Changes in Crude Protein and Fiber Contents of Small Grain Cereals for Forage over Time

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Key words: Crude protein; neutral detergent fiber; acid detergent fiber; flowering; dough stage development.

Abstract

Oat, triticale, wheat and barley are small grain cereals used as forage in many temperate Mexican regions. The objective was to determine crude protein and van Soest fiber contents of these forages cut at 80, 96, 108, 121, 138 and 153 days after seeding. Cultivars used were: Chihuahua (OC) for oat; Arne (TA), Bicentenario (TB) and Siglo XXI (TS) for triticale; Saturno (WS) for wheat; and San Marcos (BSM) for barley. Experiment was under greenhouse conditions from November 2015 to May 2016. Crude protein (CP), neutral (NDF) and acid (ADF) detergents fibers were determined on the forage harvested at each time. Statistical analysis was by linear regression with cultivar as a dummy variable (R^2=0.5843 to 0.6861), response variables were CP, NDF and ADF contents over days after seeding ($R^2 \geq 0.7693$), the model included first grade interaction. Models developed were compared based on the slopes calculated. First grade interaction was significant ($p<0.05$) in CP due to the pattern change in TS, and in NDF due to the pattern change in OC and in ADF due to the pattern change in TA. So that, individual models and coefficient confident intervals were developed for each species and cultivar to compare them and to declare similarities or differences at $p<0.05$. Overall, CP decreased ($p>0.05$) from 0.11 to 0.39; while NDF and ADF increased ($p>0.05$) from 0.60 to 1.10, and from 0.20 to 0.83 percentage units day^{-1} respectively. It was concluded that crude protein, neutral and acid detergent fiber contents in small grain cereals are not dependent on harvesting time when measured at development stages close to physiological maturity.

Introduction

Small grain cereals are a promising option to produce forage under rainfed conditions and to provide forage of good quality. Forage quality is a major consideration for farmers as it is related to how well they feed their livestock. Three forage quality measurements are mainly used to characterize forage quality of small grain cereals, these are crude protein, neutral and acid detergent fibers due to their effect on dry matter digestibility and intake (McDonald, *et al*., 2002). When harvesting small grain cereals as a forage source, farmers are mainly interested in the grain. However, it is possible to harvest small grain cereals from flowering to the dough development stage to get forage of good quality (Andesogan et al., 2002; Juskiw, *et al*., 2000; Khorasani *et al*., 1997).

The objective of this research was to describe quantitative changes in crude protein, neutral and acid detergent fiber contents in six small grain cereal entries with potential to be grown as forage crops as the time of harvest goes from the flowering to the dough development stage.

Methods and Study Site

The experiment was carried out in the greenhouse of the Animal Production Department of Universidad Autonoma Chapingo, Mexico from November 2015 to May 2016. Cereal entries were: Chihuahua (OC) for oat; Arne (TA), Bicentenario (TB) and Siglo XXI (TS) for triticale; Saturno (WS) for wheat; and San Marcos (BSM) for barley. Plant entries were grown in pots with two to three plants per pot. Six harvests were done: 80, 96, 108, 121, 138 and 153 days after sowing, material from three pots were collected at each harvest time. All plant material was dried at 55^0 C for 72 hours in a forced air flow oven, after drying plant material was ground to pass through a 1 mm screen. Crude protein, neutral and acid detergent fibers were determined. Statistical analysis was by linear regression to develop models that described quantitative changes in crude protein and fiber contents over time, cereal entries were taken as a categorical variable, general models were: $\boldsymbol{Y_{ijkl} = \beta_0 + \beta_{1i}X_i + \beta_{2i}D_i + \beta_{3j}(E * D)_j + \epsilon_{ijk}}$ (Myers, 1990). Regression coefficients were tested against a zero value.

Results

Crude protein content

The cereal entry x harvest time interaction was significant ($p<0.05$), crude protein content changed at a different rate with harvest time among the cereal entries (Table 1). Most of the linear models developed for each entry were not significant ($p>0.05$) indicating that there was no linear dependence of crude protein content with harvest time when cereal plants harvesting was done close to physiological maturity. Triticale cv Siglo XXI, showed the closest linear crude protein content change as time of harvest was delayed ($p<0.1$).

Table 1. Regression coefficients (b_0 and b_1) and determination coefficient (R^2) for linear models fitted (Pr> [t]) to determine changes in crude protein (%) in the forage of five small grain cereals over time.

Cereal entry	Intercept (b_o)	Regression coefficient (b_1)	Pr>[t]	R^2	Residual Square Sum
Oat cv Chihuahua	8.58 ± 2.243	-0.039 ± 0.018 [b]	0.1070	0.5177	5.20
Barley cv San Marcos	6.07 ± 1.372	-0.015 ± 0.011 [b]	0.2494	0.3062	1.94
Wheat cv. Cortazar	9.77 ± 1.754	-0.029 ± 0.014 [b]	0.1138	0.4961	3.18
Triticale cv Arne	5.86 ± 1.629	-0.011 ± 0.013 [b]	0.4673	0.1521	2.74
Triticale cv Bicentenario	4.46 ± 4.774	0.012 ± 0.040 [b]	0.7745	0.0234	23.58
Triticale cv. Siglo XXI	21.97 ± 6.638	-0.127 ± 0.055 [a]	0.0842	0.5630	45.60

Neutral and acid detergents fibers

The general trend was that NDF and ADF contents showed no linear relationship ($p>0.05$) with harvest time when cereals were cut close to physiological maturity; however, triticale cv Arne showed a linear relationship ($p<0.05$). The rate change for NDF ranged from 0.060 to 0.262 and for ADF from 0.020 to 0.150 ($p<0.05$), revealing little incremental changes in these fibers but not statistically significant as shown by the linear coefficient for the line slopes (Tables 2 and 3).

Table 2. Regression coefficients (b_0 and b_1) and determination coefficient (R^2) for linear models fitted (Pr> [t]) to determine changes in acid detergent fiber (%) in the forage of five small grain cereals over time,

Cereal entry	Intercept (b_o)	Regression coefficient (b_1)	Pr>[t]	R^2	Residuals square sum
Oat cv Chihuahua	25.24 ± 8.473	0.262 ± 0.071	0.0213	0.7693	74.29
Barley cv San Marcos	45.28 ± 11.624	0.110 ± 0.098	0.3238	0.2424	139.83
Wheat cv Cortazar	51.94 ± 7.218	-0.028 ± 0.060	0.6592	0.0552	53.92
Triticale cv Arne	35.76 ± 5.630	0.174 ± 0.047	0.0214	0.7745	32.8
Triticale cv Bicentenario	45.45 ± 4.716	0.060 ± 0.039	0.2017	0.368	23.01
Triticale cv Siglo XXI	45.89 ± 6.301	0.087 ± 0.053	0.1749	0.3993	41.08

Table 3. Regression coefficients (b_0 and b_1) and determination coefficient (R^2) for linear models fitted (Pr> [t]) to determine changes in neutral detergent fiber (%) in the forage of five small grain cereals over time.

Cereal entry	Intercept (b_o)	Regression coefficient (b_1)	Pr>[t]	R^2	Residual square sum
Oat cv Chihuahua	15.57 ± 5.352	0.150 ± 0.045	0.0289	0.7364	29.64

Barley cv San Marcos	24.39 ± 9.013	0.083 ± 0.076	0.3328	0.2307	84.07
Wheat cv Cortazar	25.49 ± 4.676	0.020 ± 0.039	0.6359	0.0608	22.63
Triticale cv Arne	17.54 ± 2.338	0.140 ± 0.019	0.0021	0.9282	5.66
Triticale cv Bicentenario	25.32 ± 2.960	0.049 ± 0.024	0.1191	0.5029	9.06
Triticale cv Siglo XXI	26.29 ± 4.357	0.053 ± 0.036	0.2182	0.354	19.64

Discussion

The crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) in the forage of small grain cereals harvested from flowering to dough development stages (GRDC, 2005) were not dependent on plant maturity as was expected (Andesogan et al., 2002; Juskiw, *et al*., 2000; Khorasani *et al*., 1997) which might be because there were little changes in morphological components (leaves to stem ratio) and physiological characteristics affecting CP negatively and NDF and ADF positively (dry matter accumulation and lignin content). This could be the reason that the models developed did not reveal differences on the rate of change for CP, NDF and ADF. The significant changes ($p<0.05$) in CP, NDF and ADF were caused by an interaction between cereal entry and harvest time when the amount of these chemical constituents in forage were dependent on plant maturity. This was detected for triticale cv Siglo XXI for crude protein ($p<0.10$) and for oat variety Chihuahua and triticale variety Arne for NDF and ADF ($p<0.05$). It is possible that these cereal entries underwent important changes in morphological and chemical composition. Overall crude protein content decreased by 3.28 percentage units (from 7.41 to 4.13%), but this was not enough to compute a significant regression coefficient. NDF and ADF overall increments were 9.1 (from 51.4 to 60.5%) and 18.9 (from 51.4 to 70.3%) percentage units, respectively. Based on the results of this research it seems that it is necessary to have a difference of 10 percentage units or greater to be associated with small grain cereal maturity to produce significant changes in CP, NDF and ADF when they are harvested from flowering to dough development stages.

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