Quality of canola (*Brassica napus* L.) varieties in Western Canada: Evaluation of variability due to genetic, year and environmental conditions using data from Canadian Grain Commission Harvest Surveys and from Environment Canada meteorological stations

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Abstract

Quality data (oil content, crude protein content (as oil-free protein and seed protein), the sum of oil and protein content and chlorophyll content) from Canadian Grain Commission harvest surveys coupled with meteorological data from Environment Canada (monthly minimum and maximum temperatures and monthly total precipitation by provincial crop district from 1992 to 2003) were used to evaluate quality factors for varieties of *B. napus* canola grown in Canada between 1992 and 2005. The analysis was restricted to the most popular varieties that appeared in the survey at least 3 years and for which there were at least 20 data points per year. Analysis of annual parameter means and overall variety ranks showed significant increases in protein content and oil plus protein content were noted in *B. napus* canola over the period but although oil content increased, the increase was not statistically significant. Chlorophyll content did not increase in harvest survey data but has increased in exports over the period. Statistically significant differences were found between varieties for all of the above parameters and a strong variety by location (province) effect. Sample variance within a variety was used as a rough measure of environmental sensitivity. There were significant genetic differences in the sample variance between varieties and in many cases this was consistent across years and locations. Significant correlations were noted for meteorological parameters for oil content (low temperatures in June), protein content (maximum temperatures in June and July), oil plus protein (minimum temperatures in August), chlorophyll (minimum temperatures in September) and there were significant variety differences in the responses (slopes) to these parameters. This suggests that it should be possible to design breeding strategies to develop varieties with greater or lesser sensitivity to environmental fluctuations.

Key words: quality, environment, variety, oil, protein, chlorophyll, temperature, precipitation, variability

Introduction

In order to be recommended for registration for growing in Western Canada, varieties of canola are evaluated for quality according to the rules and direction of the Western Canada Canola/Rapeseed Recommending Committee (WCC/RRC). These rules establish minimum requirements and incentives in the case of oil content and protein content for the committee's recommendation of new varieties for registration in Canada. Concerns about the performance of new canola varieties have been expressed but most of these might be put down to the recent changes in species balance (Daun, J. K. and DeClercq, D. R., 98) (Daun, J. K., 2003). At the same time the Canola Council of Canada (CCC) has undertaken a review of canola quality (Hickling, D., 2005) identifying chlorophyll, oil, protein and saturated fatty acids as ongoing issues. Furthermore, a review of environmental and agronomic factors (Goodwin, 2004) concluded that recent variations in oil content, chlorophyll and oil profile are due mostly to meteorological conditions. The study did not find a clear relationship between new genetic innovations and oil content.

Ideally, data from controlled plot studies such as variety registration trials would be most valuable in this type of study. In the Canadian situation, however, varieties require only one year of public testing before registration and the turnover of varieties, including check varieties, in these trials is very rapid. Another source of information is the Canadian Grain Commission (CGC) quality surveys of newly harvested Canadian rapeseed and canola crops (Declercq, D. R. and Daun, J. K., 2005). Since 1994, reliable data on oil and protein content, chlorophyll and more recently saturated fatty acids has been generated by NIR analysis of the individual samples in these surveys.

The present study was undertaken in order to provide a more in depth study of the performance, in terms of quality of the major canola varieties grown in Western Canada over the past 12 years. The study utilizes data from CGC surveys to evaluate differences between the major B. napus canola varieties in terms of oil content, protein content (of the meal), saturated fatty acids and, if possible, chlorophyll content. In addition, the study attempts to determine whether there are any differences between the varieties response to growing location or environmental factors for these parameters. (Daun 2006)

Materials and Methods

Statistical Methods Statistical procedures used were from either SAS version 9.1 for windows SAS Institute Inc., Cary, NC, USA., Origin version 7.5 Originlab Corporation, Northhampton MA, USA, Graphpad Instat version 3.05 GraphPad Software, San Diego CA, USA or Microsoft Excel 2002 Microsoft Corporation, Seattle, WA, USA. The following procedures were used.

Correlation: Pearson correlation coefficients were determined for the relationship between quality parameters (averaged by variety by provincial crop district) and meteorological data. The number of samples in each crop district was used as a weighting factor.

Analysis of Variance: Both simple and factorial ANOVA's were run using SAS. Type III sums of squares were used. Means tests were carried out using either the Bonferroni method, which accepts unequal sample sizes or by the Duncan's test. Repetitions found that there were no significant differences in the results by the two different means tests but the Bonferroni results were used where there were significant differences in the number of groups.

Regressions: Quality factors averaged by crop district were regressed with meteorological data using simple linear regression where correlations were significant and consistent in sign across the varieties. The number of samples per crop district was used as the frequency. Slopes for the regression lines constructed were compared using the Bonferroni method on Graphpad Instat. Regressions between quality factors and meteorological factors and location (latitude and longitude averages for crop district) were also constructed using forward selection with $\alpha = 0.05$. Partial correlations (expressed as %) were compiled and gave an indication of the factors that might be important for future study.

Comparison of Coefficiants of Variation: The Brown-Forsythe method of comparing variances was used to construct groups of equal variances by repeated analysis of variance using the Origin software. While this may not be a recognized statistical process, it does provide some interesting information. The Brown-Forsythe test is more robust than the alternative Levene test but both are questionable where samples have large differences in numbers as was the case in the data studied.

Harvest Survey Database of Canola Quality. Each year since 1956 the Canadian Grain Commission has surveyed the quality of Canadian rapeseed and canola by obtaining and testing samples of farm deliveries or farm harvested crop. The results of these have been published as crop bulletins and related reports to the Canadian canola and rapeseed industry. Databases of information gathered from these surveys also have been established and information in these was used in the current study.

Database of Environmental Information. A database of environmental information containing average values for monthly minimum and maximum temperature and precipitation by provincial crop district for the years 1971 to 2002 was prepared from Environment Canada data by the National AgriClimate Group of Agriculture Canada's Prairie Farm Rehabilitation Administration (courtesy Mr. Trevor Hadwen, AAFC-PFRA, Regina).

Results and Discussion

Oil Content. While oil content of Canadian canola has increased over the long term (Fig. 1), there was little evidence of an increase over the past 14 years, either in the overall crop or in varieties (Fig. 2). There was a 3 percent difference in the mean value of oil content between the variety with the highest and the variety with the lowest oil content and there were significant differences between varieties both in their mean values and in the variation about those mean values (Figure 3).

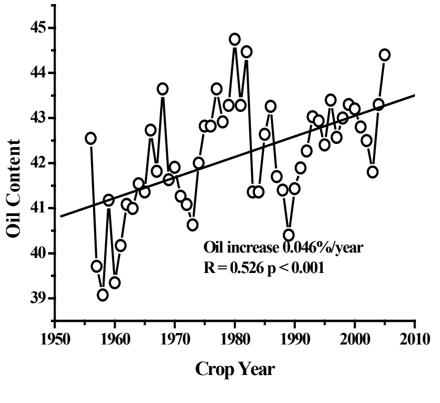

Figure 1. Oil content of Canadian Canola from CGC Harvest Surveys

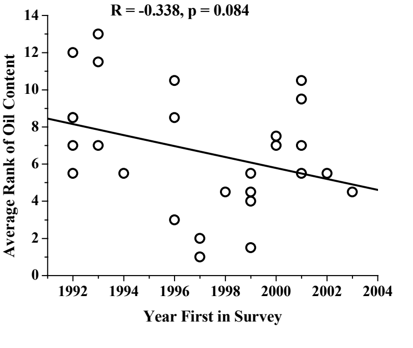

Figure 2. Rank of oil content for all varieties tested between 1994 and 2006 plotted against the first year the variety appeared in the survey.

Some varieties showed low variability in oil content in each year studied (Fig. 4). Location, as expressed by province also had a significant effect with samples from Alberta having the highest oil contents and those Manitoba the lowest. Some varieties showed a greater stability to location than others.

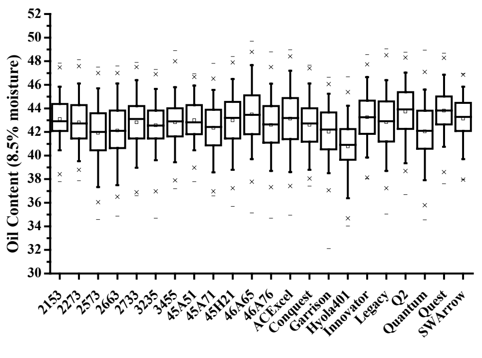

Figure 3. Mean and ranges of oil contents for varieties of Canadian Canola, 1994 to 2006.

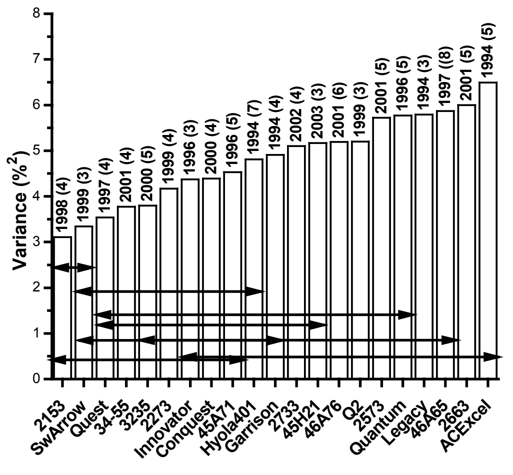

Figure 4. Comparison of variances for oil content between major varieties in the harvest survey between 1994 and 2005 showing only varieties with more than 20 samples per year for at least 3 years. Labels show the year first in the survey and the number or years in the survey (not necessarily contiguous). Arrows show groups of variances that are not significantly different according to the Brown-Forsythe test.

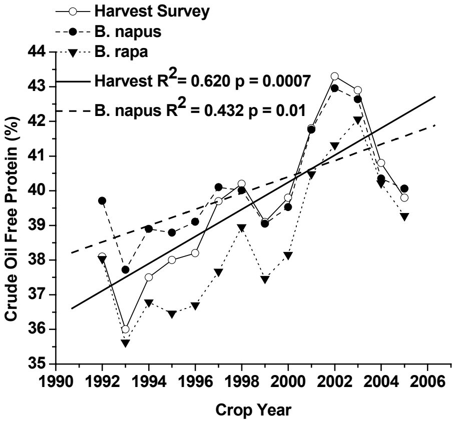

Figure 5. Average crude protein contents of oil-free Canadian canola and rapeseed from Canadian Grain Commission Harvest Surveys, 1992 to 2005. showing differences due to species makeup.

Table 1. Comparison of June minimum temperature effect on oil content between varieties. The regressions were weighted by the number of data points (variety oil contents) per crop district.

Variety	Data Points	Slope[1]	Std. Dev.	Group	R^2
AC Excel	82	-0.813	0.127	A	0.479
Garrison	63	-0.682	0.111	B	0.378
Legacy	57	-0.679	0.117	B	0.654
Quantum	94	-0.409	0.106	C	0.163
Hyola401	92	-0.391	0.087	C	0.300
2273	52	-0.260[2]	0.155	D	0.080
46A65	101	-0.252	0.114	D	0.155
Innovator	56	-0.239	0.105	D	0.088

[1] change in oil with each ºC increase in Minimum June Temperature
[2] not significantly different from 0

Minimum temperatures, particularly in June but also in May through August, had an effect on oil content and different varieties responded to different degrees to this effect (Table 1).

Crude Protein Content. Oil-free protein content remained relatively constant the long term but over the past 12 years it increased dramatically both in part due to the shift from a mixture of *B. rapa* and *B. napus* to almost complete *B. napus* and also due to a significant increase in the crude oil free protein in *B. napus* varieties (Figure 5).

As with oil content, there were significant differences between variety means and variances and some varieties showed consistency variance in each of the year's studied. Samples from Manitoba had the highest oil free protein content and those from Saskatchewan the lowest. Maximum temperatures in June and July played a significant role in determining crude oil free protein content and there were variety differences in the magnitude of that effect (Table 2).

Table 2. Comparison of July maximum temperature effect on oil free protein content between varieties. The regressions were weighted by the number of data points (variety oil contents) per crop district

Variety	Data Points	Slope[1]	Std. Dev.	R^2	Group[2]
v46A65	101	0.049	0.015	0.037	A
vQuest	80	0.058	0.009	0.079	B
v46A76	60	0.067	0.016	0.061	C
vQuantum	94	0.069	0.008	0.086	C
vConquest	47	0.082	0.019	0.100	D
v3235	39	0.090	0.022	0.147	E
vInnovator	56	0.092	0.017	0.099	E
v2273	52	0.103	0.028	0.097	F
vGarrison	63	0.103	0.018	0.127	F
v3455	38	0.105	0.015	0.310	F
v45A71	79	0.110	0.012	0.202	F
vQ2	38	0.121	0.032	0.117	G
vACExcel	82	0.128	0.015	0.138	GH
vLegacy	57	0.130	0.017	0.172	H
vSwArrow	48	0.139	0.026	0.182	H
v2153	54	0.151	0.027	0.230	I

[1] change in oil free protein with each ºC increase in Maximum July Temperature

[2] The Bonferroni test used in Table 7 was considered to be too conservative and the Student-Neuman-Keul test was used instead. Note that the standard deviations were found to be significantly different.

Sum of Oil and Protein Content. The sum of oil and protein content has increased over the long term, mostly due to increases in oil content but more recently due to the effect of increased meal protein content coupled with a steady (or slightly increasing) oil content. As with other parameters there were significant variety differences in means and variability about the means although the year to year consistency of the response by variety was not noted. Samples from Alberta had the highest oil plus protein content while those from Saskatchewan had the lowest. August minimum temperatures had a significant role in establishing oil plus protein content and there were variety differences in the magnitude of the effect (Table 3)

Table 3. Comparison of August minimum temperature effect on oil plus protein content between varieties. The regressions were weighted by the number of data points (variety oil contents) per crop district

Variety	Data Points	Slope[1]	Std. Dev.	R^2	Group
Legacy	57	-0.889	0.279	0.156	A
v34-55	38	-0.857	0.342	0.148	A
Quantum	94	-0.568	0.183	0.094	B
Conquest	47	-0.542	0.234	0.107	B
v2273	52	-0.434	0.176	0.107	B
v46A76	60	-0.431	0.198	0.075	B
Ac Excel	82	-0.294	0.111	0.081	C

[1] Change in Oil Pluse Protein Content (%) with each ºC increase in Minimum August Temperature

Table 4.. Comparison of September minimum temperature effect on chlorophyll content between varieties. The regressions were weighted by the number of data points (variety oil contents) per crop district.

Variety	Data Points	Slope[1]	Std. Dev.	R^2	Group
Quest	80	-0.133	0.043	0.110	A
2153	54	-0.132	0.040	0.171	AB
Garrison	63	-0.113	0.028	0.215	B
ACExcel	82	-0.094	0.023	0.171	C
45A71	79	-0.085	0.025	0.127	DD
2273	52	-0.062	0.026	0.103	E
46A65	101	-0.053	0.025	0.045	E

[1] Change in Chlorophyll Content (mg/kg) with each ºC increase in Minimum September Temperature

Chlorophyll Content. There was no long term trend in chlorophyll content as this factor is highly weather dependent. This weather dependency should be kept in mind when considering other observations and conclusions. Chlorophyll contents of top grade exports have increased over the past 10 years, mostly due to the lower amounts of the low chlorophyll *B. rapa* varieties in the crop. Significant differences in means and variability of chlorophyll were noted between varieties but there was no trend towards the development of lower chlorophyll varieties. Samples from Alberta and Saskatchewan had more chlorophyll than samples from Manitoba. Minimum temperatures in September played a significant role in establishing chlorophyll content and there were variety differences in the effect (Table 4).

Acknowledgements

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References

Daun, J.K. How green is green? Long-term relationships between green seeds and chlorophyll in canola grading. *J. Amer. Oil Chem. Soc.* **2003**, *80*, 119-122.

Daun, J. K. *Quality of canola (Brassica napus L.) varieties in Western Canada: Evaluation of variability due to genetic, year and environmental conditions using data from Canadian Grain Commission Harvest Surveys and from Environment Canada meteorological stations*. Canola Council of Canada, Winnipeg, 2006.

Daun, J.K.; DeClercq, D.R. Saturated Fatty Acids in Canadian Canola. Bull. GCIRC 1998, 15, 27-29

Declercq, D.R.; Daun, J.K. Canadian Canola Quality Parameters. *Bull. GCIRC* **2005**, *22*, http://195.101.239.21/publications/B22/canadiancanola%20quality.htm.

Goodwin, M. *A review of the impact of environment and agronomic practices on quality of Canadian canola oil*; Canola Council of Canada: Winnipeg, 2004.

Hickling, D. *Canola Quality Review*; Canola Council of Canada: Winnipeg, 2005.