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Grain quality and energy consumption by evaluation intermittent methods of rice drying

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Abstract

The objective of this study was to verify immediate and latent effects in qualitative parameters of rice and energy consumption in drying of long-fine class rice grains submitted to three conditions of intermittent drying: I) growing air temperature from 70 to 90 and 110 ± 5 ºC and intermittence relation of 1:3; II) growing air temperature from 70 to 90 and 110 ± 5 ºC and intermittence relation of 1:1.5; III) constant air temperature at 90 ± 5 ºC during the whole drying operation. The industrial performance was evaluated after drying and at 80 and 160 days of storage. The results allow to conclude that: 1) increasing the relation of intermittence from 1:1.5 to 1:3 increased time of drying and the consumption of energy; 2) the demand of energy for movement of the grains and air for the intermittent drying, it is smaller in relation to the demand of energy to heat the air of drying, independently of the operational handling; 3) Drying at constant temperature of the air provokes reductions in the industrial performance than with growing temperature, independently of the relation of intermittence; 4) the increase of the time of storage provokes increase of the incidence of serious defects and of the general defects of metabolic origin, independently of the drying condition of the grains.

Key words: rice, intermittent drying, quality of grains, intermittence relation, energy.

Introduction

The Brazilian politics of market opening started the last decade of XX^{th} century, mainly with the creation of MERCOSUL-Mercado Comum do Sul, generates a strong competition to Brazilian rice and a demand for an increase in productivity and better product quality, to compete with imported rice. Additional to that there is a growing demand from the national consumers for higher patterns of quality, forcing the production sector and research to be more efficient.

Rice (*Oryza sativa L.*) stands out among the cultivated cereals for being a basic food for most of the world population. Originary of the Southwest of Asia that consist of the east area of India, Indochina and South of China is a subsistence food for more than half of world population. Brazil is the largest producer of South America and one of ten largest of the world, and produces rice in two systems: irrigated and non-

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irrigated. The states of the south where the irrigated cultivation systems prevail, produce about 60 % of rice in the country (FAO, 2006; IRGA, 2006; CONAB, 2006). As a seasonal product and of constant consumption along the year, the knoledge of drying technologies and storage is fundamental for its best use.

As organisms that continue alive during the storage, grains breathe; have specific chemical constitution and interns porous structure which check them characteristics hygroscopic and bad thermal conductivity. Through interstitial spaces in the grains mass, stay in constants heat changes and moisture content with the ambient air, until the limit of obtaining of the hygroscopic balance, in a process that occurs for sorcion or dessorcion of water for the grains, in function of the differential of steam water pressure and/or of temperature between those and the interstitial atmosphere (Puzzi, 2001; Multon, 1984). The grain drying, previously to storage, is a decisive factor in that phenomenon.

The problems found in the drying of rice with hull are similar to other cereals, but the rice demands operation more controlled, in reason of the susceptibility to break during the drying and after that. During the drying of the rice can have a considerable loss for their characteristics, for the used method (continuous, intermittent, stationary), for the thermal handling of the air and for the controls of operation and of equipment (Barbosa et al., 2005; Elias, 2002; Biagi et al., 2002; Canepelle et al., 1992).

The process more used in the drying of the rice is the intermittent, which has as main characteristic the discontinued passage of the air for the grains in movement, that recirculation in the equipment. Grains susceptible to thermal shock as rice, when submitted to the alternation of heated air and environmental temperature air, have increase of fissures, intensifying the content broken rice and reducing its conservability during the storage, due to the occurrence of physical, chemical and biochemical damages (Amato and Elias, 2005; Kunze, 1979).

The whole grains yield is the main parameter of immediate effect to be considered in the commercial evaluation of the rice, for the determination of the quality and product price. Among other factors the methods and the drying handling conditions, to which the product is submitted, affect the improvement directly, interfering, mainly, in the percentage of whole grains obtained, being also responsible for latent damages, as the incidence of defects during the storage. Several studies have been accomplished to evaluate the influence of the drying and of the storage in the industrial acting of rice grains; however these studies are still insufficient (SOSBAI, 2005; Fagundes et al., 2005; Abud-Archila et al. 2000; Bonazzi et al., 1997; Kunze and Calderwood, 1980).

The objective this of work was to verify immediate and latent effects in qualitative parameters of rice grains of long-fine class, submitted to three operational handlings of intermittent drying and stored by 160 days, as well as the energy consumption during the drying operation.

Material and methods

Rice grains, of long-fine (agulhinha) class, produced in the south of Brazil, harvested mechanically with moisture content to 20 %w.b. and cleaned, before the drying. The grains were submitted to the drying intermittent method in three operational handling:

T1 - Drying at constant temperature of 90 + 5 ºC;

T2 - Drying gradually increasing temperature from 70-90-110 + 5 °C and relation of intermittence of 1:3;

T3 - Drying gradually increasing temperature from 70-90-110 + 5 °C and relation of intermittence of 1:1.5.

Pilot intermittent dryer with total static capacity of 360 kg, equipped with heating by 8 electric resistances of 700 Watt each was used. Every hour, during drying, measurements, of the total consumption of energy, of the temperature of the grains and of the air in the environmental condition, in the entrance and in the exit of the dryer were made. The total consumption of energy was measured by electric power meters. During drying, ambient, entrance and exit temperatures where measured. Moisture determinations were accomplished at 105 + 3 ºC, for 24 hours, as the official method (Brazil, 1992). After each drying test the samples were maintained in rest for 2 hours, to propitiate the operational stabilization of the temperature and moisture measurements of the grains.

After the period of stabilization, the samples were stored under controlled storage conditions in the Laboratory of Post-Harvest, Industrialization and Quality of Grains of Federal University of Pelotas, by the conventional system, in sacks of 50 kg, for a period of 160 days. Daily, with the aid of a thermo-hygrometer, the temperature and relative humidity of the storage atmosphere was monitored. The samples were submitted to the analyses of industrial performance before the drying, immediately after, and after 80 and 160 days, for the evaluation of the latent damages of drying and effects of the time of storage on the quality of the grains. The industrial performance was evaluated by tests in the dehulling operations, polishing, broken rice separation and evaluation of defects, according to the Norms of Identity, Quality, Packing and Presentation of the Rice of the Ministry of the Agriculture (Brazil, 1988), with adaptations developed by the Laboratory of Grains of UFPel (Elias, 1998). The flow chart of Figure 1 shows the operations of the determination of the industrial performance of rice. The experimental design used was completely random, being accomplished by three drying tests for each treatment. The statistical analyses, analyses of variances and tests of multiple comparisons of averages were accomplished by using the statistical analyses SAEG® program, according to procedures described by Ribeiro Júnior (2001).

The flow chart of the industrial performance operations can be observed in the Figure 1.

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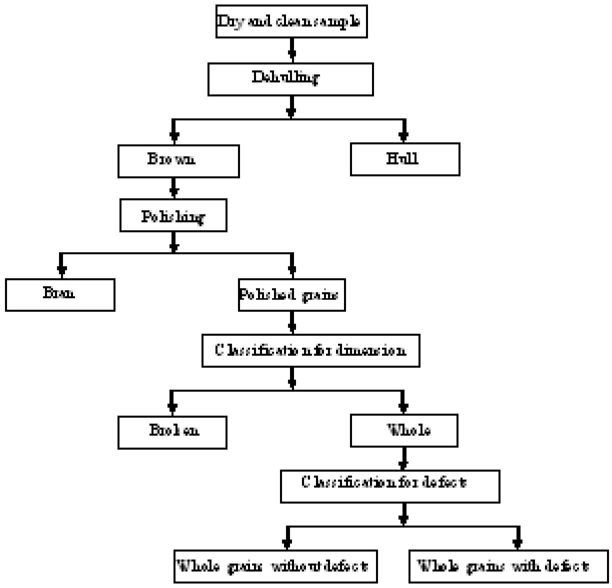

Figure 1. Flow chart of the industrial improvement of polished white rice.

Results and discussion

Figure 2 shows the average values of grains temperature that represented the tests drying in growing temperature levels, with two intermittence relations.

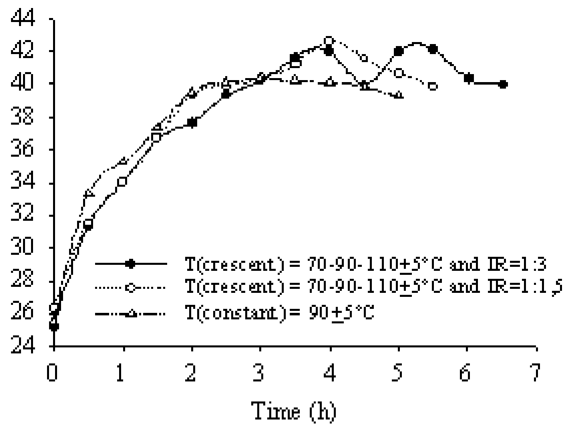

Figure 2. Mass of grains temperature in the operations of intermittent drying in three operational handlings: with heating gradual crescent of the air and intermittence relationships among chambers of 1:3 and 1:1.5 and in air constant temperature.

Figure 2 is possible to verify that in the three treatments the values of temperature of the grains are similar and that these never crossed 43 °C, demonstrating that the grains thermal handling in the drying operation was adapted (Elias & Franco, 2004).

Also observed a intense increase in the temperature in the first two hours, tending later to the stabilization. That is due the drying process composed of two stages hidrothermical different and complemented, that include the water diffusion of the interior of the grain for the periphery and the evaporation of the outlying water, being the first endothermic and the second isoenthalpic, when happen the phenomenon of heat and mass transfer, according with the beginnings of the thermodynamics (Figure 2). The grains temperature is the operational parameter that more intensively affects its thermal damages that may happen in the grains due to drying. Its, together with the thermal shock, are responsible for immediate and latent damages whose results express more in fissuring and incidence of defects in the rice grains, respectively.

In the Figure 3 the medium values of grains moisture content are represented during the tests of intermittent drying.

In agreement with the results presented in the Figure 3 is possible to observe that the variation of grains moisture content, in the three thermal handlings of the air, have similar behavior and it decreases quickly in the first hours of drying and gradually slowing this rate. That behavior is in agreement with other authors (Elias & Franco, 2004; Puzzi, 2001), and it reflects the phenomenon of the drying process with warm air, where happen, simultaneously, evaporation of the outlying water, formation of hidric gradient and increase of interns pressure, that result in diffusion of the water of central areas from the caryopsis to the periphery. Closer to the center of the grain, slower is the water diffusion to the outlying layers.

Also observed that the intensity of moisture content reduction is more accentuated in the beginning when warm air is used in constant temperature during all the operation than when that heating is gradually increased. Among the methods that used the last handling, the one of relation of larger intermittence (1:1.5) made possible reductions of moisture content of the fastest grains than for relation of smaller intermittence (1:3).

Figure 4 shows the medium values of the drying rate observed during the operation. The drying rate represents the variation, in water base, in percent points of the moisture content of the mass of grains in certain unit of time.

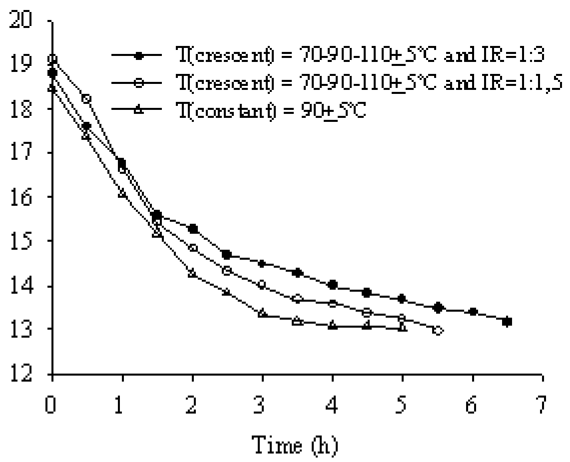

Figure 3. Grains moisture content during the intermittent drying with gradual heating of the air, in relation of intermittence of 1:3 and of 1:1.5, and with constant temperature.

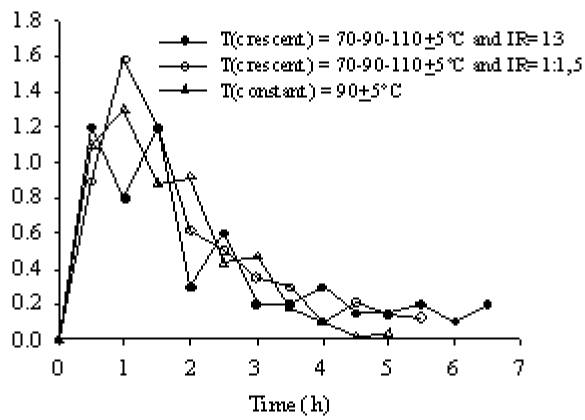

Figure 4. Rice grains rate of drying in three operational handlings in the intermittent drying, with air in constant temperature and with gradual heating of the air, these with relation of intermittence of 1:3

and of 1:1.5.

Examining the Figure 4 is possible to observe that the drying rate in the two treatments with growing temperature of the air had similar behavior, growing strongly in the first hour and decreasing a lot since then, with the moisture content reduction. When the operational thermal handling used air in constant temperature, also in the first hour the drying rate was remarkably higher than in the two other handlings. Between the first and the fourth hour the largest unbalances are observed in the referred rate.

It is also observed that the drying rate, in the treatment with relation of intermittence of 1:1.5 was always superior to exhibit in the treatment with relation of intermittence of 1:3. In the first hour of operation, the hourly rate of drying varied between 0.8 and 1.6 %, respectively, for the relations of intermittence of 1:3 and 1:1.5. Those values are inside of the strip recommended for the drying of rice in hull (Elias, 2002). These observations express the behaviors hydrothermics of the operation and they are in agreement with the specialized literature (Biagi et al., 2002; Puzzi, 2001), and assist the Brazilian official recommendations for the drying of rice (SOSBAI, 2005;), in other words, not crossing 2 percent points for hour.

In the Tables 1 and 2 the results of the consumption of energy can be observed in the drying of the rice grains in three handlings intermittent drying.

As it can be observed in Table 1, in the intermittent drying the total consumption of energy (heating of the air and grains movement) of 16.7 kwh to the relation of intermittence of 1:1.5 and of 27.8 kwh for the relation of intermittence of 1:3. Considered that in the drying with relation of intermittence of 1:1.5 the motors were switched for 5 hours, the consumption for motor was of 1.215 kwh, in other words, consumed of 2.43 kwh (2 motors) for air and grains movement, what represents 14.55 % of total used. In the drying that used relation of intermittence of 1:3, the drying time were of 6 hours and 30 minutes, with a consume of 3.16 kwh, representing 11.37 % of total used. Therefore, the energy of air heating consume were of 14.27 kwh (85.45 %) and of 24.64 kwh (88.63 %) for the relation of intermittence of 1:1.5 and of 1:3, respectively. Already the handling that used air in constant temperature consumed 14.37 kwh for air heating and 2.43 kwh for air and grains movement, being equal respectively to 84.45 % and 14.55 %.

Tables 3 and 4 are presenting the analyses results of grains moisture content and the environmental psychometric characteristics during the storage.

Analyzing the Table 3 data, was verified that the operational conditions of the drying method

Table 1. Energetic demands in the intermittent of rice grains in three operational handlings.

Drying handle operational	Air heating		Air and grains movement		Total
	kwh	%	kwh	%	kwh
Air in constant temperature (T = 90 ± 5 ºC)	14.37	85.54	2.43	14.46	16.8
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:3	24.64	88.63	3.16	11.37	27.8
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:1.5	14.27	85.45	2.43	14.55	16.7

R.I. = intermittence relation or relation volumetric among the drying and equalization chambers.

Table 2. Proportional consumption of energy in the intermittent drying of rice grains in three operational handlings.

Drying handle operational	Thermal (KJ) For load	Thermal (KJ) For hour	Thermal (KJ) For ton	Eletric (kwh) For load	Eletric (kwh) For hour	Eletric (kwh) For ton
Air in constant temperature (T = 90 ± 5 ºC)	60,526.1	12,105.2	302,630.3	16.8	3.36	84.0
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:3	60,165.8	10,939.2	188,018.1	27.8	4.28	86.9
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:1.5	100,156.2	15,408.7	500,781.0	16.7	3.04	83.5

R.I. = intermittence relation or volumetric relation among the drying and equalization chambers.

Table 3. Moisture content (%wb) of the rice grains submitted to three operational handlings in the intermittent drying and stored by the conventional system in sack[1].

Drying handle operational	Storage days 0	Storage days 80	Storage days 160
Air in constant temperature (T = 90 ± 5 ºC)	13.15 Ab	13.55 Aa	13.60 Aa
Air in constant temperature (T = 90 ± 5 ºC) e RI = 1:1.5	13.05 Ab	13.42 Aa	13.55 Aa
Air in constant temperature (T = 70-90-110 ± 5 ºC) e RI = 1:1.5	12.99 Ab	13.36 Aa	13.50 Aa

[1] Simple arithmetic's average, followed for small letters, in the same line and, for capital letters, in the same column, don't differ statistically ($p < 0.05$).

R.I. = intermittence relation or relation between the drying and equalization chambers.

Table 4. Psychometric conditions in the storage environmental.

Days of storage	Average temperature (°C)	Average relative humidity (%)
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
160	14.7	84.3

did not influence significantly in the moisture content along the storage. It can also be observed a significant increase in the moisture content of the grains stored in the first eighty days, having stability since then, in a tendency to the hygroscopic equilibrium.

It is possible to verify that the drying of all samples were accomplished values even below the equilibrium rice moisture content, in the environmental conditions of the area of Pelotas-RS.

The behavior of the moisture content expressed the dynamic character of the hygroscopic equilibrium, when is observed that after reaching such equilibrium the grains moisture content tends to suffer quick variations, accompanying the temperature conditions and relative moisture content in the storage atmosphere (Table 4).

In the Table 5 observed the analysis results of yield of whole grains before and after the drying, which express the immediate effects of the drying.

Table 5 is verified that there was reduction of whole grains immediately after to drying in all of the treatments, but the reduction was more accentuated in the treatment which used constant temperature of the drying air. Results similar were observed in other studies (Elias, 2002; Shei and Chen, 1999).

In the Table 6 are represented the analyses results of industrial performance during the storage that express the latent effects of the drying.

Being analyzed the results presented in the Table 6 is possible verifies that immediately after the drying the percentile of smallest whole grains are found, independently of the drying treatment, confirming other authors' reports (Fagundes et al., 2005; Barbosa et al., 2005; Elias and Franco, 2004; Oliveira, 1992) that soon after the drying the grains stay in state of tensions, that appear during the drying operation, and extend for a close period to 30 days, provoking decrease of grains resistance to the mechanical actions of dehulling and polishing.

It is observed also that, to the eighty days of storage, independently of the drying operational handling the percentile smallest of broken rice grains are found, because in this period it already happened the energy equilibrium, reaching its grain largest resistance to the mechanical and abrasive actions of dehulling and polishing.

Analyzing the results of the income of whole grains without defects, the largest values are observed, in the beginning of the storage having decreases with the time, for all drying treatments, what demonstrates that the drying methods used provoke more effects latent than immediate. The high ones percentile of whole grains demonstrates that this drying method is adapted for the rice.

With the analysis of the defects is possible observe that as much the general defects as the serious ones, of metabolic nature, presented the smallest values in the beginning of the storage, increasing with the time, independently of the drying conditions. This demonstrates that, for the drying methods used, the latent defects of metabolic nature are significantly larger than the immediate defects of metabolic nature, and that is also consequence of fissure that are formed during the drying operation, and during the storage period, with the increase of the grains moisture content (Table 3) supply favorable environmental conditions to the metabolism of the grains and the proliferation of microorganisms.

Table 5. Yield of whole rice grains before and after having submitted to three treatments of drying intermittent[1].

Drying handle operational	Yield of whole rice grains (%) After	Before
Air in constant temperature (T = 90 $\pm$ 5 ºC)	63.71 Aa	59.64 Bb
Air in growing temperature (T = 70-90-110 $\pm$ 5 ºC) e RI = 1:3	63.71 Aa	61.04 Ab
Air in growing temperature (T = 70-90-110 $\pm$ 5 ºC) e RI = 1:1.5	63.71 Aa	60.85 Ab

[1] Simple arithmetic's average, followed for small letters, in the same line and, for capital letters, in the same column, don't differ statistically ($p < 0.05$).

R.I. = intermittence relation or relation between the drying and equalization chamber.

Table 6. Industrial performance of rice grains submitted to three operational handlings in the intermittent drying and stored by the conventional system, in sacks[1].

	Days of storage		
Drying handle operational	0	80	160
Whole grains (%)			
Air in constant temperature (T = 90 ± 5 ºC)	59.64 Bb	60.30 Ba	60.05 Ba
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:3	61.04 Ab	61.81 Aa	61.66 Aa
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:1.5	60.85 Ab	61.61 Aa	61.35 Aa
Whole grains without defects (%)			
Air in constant temperature (T = 90 ± 5 ºC)	54.64 Ba	54.43 Bb	53.88 Bc
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:3	55.96 Aa	55.72 Ab	55.18 Ac
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:1.5	55.86 Aa	55.52 Ab	54.98 Ac
General defects of metabolic origin (%)			
Air in constant temperature (T = 90 ± 5 ºC)	1.41 Bb	1.46 Bb	1.57 Ba
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:3	1.67 Ab	1.69 Ab	1.78 Aa
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:1.5	1.60 Ab	1.68 Ab	1.77 Aa
Metabolic serious defects (%)			
Air in constant temperature (T = 90 ± 5 ºC)	0.11 Ac	0.15 Bb	0.22 Ba
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:3	0.11 Ac	0.16 Ab	0.23 Aa
Air in growing temperature (T = 70-90-110 ± 5 ºC) e RI = 1:1.5	0.10 Ac	0.15 Bb	0.22 Ba

[1] Simple arithmetic average, followed for small letters, in the same line and, for capital letters, in the same column, differ statistically ($p < 0.05$).

R.I. = intermittence relation or relation between the drying and equalization chamber.

Conclusions

- Increasing the relation of intermittence of 1:1.5 for 1:3 among the drying and equalization chambers, increase the time of operation and the consumption of energy for the air drying heating, but reduce the drying rate and the consumption of energy for amount of dried grains.
- The energy demand, for grains and air movement, for the drying in the intermittent dryer, is smaller than 1/7 of that necessary for the heating of the drying air, independently of the operational handling.
- There is significant reduction in the yield of whole grains, immediately after the drying, independently of the operational handling, but that reduction is less accentuated when the air is heated up gradually.
- The increase of the storage time provokes increase the incidence of serious defects and the general of metabolic origin, independently of the operational handling.

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