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Genotype and Environment Effects on Oat β-glucan, Total Dietary Fiber and Antioxidant Activity

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INTRODUCTION

Availability of oat cultivars with high levels of β-glucan and total dietary fiber (TDF) is essential for oat millers and food processors to meet US health claims and benefit consumer health. Plant breeding programs have responded to this market need by selecting for higher levels of β-glucan and lower oil but further improvement in these traits and other nutritional characteristics will be assisted by identifying specific genotype (G), environment (E) and genotype-by-environment (GXE) interaction effects.

While previous GXE studies (Rhymer et al, 1999) indicated genotype was the predominant factor influencing β-glucan content for five oat genotypes grown in Manitoba, it is not known if this information can be applied to a wider range of germplasm and locations or if GXE effects for TDF follow the same trends as β-glucan. This ongoing study was undertaken to assess fiber components (β-glucan and TDF) in a larger sample set of 30 oat standard check varieties and genotypes selected for high β-glucan. Antioxidant activity was also measured to assess genotype differences in adapted germplasm and test a simple method of analysis which could be used to screen breeding samples.

MATERIALS & METHODS

13 to 30 Canadian oat genotypes were grown at 2 locations in Saskatchewan during 2004 and 2005 to assess the effects of G, E and GXE interaction on oat fiber levels. Oat samples were dehulled and resulting groats were milled into whole-meal flour using a Retsch mill equipped with a 0.5mm screen. β-glucan and TDF were measured in duplicate using AACC approved method 32-23 and AACC approved method 32-07, respectively. Antioxidant activity was measured in duplicate using a method described by Miller et al. (2000).

STATISTICAL ANALYSIS

Statistical analysis was performed using SAS software. Analysis of variance (ANOVA) tests were carried out using PROC GLM which considered G, E and GXE as fixed effects and duplicates within location as random. Variance components were estimated to gain a better understanding of the role played by each factor in the observed differences for TDF and β-glucan. Variance component analysis requires all effects be considered random. A set of 4 replicated samples were grown in 2005 to calculate plot to plot variation. The variance component estimates for field reps were very low, so duplicates were used to estimate difference between two plots of the same cultivar.

RESULTS

Mean β-glucan content ranged from 4.2 to 7.5 % while mean TDF was 11.45 to 16.2%. Figures 2 and 3 illustrate the variation among selected genotypes and environments for % β-glucan and TDF. Mean antioxidant activity ranged from 1257 to 1631 Trolox Equivalents/100g (data not shown). For high β-glucan genotypes over two years compared to a test of 30 diverse genotypes grown in one year at two locations.

Significant correlations were observed between TDF and β-glucan at all locations (r^2 values ranged from 0.75 to 0.96) indicating selection for higher β-glucan should result in higher TDF. Antioxidant activity was not correlated to any of the fiber components.

Figure 1. In 2004 and 2005, Oat Genotypes were Grown at 2 Locations in Saskatchewan

Figure 2. β-glucan Content of Selected Oat Genotypes Grown at Environments

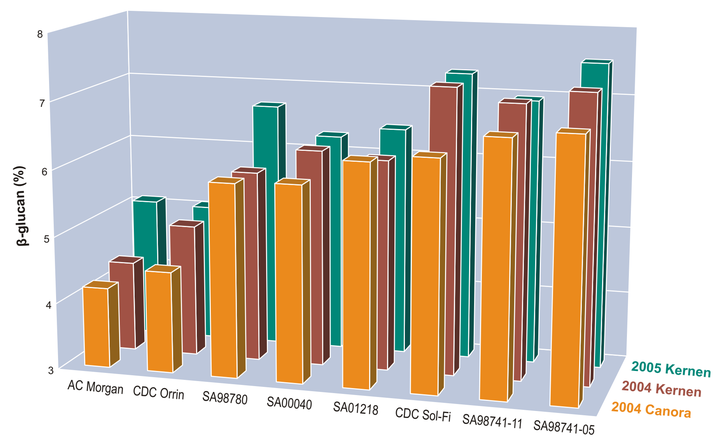


Figure 3. TDF Content of Selected Oat Genotypes Grown at Environments

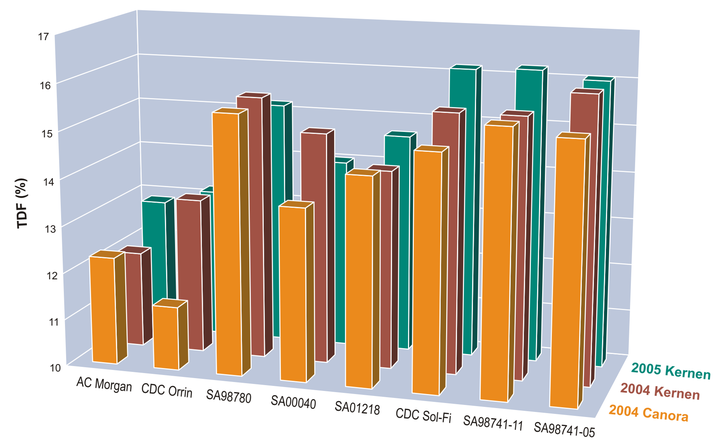


Table 1. Summary of ANOVA for Oat β-glucan, Total Dietary Fiber and Antioxidant Activity

		ANOVA *F*-Value[a]			
Characteristic	Mean	Genotype	Environment	GXE	Dup (Envir)
β-glucan (%)	5.88	229.66**	6.25^{ns}	5.73**	7.93**
Total Dietary Fiber (%)	14.40	29.97**	1.04^{ns}	1.74^{ns}	6.53*
Antioxidant Activity[b]	1478	12.30**	7.18^{ns}	4.32**	3.78*

[a] $p < 0.001$ and $p < 0.05$ indicated by ** and * respectively, ns = not significant
[b] Trolox Equivalents/100g

TDF, variability between replicates of the same cultivar was less than variability between duplicates (lab reps) indicating this test has much greater variability than β-glucan analysis.

Table 1 shows genotype was significant for oat β-glucan, TDF content and antioxidant activity ($p < 0.001$) and environment effects (location and year) were not detected. In this study genotypes represented a relatively narrow range and lower level of antioxidant activity compared to some values noted in the literature. A significant GXE ($p < 0.001$) was observed for β-glucan and antioxidant activity, but not for TDF, possibly due to the lower precision of the TDF method. Significant variation between replicates within location ($p < 0.001$) may be masking true GXE effects for TDF. Because β-glucan can be measured more precisely than TDF, the differences are easier to detect. Genotype rank order for β-glucan content did not vary across locations but genotype ranking order did vary for antioxidant activity.

Components of variation indicate that genotype is the major factor contributing to variation in β-glucan and TDF. Genotype accounted for 88% and 73% (Figures 4 and 5) of the estimated variation in oat β-glucan and TDF content, respectively.

Variance components are heavily dependent on genotypes and environments used in the study. The validity of the estimates depends on how well these factors represent the target population of genotypes and environments. For example, genotype effects were lower when considering a subset of 13

Figure 4. % Contribution of Factors to Total Variation for β-glucan

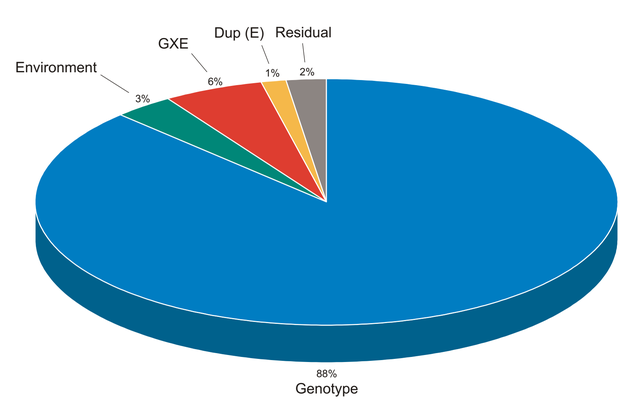
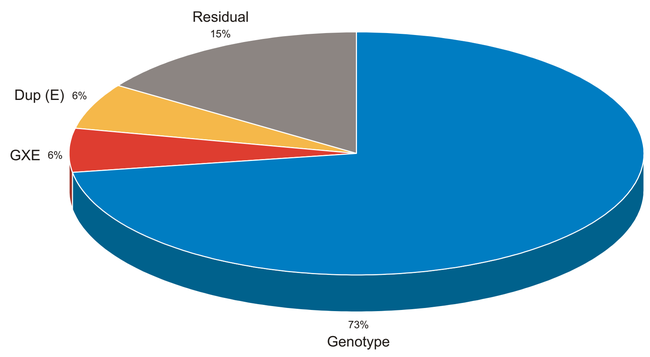


Figure 5. % Contribution of Factors to Total Variation for TDF



CONCLUSIONS

In general, both β-glucan and TDF vary significantly with genotype and are affected minimally by environment. For the genotypes and environments studied here, it appears that increases in TDF will occur through selection for high β-glucan. However, this study is ongoing so results should be considered preliminary. Some important additional observations made include: (1) the genotype X environment effect increases when considering subsets of genotypes selected for high β-glucan; (2) high rep to rep variation for TDF, masked the role of environmental and GXE interactions for this component and (3) although genotype effects were significant, the level of antioxidant activity was relatively low which is probably a refection of the sample set selected. For future work, effort must be made to reduce variation among duplicates in TDF measurement as well as testing at more diverse locations. Additional year and location data for a diverse set of genotypes will be collected and summarized in 2006.

REFERENCES

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ACKNOWLEDGEMENTS

Funding was provided by Can-Oat Milling Inc. and the AAFC Matching Investment Initiative. Special thanks to Sheila Woods (statistical support), Li Ren and Tracy Lee (technical support), and Mike Shillinglaw (poster layout) at the Cereal Research Centre.

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