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Corn grain quality at different harvesting times[1]

Qualidade de grãos de milho em diferentes épocas de colheita

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HIGHLIGHTS:

Unsatisfactory grain yield results for corn are associated with longer delays before grain harvesting.
Significant lipid and protein losses occurred as the grains dried naturally in the field.
Delaying harvesting for 28 days promotes significant changes in the lipid quality of the grain.

ABSTRACT: Harvesting time is one of the main factors that influences grain quality, largely due to their exposure to biotic and abiotic factors during pre-harvest. As such, this study aimed to assess corn grain quality in response to different harvesting times in the municipality of Campo Novo do Parecis, Mato Grosso state, Brazil. A randomized block design was used with a strip-plot scheme, consisting of three corn hybrids (NS90 PRO, NS92 PRO 2 and BG7439), five harvesting times (0, 7, 14, 21 and 28 days after physiological maturity - DAPM), with three repetitions. The variables grain yield, 1000 grain weight, bulk density, electrical conductivity and proximate composition were analyzed at each of the proposed harvesting times and lipid composition was assessed only at 0 and 28 DAPM. Data were submitted to ANOVA, regression analysis and Tukey's test ($p \leq 0.05$). Delayed harvesting influenced all the variables studied, except ash concentration. The longer the grains remain on the plant after physiological maturity, the worse the grain yield and their physical, chemical and nutritional quality.

Key words: *Zea mays*, delayed harvesting, nutritional quality, physiological maturity

RESUMO: A época de colheita é um dos principais fatores que influenciam na qualidade dos grãos, sobretudo pela sua exposição aos fatores bióticos e abióticos na pré-colheita. Assim, objetivou-se avaliar a qualidade de grãos de milho em resposta às diferentes épocas de colheita no município de Campo Novo do Parecis, MT, Brasil. O delineamento experimental foi o de blocos casualizados em esquema de faixas, com três híbridos de milho (NS90 PRO, NS92 PRO 2 e BG7439), cinco épocas de colheita (0, 7, 14, 21 e 28 dias após maturidade fisiológica dos grãos - DAMFG) e três repetições. As variáveis produtividade de grãos, massa de mil grãos, massa específica aparente, condutividade elétrica e composição centesimal foram analisadas em cada uma das épocas de colheita propostas e a composição lipídica foi avaliada apenas em 0 e 28 DAMFG. Os dados foram submetidos à ANOVA, análise de regressão e teste de Tukey ($p \leq 0,05$). O atraso na colheita influencia todas as variáveis avaliadas, exceto para os teores de cinzas. Quanto maior o período de permanência dos grãos na planta, após a maturidade fisiológica dos grãos, piores são os resultados de produtividade de grãos, de qualidade física, química e nutricional dos grãos de milho.

Palavras-chave: *Zea mays*, atraso na colheita, qualidade nutricional, maturidade fisiológica

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INTRODUCTION

Corn (*Zea mays* L.) is the second most widely produced crop in Brazil, with estimated production of 100.6 million metric tons in the 2019/2020 growing season over an area of 18.4 million ha. In addition to its economic relevance due to the amount produced, its importance lies in its versatility, especially for human and animal consumption, given its favorable protein and carbohydrate composition and lipid profile rich in fatty acids (TACO, 2011; CONAB, 2020a).

However, the quality of agricultural products is governed by genetic and particularly non-genetic factors, primarily those related to crop treatments during development in the field, harvesting and storage (Weber, 2005; Panison et al., 2016). Among these factors, delayed harvesting influences post-harvest grain quality and directly affects agronomic performance (Panison et al., 2016) as well as the microbiological quality of corn grains (Costa et al., 2018).

Despite the importance of delayed harvesting for these variables, studies on the topic are scarce. Panison et al. (2016) observed more significant grain yield losses, higher lodging indices and more broken plants in response to delayed corn harvesting. Additionally, Kaaya et al. (2005) and Costa et al. (2018) reported significant increases in fungi, insect-related damage and pathogenic mycotoxins as result of the same practice. Although there are several studies on harvesting practice for corn crops, none have investigated the effect of delayed harvesting on the chemical and nutritional composition of these plants. As such, future research in this regard could contribute to defining new harvesting strategies aimed at obtaining better quality products with higher added value. Considering the above, the aim of this study was to assess the effect of delayed harvesting on the physical, chemical and nutritional quality of corn grains.

MATERIAL AND METHODS

The experiment was conducted from March to August 2017 in the experimental area of the Federal Institute of Education, Science and Technology of Mato Grosso, in Campo Novo do Parecis, Mato Grosso state (MT), Brazil (13° 40’ 41” S and 57° 53’ 31” W, at 569 m above sea level). According to the Köppen-Geiger classification (2017), the predominant climate in the region is Aw, characterized as wet tropical with well-defined wet and dry seasons, recording average annual rainfall of 1,945 mm. Cumulative rainfall during the study period was around 920 mm, meeting the water needs of the crop of 500 to 700 mm, and evenly distributed over the cycle (Köppen & Geiger, 2017).

The soil in the experimental area was classified as Oxisol, with a slightly undulating relief and good drainage. Its initial chemical characterization at 0 to 0.20 m deep was pH ($CaCl^2$) = 5.0; OM = 35.8 mg dm^{-3}; P = 6.1 mg dm^{-3}; K = 92 mg dm^{-3}; Ca = 2.5 $cmol_c\ dm^{-3}$; Mg = 1.9 $cmol_c\ dm^{-3}$; H + Al = 4.6 $cmol_c\ dm^{-3}$ and V% = 45.

The agronomic history of the area consists of succession cropping of soybean (main crop) and corn (off-season - 2nd crop).

The corn hybrids used were NS90 PRO, NS92 PRO 2 and BG7439, with a semi-precocious cycle of approximately 138 days. Planting was performed on March 10, 2017, targeting a final population of 60,000 plants ha^{-1}.

A randomized block design was used, with a strip-plot arrangement consisting of three hybrids and five harvesting times, with three repetitions, totaling 45 plots measuring 3.15 × 7 m (22.05 m^2) with three plants per linear meter. Planting was performed using a seeder programmed for row spacing of 0.45 m, under a no-till system, preceded by weed desiccation onsite with 2 L ha^{-1} of Atrazine. Base dressing (300 kg ha^{-1} of 10-30-20 formulation {N-P_2O_5-K_2O}) and crop treatments (topdressing, monitoring and control of insect pests, diseases and post-emergent weeds) were applied according to the technical recommendations for corn.

The two center rows of each plot were considered the study area, disregarding 0.5 m on either end of each row. The grains were collected manually at physiological maturity (zero day), defined as reproductive stage R6 and characterized by the formation of a black layer at the tip of 50% or more of the grains, and at 7, 14, 21 and 28 days after physiological maturity (DAPM), and then stored at 10 °C until analysis.

Grain yield (GY) was determined according to the method proposed by Dalchiavon et al. (2016), after correcting grain moisture content to 13% (w.b.) (Eq. 1), and the results expressed in kg ha^{-1} (Silva & Dalchiavon, 2020).

$$GY = \frac{M\left(100 - Uob\right)}{\left(100 - Ud\right)} \tag{1}$$

where:

GY - corrected grain yield;
M - grain mass after harvest;
Uob - observed moisture in each plot (%); and,
Ud - desired moisture as standard (13%).

Bulk density (BD) was determined by placing the grains in a container of known volume, measuring their respective mass on a semi-analytical balance (1 mg) and dividing it by the volume, with the result expressed in kg m^{-3}. Determination of 1000 grain weight (1000-GW) was in line with the procedures described by the Regras para Análise de Sementes (Brasil, 2009).

Electrical conductivity (EC) was analyzed in five replicates for each plot. Fifty grains were weighed on a precision balance (1 mg), placed in 200 mL plastic cups containing 75 mL of deionized water and kept in a biochemical oxygen demand (B.O.D) incubator at 25 °C for 24 hours. After imbibing, electrical conductivity was measured using a conductivity meter and the results expressed in μS cm^{-1} g^{-1} (Carvalho et al., 2009).

The proximate composition, protein and ash concentrations were determined in line with the methodologies of the Association of Official Analytical Chemists (AOAC, 2016); moisture content using the oven method at 105 °C for 24 hours (Brasil, 2009); total lipids by cold extraction, as described by Bligh & Dyer (1959); and carbohydrates by subtracting the values obtained for moisture content, proteins, ash and lipids from 100. Analyses were performed in triplicate and the results expressed on a dry basis (d.b.).

The nutritional quality of the corn oils was determined by analyzing their fatty acid profile. To that end, the oils were esterified according to the methodology established by Hartman & Lago (1973). Aliquots (1 μL) of the methyl esters obtained were injected into an Agilent Technologies 7890A gas chromatograph and separated in an HP 88 capillary column (100 m × 0.25 mm id × 0.20 μm film) at an average linear velocity of 25.151 cm s^{-1} for the carrier gas (helium). Column temperature was set to 130 °C for 14 min and then increased to 230 °C at a rate of 3.0 °C min^{-1}. Additionally, a temperature of 260 °C was programmed for the injector and flame ionization detector (FID). The chromatograms were recorded on the equipment's software and fatty acids identified by comparing their average retention times with those obtained experimentally for fatty acid methyl ester standards (FAME Mix-37, Supelco), under conditions identical to those described previously. The results were expressed in grams of fatty acid per 100 g of oil (g 100 g^{-1}).

The data obtained from the physical analysis and chemical composition of the grains were submitted to analysis of variance and, when significant, to regression analysis for days after grain physiological maturity. Means for the proximate composition and the fatty acid profile of the oils were compared by Tukey's test at $p \leq 0.05$ using Sisvar 5.6 software (Ferreira, 2014).

RESULTS AND DISCUSSION

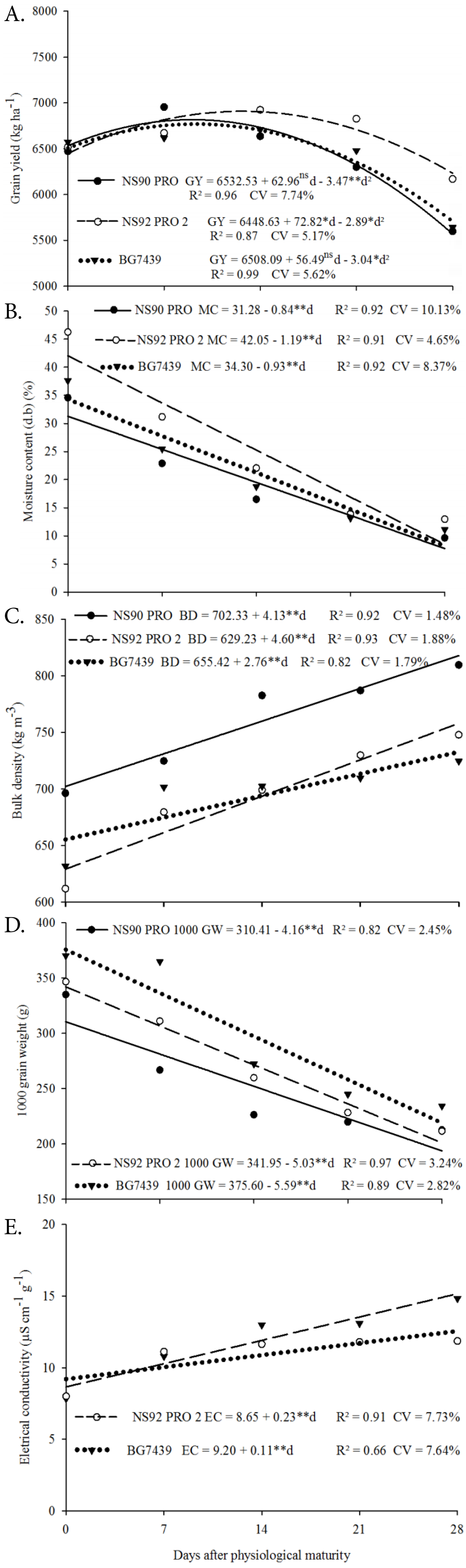
Table 1 presents analysis of variance and overall means for the quantitative and qualitative variables of corn grains. The overall mean obtained for grain yield [(grain yield - (GY)] was greater than that estimated by the Brazilian National Supply Company for the 2019-20 and 2020-21 growing seasons (CONAB, 2020b). Except for GY, protein and ash, there was a significant interaction between the days and hybrids studied for the remaining variables.

Days after physiological maturity had a significant effect ($p \leq 0.05$) on grain yield for all the hybrids studied (Figure 1A). Despite the decline in the values of this variable, for hybrid NS90 PRO this occurred at 7 DAPM and at 14 DAPM for the remaining hybrids. Initial (0 DAPM) and final (28 DAPM) grain yields were 6532.5; 6448.6; 6508.1 kg ha^{-1} and 5574.9; 6221.8; and 5707.1 kg ha^{-1}, respectively, for hybrids NS90 PRO, NS92 PRO 2 and BG7439, representing a decline of 14.65; 3.51; and 12.30% caused by delayed harvesting.

Table 1. Analysis of variance (F-values - coefficient of variation (%)) for the physical and chemical characteristics of corn grains harvested 0, 7, 14, 21 and 28 days after physiological maturity (DAPM)

Characteristics	Sources of variation		
	Days (D)	Hybrids (H)	D × H
Grain yield	5.47^{*} - 7.74	2.23^{ns} - 5.7	0.83^{ns} - 5.62
Bulk density	157.20^{**} - 1.48	120.60^{**} - 1.88	4.24^{**} - 1.79
1000 grain weight	637.49^{**} - 2.45	98.19^{**} - 3.24	13.6^{**} - 2.82
Electrical conductivity	24.55^{**} - 9.74	5.20^{ns} - 7.73	3.17^{*} - 7.64
Moisture content	235.85^{**} - 10.13	124.94^{**} - 4.65	4.82^{**} - 8.37
Protein	317.81^{**} - 2.39	35.03^{*} - 3.63	1.71^{ns} - 3.55
Lipids	122.81^{**} - 7.32	28.78^{**} - 8.53	3.69^{*} - 6.77
Ash	7.06^{**} - 4.74	0.27^{ns} - 5.31	0.39^{ns} - 7.50
Carbohydrates	302.42^{**} - 3.94	64.78^{**} - 2.46	4.84^{**} - 3.66

ns; **; * - Not significant, significant at $p \leq 0.01$ and at $p \leq 0.05$, respectively, according to the F-test



**; * - Significant at $p \leq 0.01$ and at $p \leq 0.05$, respectively, according to the F test

Figure 1. Grain yield (GY) (A), moisture content (B), bulk density (BD) (C), 1000 grain weight (1000-GW) (D), electrical conductivity (EC) (E) of corn grains as a function of days after physiological maturity

Moisture content declined (Figure 1B) while bulk density (Figure 1C) increased linearly as a function of days after physiological maturity. Significant variations ($p \leq 0.05$) in moisture content were observed in response to the different harvesting times (Figure 1B). Initial (0 DAPM) and final (28 DAPM) values were 34.58, 46.27, 37.63% and 9.29, 12.94, 11.13%, respectively, for hybrids NS90 PRO, NS92 PRO 2 and BG7439. From 0 to 14 DAPM, NS92 PRO 2 grains exhibited higher moisture contents ($p \leq 0.05$) than those obtained for the remaining hybrids, which did not differ (Table 2). The similarity ($p \geq 0.05$) between the hybrids in the subsequent time periods, as shown in Table 2, makes it possible to infer that the grains may have reached equilibrium moisture content with the study environment.

The average value obtained for hybrid NS90 PRO at 28 DAPM (818.00 kg m^{-3}) was 16.50% higher than that recorded at 0 DAPM (702.33 kg m^{-3}), with the lowest (11.82%) and highest (20.50%) percentage increases in BD recorded for NS90 PRO and BG7439, respectively. This finding corroborates the study by Oba et al. (2019), who reported increased yield values in cowpea (BRS Grariba) during drying. According to the authors, this is due to greater grain shrinkage in relation to water loss during drying. Additionally, Andrade et al. (2017) investigated the quality of harvested corn grains with different moisture contents and observed that BD was inversely proportional to moisture content, with values of 742.9 and 671.4 kg m^{-3} for 19 and 28.5% water, respectively.

In the present study, 1000-GW declined between 0 and 28 DAPM (Figure 1D), likely due to the typical metabolic and energy consumption changes that occurred as a result of delayed harvesting, confirmed by the significant effect (Table 1, Figure 1D) of time on reducing lipid and protein content in grains during the study period. This, in turn, influenced both grain weight and important seed physiological variables, such as vigor (Henning et al., 2010). A decline in 1000-GW was reported by Schuh et al. (2011) for off-season corn crops and attributed to grain deterioration associated with their intrinsic metabolism and microbial activity.

Initial (0 DAPM) and final (28 DAPM) 1000-GW values were 332.71 and 216.08 g for NS90 PRO, 350.16 and 209.11 g for NS92 PRO 2, and 383.40 and 226.75 g for hybrid BG7439, respectively (Figure 1D). Considering the physical characteristics related to grain size/weight for each hybrid, the highest 1000-GW was recorded for BG7439, since the same planting and management conditions were used for all the hybrids.

Regardless of the hybrid, EC rose as harvesting time increased (Figure 1E), with 9.2, 8.01 and 8.2 μS cm^{-1} g^{-1} at 0 DAPM and 14.83, 11.97 and 11.86 μS cm^{-1} g^{-1} at 28 DAPM for NS90 PRO, NS92 PRO 2 and BG7439, respectively. Electrical conductivity can be used to determine seed vigor because it establishes a direct relationship between the number of ions leached into the solution and plasma membrane integrity, since damaged membranes release more electrolytes (Paraginski et al., 2015).

In this case, the gradual rise in EC (Figure 1E) is related to degradation of the plasma membrane of grains due to defects typically caused by biotic and abiotic agents. Hypotheses along these lines have been confirmed in coffee beans, whose EC values were strongly associated with the severity of bean defects (normal beans < green < insect damaged > sour) (Malta et al., 2005). Similarly, storage and drying temperature, planting and harvesting times, moisture content, time between harvesting and drying and solar radiation index were found to have a strong influence on the physiological quality of corn and rice, expressed by EC (Paraginski et al., 2015; Venske et al., 2015).

Based on these values, the corn hybrids were deemed to have achieved optimal moisture content for harvesting (12 to 13% w.b.) only at 28 DAPM (Table 2); according to Schuh et al. (2011), this ideal level ensures the hygroscopic balance of corn grains during storage.

However, it is important to note that, in addition to a decline in physical quality, environmental exposure can cause chemical and nutritional losses in corn grains due to consumption of energy reserves during metabolic activities, as demonstrated in a previous study (Paraginski et al., 2015). As such, it is not advisable to wait for the moisture content of grains to decline naturally in the field before harvesting them (Kaaya et al., 2005; Weber, 2005; Panison et al., 2016).

Significant losses ($p \leq 0.05$) in protein concentration were observed from 0 DAPM (9.16, 9.69 and 8.47%) to 28 DAPM (6.61, 6.47 and 6.04%), respectively, for hybrids NS90 PRO, NS92 PRO 2 and BG7439, corresponding to a loss of approximately 27.83, 33.23 and 28.77% (Figure 2A).

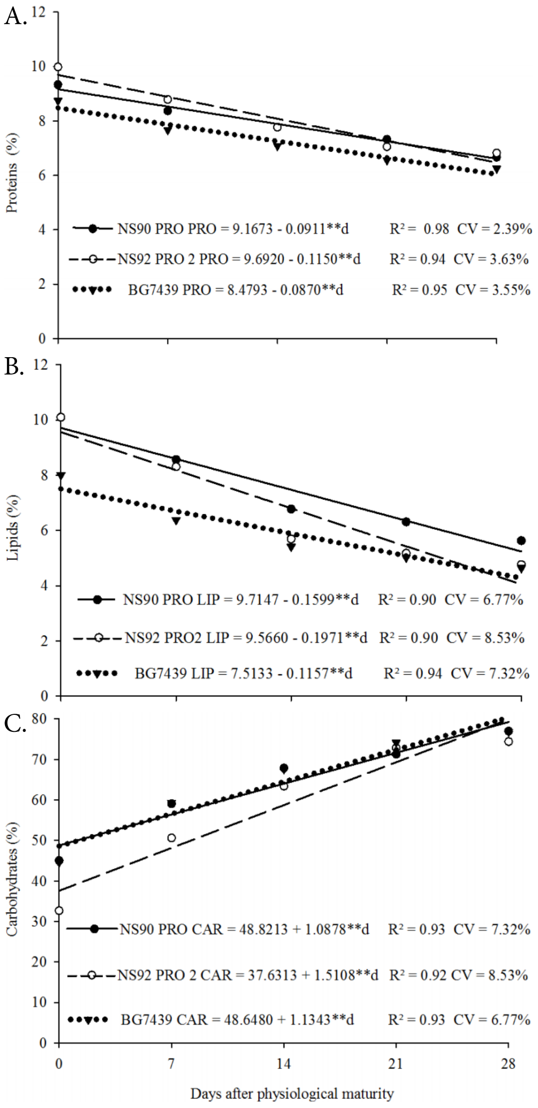
Conversely, Andrade et al. (2017) obtained protein concentration reduction of only 1% in wet (19 to 28%) and dried corn grains 10 days after harvesting. Harvesting wet corn grains followed by artificial drying may therefore be an important strategy to avoid compromising their nutritional quality.

In general, the results obtained are consistent with the Tabela Brasileira de Composição de Alimentos (TACO, 2011),

Table 2. Interaction between harvesting times × hybrids for mean bulk density (BD), 1000 grain weight (1000-GW), electrical conductivity (EC), moisture content, lipids and carbohydrates in corn grains harvested 0, 7, 14, 21 and 28 days after physiological maturity (DAPM)

Characteristics	Hybrids	Harvesting time				
		0	7	14	21	28
BD (kg ha^{-1})	NS90 PRO	696.30 a	724.85 a	782.80 a	787.16 a	809.73 a
	NS92 PRO 2	611.96 b	679.60 b	699.11 b	729.99 b	748.03 b
	BG7439	632.00 b	701.69 ab	702.52 b	709.88 b	724.77 b
1000-GW (kg m^{3})	NS90 PRO	334.98 a	266.75 c	226.27 b	219.84 b	212.64 b
	NS92 PRO 2	346.54 a	311.01 b	25968 a	228.32 b	211.56 b
	BG7439	370.12 a	364.83 a	272.31 a	244.85 a	234.30 a
EC (μS cm^{-1} g^{-1})	NS90 PRO	8.95 a	11.82 a	11.87 a	11.90 a	11.97 b
	NS92 PRO 2	7.84 a	10.80 a	11.99 a	13.10 a	14.84 a
	BG7439	8.00 a	11.12 a	11.64 a	11.80 a	11.86 b
Moisture contente (%)	NS90 PRO	34.58 b	22.90 b	16.49 b	13.94 a	9.62 a
	NS92 PRO 2	46.27 a	31.17 a	22.05 a	13.88 a	12.94 a
	BG7439	37.63 b	25.48 b	18.78 b	13.16 a	11.13 a
Lipids (%)	NS90 PRO	10.10 a	8,57 a	6.78 a	6.31 a	5.63 a
	NS92 PRO 2	10.09 a	8.31 a	5.70 b	5.17 b	4.76 ab
	BG7439	8.01 b	3.38 b	5.41 b	5.01 b	4.64 b
Carbohydrates (%)	NS90 PRO	45.03 a	59.06 a	67.88 a	71.29 a	76.99 a
	NS92 PRO 2	32.64 b	50.61 b	63.40 a	72.85 a	74.40 a
	BG7439	44.59 a	59.35 a	67.65 a	74.18 a	76.88 a

Means followed by the same letter in the columns do not differ according to Tukey's test at $p \leq 0.05$



** - Significant at $p \leq 0.01$ according to the F test

Figure 2. Protein (A), lipid (B) and carbohydrate (C) concentrations of corn grains in function of days after physiological maturity

which stipulates 7.2% protein in 100 g of corn containing 11% water, since the average moisture content for the hybrids varied from 7.33 to 8.47% at 28 DAPM for protein concentration between 6.04 and 6.61%, and the overall mean recorded in this study was 7.74%.

These results are also similar to those reported by Tsukahara et al. (2016), who attributed the decline in soybean quality to the seed respiration process. According to the authors, the later the harvesting time, the longer the crop remains in the field and the more susceptible plants become to pests, diseases and other damage, severely affecting the physical and chemical characteristics of the grains.

In regard to lipids (Figure 2B), delayed harvesting resulted in a significant decline ($p \leq 0.05$) in lipid concentration. An average reduction of approximately 52.60% was observed for hybrids NS90 PRO and NS92 PRO 2, whose lipid concentrations were similar ($p \geq 0.05$) at 0 and 28 DAPM (Table 2). At the end of the same period, BG7439 exhibited a 42.07% decrease in lipid concentration (Table 2). Delayed harvesting, particularly for grains with a high moisture content, makes them highly susceptible to chemical and biological changes due to deterioration and consumption of energy reserves, which compromises grain yield as a function of time until harvesting (Weber, 2005; Panison et al., 2016).

By contrast, Schuh et al. (2011) studied the quality of off-season corn grains harvested wet (31.88%) and immediately dried (13.39 to 15.70%) in a drying silo with ambient and heated natural air and found far smaller lipid content reductions (8.37 to 18.36%) after six months of storage than those observed here.

The regression models for ash were not significant (NS90 PRO - ash = $1.1020 + 0.0043^{ns}d$, $R^2 = 0.48$; NS92 PRO 2 - ash = $1.0593 + 0.0005^{ns}d$, $R^2 = 0.24$; BG7439 - ash = $1.0593 + 0.0016^{ns}d$; $R^2 = 0.42$).

Among other chemical constituents of corn, the mineral component represented by ash content exhibited the smallest variation in total content after harvesting. According to Schuh et al. (2011), the metabolic activity of grains and associated microorganisms consumes organic matter, metabolizing it into CO_2, water, heat and other products, thereby structurally altering the mineral composition without changing its total content.

The results obtained for carbohydrates (Figure 2C) indicated a significant variation ($p \leq 0.05$) between different harvesting times. According to the literature, the rise in carbohydrate concentration is a virtual apparent or relative increase, since it occurs due to the decline in moisture, ash, proteins and lipids during delayed harvesting (Schuh et al., 2011). Comparison of the carbohydrate values between hybrids at the same harvesting time indicated that only hybrid BG7439 differed significantly ($p \leq 0.05$) (Table 2), exhibiting a higher carbohydrate concentration for lower protein and lipid values. This is largely due to the characteristics of this conventional hybrid, which was significantly damaged during the study and is not resistant to insect attack, one of the contributing factors to varying proximate composition.

With respect to lipid quality, the lipid profiles of corn oil are favorable to health, containing predominantly polyunsaturated fatty acids (average of 49.24 g 100 g^{-1} of oil), followed by monounsaturated fatty acids (33.09 g 100 g^{-1} oil) (Table 3).

Among saturated fats, harvesting at 28 DAPM influenced the 4.64 and 3.05% decline in saturated fat content in NS90 PRO and BG7439 grains, respectively, with a more significant effect on the result obtained for palmitic acid in the latter hybrid (Table 3).

Similarly to the stability of palmitic acid content in NS92 PRO 2, the stearic acid content of corn grains analyzed at physiological maturity (0 DAPM) remained unchanged up to 28 DAPM (Table 3). Stearic acid is a saturated fatty acid whose properties tend to benefit oxidation stability, exhibiting lower losses for delayed harvesting, as expected.

Oleic acid content increased slightly in NS92 PRO 2 grains harvested at 28 DAPM (Table 3). However, these losses (4.94%) represent an important decline in grain quality, particularly because of the relevance of this monounsaturated fatty acid to human health due to its cardioprotective properties and beneficial effects on serum lipid levels and blood pressure

Table 3. Fatty acid profile ($g\ 100\ g^{-1}$ of oil) of corn grains harvested at 0 and 28 days after physiological maturity (DAPM)

Fatty acids	Hybrids					
	NS90 PRO		NS92 PRO 2		BG7439	
	0 days	28 days	0 days	28 days	0 days	28 days
Saturated	13.57 a	12.94 b	12.74 a	12.05 a	14.70 a	14.14 b
Palmitic acid C16:0	11.67 a	11.16 a	10.95 a	10.28 a	12.46 a	12.08 b
Stearic acid C18:0	1.91 a	1.77 a	1.79 a	1.76 a	2.24 a	2.06 a
Monounsaturated	34.30 a	33.43 a	34.63 a	32.92 b	31.97 a	30.74 a
Oleic acid C18:1	34.30 a	33.43 a	34.63 a	32.92 b	31.97 a	30.74 a
Polyunsaturated	47.73 a	49.23 a	48.22 a	50.63 a	48.93 a	50.70 a
Linoleic acid C18:2	46.83 a	48.18 a	47.00 a	49.15 a	47.81 a	49.36 a
Alpha-linoleic acid C18:3	0.90 b	1.05 a	1.22 b	1.49 a	1.12 a	1.34 a

Means followed by the same letter in the columns, do not differ according to Tukey's test at $p \le 0.05$

(Gillingham et al., 2011). Unlike NS92 PRO 2, oleic acid content remained unchanged in hybrids NS90 PRO and BG7439 during the study period (Table 3), similarly to the findings of Paraginski et al. (2015), who studied the quality of corn grains stored for 12 months at different temperatures and observed no reduction in oleic acid content.

However, it is important to note that, for three of the five harvesting times assessed (0, 7 and 14 DAPM), moisture content was higher ($p \le 0.05$) (Figure 1B) for NS92 PRO 2 than in the other hybrids, possibly compromising the lipid quality of the oil.

The linoleic acid composition of all the hybrids remained unchanged ($p \ge 0.05$) up to 28 DAPM, which is a relevant chemical and nutritional finding given the compound's importance for different functions in the human body, such as combating high cholesterol and preventing cardiovascular disease (Gillingham et al., 2011; Paraginski et al., 2015). Unlike oleic acid, grain quality increased in hybrids NS90 PRO and NS92 PRO 2, expressed by the 16.66% rise in alpha linolenic acid content up to the end of the study period (Table 3). A consistent explanation for this fact is that the synthesis and accumulation of substances in grains does not stop completely even after reproductive stage R6, and particularly due to the formation of a black film on 50% or more of the grains, which in this study is only suggestive of complete physiological maturity.

CONCLUSIONS

1. Delaying harvesting after physiological maturity promotes significant changes in the physical quality of corn grains, causing yield losses.
2. Delayed harvesting significantly compromises the chemical and nutritional quality of corn grains due to their exposure to environmental factors.
3. Delaying harvesting until 28 days after physiological maturity affects the lipid quality of grains. The decline in total saturated fatty acids and rise in polyunsaturated fatty acid concentration, particularly alpha linoleic acid, which is essential to human health, vary in accordance with the corn hybrid used.

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