Journal of Agricultural Science; Vol. 12, No. 1; 2020
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Technological Quality of Dual-purpose Wheat Submitted to Successive Defoliations

Giselle R. Rodolfo[1], Clovis A. Souza[1], Luiz C. Gutkoski[2] & Deivid L. V. Stefen[1]

[1] Department of Agronomy, Faculty of Agronomy, Santa Catarina State University, Lages, Brazil

[2] Department of Food Science, Faculty of Agronomy, Passo Fundo University, Passo Fundo, Brazil

Correspondence: Clovis A. Souza, Department of Agronomy, Faculty of Agronomy, Santa Catarina State University, Lages, Brazil. Tel: 55-49-3289-9189. E-mail: souza_clovis@yahoo.com.br

Received: August 18, 2019 Accepted: October 20, 2019 Online Published: December 15, 2019

doi:10.5539/jas.v12n1p95 URL: https://doi.org/10.5539/jas.v12n1p95

Abstract

Defoliation may interfere in the sink-source relationship and influence grain production and the respective technological quality of wheat flour, particularly in cultivars with potential as forage and in subsequent grain production. This study aimed to determine the effects of plant cutting heights and number of cuttings on the technological wheat flour quality of BRS Umbu and BRS Tarumã cultivars. A completely randomized design with four repetitions was used and treatments consisted of a combination of cutting heights (20 and 30 cm) and number of cuttings (no cutting, 1, 2 and 3 cuttings), resulting in the following treatments: 20/1, 20/2, 20/3 30/1, 30/2, 30/3 and controls with no cuttings. Hectoliter weight, grain crude protein, tenacity: extensibility ratio, gluten strength, falling number and wet gluten were measured. Regardless of the cutting height used, and after defoliation, the variables exhibited higher values than in non-defoliated plants, with protein content increasing by 6 and 11.3% for the BRS Tarumã and BRS Umbu cultivars, respectively. As such, it can be inferred that defoliation does not negatively affect the technological quality of wheat flour grown in a dual-purpose system.

Keywords: flour quality parameters, leaf cuttings, *Triticum aestivum* L.

1. Introduction

Wheat is one of the most widely used cereals in human food, primarily as a source of protein, and for this reason it is necessary to understand the mechanisms that determine and influence the quality of the grains and flour components produced (Moore et al., 2016). The technological quality of wheat is influenced by genetic, environmental and crop management factors (Franceschi et al., 2009; Denčić et al., 2011; Freo et al., 2011). Thus, alterations such as defoliation undertaken in the vegetative and reproductive stages of crops may influence sink-source balance, reflecting in the amount and quality of the grains produced (Asseng et al., 2017).

Flour quality determines the industrial use of the final product (Mandarino, 1993; Denčić et al., 2011). The proteins present in wheat grains can be classified as those that form gluten (prolamins) and those that do not (globulins and albumins) (Hernández-Espinosa et al., 2015). As such, wheat quality depends on the amount and quality of these proteins (Pomeranz, 1973), primarily the gluten-forming variety, which accounts for 80% of total proteins in the grain (Torbica et al., 2007), consisting of gliadin and glutenin.

Most of the results reported in the literature that use management practices involved parceled doses of nitrogen fertilizers, the application of growth regulators and their effects on the technological quality of wheat (Penckowski, Zagonel, & Fernandes, 2010; Gutkoski et al., 2011; Pinnow et al., 2013; Stefen et al., 2015). Dual-purpose cereals provide animals with forage and later produce grains in the same crop (Mariani et al., 2012). However, there is a lack of information on the technological quality of the wheat produced in this system, especially using cutting height as a practical management tool and its results when applied to cultivars with different plant architectures and development cycles. Thus, the aim of this study was to determine the effects of cutting heights and number of plant cuttings on the technological quality of *Triticum aestivum* L. flour from BRS Umbu and BRS Tarumã cultivars.

2. Material and Methods

2.1 Plant Material, Study Site and Weather Conditions

To obtain the grains, the experiments were conducted in 2013 and 2014 with the BRS Umbu wheat cultivar (semi-late cycle and erect-cespitose growth habit) and in 2014 and 2015 using the BRS Tarumã cultivar (late cycle and prostrate-cespitose habit), in Lages, Santa Catarina (SC) state, Brazil (27°49′ south latitude, 50°20′ west longitude and altitude of 937 meters). Climatic data for the experimental period were obtained from the Weather Station of the Agricultural Research and Rural Extension of Santa Catarina (INMET/EPAGRI/CIRAM) in Lages, SC (Figure 1).

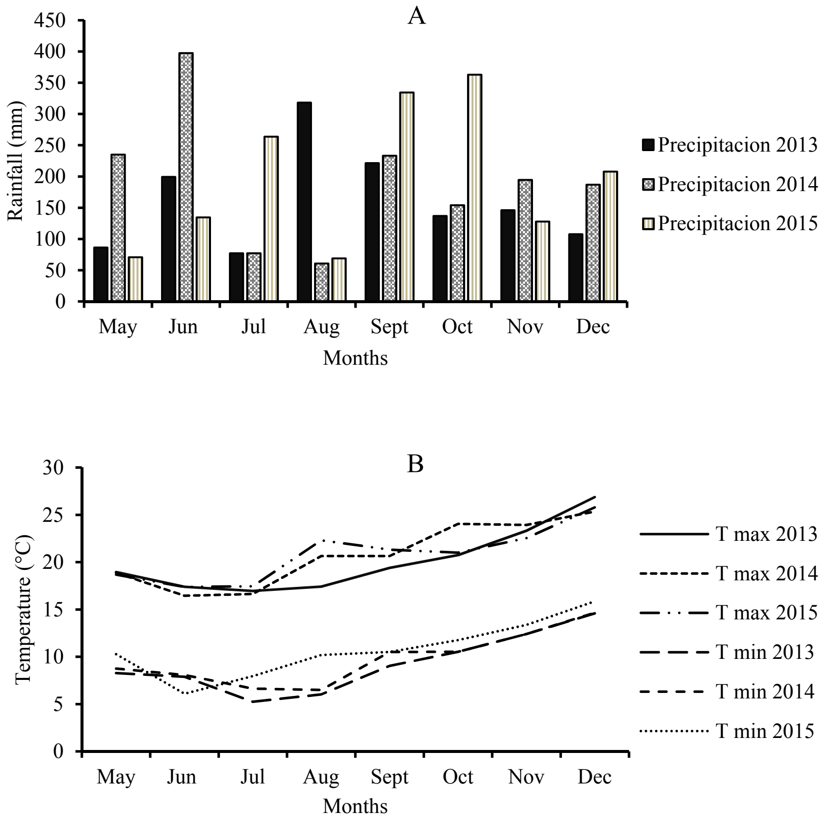

Figure 1. Climatic data of accumulated monthly rainfall (A) and average monthly temperatures (B) in the experimental period, in Lages, SC

2.2 Soil Characteristics

The soil in the experimental area was classified as argillaceous leptic aluminic humic cambisol (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 2013), and, according to soil analysis (0-20 cm layer), showed pH of water = 5.6; organic matter = 33 g kg^{-1}; P = mg dm^{-3} (Mehlich-1), K = 0.47 cmolc dm^{-3}; Ca = 4.5 cmolc dm^{-3}; Mg = 2.4 cmolc dm^{-3}, Al = 0.7 cmolc dm^{-3} and H+Al = 9.9 cmolc dm^{-3}.

2.3 Crop Management

Plant height was the criterion used for defoliations, namely 20 and 30 cm, in accordance with Fontaneli et al. (2009), Hastenpflug et al. (2011), Meinerz et al. (2012), and Martin et al. (2013). Defoliation intensity was 50% in relation to initial plant height, based on the intensities used by Mezzalira et al. (2014) in black oat (*Avena strigosa* Schreb.), corresponding to a residual height of 10 and 15 cm. In line with Meinerz et al. (2012) and Carletto, Neumann, Leão, Horst, and Askel (2015), up to three successive cuttings were made after plant regrowth. After defoliation, according to each treatment, cuttings were suspended to allow plants to proceed with their reproduction cycle and grain production. Weekly plants phenologic stage subjected to each treatment, was evaluated using the Zadoks scale (Zadoks et al., 1974).

The previous culture was soybean and a 5-20-10 (%) formulation of mineral fertilizer N-P_2O_5-K_2O was applied at sowing date, at a dose of 400 kg ha^{-1}. Urea was used as N source for topdressing, at a dose of 50 kg N ha^{-1} per application, applied in the tilling stage (phenological growing stage GS 21) and at the first visible node (GS 31) (Zadoks et al., 1974). After each cutting, was made an N fertilization, as the replenishment. When its replenishment fertilizing coincided with stage GS 31, it was performed alone without N topdressing preprogramed.

Sowing was performed using a plot seeder and plots consisted of five rows spaced 20 cm apart, with seeds planted 2 to 5 cm deep. A seeding density of 350 viable seeds per m^2 was used (Fontaneli et al., 2012). Each plot measured 6 m^2 and the experiment consisted of 32 plots per cultivar.

2.4 Treatments and Experimental Design

Treatments involved a combination of cutting heights (20 and 30 cm) and number of cuttings (no cuttings, 1, 2 and 3), resulting in the following: 20/1, 20/2, 20/3, 30/1, 30/2, 30/3 and controls without cuttings. A completely randomized design with four repetitions was used. Each cultivar was considered an independent experiment and analyzed separately.

2.5 Obtaining Samples and Evaluated Characteristics

Grains were harvested with a Wintersteiger plot combine. The grains were homogenized to form samples of each treatment and for use in laboratory analyses, which were conducted to the Passo Fundo University (UPF), UPF Cereal Laboratory, Rio Grande do Sul state, Brazil, applying the methodologies described below:

2.5.1 Hectoliter Weight

Determined according the rules for seed analysis (Brazil, 2009), using a Dalle Molle scale, with results expressed in kg 100 L^{-1}.

2.5.2 Crude Protein

Whole grain crude protein content was determined using an Infratec 1241 near-infrared reflectance spectrophotometer (NIRS) for wavelengths between 700 and 1100 nm, the near-infrared region. The results were expressed in percentage.

2.5.3 Alveography

The viscoelastic characteristics of wheat flour were determined in an NG Chopin alveograph (Villeneuve-la-Garenne Cedex, France), using method 54-30 of the American Association of Cereal Chemists (AACC,1999), which consists of weighing 250 g of flour and a volume of 129.4 mL of water, with correction of sample weight to 14% moisture basis. Gluten strength (W), which represents the necessary mechanical work to expand the bubble until rupture, expressed in 10-4J; tenacity (P), which is the maximum pressure required to expand mass, expressed in mm; extensibility (L), which indicates the maximum mass extension capacity without rupturing, expressed in mm; and tenacity/extensibility ratio (P/L), which expresses mass equilibrium (non-dimensional).

2.5.4 Falling Number

Was determined in wheat flour using a Perten Instruments 1500 falling number device, according to AACC method 56-81B (1999), using seven grams of sample, corrected for 14% of moisture. The results were expressed in seconds.

2.5.5 Wet Gluten

Was determined using a Glutomatic gluten tester, according to AACC method 38-12 (1999). The results were expressed in percentage.

2.6 Data Analysis

The growing seasons and cultivars were not considered factors for statistical analysis. The growing seasons were repeated to ensure reliable results; however, the aim was not to compare time or the different cultivars, but rather to obtain results for grains with different characteristics, such as growth habit. The data were submitted to analysis of variance (ANOVA) and the means compared using Tukey's test at 5% probability, applying the SAS® (Statistical Analysis System) software, version 9.0.

3. Results

Times in which the cuts were applied in plants, the subsequent anthesis and phonological stages helps to explain the results obtained (Table 1).

Table 1. Days after sowing (DAS) at wich cuttings are permormed and occured the anthesis and respectives phenological stages of dual-purpose BRS Umbu and BRS Tarumã cultivars as a funtion of plant cutting heights and number of cuttings, in two growing seasons

	20 cm			30 cm		
	DAS-cuttings	DAS-anthesis	Stage	DAS-cuttings	DAS-anthesis	Stage
BRS Umbu 2013						
Control	-	126	-	-	126	-
1 cutting	57	126	23	70	126	25
2 cuttings	70	133	25	91	141	31
3 cuttings	84	133	31	105	147	33
BRS Umbu 2014						
Control	-	120	-	-	120	-
1 cutting	50	120	23	63	120	25
2 cuttings	63	123	25	77	126	31
3 cuttings	70	123	27	85	133	32
BRS Tarumã 2014						
Control	-	126	-	-	126	-
1 cutting	56	126	23	91	126	28
2 cuttings	78	130	25	104	136	32
3 cuttings	85	130	27	111	143	33
BRS Tarumã 2015						
Control	-	136	-	-	136	-
1 cutting	73	136	25	89	136	28
2 cuttings	88	141	28	100	151	31
3 cuttings	96	144	31	109	158	33

For the first evaluated grain characteristic, the number of cuttings and height used influenced the crude protein (CP) levels of grains produced. Regardless of the cutting height used, protein content increasing with cuttings by 6 and 11.3% for the BRS Tarumã and BRS Umbu cultivars, respectively, in the average growing seasons (Table 2). For the two cultivars assessed, CP increased with the number of cuttings, with a tendency to present the highest level in the grains submitted to the three cuttings treatment. For BRS Tarumã in the 2015 growing season, have exhibited higher CP values in grains obtained from 30 cm high plants in all cuttings (Table 2). This result may have occurred because, in the 2015 crop, higher temperatures were recorded during the vegetative stage than in the other growing seasons (Figure 1). This could be related to accelerated plant growth, resulting in a shorter time period between the cuttings and nitrogen fertilizer replenishment, producing high-protein grains from plants grown to 30 cm. Thus, the highest CP value found was 17.4% and 19.2% for the BRS Umbu and BRS Tarumã cultivars, respectively, in the average growing seasons (Table 2).

Table 2. Grain crude protein (CP) (%) of dual-purpose wheat of BRS Umbu and BRS Tarumã cultivars, submitted to plant cutting heights and number of cuttings, in two growing seasons

Number of cuttings	Plant cutting heights (cm)					
	2013		Mean	2014		Mean
	20	30		20	30	
	CP BRS Umbu					
0	15.87 c A	15.77 c A	15.82	15.25 d A	15.10 c A	15.18
1	16.23 bc A	16.30 b A	16.27	16.20 c A	16.20 b A	16.20
2	16.30 b B	16.70 b A	16.50	16.35 b B	16.75 b A	16.55
3	17.17 a B	17.60 a A	17.38	17.00 a B	17.23 a A	17.12
Mean	16.39	16.59	16.49	16.30	16.22	16.26
CV (%)*	0.87			0.65		
F values**	0.0128			0.0008		
Number of cuttings	Plant cutting heights (cm)					
	2014		Mean	2015		Mean
	20	30		20	30	
	CP BRS Tarumã					
0	17.55 d A	17.50 d A	17.53	18.03 d B	18.67 c A	18.35
1	17.77 c A	17.75 c A	17.76	18.40 c B	18.87 b A	18.63
2	18.25 b A	18.20 b A	18.22	18.53 b B	18.87 b A	18.70
3	18.80 a B	19.10 a A	18.95	18.86 a B	19.27 a A	19.07
Mean	18.09	18.14	18.11	18.46	18.92	18.69
CV (%)*	0.34			0.29		
F value**	0.0003			0.0013		

Note. *CV: Coefficient of variation; **Means followed by the same letter, lowercase within column and uppercase within row, do not differ by Tukey test at 5% probability.

Hectoliter weight (HW) is used as the traditional measure for wheat commercialized in a number of countries and indirectly expresses grain quality. For the two cultivars and the two growing seasons, defoliation did not influence the HW of grains from plants cuts at a height of 20 cm. However, for 30 cm high plants, the HW of the grains increased with the number of cuttings, resulting 5.5 and 7.8% increase, respectively for BRS Umbu and Tarumã cultivars at 30/3 treatment concerning controls without cuttings, in the average growing seasons (Table 3).

Table 3. Hectoliter weight (kg. 100 L^{-1}) (HW) of dual-purpose wheat of BRS Umbu and BRS Tarumã cultivars, submitted to plant cutting heights and number of cuttings, in two growing seasons

Number of cuttings	Plant cutting heights (cm)					
	2013		Mean	2014		Mean
	20	30		20	30	
	HW BRS Umbu					
0	76.15 a A	75.15 c A	75.65	70.69 a A	69.68 b A	70.18
1	76.23 a A	75.19 c A	75.71	70.28 a A	69.63 b A	69.95
2	76.57 a A	76.65 b A	76.61	70.22 a B	71.98 ab A	71.10
3	75.96 a B	78.95 a A	77.46	69.32 a B	73.81 a A	71.56
Mean	76.23	76.48	76.35	70.13	71.27	70.70
CV (%)*	0.99			1.46		
F values**	< 0.0001			< 0.0001		
Number of cuttings	Plant cutting heights (cm)					
	2014		Mean	2015		Mean
	20	30		20	30	
	HW BRS Tarumã					
0	70.11 a A	71.29 bc A	70.70	61.49 a A	61.97 c A	61.73
1	69.04 a A	70.34 c A	69.69	61.29 a B	64.82 b A	63.05
2	67.69 a B	73.09 ab A	70.39	62.50 a B	66.39 ab A	64.44
3	69.19 a B	75.39 a A	72.29	62.29 a B	68.12 a A	65.20
Mean	69.01	72.52	70.77	61.89	65.32	63.61
CV (%)*	2.34			1.63		
F values**	0.0081			0.0005		

Note. *CV: Coefficient of variation; **Means followed by the same letter, lowercase within column and uppercase within row, do not differ by Tukey test at 5% probability.

For BRS Umbu, irrespective of cutting height, the P/L ratio increased with the number of cuttings (Table 4), along with a rise in grain protein and, for 2014 BRS Tarumã crop, the P/L ratio was higher only in the third cutting, likely due to the late cycle of this cultivar. In the 2015 growing season, only cutting effects on the P/L ratio, which were significant in the last cutting: 0.55 for the control; 0.57 for the first; 0.64 for the second and 0.79 for the third cutting.

Gluten strength (W) expresses the capacity of flour to withstand mechanical treatment when mixed with water (Tipples, Preston & Kilborn, 1982). For both cultivars, W increased with cuttings, resulting 25 and 70% increase, respectively for BRS Umbu and Tarumã cultivars at 30/3 treatment concerning controls without cuttings, in the average growing seasons and plant cutting heights (Table 4). Similar to the results of the P/L ratio, in the 2015 BRS Tarumã crop, cuttings only affected W, which was significant in the last cutting: 66.00 $10E^{-4}J$ for the control; 67.67 $10E^{-4}J$ for the first; 99.67 $10E^{-4}J$ for the second and 136.67 $10E^{-4}J$ for the third cutting.

Table 4. Tenacity/extensibility ratio (P/L) and gluten strength (W) ($10E^{-4}J$) of dual-purpose wheat of BRS Umbu and BRS Tarumã cultivars, submitted to plant cutting heights and number of cuttings, in two growing seasons

Number of cuttings	Plant cutting heights (cm)					
	2013		Mean	2014		Mean
	20	30		20	30	
	P/L BRS Umbu					
0	0.35 c A	0.38 c A	0.36	0.42 b A	0.41c A	0.41
1	0.43 b A	0.43 bc A	0.43	0.47 ab B	0.54 b A	0.50
2	0.49 a A	0.48 b A	0.49	0.48 a B	0.55 ab A	0.52
3	0.47 ab B	0.57 a A	0.52	0.52 a B	0.59 a A	0.55
Mean	0.44	0.46	0.45	0.47	0.52	0.50
CV (%)*	4.89			3.58		
F values**	0.0021			0.0017		
Number of cuttings	Plant cutting heights (cm)					
	2014		Mean	2015		Mean
	20	30		20	30	
	W BRS Umbu					
0	232.33 c A	237.33 d A	234.83	130.00 c A	132.67 d A	131.33
1	269.00 b A	265.33 c A	267.17	139.00 bc A	143.00 c A	141.00
2	267.00 b B	280.67 b A	273.83	147.67 b B	156.00 b A	151.83
3	282.67 a B	290.67 a A	286.67	160.67 a B	174.33 a A	167.50
Mean	262.75	268.50	265.63	144.33	151.50	147.92
CV (%)*	1.43			2.32		
F values**	0.0089			0.0448		
Number of cuttings	Plant cutting heights (cm)					
	2014		Mean	2014		Mean
	20	30		20	30	
	P/L BRS Tarumã			W BRS Tarumã		
0	0.47b A	0.48 b A	0.48	127.67 c A	126.00 d A	126.83
1	0.40 b A	0.40 b A	0.40	129.00 c B	153.67 c A	141.33
2	0.39 b B	0.47 b A	0.43	141.00 b B	191.00 b A	166.00
3	0.58 a B	0.80 a A	0.69	156.00 a B	276.00 a A	216.00
Mean	0.46	0.54	0.50	138.42	186.67	162.54
CV (%)*	8.12			2.92		
F values**	0.0007			< 0.0001		

Note. *CV: Coefficient of variation; **Means followed by the same letter, lowercase within column and uppercase within row, do not differ by Tukey test at 5% probability.

Situations predisposed to an increase in pre-harvest grain moisture may favor their germination while still on the spike, affecting the falling number (FN). The FN of wheat flour from BRS Umbu and BRS Tarumã cultivars increased with the number of cuttings, showing 15.5 and 31% increase, respectively for BRS Umbu and Tarumã cultivars at 30/3 treatment concerning controls without cuttings, in the average growing seasons and plant cutting heights (Table 5).

Table 5. Falling number (FN) (s) of dual-purpose wheat of BRS Umbu and BRS Tarumã cultivars, submitted to plant cutting heights and number of cuttings, in two growing seasons.

Number of cuttings	Plant cutting heights (cm)					
	2013		Mean	2014		Mean
	20	30		20	30	
	FN BRS Umbu					
0	262.00 c A	263.00 c A	262.50	204.67 b A	205.33 c A	205.00
1	293.00 b A	289.00 b A	291.00	218.00 ab A	217.67 b A	217.83
2	292.00 b A	292.00 b A	292.00	217.67 ab A	218.67 b A	218.17
3	302.00 a B	328.00 a A	315.00	220.00 a B	234.00 a A	227.00
Mean	287.25	293.00	290.13	215.08	218.92	217.00
CV (%)*	0.94			1.87		
F values**	< 0.0001			0.0224		

Number of cuttings	Plant cutting heights (cm)					
	2014		Mean	2015		Mean
	20	30		20	30	
	FN BRS Tarumã					
0	190.00 d A	194.00 d A	192.00	156.33 d A	156.67 d A	156.50
1	195.00 c B	210.67 c A	202.83	161.67 c B	165.33 c A	163.50
2	210.00 b B	220.00 b A	215.00	168.00 b B	174.67 b A	171.33
3	242.67 a B	285.00 a A	263.83	191.00 a B	199.33 a A	195.17
Mean	209.42	227.42	218.42	169.25	174.00	171.63
CV (%)*	1.25			0.99		
F values**	< 0.0001			0.0045		

Note. *CV: Coefficient of variation; **Means followed by the same letter, lowercase within column and uppercase within row, do not differ by Tukey test at 5% probability.

In both cultivars, wet gluten (WG) content rose with the number of cuttings, obtaining higher values at 30/3 treatment with 41.9 and 47.8% for the BRS Umbu and BRS Tarumã cultivars, respectively, as average data on growing seasons (Table 6).

Table 6. Wet gluten (WG) (%) of dual-purpose wheat of BRS Umbu and BRS Tarumã cultivars, submitted to plant cutting heights and number of cuttings, in two growing seasons

Number of cuttings	Plant cutting heights (cm)					
	2013		Mean	2014		Mean
	20	30		20	30	
	WG BRS Umbu					
0	39.03 ab A	37.95 b A	37.99	32.40 c A	32.41 d A	32.40
1	37.94 ab A	38.18 b A	38.06	34.30 bc A	34.83 c A	34.57
2	37.29 b B	40.88 a A	39.08	36.12 ab B	38.72 b A	37.42
3	41.24 a B	43.24 a A	42.24	38.04 a B	40.51 a A	39.27
Mean	38.62	40.06	39.34	35.21	36.62	35.92
CV (%)*	2.72			1.93		
F values**	0.0310			0.0088		
Number of cuttings	**Plant cutting heights (cm)**					
	2014		Mean	2015		Mean
	20	30		20	30	
	WG BRS Tarumã					
0	34.77 c A	34.64 c A	34.71	40.25 d A	40.19 d A	40.22
1	34.89 c A	34.45 c A	34.67	43.58 c B	50.11 c A	46.84
2	36.22 b B	37.49 b A	36.85	44.30 b B	52.48 b A	48.39
3	37.34 a B	41.62 a A	39.48	50.07 a B	53.98 a A	52.02
Mean	35.80	37.05	36.43	44.55	49.19	46.87
CV (%)*	0.86			0.37		
F values**	< 0.0001			< 0.0001		

Note. *CV: Coefficient of variation; **Means followed by the same letter, lowercase within column and uppercase within row, do not differ by Tukey test at 5% probability.

4. Discussion

Grain quality is influenced by factors such as genotype, management practices and environmental conditions (Nuttall et al., 2017). Thus, abiotic stresses such as defoliation that imply source restriction may cause changes in production and distribution of photoassimilates to the grains produced (Zhang et al., 2012). Grain CP content is the most important indicator of wheat grain quality (Litke, Gaile, & Ruža, 2018). Nitrogen fertilizer interferes with grain quality (Stefen et al., 2015), and late nitrogen applications, that is, near or during heading, increase grain protein content (Fuertes-Mendizábal et al., 2010). Although fertilizers were not applied late, and since most of the nitrogen used to synthesize protein in grains is absorbed until flowering, remaining stored in plant tissues for subsequent deposition (Gutkoski et al., 2011), nitrogen replenishment fertilizers may have increased grain protein content. In this work, fot both cultivars at 30/3 treatment the grain protein content was significantly higher ($p < 0.05$) (Table 2), since the crop was closer to the flowering stage (Table 1) due to replenishment fertilizing.The average increases in grain protein content were from 6.0 and 9.1% for 20 and 30 cm of the BRS Tarumã cultivar and 9.8 and 11.5% for 20 and 30 cm of BRS Umbu, higher than the 2.8% rise found by Birsin (2005) when the flag leaf was removed from wheat, compared to the control without defoliation.

The higher the HW, means the higher the commercial value of the product (Costa, Zucareli, & Riede, 2013), better grain maturation and richness with nutrients; more flour can be obtained from such grain during processing as well (Liniņa & Ruža, 2015). The rise in HW was a positive result, although the HW of the grains was lower than the value classifying wheat as type 1 (> 78 kg 100 L^{-1}) (Theago et al., 2014). The increase in the HW of grains from 30 cm high plants may be related to the application of replenishment nitrogen fertilizers nearer to the flowering stage and the prolonged crop cycle. The lower HW values found for the BRS Tarumã cultivar in 2015 are related to the rainfall regime during the grain filling period, since the lower solar radiation intensity associated with the wetting and subsequent drying of grains creates conditions that reduce hectoliter weight, due to the decline in grain density (Finney & Yamazaki, 1967) (Table 3).

Proteins that form gluten, gliadin and glutenin are related to extensibility (L) and tenacity (P), respectively (Guarienti, 1996). Rheological properties depend primarily on glutenin content (Ashraf, 2014). However, there must be mass equilibrium, expressing proportionality between P and L (P/L ratio), so that values associated with gluten strength (W) express good bread-making potential (Chen & D'appolonia, 1985). Gluten is responsible for mass formation, conferring the viscoelastic characteristic it exhibits. It is largely composed of the main proteins in wheat, gliadin and glutenin (Módenes, Silva, & Trigueros, 2009). Flour with P/L values of less than 0.60 are considered extensible gluten, between 0.61 and 1.20 balanced gluten and over 1.21 tenacious gluten (Guarienti, 1996). Balanced flour is ideal for bread making and tenacious flour for dried pasta (Módenes et al., 2009). Thus, in general, for both cultivars the flour can be classified as extensible gluten (Table 4). Abiotic stresses cause changes in the metabolism of plants and consequently influence the composition and quality of cereal grains (Ashraf, 2014). Therefore, in 2015 growing season, days with negative temperatures during the grain filling period were recorded, revealing cutting effects on the P/L ratio only for the flour from BRS Tarumã cultivar.

Concerning gluten strength, Gutkoski et al. (2011) found that the rise in N dose applied to the soil caused an increase in this trait. As stated earlier, replenishment nitrogen fertilizers may have resulted in an increase in grain protein content. Thus, a rise in gluten strength may be associated with an increase in protein content, which made the mass more resistant to mechanical work (Table 4).

Situations predisposed to an increase in pre-harvest grain moisture may favor their germination while still on the spike, affecting the falling number (FN). The FN determines alpha-amylase activity, which is responsible for hydrolyzing starch in the wheat grain during germination, possibly precluding the flour for industrial purposes (Mandarino, 1993). Falling number increase may be related to replenishment nitrogen fertilizing in the vegetative stage of the crop. A similar finding was reported by Stefen et al. (2015), where flour from grains that received nitrogen fertilizer in the vegetative stage displayed a higher FN value. Based on FN values, wheat grains can be classified as exhibiting high enzyme activity (< 200 s), ideal enzyme activity (201-350 s) and low enzyme activity (> 350 s) (Perten, 1964). As such, according to the treatments applied, BRS Umbu and Tarumã grains in general display ideal enzyme activity, without showing mass liquefaction or difficulty in the bread-making process (Table 5). In the 2015 growing season, higher rainfall in the harvest period (Figure 1) likely accounted for the increase in grain germination on the spike and decline in FN, classifying BRS Tarumã grains as exhibiting high enzyme activity (Table 5). Similar behavior was reported by Boschini et al. (2011), who observed a drop in FN values with a rise in water depth, demonstrating that lower alpha-amylase enzyme activity occurs at shallower depths.

The increase of the gluten content verified may be related to the increase in protein content (Table 6), since it is generally accepted that the protein content of wheat flour is closely related to gluten (Moraes, Gutkoski, & Elias, 2011). Pinnow et al. (2013) also found an effect of nitrogen fertilizer on the percentage of wet gluten in wheat grains. In this respect, the rise in gluten content formed a more cohesive and elastic mass, contributing to increased gluten strength.

Wheat is one of the most produced cereals in the world and although yields globally tend to increase, in many countries a yield stagnation is experienced (Hellemans et al., 2018), like in Brazil. In some countries like Australia (Sprague et al., 2018; Zeleke, 2019) uses dual-purpose wheat crop for greater flexibility in utilizing available feed or allowing for grain recovery, based on seasonal conditions or commodity prices (Newell & Hayes, 2017), in addition to others system benefits. Thus, this is a way to encourage the wheat production, however there is a lack of research about the plant use in this system and possible effects on technological grains quality.

5. Conclusions

Based on the results obtained, the cutting heights and number of cuttings used did not diminish the technological quality of wheat flour from grains produced by different growth habits and development cycles cultivars grown in a dual-purpose system. The grains from of plants cut at 30 cm resulted in higher protein values and consequently in the other flour variables analyzed, which, in addition to the nutritional benefits, improved the classification of wheat flour in terms of quality.

Acknowledgements

The authors would like to thank Brazilian institutions CNPq, CAPES/PROAP, FAPESC/UDESC/PAP, UDESC/PIC, UDESC/PROMOP and UNIEDU/Fumdes for providing financial support for this research and students, in addition to acknowledging CNPq Research Productivity Scholarship, for grants 306314/2015-0 and 460983/2014-8, on behalf of C.A.S. Authors' contributions: This work was carried out in collaboration among all authors. GRR and CAS designed the study, GRR, CAS and DLVS performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. LCG, GRR and CAS provided facilities and managed the

analyses of the study. GRR, CAS, LCG and DLVS managed the literature searches. All authors read and approved the final manuscript.

References

American Association Cereal Chemists. (1999). *Approved methods* (8th ed.). Saint Paul.

Ashraf, M. (2014). Stress-induced changes in wheat grain composition and quality. *Food Science & Nutrition, 54*, 1576-1583. https://doi.org/10.1080/10408398.2011.644354

Asseng, S., Kassie, B. T., Labra, M. H., Amador, C., & Calderini, D. F. (2017). Simulating the impact of source-sink manipulations in wheat. *Field Crops Research, 202*, 47-56. https://doi.org/10.1016/j.fcr.2016.04.031

Birsin, M. A. (2005). Effects of removal of some photosynthetic structures on some yield components in wheat. *Journal of Agricultural Science, 11*, 364-367. https://doi.org/10.1501/Tarimbil_0000000559

Boschini, A. P. M., Silva, C. L., Oliveira, C. A. S., Oliveira Júnior, M. P., Miranda, M. Z., & Fagioli, M. (2011). Quantitative and qualitative aspects of wheat grains influenced by nitrogen and water depth. *Revista Brasileira de Engenharia Agrícola e Ambiental, 15*, 450-457. https://doi.org/10.1590/S1415-43662011000500003

Brazil, Ministério da Agricultura, Pecuária e Abastecimento. (2009). *Regras para Análise de Sementes*. Brasília: MAPA.

Carletto, R., Neumann, M., Leão, G. F. M., Horst, E. H., & Askel, E. J. (2015). Effect of cut systems on production and quality of dual-purpose wheat grains. *Revista Acadêmica Ciência Animal, 13*, 125-133. https://doi.org/10.7213/academica.13.FC.AO13

Chen, J., & D'appolonia, B. L. (1985). *Alveograph studies on hard red spring wheat flour*. Cereal Foods World.

Costa, L., Zucareli, C., & Riede, C. R. (2013). Splitting of nitrogen fertilization on the yield performance of wheat genotypes. *Revista Ciência Agronômica, 44*, 215-224. https://doi.org/10.1590/S1806-66902013000200002

Denčić, S., Mladenov, N., & Kobiljski, B. (2011). Effects of genotype and environment on breadmaking quality in wheat. *International Journal of Plant Production, 5*, 71-82. https://doi.org/10.22069/ijpp.2012.721

Embrapa (Empresa Brasileira de Pesquisa Agropecuária). (2013). *Sistema Brasileiro de Classificação de Solos*. Brasília: Embrapa.

Finney, K., & Yamazaki, W. (1967). Quality of hard, soft and durum wheat's. In K. S. Qunsenberry & L. P. Reitz (Eds.), *Wheat and wheat improvement*. Madison: American Society of Agronomy.

Fontaneli, R. S., Fontaneli, R. S., Santos, H. P., Nascimento Júnior, A., Minella, E., & Caierão, E. (2009). Yield and nutritive value of dual purpose winter cereals: green forage, silage or grain. *Revista Brasileira de Zootecnia, 38*, 2116-2120. https://doi.org/10.1590/S1516-35982009001100007

Fontaneli, R. S., Santos, H. P., & Fontaneli, R. S. (2012). *Forrageiras para integração lavoura-pecuária-floresta na região sul-brasileira* (2nd ed). Passo Fundo: Embrapa Trigo.

Franceschi, L., Benin, G., Guarienti, E., Marchioro, V. S., & Martin, T. N. (2009). Pre-harvest factors that affect wheat technological quality. *Ciência Rural, 39*, 1624-1631. https://doi.org/10.1590/S0103-84782009005000060

Freo, J. D., Rosso, N. D., Moraes, L. B. D., Dias, A. R. G., Elias, M. C., & Gutkoski, L. C. (2011). Physicochemical properties and silicon content in wheat flour treated with diatomaceous earth and conventionally stored. *Journal of Stored Products Research, 47*, 316-320. https://doi.org/10.1016/j.jspr.2011.05.001

Fuertes-Mendizábal, T., Aizpurua, A., Gonzáles-Moro, M. B., & Estavillo, J. M. (2010). Improving wheat breadmaking quality by splitting the N fertilizer rate. *European Journal of Agronomy, 33*, 52-61. https://doi.org/10.1016/j.eja.2010.03.001

Guarienti, E. M. (1996). *Qualidade industrial de trigo*. Passo Fundo: Embrapa.

Gutkoski, L. C., Klein, B., Colussi, R., & Santeti, T. A. S. (2011). Effect of nitrogen fertilization on the technological characteristics of wheat. *Revista Brasileira de Agrociência, 17*, 116-122.

Hastenpflug, M., Braida, J. A., Martin, T. N., Ziech, M. F., Simionatto, C. C., & Castagnino, D. S. (2011). Dual-purpose wheat cultivars submitted to nitrogen fertilization and cutting regimes. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 63*, 196-202. https://doi.org/10.1590/S0102-09352011000100029

Hellemans T., Landshoot S., Dewitte K., Van Bockstaele F., Vermeir P., Eeckhout M., & Haesaert G. (2018). Impact of Crop Husbandry Practices and Environmental Conditions on Wheat Composition and Quality: A Review. *Journal of Agriculture and Food Chemistry, 66*, 2491-2509. https://doi.org/10.1021/acs.jafc.7b05450

Hernández-Espinosa N., Reyes-Reyes M., González-Jiménez F. E., Núñez-Bretón L. C., & Cooper-Bribiesca, B. L. (2015). The Importance of the Storage Proteins in Cereals (Prolamins). *Vertientes, 18*, 3-7.

Liniņa, A., & Ruža, A. (2015). *Influence of nitrogen fertilizer and meteorological conditions on winter wheat grain physical indices*. Proceedings of the Scientific and Practical Conference Harmonious Agriculture, Jelgava.

Litke, L., Gail, Z., & Ruža, A. (2018). Effect of nitrogen fertilization on winter wheat yield and yield quality. *Agronomy Research, 16*, 500-509. https://doi.org/10.15159/ar.18.064

Mandarino, J. M. G. (1993). *Aspectos importantes para a qualidade do trigo* (p. 32). Londrina: Embrapa-CNPSo.

Mariani, F., Fontaneli, R. S., Vargas, L., Santos, H. P. S., & Fontaneli, R. S. (2012). Double purpose wheat and oat pasture evaluation after perennial forage and summer crops in crop-livestock systems. *Ciência Rural, 42*, 1752-1757. https://doi.org/10.1590/S0103-84782012001000006

Martin, T. N., Storck, L., Benin, G, Simionatto, C. C., Ortiz, S., & Bertoncelli, P. (2013). Importance of the relationship between characters in dual purpose wheat in crop breeding. *Bioscience Journal, 29*, 1932-1940.

Meinerz, G. R., Olivo, C. J., Fontaneli, R. S., Agnolin, C. A., Horst, T., & Bem, C. M. (2012). Productivity of double-purpose winter cereals in the Depressão Central region of Rio Grande do Sul state. *Revista Brasileira de Zootecnia, 41*, 873-882. https://doi.org/10.1590/S1516-35982012000400007

Mezzalira, J. C., Carvalho, P. C. F., Fonseca, L., Bremm, C., Cangiano, C., Gonda, H. L., & Laca, E. A. (2014). Behavioural mechanisms of intake rate by heifers grazing swards of contrasting structures. *Applied Animal Behaviour Science, 153*, 1-9. https://doi.org/10.1016/j.applanim.2013.12.014

Módenes, A. N., Silva, A. M., & Trigueros, D. E. G. (2009). Rheological properties evaluation of stored wheat. *Ciência e Tecnologia de Alimentos, 29*, 508-512. https://doi.org/ 10.1590/S0101-20612009000300008

Moore, K. L., Tosi, P., Palmer, R., Hawkesford, M. J., Grovenor, C. R. M., & Shewry, P. R. (2016). The dynamics of protein body formation in developing wheat grain. *Plant Biotechnology Journal, 14*, 1876-1882. https://doi.org/ 10.1111/pbi.12549

Moraes, L. B. D., Gutkoski, L. C., & Elias, M. C. (2011). Constituintes do trigo e avaliação da qualidade do glúten pelo sistema glutomatic. In L. C. Gutkoski (Ed.), *Trigo: Segregação, tipificação e controle de qualidade*. Passo Fundo: Passografic.

Newell, M. T., & Hayes, R. C. (2017). An initial investigation of forage production and feed quality of perennial wheat derivatives. *Crop & Pasture Science, 68*, 1141-1148. https://doi.org/10.1071/CP16405

Nuttall, J. G., O'Leary, G. J., Panozzo, J. F., Walker, C. K., Barlow, K. M., & Fitzgerald, G. J. (2017). Models of grain quality in wheat—A review. *Field Crops Research, 202*, 136-145. https://doi.org/10.1016/j.fcr.2015.12.011

Penckowski, L. H., Zagonel, J., & Fernandes, E. C. (2010). Industrial quality of wheat as a function of trinexapac-ethyl and nitrogen doses. *Ciência e Agrotecnologia, 34*, 1492-1499. https://doi.org/10.1590/S1413-70542010000600020

Perten, H. (1964). Application of the falling number method for evaluating alpha-amylase activity. *Cereal Chemistry, 41*, 127-140.

Pinnow, C. G., Benin, G., Viola, R., Silva, C. L., Gutkoski, L. C., & Cassol, L. C. (2013). Baking quality of wheat in response to green manure and nitrogen rates. *Bragantia, 72*, 20-28. https://doi.org/10.1590/S0006-87052013005000019

Pomeranz, Y. (1973). From wheat to bread: a biochemical study. *American Scientist, 61*, 683-691.

Sprague, S. J., Kirkegaard, J. A., Bell, L. W., Seymour, M., Graham, J., & Ryan, M. (2018). Dual-purpose cereals offer increased productivity across diverse regions of Australia's high rainfall zone. *Field Crops Research, 227*, 119-131. https://doi.org/10.1016/j.fcr.2018.08.008

Stefen, D. L. V., Souza, C. A., Coelho, C. M. M., Gutkoski, L. C., & Sangoi, L. (2015). Nitrogen topdressing during heading improve the industrial quality of wheat (*Triticum aestivum* cv. Mirante) grown with plant growth regulator etyl-trinexapac. *Revista de la Facultad de Agronomía, 114*, 161-169.

Theago, E. Q., Buzetti, S., Teixeira Filho, M. C. M, Andreotti, M., Megda, M. M., & Benett, C. G. S. (2014). Nitrogen application rates, sources, and times affecting chlorophyll content and wheat yield. *Revista Brasileira de Ciência do Solo, 38*, 1826-1835. https://doi.org/10.1590/S0100-06832014000600017

Tipples, K. H., Preston, K. R., & Kilborn, R. H. (1982). *Implications of the term strength as related to wheat and flour quality*. Bakers Digest: Merrian.

Torbica, A., Antov, M., Mastilovic, J., & Knezevic, D. (2007). The influence of changes in gluten complex structure on thechnological quality of wheat (*Triticum aestivum* L.). *Food Research Internacional, 40*, 1038-1045. https://doi.org/ 10.1016/j.foodres.2007.05.009

Zadoks, J. C., Chang, T. T., & Konzak, C. F. (1974). A decimal code for the growth stages of cereals. *Weed Research, 14*, 415-421.

Zeleke, K. T. (2019). Effect of grazing time and intensity on growth and yield of spring wheat (*Triticum aestivum* L.). *Journal of Integrative Agriculture, 18*, 1138-1147. https://doi.org/10.1016/S2095-3119(18)62125-2

Zhang, Y., Zhang, Y., Liu, N., Su, D., Xue, Q., Stewart, B. A., & Wang, Z. (2012). Effect of source–sink manipulation on accumulation of micronutrients and protein in wheat grains. *Journal of Plant Nutrition and Soil Science, 175*, 622-629. https://doi.org/10.1002/jpln.201100224