) height of the bed = 0.60 m; e) engine power of the ventilator = 0.33 cv; f) bin capacity, with reducer = 100 kg; g) bin transversal diameter = 0.92 m;

For each test of drying were used 100 kg of rough rice. In this treatment the grains were submitted to drying with warm air at 30 ± 5 ºC until its moisture content was reduced to 13 % (w.b.).

For the intermittent drying was used a pilot drier with the following basic operational parameters: a) static capacity of the inferior funnel = 40 kg; b) static capacity of the drying chamber = 80 kg; c) static capacity of the equilibrium chamber = 240 kg; d) total static capacity = 360 kg; e) outflow of the centrifugal ventilator = 196 m^3 air h^{-1}; f) specific airflow drying = 1,470 m^3 of grains; g) thickness of grain layer in the drying chamber = 178 mm; h) capacity of the elevator = 752 kg h^{-1}.

In the treatment of intermittent drying the air temperature was kept at 70 ± 5 ºC during the first hour, 90 ± 5 ºC during the second hour and 110 ± 5 ºC from the end of the second hour, remaining in this condition until the grains reduce its moisture for about 15 %. After, the air temperature was regulated equal grains mass, remaining in this condition for 30 min. after 30 min, the temperature were regulated to hit 10 ºC above room temperature.

The total consumption of energy was measured using electric energy gauge installed before the plug where the electric engines of the ventilator were on, the elevator of dumps-cart_and the thermostats of the electric resistor. To estimate the consumption of energy for air and the grain movement and for air heating, were made calculations from the measure of the total consumption of energy in the drying operation, of power of the drive engines of the dumps-cart elevator and the ventilator and the drying times, applying relations of energy equivalence, where 1 cv corresponds the 0.7355 kw (Provenza, 1990).

For the measurements of air room

temperature, drying air and the exit air of the drier psicrometers and thermometers were used. To accompany the grains moisture during drying tests were removed samples for determination on fast way and for the method of the oven in 105 ± 3 ºC, with natural air circulation for 24 hours (Brasil, 1992).

In intermittent drying samples were collected in the elevator foot of the drier and in the stationary drying samples were removed with relief of a "calador" in three heights of grains layer 0.10, 0.40 and 0.60 m of the bin bottom.

After each drying test samples remained inside of the drier in rest during 2 h, at least, to propitiate the stabilization of temperature and the moisture of the grains. After the stabilization period, samples were stored in warehouse of the Post-Harvest and Grain Industrialization Laboratory, for the conventional system, in nylon bags of 50 kg, with plagues and insects control, for a period of 160 days.

The samples were submitted to industrial performance analyses immediately after drying (storage time zero) and in the 80 days and 160 days of storage.

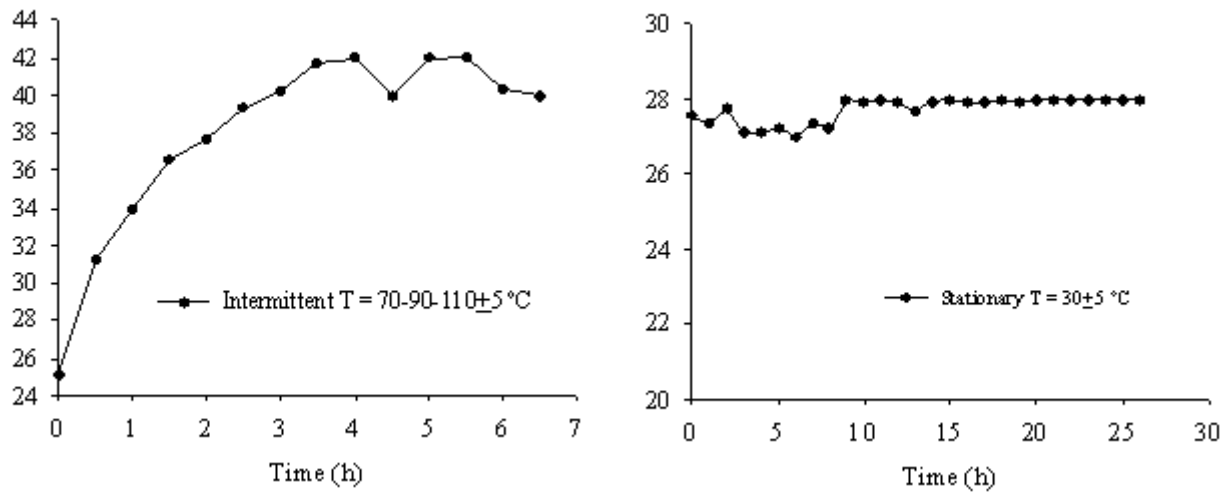
The operations of dehusking, polishing, broken separation and defects evaluation were carried as the Official Norms of Identity, Quality, Packing and Presentation of the Rice (Brasil, 1988).

The dehusking and polishing were carried using samples of 100 g, prepared in triple for each treatment. The polishing time was of 90 seconds, being defined by preliminary tests. The identification of the defects was made visually and its separation manually.

The experimental delineation used was completely random, being carried three tests of drying for each treatment. For statistical analyses, analyses of variances and tests of multiple comparisons of averages were carried, using the program statistical analyses SAEG®, according to described procedures in Ribeiro Junior (2001).

Results and discussion

In Figure 1, are represented the mean values of mass of grains temperature during the tests of intermittent and stationary drying. Observing the Figure 1a its possible to verify that, in the treatment where was used intermittent drying the values of temperature had never exceeded 43 °C, showing that the grains thermal handling in the operation of drying was adequate (Elias, 1998). A higher increase in the temperature in the two first hours can be observed, tending later to the stabilization, because drying process is composed of two distinct and complementary hydrothermal stages, that include



(a) (b)

Figure 1. Mass of grain temperature in drying.

water diffusion from the interior of the grain to the periphery and the evaporation of the peripheral water, being first endothermic and the second isoentalpic, when the phenomenon of heat and mass transference occur, in agreement with the principles of the thermodynamics.

In Figure 1b is verified that the mass of grains temperature in the stationary drying practically did not vary during all the operation. This occurs because the temperature of the drying air is practically constant.

The mass of grains temperature is the most connected operational parameter to the thermal damages that can occur in the grains in function of the operation of drying, and together with the thermal shock they are responsible for the immediate and latent damages whose results are express more in crackers and incidence of defects in the rice grains, respectively.

In Figure 2, are represented the average values of grains moisture during the tests of intermittent and stationary drying.

According to the results presented in the Figure 2a possible to observe that the grains moisture in the intermittent drying decreased quickly in the first hours, attenuating this reduction from now on. This behavior is in agreement with related for other authors (Elias, 2002; Puzzi, 2001).

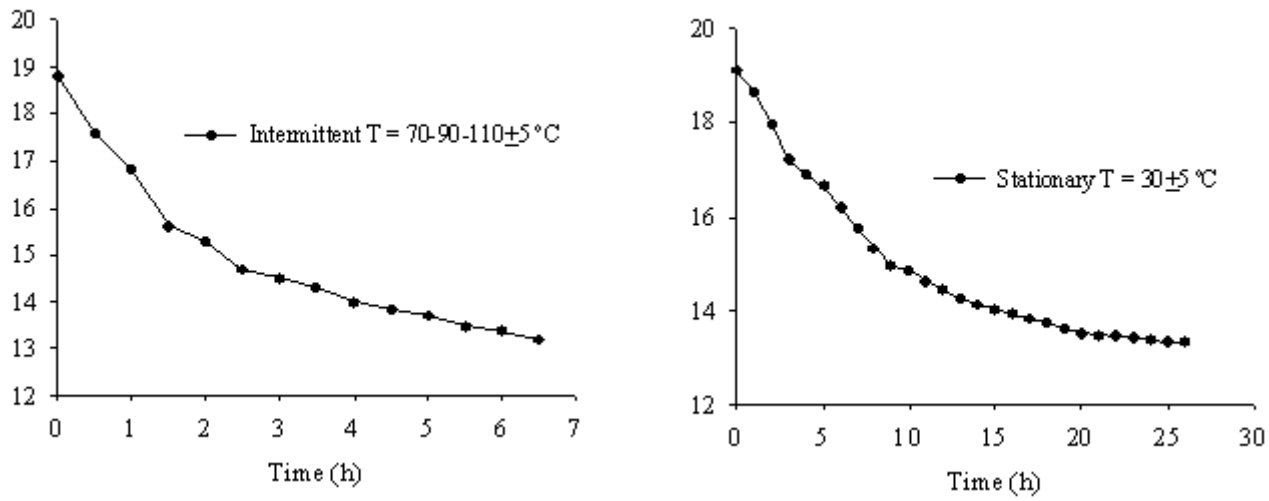
Observing Figure 2b it is possible to verified that in the stationary drying, in silo-drier, with little warm air, occurs gradual and slow reduction of moisture, differently of what occurs in the intermittent one, where occurs a fast reduction of moisture in the first hours and later a gradual reduction. The observed results are in agreement with related for other authors (SOSBAI, 2005; Muir, 2000).

In Figure 3 can be observed the average values of the drying rate during the intermittent and stationary dryings. The drying rate represents the variation in percentile points of the mass of grains moisture in wheat base (% w.b.).

In Figure 3a it is possible to observe that the drying rate grows greatly in the first hour and decrease from there, with the reduction of the moisture. It is also observed, that the rate of maximum drying was of 1.2 kg of water by hour.

Examining Figure 3b it is possible to observe, that the maximum hourly rate of drying in the stationary method was of 0.7, being lower of the intermittent one. As much in the stationary drying as in the intermittent one the behavior is similar, despite time last between enters drying methods.

The values found for the intermittent drying as much for the stationary one reaches the official recommendations for the rice drying (Elias et al., 2000).



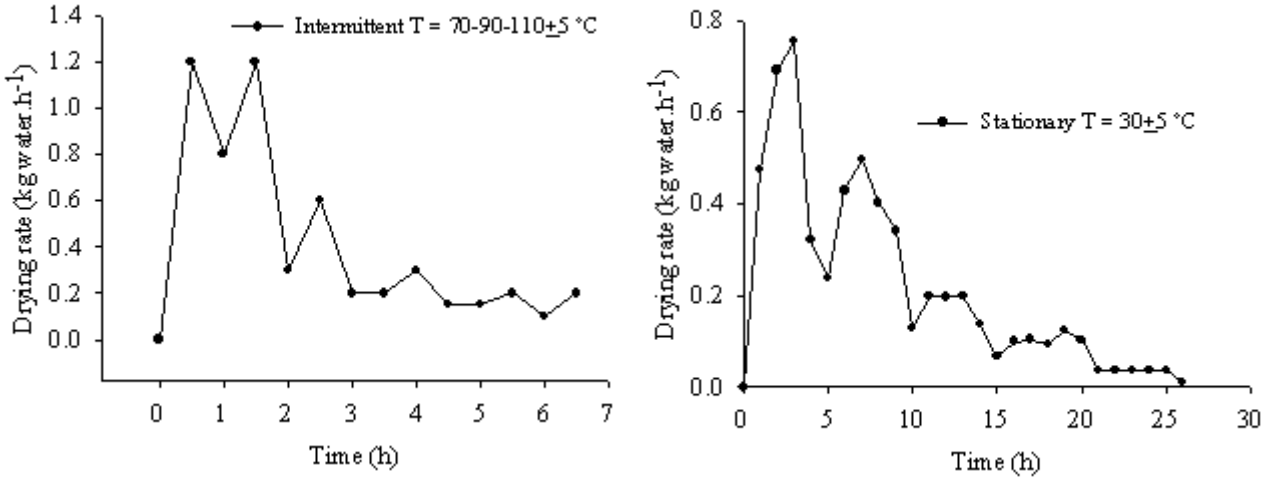
(a) (b)

Figura 2. Mass of grains moisture during the intermittent and stationary drying.

These comments express the hydrothermal behaviors of the operation and are in accordance with specialized literature (Elias, 2002; Puzzi, 2001; Rombaldi, 1988).

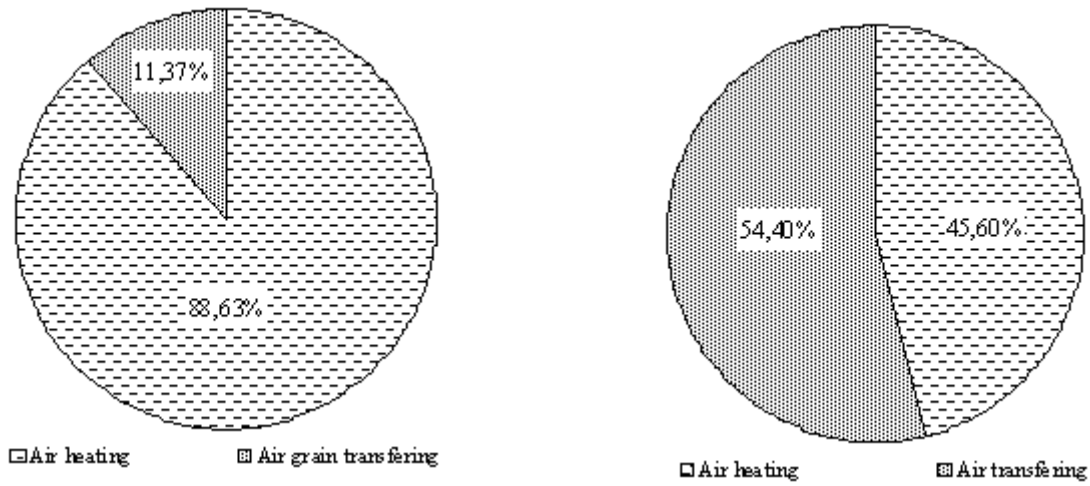
In stationary drying operation with little warm air (30 ± 5 °C), the total consumption of energy (heating and air movement) was 11.6 kwh. As the ventilator engine has power of 0.33 cv and was turned on during 26 h, the energy consumption for air movement was 6.31 kwh. Therefore, the energy consumption for air heating was of 5.29 kwh. In intermittent drying, was observed a total consumption of energy (air heating and air and grains movement) of 27.8 kwh. Considering that the engines had been turned on during 6.5 hours, the engine consumption was of 1.58 kwh, what mean 3.16 kwh consumption (2 engines) for air and grains movement. Therefore, the energy consumption for air heating was of 24.64 kwh. In Figure 4 the percents of the energy consumption are illustrated.

Comparing the drying methods (intermittent



(a) (b)

Figure 3. Drying rate of rice grains submited to intermittent and stationary dryings.



(a) (b)

Figure 4. Percent energy consumption during the operations of Intermittent (a) and stationary (b) rice grains drying.

and stationary) it is observed that in intermittent most of the energy is spend for the heating of the drying air. In the other side, stationary drying, the energy consumption is a little higher for grains movement.

In relation to the relative consumption of energy (kwh kg of dry grain^{-1}) it is observed that in the stationary drying the consumption was 0.116 kwh kg of dry grain^{-1}, while in the intermittent drying the consumption was of 0.087 kwh kg of dry grain^{-1}. These results can be attributed to the fact that stationary drying is slower than the intermittent one.

These information are important for the evaluation of the economist of the drying operation, mainly when works with noble input of high unitary value, situation applied such in relation to the fuel for the air heating, as in relation to the system of energy for activate the gadget of air and grains movement.

In Tables 1 and 2 are presented the results of the rice grain moisture analyses submitted to the drying for stationary and intermittent methods and stored during 160 days, in conventional system, with technical operational control and the psicrometers conditions of room air during storage.

Analyzing the data of Table 1, it is verified that the drying method did not influence significantly in the moisture. It can still be observed a significant increase in the grains moisture stored in the first eighty days, having stability from there.

The analysis of found values allows to verify a trend to the hygroscopic balance in all the treatments, whose speeds and intensities depend on the gradient between the moisture degree with that the grains leave the drier and the moisture that they gets in balance with the environment where they are stored.

It is possible also to verify that the dryings of all samples were carried until values below of the balance moisture for the rice, in the room conditions of the region of Pelotas-RS. The moisture behavior express the dynamic character

Table 1. Moisture (%w.b.) of rice grains submitted to two drying treatments and stored by the conventional system, in sacks[1].

	Time of storage (days)		
Drying treatment	0	80	160
Stationary T = 30 ± 5 ºC	12.91 Ab	12.99 Aa	13.10 Aa
Intermittent T = 70-90-110 ± 5 ºC	13.05 Ab	13.42 Aa	13.55 Aa

[1] Simple arithmetic average, followed by different lower case letters in the same column and capital letters in the same line, did not differ between itself for the Tukey test 5 % from probability ($P \leq 0.05$).

Table 2. Psicrometric conditions on the storage place.

Days of storage	Temperature average (°C)	Relative moisture average (%)
20	19.6	81.0
40	15.3	86.5
60	14.8	87.6
80	10.7	80.9
100	12.4	80,7
120	14.0	84.6
140	14.5	84.5

[1] Simple arithmetical averages, followed for lower case, in the same line and, for capital letters, in the same column, do not differ estatistic for the Tukey test from 5 % of probability ($P \leq 0.05$).

of the hygroscopic balance, when it is observed that after to reach such balance, the grains moisture tends to suffer slight variations, following the regional ambient conditions of temperature and relative moisture (Table 2)

As organisms alive, grains can breathe, have specific chemical constitution and internal porous structure that confer them hygroscopic characteristics and of poorly thermal conductivity. Through the interstitial mass of grains spaces, during storage, they remain in constant exchanges of heat and moisture with room air, until the limit of achievement of the hygroscopic balance, in a process that happens by sorption or desorption of moisture by grains, in function of the differential of water vapor pressure and/or temperature between these and the interstitial atmosphere (Muir, 2000).

The verified values are compatible with those found by other authors (Elias, 1998; Rombaldi, 1988). The small amplitude of variation between the values is due to the operational technician handling kept in the storage, with control of the temperature and of insects infestations, using aeration always that the temperature remained more than three days above 20ºC and of expurgation, with aluminum phosphate, in the appearance of insect.

In Table 3 are represented the results of the industrial performance analyses of rice grains dried by the stationary and intermittent methods and stored for 160 days.

Analyzing the results presented in Table 3 it is possible to verify that in storage time zero (immediately after the drying) are found the minors percentile of entire grains, independently of the drying treatment, confirming the conclusions of others authors (Barbosa et al., 2005; Fagundes et al., 2005; Elias, 2002), who found that soon after the drying, grains remain in tensions condition, that appears during drying operation, and extended for a period of up to 30 days, provoking the reduction of grains resistance to the mechanics action of dehusking and polishing.

It was also observed, that at eighty days of storage, independently of the treatment, are found the minors percentile of rice broken grains, because in this period already occurred the energy balance, when the internal tensions are also balanced, reaching the grain its bigger resistance to the mechanical and abrasive actions of the dehusking and polishing.

After to reach the energy balance, rice grains start to decrease its resistance to the mechanics

Table 3. Industrial performance of rice grains submitted to two drying treatments and stored by the conventional system, in sacks[1].

	Time of storage (days)		
Drying treatment	0	80	160
Whole grain with defect			
Stationary T = 30 ± 5 ºC	62.61 Ac	63.34 Aa	63.09 Ab
Intermittent T = 70-90-110 ± 5 ºC	61.04 Bc	61.81 Ba	61.56 Bb
Whole grain with defect			
Stationary T = 30 ± 5 ºC	57.49 Aa	57.13 Ab	56.69 Ac
Intermittent T = 70-90-110 ± 5 ºC	55.96 Ba	55.72 Bb	55.18 Bc
Total defect			
Stationary T = 30 ± 5 ºC	5.12 Ac	6.21 Ab	6.40 Aa
Intermittent T = 70-90-110 ± 5 ºC	5.08 Ac	6.09 Bb	6.38 Ba

[1] Simple arithmetical averages, followed for lower case, in the same line and, for capital letters, in the same column, do not differ estatistic for the Tukey test from 5 % of probability ($P \leq 0.05$).

action, increasing the broken grains percent, what is a characteristic of this species, due to the interaction that establish between amylose, amylopectin and the others polymers of starch (Hoseney, 1991).

It is still observed that the greater percent of entire grains was gotten in the treatment where used stationary drying.

Analyzing the results of entire grains yield without defects, the biggest values are observed in the beginning of the storage decreasing with time, for all drying treatments, what demonstrates that drying methods provoke more latent damages than immediate defects. It is still observed that the greater percent of entire grains without defects was gotten in the treatment where stationary drying was used, what demonstrates that this method of drying is appropriated for rice.

It is observed, also, that in the stationary drying method (slower) the totals defects were significantly higher that the faster method of drying, the intermittent. This happens because the more raised it will be the hourly rate of drying, more quickly will be reduced the metabolic activities of grains, decreasing the occurrence of serious defects, during storage. If on the other hand this effect of the fast drying is desirable, for another one, these methods provoke greater occurrences of broken grains.

Conclusions

In the conditions where the study was carried through it is possible to conclude that:

1) As the stationary method of drying, as the intermittent one is appropriate for the rice drying;

2) The demand of energy, for grains and air movement, for drying in the intermittent dryer, is small in relation of the energy demanded for the drying air heating, and in the stationary drying the energy demand for heating of the air drying is bigger that the energy spent for air movement;

3) The minors percents of entire grains are observed immediately after the drying, independently of the drying method used;

4) The greater percent of entire grains were gotten in the treatment where was used stationary drying;

5) The increase of the storage time provokes increase of the incidence of defects, independently of the grains drying condition.

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