Dietary fiber content in common bean from the middle american gene pool

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Contents

Introduction

275 entries from the BeanCAP study were grown in Fort Collins, CO in 2015. All entries originated from the Middle American gene pool and were further subdivided into three races and twelve market classes (Table 1). Beans were analyzed for various fiber components to determine the effect of marketclass and race (Table 2).

Table 1: Number of entries by race and market class included in the study.

Race	Market Class	No. Entries
Durango		**183**
	GN	43
	pink	22
	pinto	91
	small red	30
Mesoamerican		**92**
	black	41
	small white	48

Table 2: Fiber components measured in the study. Faffinose, stachyose, and verbascose are grouped together broadly as total oligosaccharides. These carbohydrates are not digested in the small intestine and are instead passed into the large intestine to be fermented by microflora with the production of gas.

Fiber component	Description
Soluble	Dissolves in water
Insoluble	Does not dissolve in water
Raffinose	A trisaccharide
Stachyose	A tetrasaccharide
Verbascose	A pentasachharide
Total Oligosaccharides	Sum of verbascose, raffinose, and stachyose
Total Dietary Fiber	Sum of soluble fiber, insoluble fiber, and total oligosaccharides

The red mottle market class had the greatest mean total dietary fiber, as well as the greatest mean verbascose, stachyose, total oligosaccharide, and insoluble fiber. The black mottle market class had the greatest mean raffinose and soluble dietary fiber content. Both of these market classes included only one entry each ('Orcha' a black mottle; 'Ind. Jamaica Red' a red mottle) making these findings not as insightful. A one-way analysis of variance revealed a significant effect ($p<0.5$) of market class on all fiber components.

A one-way analysis of variance revealed a significant effect ($p<0.5$) of race on all fiber components except total oligosachharide content. Durango and jalisco races had the greatest mean verbascose and stachyose content, mesoamerican race had the greatest mean raffinose content. Jalisco had the greatest mean insoluble DF, soluble DF, and total dietary fiber content.

Results: Entry Rankings

Tables below show the five entries with the greatest and five entries with the lowest values of each fiber component averaged across the two replications including standard deviation (sd), standard error (se) and confindence intervals (ci).

– Insoluble Dietary Fiber (IDF)

Table 3: Five entries with greatest IDF content.

Entry	mktclass	race	IDF	sd	se	ci
PR0443-151	black	mesoamerican	16.91	1.55	1.09	13.89
CDC Pinnacle	pinto	durango	16.73	2.76	1.95	24.80
CDC Jet	black	mesoamerican	16.71	1.32	0.94	11.90
TARS-VCI-4B	pinto	durango	16.46	3.43	2.42	30.79
TARS09-RR007	small red	durango	16.42	0.51	0.36	4.59

Table 4: Five entries with lowest IDF content.

Entry	mktclass	race	IDF	sd	se	ci
BelMiNeb-RMR-4	GN	mesoamerican	12.34	0.11	0.08	0.97
BelMiNeb-RMR-8	GN	mesoamerican	12.05	0.38	0.27	3.43
BelMiNeb-RMR-7	GN	mesoamerican	11.77	0.31	0.22	2.77
BelMiNeb-RMR-3	GN	durango	11.75	0.22	0.15	1.97
AC Pintoba	pinto	durango	11.44	0.19	0.13	1.70

– Soluble Dietary Fiber (SDF)

Table 5: Five entries with greatest SDF content.

Entry	mktclass	race	SDF	sd	se	ci
Voyager	small white	mesoamerican	10.29	0.12	0.08	1.03
SR7-3	small red	durango	9.83	0.83	0.59	7.48
NW-63	small red	durango	9.81	0.43	0.30	3.84
IP08-2	pinto	durango	9.48	0.76	0.53	6.79
BelMiNeb 2	GN	durango	9.45	0.05	0.03	0.42

Table 6: Five entries with lowest SDF content.

Entry	mktclass	race	SDF	sd	se	ci
ABCP-15	pinto	durango	5.76	0.56	0.39	5.00
Quincy	pinto	durango	5.53	0.22	0.16	2.00
Centa Pupil	small red	durango	5.34	0.52	0.37	4.69
TARS-VCI-4B	pinto	durango	5.16	1.32	0.93	11.84
I9365-5	pink	durango	5.09	1.57	1.11	14.13

– Raffinose (Raff)

Table 7: Five entries with greatest raffinose content.

Entry	mktclass	race	Raff	sd	se	ci
NE1-09-20	GN	durango	0.92	0.06	0.04	0.50
CDC Crocus	GN	durango	0.85	0.05	0.04	0.47
I9365-31	black	mesoamerican	0.85	0.25	0.18	2.24
A-55	black	mesoamerican	0.79	0.06	0.04	0.56
NE1-09-9	GN	durango	0.79	0.10	0.07	0.86

Table 8: Five entries with lowest raffinose content.

Entry	mktclass	race	Raff	sd	se	ci
Marquis	GN	durango	0.30	0.03	0.02	0.30
Sawtooth	GN	durango	0.30	0.11	0.08	0.96
USRM-20	small red	durango	0.30	0.03	0.02	0.28
Bill Z	pinto	durango	0.28	0.01	0.01	0.13
Apache	pinto	durango	0.27	0.01	0.01	0.07

– Stachyose (Stach)

Table 9: Five entries with greatest stachyose content.

Entry	mktclass	race	Stach	sd	se	ci
ND021717	black	mesoamerican	5.16	1.86	1.31	16.69
Centa Pupil	small red	durango	4.90	0.26	0.18	2.29
GN Star	GN	durango	4.78	0.17	0.12	1.57
Inta Precoz	small red	durango	4.70	0.28	0.20	2.48
USWA-13	GN	durango	4.69	0.19	0.14	1.72

Table 10: Five entries with lowest stachyose content.

Entry	mktclass	race	Stach	sd	se	ci
ND040494-4	pinto	durango	3.10	0.24	0.17	2.11
NE1-09-9	GN	durango	3.07	0.32	0.23	2.86
NE1-09-20	GN	durango	3.03	0.08	0.05	0.69
T9905	small white	mesoamerican	3.00	0.10	0.07	0.93
F07-449-9-3	small red	durango	2.99	0.18	0.13	1.61

– Verbascose (Verb)

Table 11: Five entries with greatest verbascose content.

Entry	mktclass	race	Verb	sd	se	ci
Pink Floyd	pink	durango	0.233	0.002	0.001	0.017
ROG 312	pink	durango	0.229	0.024	0.017	0.216
ABC-Weihing	GN	durango	0.201	0.016	0.011	0.143
GN Star	GN	durango	0.201	0.002	0.002	0.020
CDCWM-2	pinto	durango	0.197	0.028	0.020	0.253

Table 12: Five entries with lowest verbascose content.

Entry	mktclass	race	Verb	sd	se	ci
NE1-09-22	GN	durango	0.038	0.001	0.001	0.012
T9905	small white	mesoamerican	0.037	0.011	0.008	0.096
A-55	black	mesoamerican	0.036	0.035	0.025	0.317
GN9-4	GN	durango	0.033	0.032	0.022	0.284
McHale	small white	mesoamerican	0.021	0.006	0.004	0.050

– Total Oligosachharides (TOligos)

Table 13: Five entries with greatest oligosaccharide content.

Entry	mktclass	race	TOligos	sd	se	ci
ND021717	black	mesoamerican	5.98	2.22	1.57	19.92
Centa Pupil	small red	durango	5.45	0.18	0.13	1.62
GN Star	GN	durango	5.39	0.23	0.16	2.04
Inta Precoz	small red	durango	5.32	0.25	0.18	2.24
USWA-13	GN	durango	5.26	0.23	0.16	2.04

Table 14: Five entries with lowest oligosaccharide content.

Entry	mktclass	race	TOligos	sd	se	ci
Mariah	pinto	durango	3.60	0.30	0.21	2.67
NE1-09-19	GN	durango	3.57	0.08	0.06	0.71
ND040494-4	pinto	durango	3.55	0.14	0.10	1.24
T9905	small white	mesoamerican	3.53	0.12	0.09	1.08
F07-449-9-3	small red	durango	3.50	0.06	0.04	0.57

– Total Dietary Fiber (TDF)

Table 15: Five entries with greatest total DF content.

Entry	mktclass	race	TDF	sd	se	ci
PR0443-151	black	mesoamerican	30.23	1.22	0.87	11.00
IP08-2	pinto	durango	30.06	0.15	0.11	1.39
ND021717	black	mesoamerican	29.78	0.83	0.59	7.48
AC Resolute	GN	durango	29.45	1.57	1.11	14.08
Max	pinto	durango	28.59	0.81	0.57	7.26

Table 16: Five entries with lowest total DF content.

Entry	mktclass	race	TDF	sd	se	ci
T9905	small white	mesoamerican	23.59	0.93	0.66	8.39
Norstar	small white	mesoamerican	23.43	0.31	0.22	2.77
BelMiNeb-RMR-7	GN	mesoamerican	23.36	0.12	0.08	1.05
Topaz	pinto	durango	23.18	0.00	0.00	0.02

Entry	mktclass	race	TDF	sd	se	ci
AC Pintoba	pinto	durango	22.82	0.80	0.57	7.19

Results: Marketclass

– Boxplots

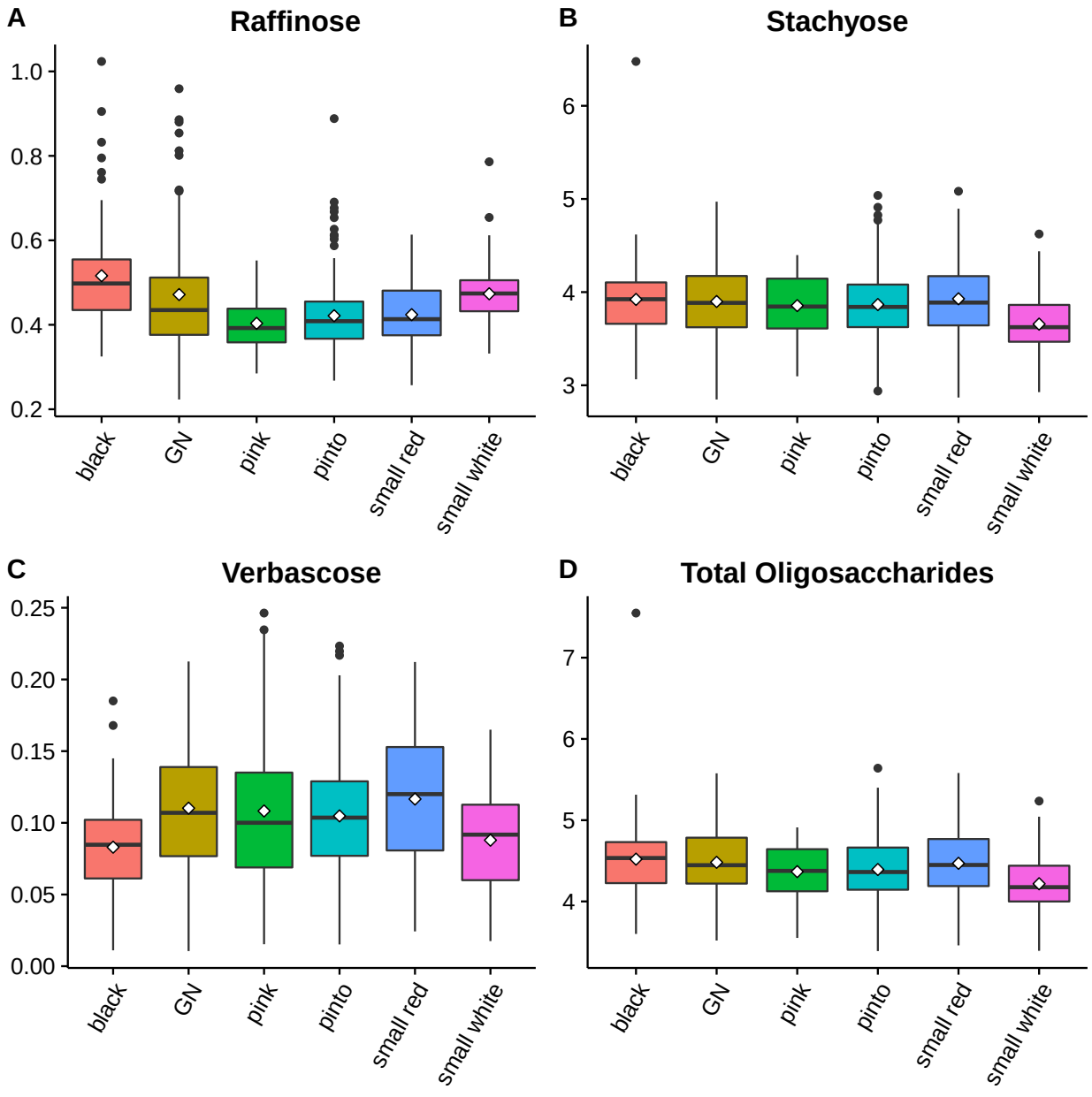

Figure 1: Oligosaccharide content in 282 common bean genotypes by marketclass (A) Raffinose, (B) Stachyose, (C) Verbascose, and (D) total oligosaccharides (= Raff + Stach + Verb).

Table 17: Mean fiber component content by market class. Values with different letters differ significantly between market classes ($p<0.05$). Bolded values are the greatest among market classes.

Marketclass	Verbascose	Raffinose	Stachyose	Total Oligosaccharides
black	0.083 a	0.516 c	3.92 b	4.52 bc
black mottle	0.057 ab	**0.533 bc**	3.14 ab	3.73 ab
carioca	0.09 ab	0.422 bc	3.8 ab	4.31 abc
flor de mayo	0.149 abd	0.315 bc	3.61 ab	4.07 abc
GN	0.11 b	0.472 ac	3.9 b	4.48 bc
navy	0.112 ac	NaN ac	NaN a	NaN a
pink	0.108 bc	0.403 b	3.86 ab	4.37 ab
pinto	0.105 b	0.421 b	3.87 b	4.39 b
red mottle	**0.233 d**	0.276 ab	**4.89 c**	**5.4 c**
small red	0.117 b	0.424 ab	3.93 b	4.47 bc
small white	NaN ab	NaN bc	NaN ab	NaN abc
tan	0.059 ab	0.382 bc	3.75 ab	4.19 ab

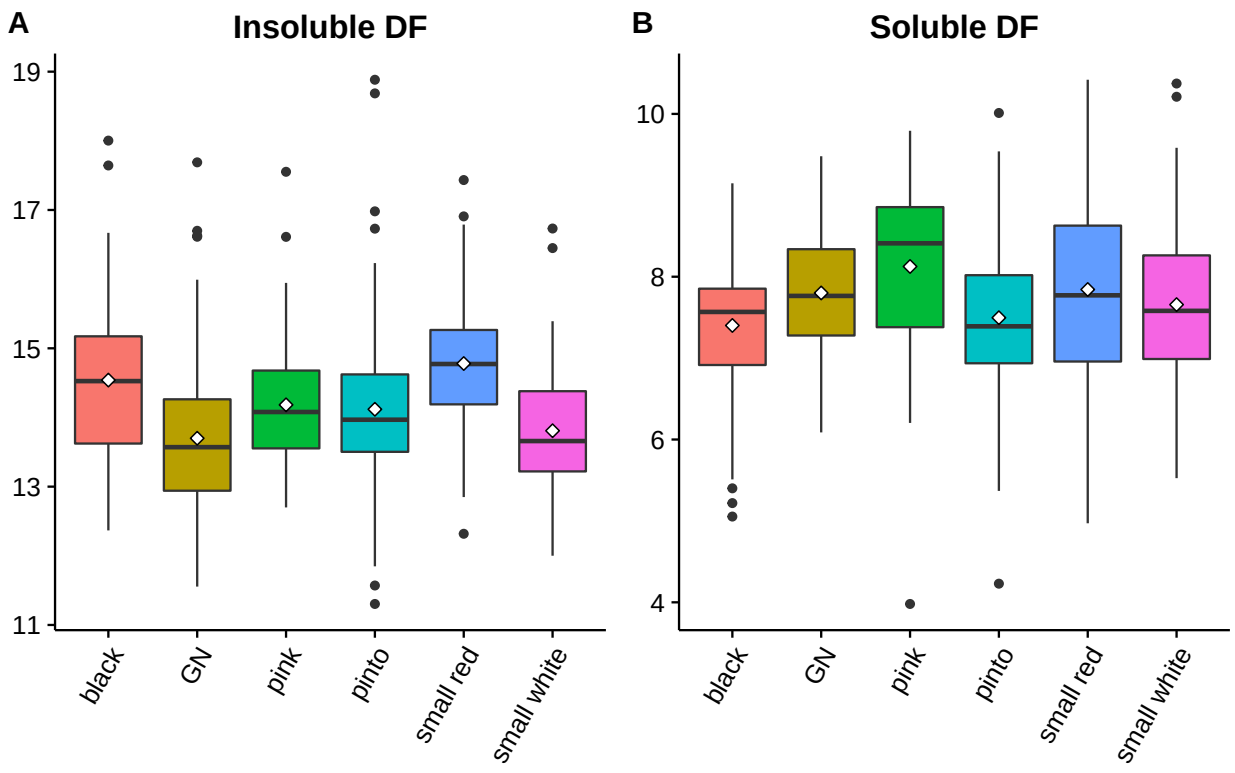

Figure 2: (A) Soluble and (B) insoluble dietary fiber in 282 common bean genotypes by marketclass.

Table 18: Mean fiber component content by market class. Values with different letters differ significantly between market classes ($p<0.05$). Bolded values are the greatest among market classes.

Marketclass	Insoluble DF	Soluble DF
black	14.54 cd	7.4 b
black mottle	12.91 abc	**8.21 ab**
carioca	13.98 abc	8.17 ab
flor de mayo	13.16 abc	8.05 ab
GN	13.7 ab	7.8 ab
navy	NaN a	NaN ab
pink	14.18 abc	8.13 a
pinto	14.12 bd	7.5 b
red mottle	**15.62 abc**	7.36 ab
small red	14.78 c	7.84 ab
small white	NaN abc	NaN ab
tan	14.65 abc	6.95 ab

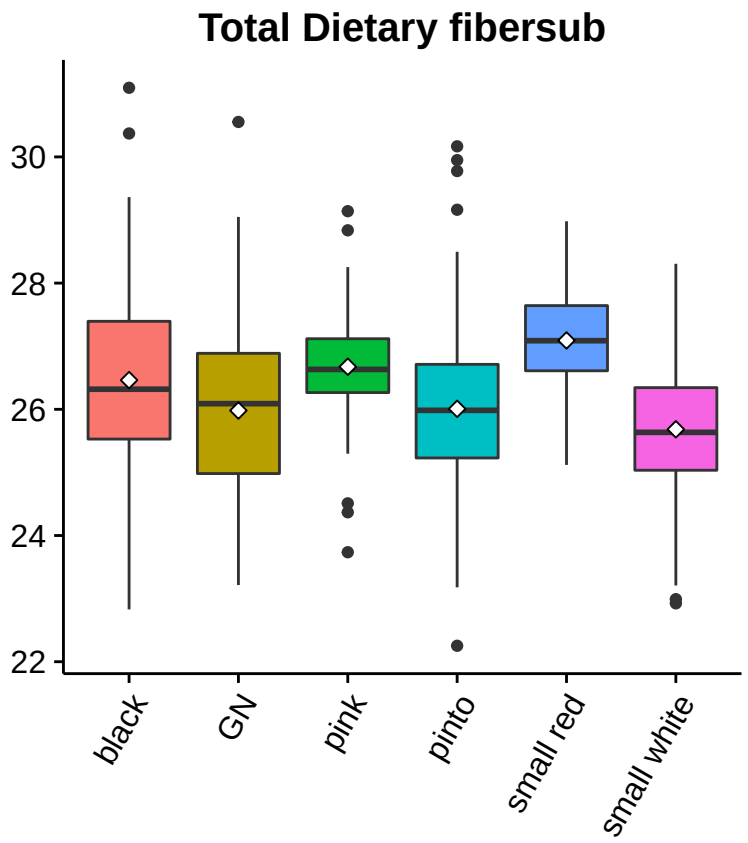

Figure 3: Total Dietary Fiber content in 282 common bean genotypes by marketclass.

Table 19: Mean total dietary fiber component content by market class. Values with different letters differ significantly between market classes ($p<0.05$).

Marketclass	Total DF
black	26.46 bc
black mottle	24.85 abc
carioca	26.45 abc
flor de mayo	25.29 abc
GN	25.98 cd
navy	NaN a
pink	26.67 bd
pinto	26.01 ac
red mottle	**28.38 bc**
small red	27.09 b
small white	NaN abc
tan	25.78 abc

Results: Race

– Boxplots

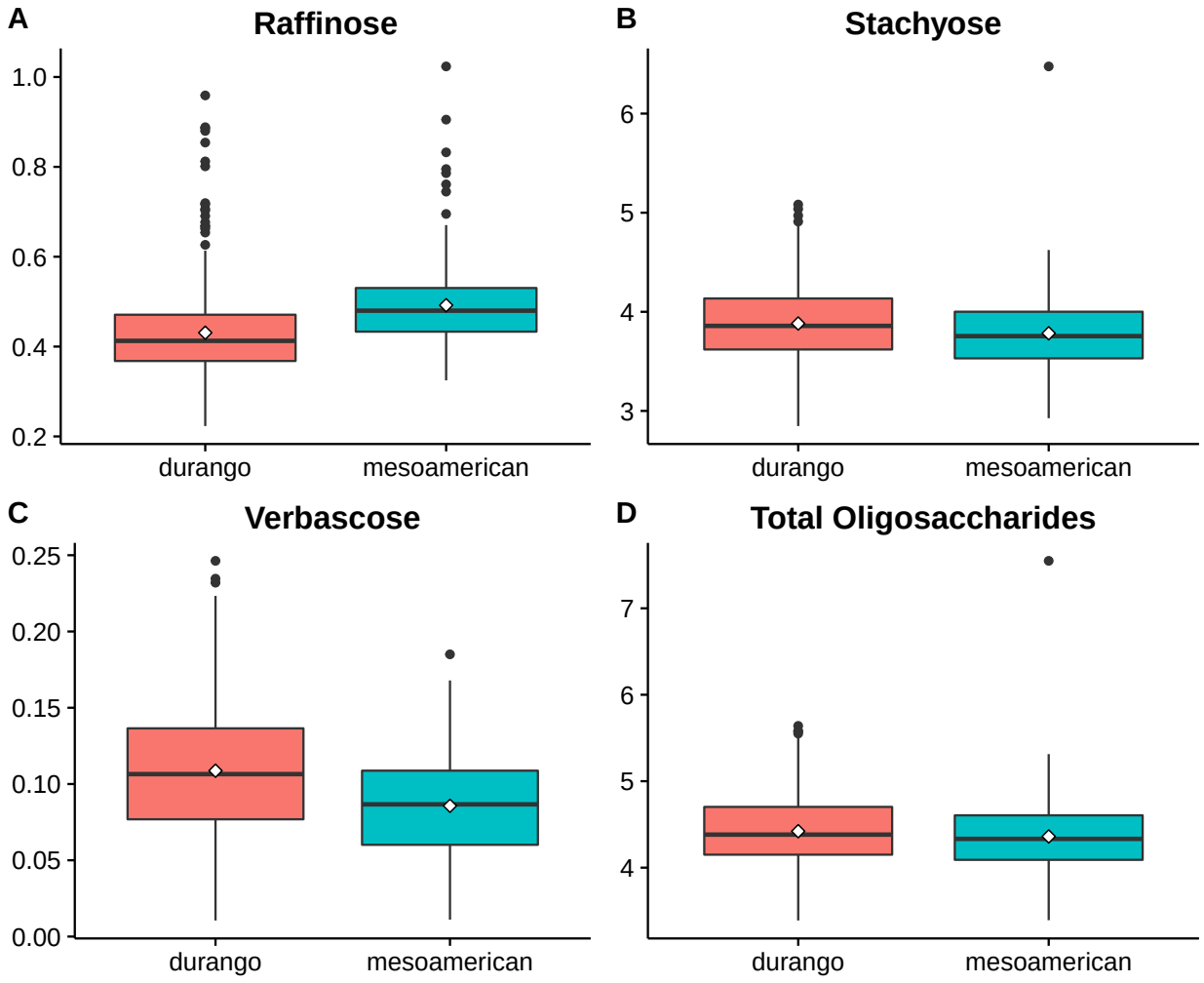

Figure 4: Oligosaccharide content in 282 common bean genotypes by race (A) Raffinose, (B) Stachyose, (C) Verbascose, and (D) total oligosaccharides (= Raff + Stach + Verb).

Table 20: Mean fiber component content by race. Values with different letters differ significantly between races ($p<0.05$).

Race	Verbascose	Raffinose	Stachyose	Total Oligosaccharides
Durango	0.108 b	0.431 a	3.88 b	4.42 a
Jalisco	0.149 b	0.315 a	3.61 ab	4.07 a
Mesoamerican	0.086 a	0.491 b	3.78 a	4.36 a

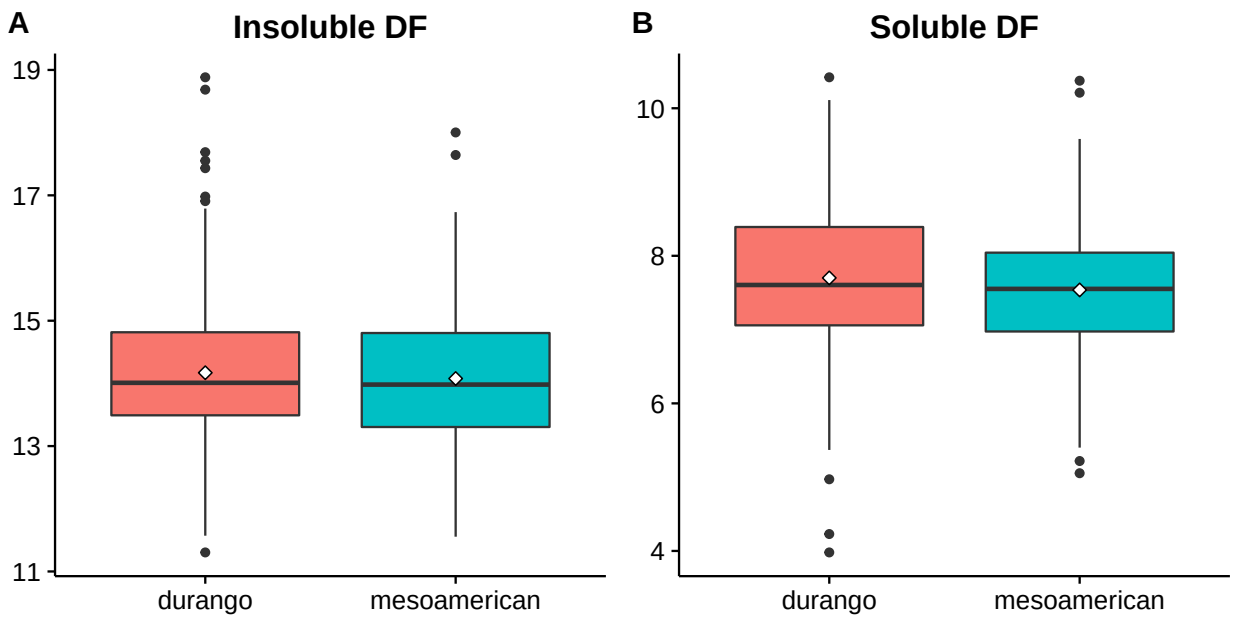

Figure 5: (A) Soluble and (B) insoluble dietary fiber in 282 common bean genotypes by race,

Table 21: Mean fiber component content by race. Values with different letters differ significantly between races ($p<0.05$).

Race	Insoluble DF	Soluble DF
Durango	14.17 a	7.69 a
Jalisco	13.16 b	8.05 b
Mesoamerican	14.08 a	7.55 a

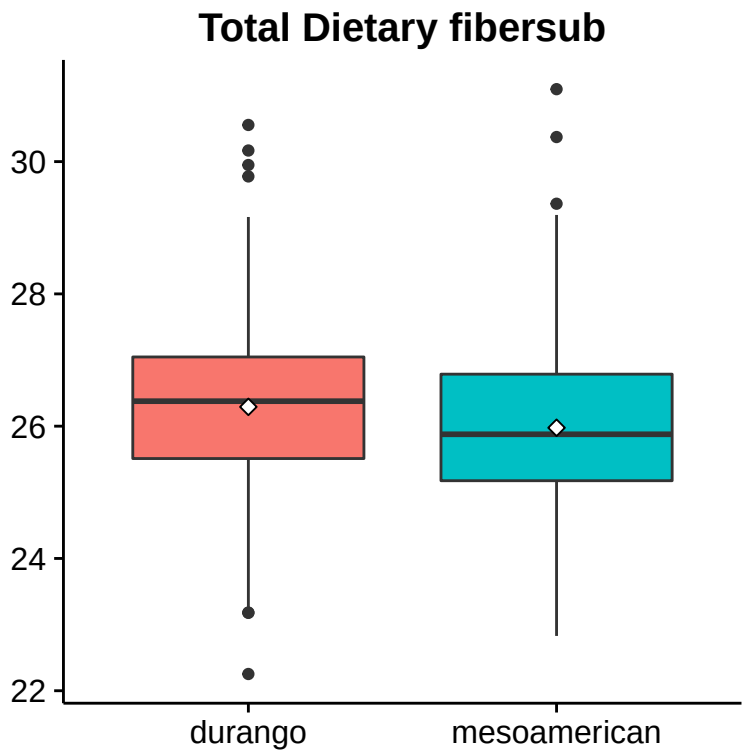

Figure 6: Total Dietary Fiber content in 282 common bean genotypes by race

Table 22: Mean total dietary fiber content by race. Values with different letters differ significantly between races ($p<0.05$).

Race	Total DF
Durango	26.28 a
Jalisco	25.29 b
Mesoamerican	25.99 a

Statistical Methods

Statistical analyses, figures, tables, and reporting was completed using RStudio Version 0.98.1062.

– *ANOVA Assumptions*

Insoluble fiber, soluble fiber, raffinose, stachyose, and verbascose data were concluded to meet the assumptions of normality of residuals and equality of variance after plotting qqplots, and residuals versus predicted values. Diagnostic plots are shown below.

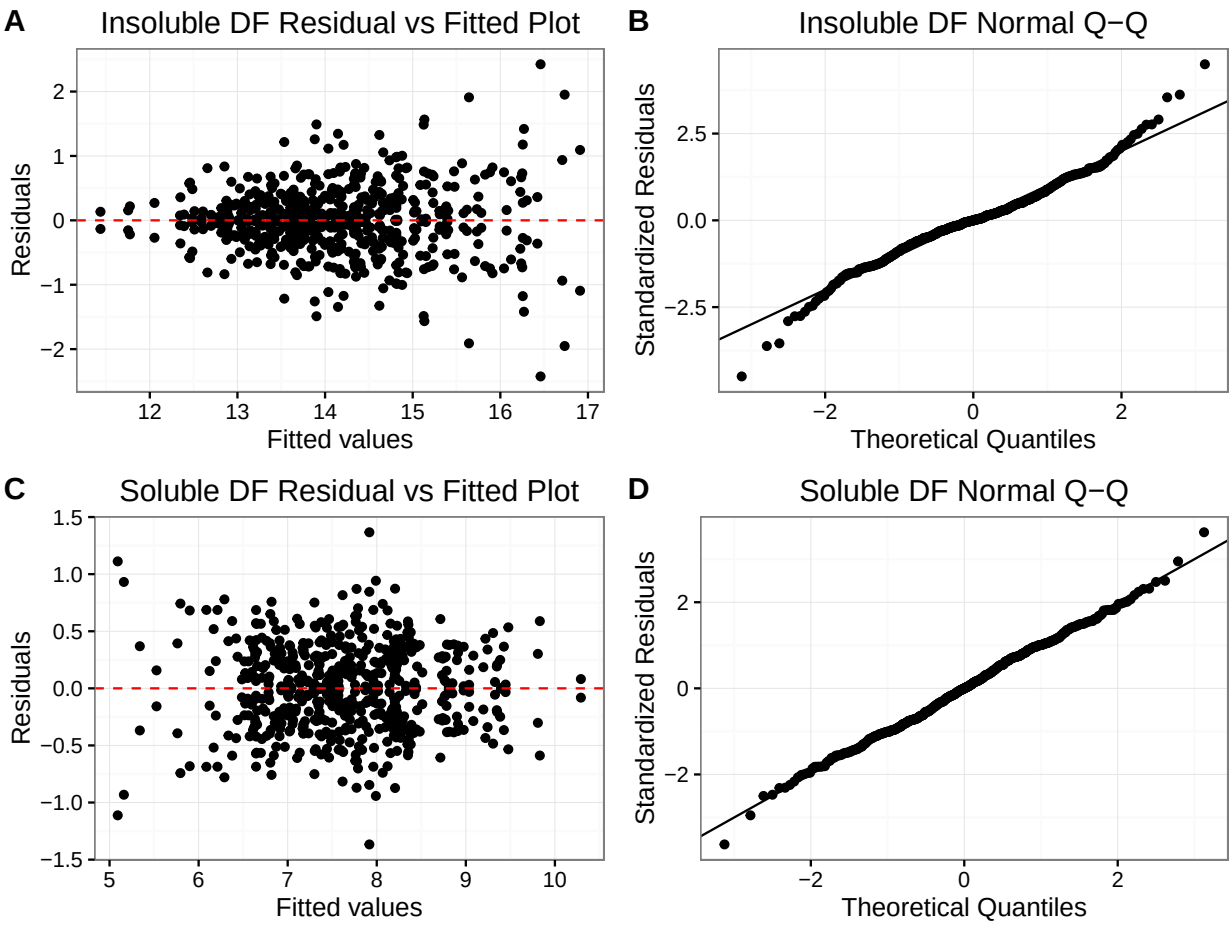

Figure 7: Residual versus fitted and q-q plots of insoluble and soluble DF. The insoluble DF plots look to reveal non-homogeneity of variance, but both the log and square root transformations did not improve it enough to warrant transforming the data.

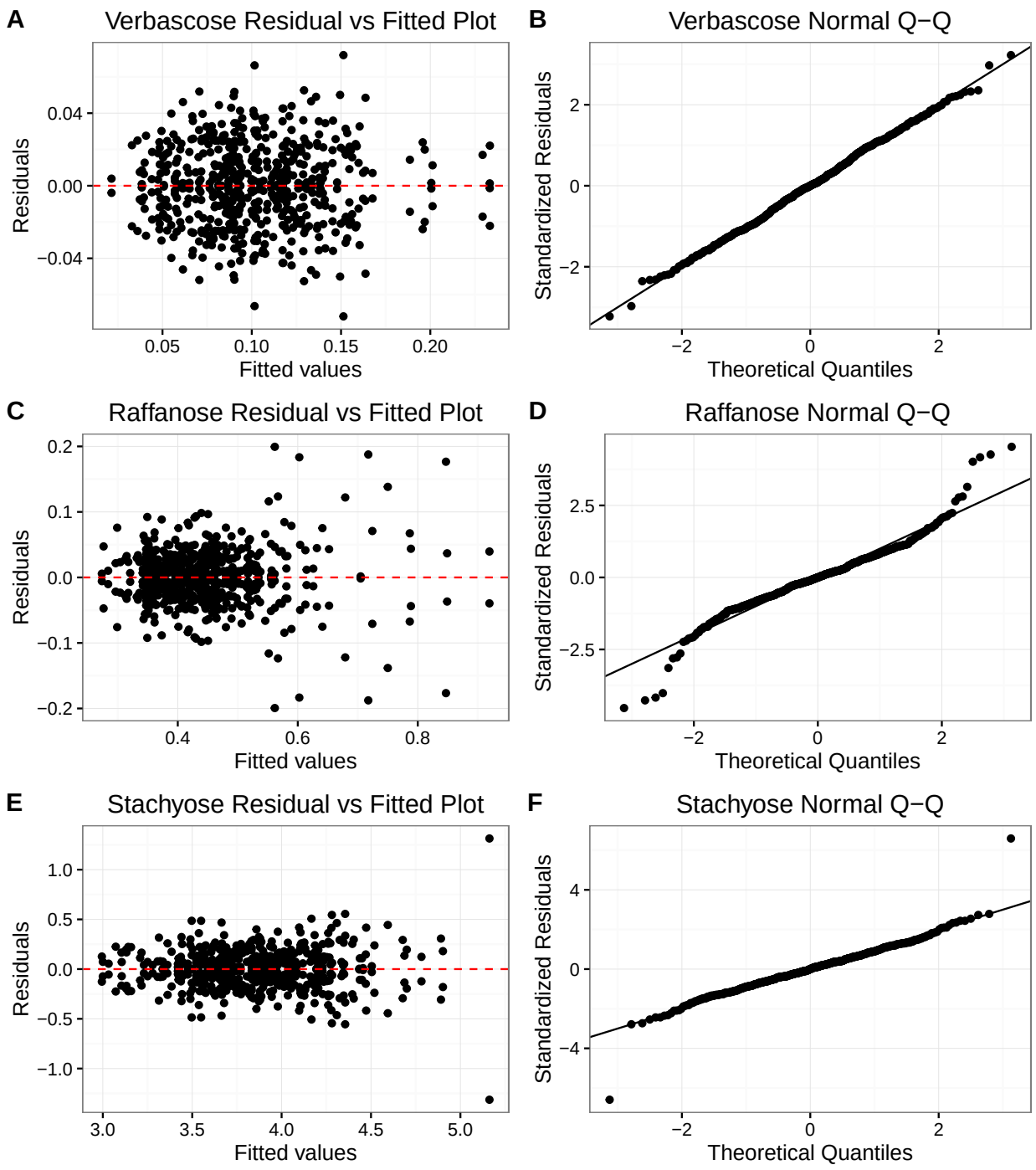

Figure 8: Residual versus fitted and q-q plots of verbascose, raffinose, and stachyose. The raffinose plots look to reveal non-homogeneity of variance, but both the log and square root transformations did not improve it enough to warrant transforming the data.

– *ANOVA*

One-way analysis of variance was conducted to determine the effect of 1) rep, 2) race, and 3) marketclass. Rep was treated as random, race and marketclass were treated as fixed with marketclass nested within race.

1) Market class

Differences between market classes were significant ($p<0.05$) across all fiber components.

Table 23: ANOVA table testing insoluble DF.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	7.9048	7.9048	7.0732	0.0081
race	1	1.0480	1.0480	0.9377	0.3333
race:mktclass	5	81.4865	16.2973	14.5828	0.0000
Residuals	542	605.7233	1.1176	NA	NA

Table 24: ANOVA table testing soluble DF.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	0.3447	0.3447	0.4000	0.5274
race	1	3.2403	3.2403	3.7603	0.0530
race:mktclass	5	20.8870	4.1774	4.8479	0.0002
Residuals	542	467.0361	0.8617	NA	NA

Table 25: ANOVA table testing raffinose.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	0.0151	0.0151	1.5207	0.2181
race	1	0.4582	0.4582	46.1605	0.0000
race:mktclass	5	0.2773	0.0555	5.5869	0.0000
Residuals	542	5.3804	0.0099	NA	NA

Table 26: ANOVA table testing stachyose.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	3.7460	3.7460	24.8969	0.0000
race	1	1.1905	1.1905	7.9123	0.0051
race:mktclass	5	3.4612	0.6922	4.6008	0.0004
Residuals	542	81.5489	0.1505	NA	NA

Table 27: ANOVA table testing verbascose.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	0.0104	0.0104	6.4778	0.0112
race	1	0.0647	0.0647	40.3921	0.0000
race:mktclass	5	0.0084	0.0017	1.0466	0.3894
Residuals	542	0.8682	0.0016	NA	NA

Table 28: ANOVA table testing total oligosaccharides.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	3.8277	3.8277	21.9080	0.0000
race	1	0.4469	0.4469	2.5581	0.1103
race:mktclass	5	4.8464	0.9693	5.5477	0.0001
Residuals	542	94.6963	0.1747	NA	NA

Table 29: ANOVA table testing total DF.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	17.4799	17.4799	12.4010	0.0005
race	1	12.1962	12.1962	8.6525	0.0034
race:mktclass	5	112.1553	22.4311	15.9135	0.0000
Residuals	542	763.9814	1.4096	NA	NA

– *Pairwise Comparisons*

Tukey adjusted pairwise comparisons were made between each market class and each race for each fiber component using the TukeyHSD funcion. These results were used in mean summary tables below boxplots.

```
OneWayFit <- aov(IDF~race, data=fiber)
TukeyHSD(OneWayFit)

library(multcomp)
PairComps <- glht(OneWayFit, linfct=mcp(race="Tukey"))
summary(PairComps)
cld(PairComps)
```