PS7-20 – 6204

Effects of diatomaceous earth used to control stored grain pests on technological, physical and cooking characteristics of parboiled and conventionally processed rice

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Abstract

The use of inert dust may be an alternative method to control stored grain pests. The aim of this study was to assess the effects of diatomaceous earth used to control stored grain pests, on technological, physical and cooking characteristics of rice. The "agulhinha" (*Oryza sativa* L.) rice grain class was used. A complete randomized design of 13 treatments, replicated three times was set-up with two diatomaceous earth products, Keepdry and Bugram in three dosages each and one control. Samples of paddy rice were taken at the beginning of the experiment, without any treatment, and at 4, 8 and 12 months after treatment. The grain moisture content, volumetric weight, lipid acidity and index of the lipid extract were assessed. After cooking the rice, the volumetric yield, water absorption, and gravimetric yield of faultless whole grain were determined on the conventional and parboiled rice methods. The diatomaceous earth used in the rice grain showed to be efficient in grain conservation and rice quality, and also showed no effect in technological quality and rice cooking parameters on parboiled and conventionally processed rice after twelve months of storage.

Key words: rice, diatomaceous earth, propionic acid, grain quality, stored grain pests.

Introduction

Rice (*Oryza sativa* L.) is a world important food that grew in all continents, and having in Asia its greatest producer. In South America the greatest producer is Brazil, who is also one of the top ten rice producers in the world. The southern States are the greatest national producers and have also the highest number of rice industries, mainly in the parboiling sector, whose product's acceptance by the Brazilian consumer is increasing (Behrens et al., 2006), as with the rest of the world.

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No matter how good the warehouse and how sophisticated the conservation structure is, the grain quality can't be improved during storage but only relatively preserved. During grain storage, physical, chemical, enzymatic and microbiological modifications may occur, these are activated by heat and moisture content and intensified along storage time. These modifications should be added to those caused by the grain's own metabolism (Elias, 2002, 2004).

The diatomaceous earth-based inert dust or silicate compounds have shown efficiency as a natural broad action specter insecticide for stored grain pests (Fields and Korunic, 2000). The use of diatomaceous earth presents some advantages over chemical residual protetants pesticides commonly used on grain, such as: low toxicity in mammals, efficiency for a range of pest species and it's easily removed from the product during processing (Subramanyam and Roesli, 2000; Stathers et al., 2004). However, their effect on rice consumption quality is an information not yet available in specialized literature.

We sought with this research to verify the effects of the application of diatomaceous earth on the conservation of rice grain, assessed on physical and technological aspects during storage as well as it's interference in the cooking characteristics (gravimetric yield) after conventional and parboil rice processing.

Materials and methods

The grain was dried and stored in the Post Harvest and Grain Quality Laboratory of DCTA, FAEM of UFPEL, where dosages of inert dust were applied. The treatments consisted of the dosages of two commercial formulations of diatomaceous earth-based inert dust as Keepdry with 1.0 kg/ton and Bugram with 2.0 kg/ton, besides de control treatment. The rice samples taken immediately after treatment application and at 4, 8 and 12 months of storage, were analyzed as to moisture content, volumetric weight, whole grain yield and gravimetric yield in cooking.

The moisture content was established by the oven method at 105 ± 3 °C, with natural air circulation, for 24 hours, as determined by the official seed analysis method established by the Ministry of Agriculture (Brasil, 1992).

The volumetric weight was determined using a Dalle Molle hectoliter weight scale with ¼ liter capacity, later transformed to $kg.m^{-3}$, and a digital electronic scale with 0.01 g precision. The results are the mean of three replicates expressed in $kg.m^{-3}$.

To obtain the industrial grain yield all samples were submitted to cleaning operations and selection in prototype air machines with flat and cylindrical sieves, in which impurities and non-rice materials, that harm the product flow in processing damaging equipment and reducing the final product's quality, were removed. The rice industrial processing followed the Rice Identity, Quality and Packing Brazilian Standards (Brasil, 1988).

To assess de cooking characteristics (gravimetric yield) the rice was processed by the conventional method and by parboiling. In the rice parboiling process, done according to the experimental procedure developed in the Grain Laboratory of UFPEL (Elias, 1998), the operations corresponding to the conventional processing were preceded by hydrothermal treatment.

The cooking characteristics were assessed according to the methodology proposed by Martinez and Cuevas (1989) with some adaptations needed for the process.

To assess the gravimetric yield (in weight) a calibrated methodology was used in the Grain Laboratory of UFPEL, which measured the grain water absorption during cooking. The value was calculated by the percentage difference between cooked and raw rice samples' weight.

The results were submitted to statistical analyses and to F test ($p \leq 0.05$). The means were compared between themselves by Tukey test ($p \leq 0.05$). The software used was SAS Institute (Coimbra et al., 2004).

Results and Discussion

The results showed a variation in the grain moisture content (Table 1) during the storage period, as it changes to maintain the hygroscopic equilibrium that varied according to the temperature and relative air humidity. There wasn't any difference between the moisture content of the rice treated with Keepdry and Bugram and that of the control treatment, which means that the diatomaceous earth did not affect the stored rice's moisture equilibrium.

Grain when in contact with the environment air in which the relative humidity oscillates will suck up or lose water when the vapor pressure increases or decreases. At the hygroscopic equilibrium point the air pressure is equal to the grain vapor pressure.

The behavior of the moisture content, no matter which treatment, confirms the dynamic character of the hygroscopic equilibrium, which causes moisture variations in the grain, even after hydric stability is achieved, according to the local environment temperature and relative humidity conditions.

The grain suffered water grade oscillations (Table 2) depending on the environment conditions (Table 1). Comparing the first with the other moisture measurements, all treatments lost water to the environment, agreeing with the high temperatures and low relative humidity of those months.

From the 8th month onwards, the moisture oscillations were greater with a tendency of humidity increase, coinciding with the months of lowest temperature and highest relative humidity. This behavior corresponds to that one reported by Elias (2004), according to whom, rice grain, despite not being a good thermal conductor, as a living organism with porous intra and inter granular structures and a chemical composition which grants them hygroscopicity, are constantly trading heat and humidity with the environment air. In this manner, by the conventional storage system this grain is exposed to the air's psychometric characteristic variations.

The diatomaceous earth on rice did not significantly interfere in the grain's volumetric weight until the fourth month of storage (Table 3). In the 8th and 12th months, the treated grain showed lower volumetric weight. The grain treated with both commercial formulations of diatomaceous earths showed a greater volumetric weight then the control treatment from the fourth month on.

Table 1. Average environment temperature and relative air humidity in the rice grain storage location at the time in which the tests were performed.

Parameter	Unit	Month of Storage 1º	4º	8º	12º
Temperature	ºC	12.3	19.9	21.8	12.8
Relative Humidity	%	82.8	79.0	80.6	83.4

Table 2. Average rice grain moisture content (%) during the storage time of the experiment.

Treatment	Dose (kg t^{-1})	Month of Storage Beginning*	4º	8º	12º
Keepdry	1.0	13.96 a A	12.14 a C	12.81 a B	14.38 a A
Bugram	2.0	13.96 a A	12.25 a C	12.87 a B	14.33 a A
Control	-	13.96 a A	12.33 a C	12.86 a B	14.35 a A

Simple arithmetic averages of three replicates followed by the same lower letters in the same column and the same capital letters in the same line, did not differs between themselves by the Tukey test at 5% of probability.

* Assessment done before treatment application.

Due to the increased relative humidity in the 8th and 12th months, the grain moisture content also increased accelerating the grain metabolism and so increasing the reserves consumption and reducing the volumetric weight.

Because of its breakage susceptibility, paddy rice needs special care so as to the methods and conditions of its handling, as its commercial value depends mainly on whole grain yield and on the classification faults. The results showed that there was no statistic difference between the diatomaceous earth treatments and the control treatment in the percentage of whole faultless rice grain (Table 4), demonstrating efficacy on grain preservation of the commercial quality and in the industrial rice grain yield.

The percentage of whole grain in processing, commonly known as industrial yield, is one of the most important parameters on establishing the grain's commercial value. The price paid to the producer depends on the grain's physical quality which is verified after processing, so the higher the whole grain percentage is, the higher the grain's price. Grain breakage occurs mainly during the husking and burnishing operations, as most grain broken during processing have fissures previous to the process due to climatic alterations, pre-harvest sanitary occurrences and operational effects of harvesting and drying (Elias, 1998).

According to Dias (1993), the broken grain percentage is affected by grain moisture content when processed. Grain with moisture content of above 15 % are harder to process which leads to an increase in grain breakage when passing though the husker.

The highest conventionally processed grain samples' gravimetric yield percentage occurred in the proportions of 2.2:1, although in this proportion some residual water was left in the recipient, which is not desirable (Table 5 and 6). The diatomaceous earth treated grain did not differ from the control treatment in this assessed parameter. The gravimetric yield did not show statistical differences in the four assessments of the 2.0 and 2.1:1 proportions, these being the proportions with the best yield.

Table 3. Average rice grain's volumetric weight (kg m^{-3}) during the storage time of the experiment.

	Dose	Month of Storage			
Treatment	(kg.t^{-1})	Beginning*	4º	8º	12º
Keepdry	1.0	561.75 a A	560.04 a A	557.73 a A	544.24 a B
Bugram	2.0	561.75 a A	560.13 a A	557.64 a A	545.46 a B
Control	-	561.75 a A	557.61 b B	551.29 b BC	534.18 b C

Simple arithmetic averages of three replicates followed by the same lower letters in the same column and the same capital letters in the same line, did not differs between themselves by the Tukey test at 5 % of probability.
* Assessment done before treatment application.

Table 4. Average whole faultless rice grain (%), treated with diatomaceous earth, stored for 12 months and processed by the conventional system.

	Dose	Month of Storage			
Treatment	(kg t^{-1})	Beginning*	4º	8º	12º
Keepdry	1.0	55.48 a AB	54.09 a BC	58.70 a A	52.36 a C
Bugram	2.0	55.48 a ABC	55.39 a ABC	58.73 a A	53.17 a BC
Control	-	55.48 a BC	54.50 a ABC	57.26 a A	51.51 a C

Simple arithmetic averages of three replicates followed by the same lower letters in the same column and the same capital letters in the same line, did not differs between themselves by the Tukey test at 5 % of probability.
* Assessment done before treatment application.

Table 5. Gravimetric yield (%) of cooked rice, treated with diatomaceous earth, stored for 12 months and processed by the conventional method.

Treatment	Dose kg t-1	Water/ Grain Prop.	Month of Storage 1º	4º	8º	12º	Means
Keepdry	1.0	1.8:1	259 b A	258 b A	263 c A	269 b A	262
		1.9:1	265 b A	264 b A	277 bc A	283 ab A	272
		2.0:1	293 a A	285 a A	304 ab A	305 a A	297
		2.1:1	302 a A	293 a A	305 ab A	306 a A	302
		2.2:1	310 a A	314 a A	313 a A	314 a A	313
Bugram	2.0	1.8:1	260 b A	262 b A	285 ab A	288 ab A	274
		1.9:1	268 b A	271 b A	272 ab A	276 b A	272
		2.0:1	287 ab A	294 ab A	297 a A	299 ab A	294
		2.1:1	288 ab A	289 ab A	301 a A	302 ab A	295
		2.2:1	308 a A	306 a A	314 a A	315 a A	311
Control	-	1.8:1	271 a A	268 a A	281 a A	284 a A	276
		1.9:1	280 a A	272 a A	279 a A	285 a A	279
		2.0:1	284 a A	281 a A	297 a A	298 a A	290
		2.1:1	283 a A	291 a A	296 a A	300 a A	293
		2.2:1	291 a A	301 a A	306 a A	308 a A	302

Simple arithmetic averages of three replicates followed by the same lower letters in the same column and the same capital letters in the same line, did not differs between themselves by the Tukey test at 5 % of probability.
Water/Grain Proportion: Volumetric proportion of water added to cook the grain. Thus, 2.0:1 means the use of 2.0 volumes of water for each rice volume in the pan.

Table 6. Gravimetric yield (%) of cooked rice, treated with diatomaceous earth, stored for 12 months and processed by parboiling.

Treatment	Dose kg t-1	Water/ Grain Prop.	Month of Storage 1º	4º	8º	12º	Means
Keepdry	1.0	2.3:1	283 b A	286 b A	291 b A	294 a A	289
		2.4:1	294 ab A	297 ab A	299 ab A	300 a A	298
		2.5:1	298 ab A	299 ab A	303 ab A	306 a A	302
		2.6:1	299 a A	301 ab A	305 ab A	307 a A	303
		2.7:1	300 a A	303 a A	307 a A	308 a A	305
Bugram	2.0	2.3:1	287 a A	292 a A	297 a A	299 a A	294
		2.4:1	292 a A	294 a A	301 a A	303 a A	298
		2.5:1	296 a A	298 a A	303 a A	305 a A	301
		2.6:1	300 a A	303 a A	307 a A	310 a A	305
		2.7:1	302 a A	305 a A	308 a A	312 a A	307
Control	-	2.3:1	294 a A	296 a A	297 a A	305 a A	298
		2.4:1	299 a A	300 a A	302 a A	307 a A	302
		2.5:1	300 a A	303 a A	306 a A	312 a A	305
		2.6:1	301 a A	306 a A	308 a A	313 a A	307
		2.7:1	304 a A	309 a A	310 a A	316 a A	310

Simple arithmetic averages of three replicates followed by the same lower letters in the same column and the same capital letters in the same line, did not differs between themselves by the Tukey test at 5 % of probability.
Water/Grain Proportion: Volumetric proportion of water added to cook the grain. In this manner, 2.0:1 means the use of 2.0 volumes of water for each rice volume in the pan.

All diatomaceous earth treated grain had statically equivalent water absorption and yield, from the 1st to the 12th months assessed, although an operational tendency of percentage value increase can be observed along time, with a higher intensity in the non treated grain. This fact is explained by the hygroscopic consequences of grain deterioration during storage.

These results agree those reported by Gularte (2005). The use of diatomaceous earth on rice, conventionally processed or parboiled, did not interfere in the assessed gravimetric yield parameters. The highest operational values assessed were obtained in the water proportions of 2.1:1 of cooking of the conventionally processed rice and 2.6:1 for the parboiled.

Acknowledgments

The senior author thanks the National Council for Scientific and Technological Development (CNPq), CAPES, SCT-RS (Pólo de Inovação Tecnológica da Região Sul), Embrapa Wheat, COREDE-SUL, ABIAP and the private companies Rio Deserto Mineração e Pesquisa Brasileira Ltda., Vetquímica, GP Representações and Keepdry, for providing laboratory facilities and support for this study.

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