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# Sanitary and technological quality analysis of five brazilian wheat cultivars, in the 2005 cropping season

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## Abstract

The 2005 wheat cropping season, in Rio Grande do Sul, southern of Brazil, was characterized by high rainfall, specially in October (384 mm), which is an indicative of problems of sanitary and technological grain quality. Qualitative losses are more important than physical losses. Food safety problems, generally, are related to mycotoxins and pests of stored grains. During the harvest process mechanical damages are common and usually it serves as an entrance for fungi, which in the presence of moisture and appropriate temperature can lead to mycotoxin production. The objective of this paper was to evaluate wheat grain samples, harvested in Passo Fundo, during the 2005 cropping season, as for sanitary and technological quality during grain storage. Grain of five Embrapa wheat cultivars: BRS 177, BRS 179, BRS Camboatá, BRS Guabiju, and BRS Guamirim, harvested in 2005 season, were stored in the laboratory, at room temperature, from January to April 2006. For characterization water activity (Aw), mycotoxin, and microscopy analyses were carried out; and, during the storage period, pathology of seeds (fungi) and wheat technological quality (test weight, thousand kernel weight, hardness index, experimental milling, alveography, falling number and, flour color) were determined. The predominant fungi were *Alternaria* spp., *Fusarium graminearum* and, *Aspergillus* spp. Insects and/or its fragments in grain and flour of some cultivars were found. Medium values of 0.58 for Aw; 1,321.3 mg kg$^{-1}$ for deoxynivalenol; 55.1 mg kg$^{-1}$ for zearalenon, 242.2 mg kg$^{-1}$ for fumonisin B1; and, 24.1 mg kg$^{-1}$ for ergosterol were detected. Significant correlations among technological quality parameters were found. However, the time of storage was only correlated with grain and flour moisture content and with fungi, that had decreased with storage time.

*Key words:* Wheat, rainy cropping season, sanitary, technological quality, storage.

## Introduction

About 90 % of Brazilian wheat production comes from Paraná, Rio Grande do Sul, and

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Santa Catarina states. In those states, the climatic variability is very high, so that wheat production becomes a risky activity (Guarienti et al., 2003).

The 2005 wheat season in RS, was characterized by occurrence of 384,8 mm of rainfall, in October, while the historical average is 167,1 mm (Embrapa Trigo, 2005), inducing pre-harvest sprouting and fungi diseases as major problems to technological product quality.

Quality losses are usually more important than physical losses. Food safety problems, generally, are related to pesticide residual, mycotoxins and pest of stored grains (insects).

During the harvest process mechanical damage can occur, which serves as an entry for fungi that in presence of moisture and appropriate temperature induce mycotoxin production.

There are five agriculturally-important fungal toxins, deoxynivalenol (DON= vomitoxin), zearalenone (ZEA), ochratoxin A, fumonisin and aflatoxin. Toxigenic fungi in crops have been separated into distinct groups: field fungi and storage fungi (Miller, 1995). Among the field fungi, the genus *Fusarium* is the most important by producing zearalenone, tricotecens (deoxynivalenol, toxin T2), and fumonisins.

Fusariose or giberela is a fungal disease of wheat that affects the heads. It is caused, mainly, by *Gibberella zeae* (*Fusarium graminearum*) that could reduce yield and quality, and produce mycotoxin.

According to Nightingale et al. (1999), wheat endosperm proteins play an important role in determining the viscoelastic and processing characteristics (baking and pasta making) of dough, however, the presence of fungal proteases in grains with *Fusarium*, can lead to the loss of dough functionality and loaf volume potencial.

The presence of filthness in wheat grain and wheat flour is an indicative of absence of hygienic-sanitarium control during processing and storage. Insects can work as carryers of fungal contaminants. For this reason microscopy is being used as usual practice in food products quality evaluation (Nunes et al., 2003).

The objective of this study was to evaluate, preliminarly, sanitary and technological quality of grain of 5 wheat cultivars grown in the southern area of Brazil, obtained in the 2005 cropping season, characterized by rainfall in excess.

## Material and methods

Samples of 5 wheat cultivars of Embrapa, were evaluated: BRS 177, BRS 179, BRS Camboatá, BRS Guabiju, and BRS Guamirim, harvested in December of 2005, in Passo Fundo, RS, Brazil, by Embrapa-SNT. Samples from each cultivar were homogenized and expurgated previously, and after stored in laboratory, at room temperature (≈ 25 ºC) for 3 consecutive months, starting at the beginning of January of 2006.

The wheat grain water activity (Aw) was determined in digital Aqualab equipment (Decagon CX-2 to 28ºC). The determination of the percentage of grains with giberela symptoms was visual and executed in a sample of thousand grains.

For mycotoxins analysis, sampling was performed following Fonseca (1991). The mycotoxins extraction aflatoxins B1, B2, G1 and G2 were carried out according to Mallmann et al. (2000); zearalenona and deoxynivalenol according to Romer et al. (without date); fumonisins B1 and B2 according to Dilkin et al. (2001); toxina-T2 according to Krska et al. (2001) and ergosterol followed method proposed by Young (1995), with modifications. Mycotoxins toxin-T2 and DON (tricotecens) were analyzed by gas chromatography-mass spectrometry coupled (GC-MS) techniques, and other mycotoxins were quantified by high performance liquid cromatography (HPLC).

The microscopic analysis was done at beginning and at the end of the storage period by flotation method in heptan nº 950.86 (AOAC, 2000), for isolation of light and external filthiness of wheat grain and method of acid digestion nº 965.39b (AOAC, 2000) for filthiness isolation in wheat flour.

Grain pathology was performed at 30, 60, and 90 days of storage by the plating method in PDA culture medium (potato-dextrose-agar + streptomycin), without sanitary care, with 3 replications of 100 seeds each. The incubation period was at temperature of 22 ± 2 ºC and light regime of 12 hours. The evaluation was done 5 days after, with the aid of binocular stereoscopic microscope.

Grain moisture content was analyzed by direct reading with Dickey-John equipment, while flour moisture content was determined by AACC Method 44-15A (AACC, 2000).

The wheat grains were evaluated as test weight – TW (the mass of 100 liters of wheat, determined according to Brasil, 2001); thousand kernel weight – TKW (carried out according to Brasil, 1992) and hardness index – HI (method 55-31 of AACC, 2000, using SKCS equipment - Single Kernel Characterization System, model 4100).

Experimental milling (flour extraction rate) was determined using Brabender Quadrumat Senior laboratory mill (method 26-94 of AACC, 2000).

Alveography was performed with a Chopin alveograph by AACC Method 54-30A (2000). The alveograms were evaluated in terms of T, dough tenacity; E, dough extensibility; ratio T/E; SI, swelling index; W, dough strength; and EI, elasticity index (prediction of the rheologic behavior of dough used in baking).

The falling number of grain and flour was analyzed according to AACC method 56-81B (AACC, 2000), with moisture and altitude corrections (Passo Fundo, 687 m).

The flour color was determined in Minolta colorimeter (model CR 310), with values expressed in L* (lightness), a* and, b* (cromaticity coordinates). The color difference (DE), was calculated by: $\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$, where: $\Delta L^* = Lf - Li$, $\Delta a^* = af - ai$, $\Delta b^* = bf - bi$. that is, $\Delta L^*$, $\Delta a^*$ e $\Delta b^*$ represent the differences in values of L*, a* and, b*, respectively, between the color at the final storage time (f) and, at the beginning (i = initial time).

Analysis of variance (ANOVA) and multiple comparisons (Tukey's test) were used for the statistical analysis, of some data. The correlation analysis was performed with the average sanitary results and technological wheat quality.

## Results and discussion

### Sanitary characterization of wheat samples

In Table 1 is showed the sample data of the 5 wheat cultivars, with relationship to the water activity (Aw), to the visual percentage of grains with giberela symptoms (tombstone grains), and micotoxins content.

To obtain growth and metabolism of microorganisms it is necessary free water (water in available form), being the water activity (Aw),

**Table 1.** Water activity, percentage of tombstone grains and micotoxins content present in the samples of wheat cultivars, of 2005 cropping season, in Passo Fundo, RS, Brazil.

| Cultivar | Aw | Tombstone grain (%) | DON | Toxin T-2 | F B1 | F B2 | ZEA | AF B1 | AF B2 | AF G1 | AF G2 | ERG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ($\mu$g kg$^{-1}$) | | | | | | | | | (mg kg$^{-1}$) |
| BRS 177 | 0.58 | 13.7 | 2,002.4 | ND | 180.0 | ND | 28.7 | ND | ND | ND | ND | 26.5 |
| BRS 179 | 0.59 | 11.9 | 1,315.5 | ND | 184.6 | ND | ND | ND | ND | ND | ND | 19.1 |
| BRS Camboatá | 0.58 | 6.2 | 1,264.3 | ND | 288.5 | ND | ND | ND | ND | ND | ND | 23.3 |
| BRS Guabiju | 0.58 | 3.9 | 565.4 | ND | 270.0 | ND | ND | ND | ND | ND | ND | 13.5 |
| BRS Guamirim | 0.58 | 7.3 | 1,458.7 | ND | 287.8 | ND | 81.4 | ND | ND | ND | ND | 38.1 |
| Mean values | 0.58 | 8.6 | 1,321.3 | - | 242.2 | - | 55.1 | - | - | - | - | 24.1 |

Where: ND= < detection limit; Aw= water activity; ; DON= deoxynivalenol or vomitoxin; F= fumonisin; ZEA= zearalenona, AF= aflatoxin; and ERG= ergosterol.

one of the ways used to express the availability of water in foods. The wheat samples presented mean values of Aw of 0.58. In Aw below 0.60, the microorganisms do not multiply, but can remain viable for long periods.

Among the analyzed micotoxins was detected the presence of DON and fumonisin B1 in all cultivars. DON was found in quite high levels specially in cultivar BRS 177 (2,002.4 mg $kg^{-1}$) and the smallest in BRS Guabiju (565.4 mg $kg^{-1}$). The largest concentration of fumonisin B1 was observed in BRS Camboatá (288.5 mg $kg^{-1}$) and the smallest one in cultivar BRS 177 (180 mg $kg^{-1}$). ZEA was detected only in cultivars BRS 177 (28.7 mg $kg^{-1}$) and BRS Guamirim (81.4 mg $kg^{-1}$), however, fumonisin B2 and aflatoxins were not found. Ergosterol was present in all cultivars whose concentration ranged from 19 to 38 mg $kg^{-1}$.

Under Brazilian legislation there is no limit for mycotoxins in wheat. The DON limit, in wheat without processing, allowed by the European Commission (HGCA, 2005) is of 1,250 mg $kg^{-1}$, and by Canadá, of 2,000 mg $kg^{-1}$ (Lamic, 2006). Considering the analyzed samples, 4 out of 5 presented higher values for this limit, indicating that in crop seasons with rainfall in excess, micotoxins content can be quite elevated and therefore it should be monitored. The DON content was proportional to visual percentage of tombstone grains.

The maximum limit allowed for ZEA in cereals, in France is 200 mg $kg^{-1}$ and in Italy 100 mg $kg^{-1}$, being the samples of the present study within acceptable values. Limits for fumonisin B1 and ergosterol were not found in the legislation in other countries.

In Table 2 the microscopic analysis of wheat and its flour are presented.

At the beginning of the experiment, 5 wheat grain samples were analyzed in relation to the filthness presence, 2 cultivars (BRS 179 and BRS Camboatá) presented insects and insect fragments, while at the end of the storage period filthness was only detected in cultivar BRS 179. As for wheat flour, in the beginning insect fragments were found in 3 cultivars (BRS Guamirim, BRS Camboatá, and BRS Guabiju) and at the end of storage, only in 2 cultivars (BRS Guamirim and BRS Guabiju).

In the case of wheat flour, according to the current Brazilian Ministry of Agriculture legislation, Resolution RDC nº 175, July 08, 2003, denominated "Technical regulation of macroscopic and microscopic matter evaluation, harmful to human health in packed foods", "the packed foods should not contain insects, alive or dead, whole or in parts, being recognized as mechanical vectors; nor rigid, sharp, and or cutting objects, that can cause harm to the consumer". However, it is very difficult to find wheat flour without insect fragments. The extinct Brazilian legislation, limited up to 75 insect fragments for each 50 g of sample and absence of live insects.

**Table 2.** Microscopic analysis of wheat and wheat flour, of 5 wheat cultivars, of 2005 cropping season, in Passo Fundo, RS, Brazil.

| | Initial time (beginning of January) | | Final time (beginning of April) | |
|---|---|---|---|---|
| Cultivar | Grain | Wheat flour | Grain | Wheat flour |
| BRS 179 | 4 wi/3 if* | absence | 3 wi/4 if* | absence |
| BRS 177 | absence | absence | absence | absence |
| BRS Camboatá | 2 if | 4 if | absence | absence |
| BRS Guabiju | absence | 4 if | absence | 6 if/1 mp |
| BRS Guamirim | absence | 2 if | absence | 2 if |

* storage wheat pest. Where: wi= whole insects; if= insect fragments, and mp= metalic particle.

## Effect of storage in the wheat grain pathology

As can be observed in Table 3, in general the fungi frequency (%) decreased with the duration of grain storage. This was already expected, especially for field fungi, which in general die when cereal grain is stored, at 13-14 % of moisture and with temperature of 25 ºC (Scussel, 1998).

The largest fungi frequency was registered for *Alternaria* spp. (72 %) and *F. graminearum* (62 %) in cultivar BRS 177. *Alternaria* spp., as well *B. sorokiniana*, which were detected in low frequency are pathogens transmitted by seeds (Reunião, 2005). In cultivars BRS Camboatá and BRS Guamirim, the frequency of *Alternaria* spp. was not affected by the storage. BRS Guamirim was the cultivar that presented the smallest frequency of *F. graminearum. Aspergillus* spp. was just found in larger frequencies in cultivars BRS Guabiju (25 %) and BRS Guamirim (19 %). *Fusarium* spp. and *Penicillium* spp. were detected in low frequency and many times were not present at all.

The storage fungi, *Aspergillus* spp. and *Penicillium* spp. commonly invade the grain during storage. They need moisture from 13 to 18 % corresponding to the relative humidity of 70-85 % and, preferentially, located in the germ of the grain. The endosperm is not much affected (Gomes et al, 1995; Scussel, 1998).

## Effect of grain storage in technological wheat quality

Tables 4 and 5 present the results of technological wheat quality during the storage period for 3 months.

It was observed that with increase of storage period, in general, PH and PMG presented little variation; UMID-G and NQ-G had decreased contrasting with UMID-F that increased, probably due to the hygroscopic properties of the flour; while NQ-F and flour extraction rate had decreased slightly.

Grain hardness was determined by the experimental measure of the force necessary to triturate wheat grain. Grain texture was not variable in each cultivar in different times of storage, as shown by the classification of the grain that had not changed. According to Dexter et al. (1997), the texture (hardness) is not altered, possibly because the protein content, primary factor associated with the texture, is not affected.

The alveography and color determined by Minolta colorimeter varied a lot with the increase of storage time, by unknown reasons. Tendencies were not evident, neither to increase nor to decrease as time passed.

For cultivars BRS 177, BRS 179 and BRS Guamirim there was a tendency of T value (tenacity or resistance to extension) to decrease from the initial to the final storage period (90 days) that can be related to the presence of *F. graminearum*.

Nightingale et al. (1999) reported that fungal proteases, present in wheat grain steming from *Fusarium*, act in the wheat storage proteins (responsible for the dough viscoelasticity), making them exhibit weak dough properties (decrease of dough consistency and resistance to extension) and baking quality is unsatisfactory, that is, the loaf volume decreases.

## Correlation among parameters analysed

Correlation among average values of each variable analyzed (mean of all storage periods, for cultivar), had shown interesting results, such as:

- *Alternaria* spp. correlated with FMC (*0.89), T/E (*-0.92), and HI (*-0.89);
- *Aspergillus* spp. with FFN (*0.98) and EXT (*0.93);
- *Fusarium graminearum* spp. with color b* (*-1.00);
- *Penicillium* spp. with GMC (*0.97), FMC (-0.93*), EXT (*0.94), T (*0.93), and HI (*0.99).
- tombstone grains (TG) correlated with GMC (*-0.89), with T (*-0.93) and W (*-0.88) of the alveography; and,
- DON presented negative correlation with TW (*-0.93).

**Table 3.** Fungi frequency in grain of 5 wheat cultivars, of 2005 cropping season, in Passo Fundo, RS, Brazil, during storage*.

| Cultivar | Nº of storage days | Nº of fungi / 100 g of wheat grain | | | | | |
|---|---|---|---|---|---|---|---|
| | | ALTER | ASP | BS | FG | FSP | PEN |
| BRS177 | 30 | 72 a,b | 6 a | 5 a | 62 a | 0 a | 0 a |
| | 60 | 76 a | 4 a | 0 b | 45 b | 1 a | 0 a |
| | 90 | 60 b | 4 a | 3 a,b | 28 c | 0 a | 0 a |
| BRS179 | 30 | 63 a | 4 a | 3 a | 51 a | 1 a | 1 a |
| | 60 | 53 a,b | 3 a | 5 a | 12 b | 3 a | 1 a |
| | 90 | 34 b | 6 a | 4 a | 7 b | 2 a | 1 a |
| BRS Camboatá | 30 | 63 a | 4 a | 1 a | 49 a | 0 a | 0 b |
| | 60 | 68 a | 1 a | 1 a | 46 a | 1 a | 0 b |
| | 90 | 56 a | 2 a | 2 a | 16 b | 1 a | 3 a |
| BRS Guabijú | 30 | 49 a | 25 a | 1 a | 14 c | 1 a | 2 a |
| | 60 | 51 a | 4 b | 3 a | 47 a | 3 a | 0 a |
| | 90 | 37 b | 5 b | 2 a | 29 b | 2 a | 2 a |
| BRS Guamirim | 30 | 46 a | 12 a,b | 3 a | 9 a,b | 1 a | 1 a |
| | 60 | 46 a | 10 b | 2 a | 13 a | 1 a | 2 a |
| | 90 | 35 a | 19 a | 1 a | 3 b | 0 a | 2 a |

Means followed by different letter in the same column, by cultivar, differ at 5% probability by Tukey's Test (P£0.05). *Mean values for 3 determinations. ALTER= *Alternaria* spp.; ASP= *Aspergillus* spp.; BS= *Bipolaris sorokiniana;* FG=*Fusarium graminearum;* FSP= *Fusarium* spp.; PEN= *Penicillium* spp.

**Table 4.** Physical caracteristics of grain and wheat flour, and flour extraction, of 5 wheat cultivars, of 2005 cropping season, in Passo Fundo, RS, Brazil, during storage.

| Cultivar | Nº of storage days | TW (kg/hL) | TKW (g) | GFN (s) | GMC (%) | FFN (s) | FMC (%) | EXT (%) | HI | Grain texture classification* |
|---|---|---|---|---|---|---|---|---|---|---|
| BRS177 | 0 | 77.00 | 32.9 | 479 | 12.6 | 385 | 14.0 | 52.06 | 32 | soft |
| | 30 | 76.80 | 35.0 | 402 | 12.0 | 271 | 13.6 | 44.35 | 31 | soft |
| | 60 | 77.25 | 34.2 | 460 | 11.9 | 321 | 14.2 | 47.90 | 34 | soft |
| | 90 | 77.45 | 34.2 | 387 | 11.8 | 331 | 14.2 | 49.55 | 33 | soft |
| BRS179 | 0 | 78.15 | 31.6 | 439 | 12.3 | 368 | 13.5 | 47.83 | 52 | medium hard |
| | 30 | 78.15 | 30.7 | 385 | 12.0 | 331 | 13.6 | 50.26 | 54 | medium hard |
| | 60 | 78.80 | 32.3 | 408 | 12.2 | 328 | 13.9 | 47.12 | 53 | medium hard |
| | 90 | 77.70 | 32.8 | 396 | 12.2 | 276 | 14.0 | 49.32 | 54 | medium hard |
| BRS Camboatá | 0 | 78.60 | 33.7 | 317 | 12.8 | 299 | 13.9 | 44.53 | 57 | medium hard |
| | 30 | 78.35 | 33.6 | 304 | 12.6 | 346 | 13.0 | 60.63 | 56 | medium hard |
| | 60 | 78.80 | 31.9 | 314 | 12.5 | 310 | 13.6 | 50.31 | 54 | medium hard |
| | 90 | 78.35 | 33.4 | 303 | 11.9 | 281 | 14.7 | 44.48 | 56 | medium hard |
| BRS Guabijú | 0 | 83.10 | 33.9 | 450 | 13.1 | 356 | 12.6 | 60.47 | 83 | very hard |
| | 30 | 81.50 | 33.0 | 409 | 12.6 | 335 | 13.5 | 54.29 | 83 | very hard |
| | 60 | 83.10 | 34.4 | 369 | 13.3 | 382 | 13.3 | 58.85 | 82 | very hard |
| | 90 | 82.90 | 34.0 | 378 | 12.2 | 362 | 13.9 | 43.87 | 84 | very hard |

Continue...

**Table 4.** Continue

| Cultivar | Nº of storage days | TW (kg/hL) | TKW (g) | GFN (s) | GMC (%) | FFN (s) | FMC (%) | EXT (%) | HI | Grain texture classification* |
|---|---|---|---|---|---|---|---|---|---|---|
| BRS Guamirim | 0 | 77.90 | 37.8 | 415 | 13.2 | 423 | 13.1 | 57.39 | 84 | very hard |
| | 30 | 78.80 | 37.7 | 384 | 12.7 | 375 | 13.2 | 61.63 | 81 | very hard |
| | 60 | 78.80 | 37.8 | 433 | 12.6 | 359 | 13.6 | 42.25 | 81 | very hard |
| | 90 | 78.80 | 37.5 | 369 | 12.7 | 390 | 13.9 | 57.30 | 84 | very hard |

Where: TW= test weight; TKW= thousand kernel weight; GFN and FFN= grain and flour falling number, respectively; GMC and FMC= grain and flour moisture content, respectively; EXT= flour extraction; and HI= hardness index. *AACC (2000).

**Table 5.** Rheological characteristics of grain and wheat flour color, of 5 wheat cultivars, of 2005 cropping season, in Passo Fundo, RS, Brazil, during storage.

| Cultivar | Nº of storage | Alveography | | | | | | Minolta color | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | days | W (x $10^{-4}$J) | T (mm) | E (mm) | T/E | SI | Ie (%) | L* | a* | b* |
| BRS177 | 0 | 97 | 39 | 87 | 0.45 | 20.7 | 44.90 | 93.51 | 0.16 | 8.69 |
| | 30 | 82 | 35 | 83 | 0.42 | 20.3 | 43.30 | 95.42 | -0.11 | 6.61 |
| | 60 | 75 | 41 | 47 | 0.87 | 15.2 | 47.60 | 95.73 | -0.03 | 6.06 |
| | 90 | 81 | 31 | 102 | 0.31 | 22.5 | 41.20 | 95.66 | -0.12 | 6.36 |
| BRS179 | 0 | 75 | 50 | 50 | 1.00 | 15.7 | 29.60 | 95.29 | -0.67 | 8.16 |
| | 30 | 57 | 52 | 31 | 1.68 | 12.4 | 0.00 | 95.28 | -0.88 | 9.02 |
| | 60 | 56 | 50 | 33 | 1.49 | 12.9 | 0.00 | 95.45 | -0.73 | 8.68 |
| | 90 | 46 | 39 | 38 | 1.03 | 13.8 | 0.00 | 95.52 | -0.69 | 8.29 |
| BRS Camboatá | 0 | 142 | 64 | 80 | 0.80 | 19.9 | 40.40 | 95.98 | -0.10 | 5.31 |
| | 30 | 142 | 73 | 64 | 1.15 | 17.8 | 39.90 | 94.97 | -0.68 | 9.12 |
| | 60 | 150 | 63 | 68 | 0.94 | 18.3 | 50.80 | 94.87 | -0.34 | 8.49 |
| | 90 | 161 | 64 | 91 | 0.71 | 21.2 | 43.60 | 93.94 | -0.52 | 9.18 |
| BRS Guabijú | 0 | 290 | 89 | 95 | 0.94 | 21.7 | 58.20 | 95.66 | -0.84 | 8.08 |
| | 30 | 361 | 94 | 113 | 0.83 | 23.7 | 59.90 | 93.45 | 0.13 | 8.98 |
| | 60 | 299 | 114 | 63 | 1.80 | 17.7 | 64.30 | 93.73 | 0.18 | 8.84 |
| | 90 | 349 | 100 | 98 | 1.02 | 22.1 | 61.40 | 93.35 | 0.21 | 9.17 |
| BRS Guamirim | 0 | 237 | 91 | 85 | 1.07 | 20.6 | 47.90 | 93.69 | -0.10 | 8.97 |
| | 30 | 196 | 74 | 101 | 0.73 | 22.4 | 42.40 | 93.65 | -0.20 | 9.56 |
| | 60 | 163 | 89 | 51 | 1.76 | 15.8 | 44.40 | 93.69 | -0.11 | 9.09 |
| | 90 | 154 | 82 | 57 | 1.44 | 16.8 | 41.40 | 94.07 | -0.23 | 9.40 |

Where: Alveography parameters: W= gluten strenght, T= tenacity, E= extensibility, T/E= tenacity to extensibility ratio; SI= swelling index and EI= elasticity index; Minolta color parameters: L*= lightness, a* e b*= cromaticity coordinates (+a= red and –a= green, +b= yellow and -b= blue).

Besides that, a very well-known correlation were confirmed once more: as hardness of the grain with EXT (0.94 *) and T (0.91 *), and alveography parameters among each other.

In Table 6 the correlations are presented, among the averages of variables of sanitary quality and technological quality.

It can be observed that some parameters of technological quality are correlated with pathogenical fungi of grains and with some micotoxins. The color red/green was affected significantly by all the studied parameters of sanitary quality. Dexter et al. (1997) studied the effect of *F. graminearum*, in semolina quality and pasta made from durum wheat, and observed that semolina became duller and redder.

Production seasonality affects wheat prices, which are higher in between cropping seasons and therefore estimulates to the producer to store the grain, to obtain higher income. However, farmers need to be aware that losses in quality and presence of DON and other micotoxins can occur, drastically impacting the price of the product.

Besides affecting the technological quality, results of this research show the need to monitor the sanitary quality of wheat and flour for the fithness presence and micotoxins occurrence, especially in cropping seasons with rainfall in excess, as it happened in 2005. This control can provide the base for future studies and for the establishment of limits for specific legislation for wheat and wheat flour, as already exist in developed countries.

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**Table 6.** Correlations between sanitary and technological quality, of 5 wheat cultivars, of 2005 cropping season, in Passo Fundo, RS, Brazil.

| Fator | ALTER | ASP | BS | FG | FSP | PEN | TG | FB1 | DON | ZEA | ERG | Aw |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TW (kg $hL^{-1}$) | -0.56 | 0.53 | -0.32 | -0.14 | 0.71 | 0.63 | -0.80 | 0.48 | *-0.93 | 0.55 | -0.57 | -0.49 |
| TKW (g) | -0.40 | 0.78 | -0.54 | -0.57 | -0.46 | 0.58 | -0.24 | 0.51 | 0.17 | -0.25 | 0.81 | 0.06 |
| GFN (s) | -0.15 | 0.35 | 0.59 | -0.10 | 0.16 | -0.19 | 0.52 | -0.63 | 0.27 | -0.55 | 0.06 | 0.65 |
| GMC (%) | -0.75 | 0.83 | -0.68 | -0.59 | 0.24 | *0.97 | *-0.89 | 0.87 | -0.67 | 0.50 | 0.13 | -0.38 |
| FFN (s) | -0.78 | *0.98 | -0.27 | -0.75 | 0.10 | 0.77 | -0.37 | 0.42 | -0.23 | 0.04 | 0.45 | 0.21 |
| FMC (%) | *0.89 | -0.85 | 0.37 | 0.66 | -0.56 | *-0.93 | 0.79 | -0.64 | 0.80 | -0.58 | 0.09 | 0.16 |
| EXT (%) | -0.77 | *0.93 | -0.59 | -0.62 | 0.22 | *0.94 | -0.78 | 0.75 | -0.59 | 0.34 | 0.19 | -0.25 |
| T (mm) | -0.73 | 0.77 | -0.63 | -0.49 | 0.40 | *0.93 | *-0.93 | 0.82 | -0.81 | 0.57 | -0.08 | -0.45 |
| E (mm) | 0.11 | 0.40 | -0.76 | 0.30 | -0.23 | 0.28 | -0.54 | 0.51 | -0.24 | -0.24 | -0.01 | -0.76 |
| SI | 0.13 | 0.39 | -0.79 | 0.30 | -0.26 | 0.28 | -0.54 | 0.53 | -0.22 | -0.24 | 0.02 | -0.77 |
| W (x $10^{-4}$J) | -0.52 | 0.69 | -0.61 | -0.19 | 0.40 | 0.74 | *-0.88 | 0.69 | -0.79 | 0.38 | -0.27 | -0.60 |
| T/E ratio | *-0.92 | 0.49 | 0.12 | -0.85 | 0.66 | 0.72 | -0.43 | 0.33 | -0.61 | 0.80 | -0.05 | 0.31 |
| EI (%) | -0.15 | 0.53 | -0.64 | 0.17 | 0.15 | 0.44 | -0.69 | 0.52 | -0.55 | 0.02 | -0.26 | -0.71 |
| HI | *-0.89 | 0.84 | -0.47 | -0.73 | 0.44 | *0.99 | -0.83 | 0.75 | -0.74 | 0.62 | 0.05 | -0.19 |
| Color L* | 0.45 | -0.74 | 0.81 | 0.54 | 0.34 | -0.77 | 0.61 | -0.83 | 0.15 | -0.08 | -0.63 | 0.29 |
| Color a* | 0.14 | 0.42 | -0.84 | 0.19 | -0.48 | 0.29 | -0.46 | 0.57 | -0.03 | -0.33 | 0.29 | -0.67 |
| Color b* | -0.86 | 0.67 | -0.07 | *-1.00 | 0.16 | 0.75 | -0.28 | 0.41 | -0.20 | 0.44 | 0.51 | 0.45 |

* Significant correlations at 5 % of probability, mean values by cultivar, without considering storage time. Where: ALTER= *Alternaria* spp.; ASP= *Aspergillus* spp.; BS= *Bipolaris sorokiniana;* FG=*Fusarium graminearum;* FSP= *Fusarium* spp.; PEN= *Penicillium* spp.; TG= tombstone grains; FB1= fumonisina B1; DON= deoxynivalenol; ZEA= zearalenona; ERG= ergosterol; Aw= water activity; TW – test weight; TKW – thousand kernel weight; GFN – grain falling number; GMC – grain moisture content; FFN – flour falling number; FMC – flour moisture content; EXT – flour extraction or flour yield; T – tenacity; E – extensibility; SI – swelling index; W – gluten strenght; T/E –tenacity/ extensibility ratio; EI – elasticidade index; HI – hardness index; Color L* – lightness; Color a* – red/green color, and Color b* – yellow/blue color.

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