

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

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## 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 two races and six market classes after removing lesser important 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		<b>186</b>
	GN	43
	pink	22
	pinto	91
Mesoamerican	small red	30
		<b>89</b>
	black	41
	small white	48

Table 2: Fiber components measured in the study. Raffinose, 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
Verbascope	A pentasachharide
Total Oligosaccharides	Sum of verbascose, raffinose, and stachyose
Total Dietary Fiber	Sum of soluble fiber, insoluble fiber, and total oligosaccharides

## 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 confidence intervals (ci).

– **Total Dietary Fiber (TDF)**

Table 3: Five entries with greatest TDF 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 4: Five entries with lowest TDF 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	durango	23.36	0.12	0.08	1.05
Topaz	pinto	durango	23.18	0.00	0.00	0.02
AC Pintoba	pinto	durango	22.82	0.80	0.57	7.19

– **Raffinose (Raff)**

Table 5: Five entries with greatest Raff 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 6: Five entries with lowest Raff 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 7: Five entries with greatest Stach 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 8: Five entries with lowest Stach 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

– **Verbascore (Verb)**

Table 9: Five entries with greatest Verb content.

Entry	mktclass	race	Verb	sd	se	ci
Pink Floyd	pink	durango	0.23	0.00	0.00	0.02
ROG 312	pink	durango	0.23	0.02	0.02	0.22
ABC-Weihing	GN	durango	0.20	0.02	0.01	0.14
GN Star	GN	durango	0.20	0.00	0.00	0.02
CDCWM-2	pinto	durango	0.20	0.03	0.02	0.25

Table 10: Five entries with lowest Verb content.

Entry	mktclass	race	Verb	sd	se	ci
NE1-09-22	GN	durango	0.04	0.00	0.00	0.01
T9905	small white	mesoamerican	0.04	0.01	0.01	0.10
A-55	black	mesoamerican	0.04	0.04	0.02	0.32
GN9-4	GN	durango	0.03	0.03	0.02	0.28
McHale	small white	mesoamerican	0.02	0.01	0.00	0.05

– **Total Oligosachharides (TOligos)**

Table 11: Five entries with greatest TOligos 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 12: Five entries with lowest TOligos 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

– Insoluble Dietary Fiber (IDF)

Table 13: 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 14: Five entries with lowest IDF content.

Entry	mktclass	race	IDF	sd	se	ci
BelMiNeb-RMR-4	GN	durango	12.34	0.11	0.08	0.97
BelMiNeb-RMR-8	GN	durango	12.05	0.38	0.27	3.43
BelMiNeb-RMR-7	GN	durango	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 15: 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 16: 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

## Results: Marketclass

### – Boxplots

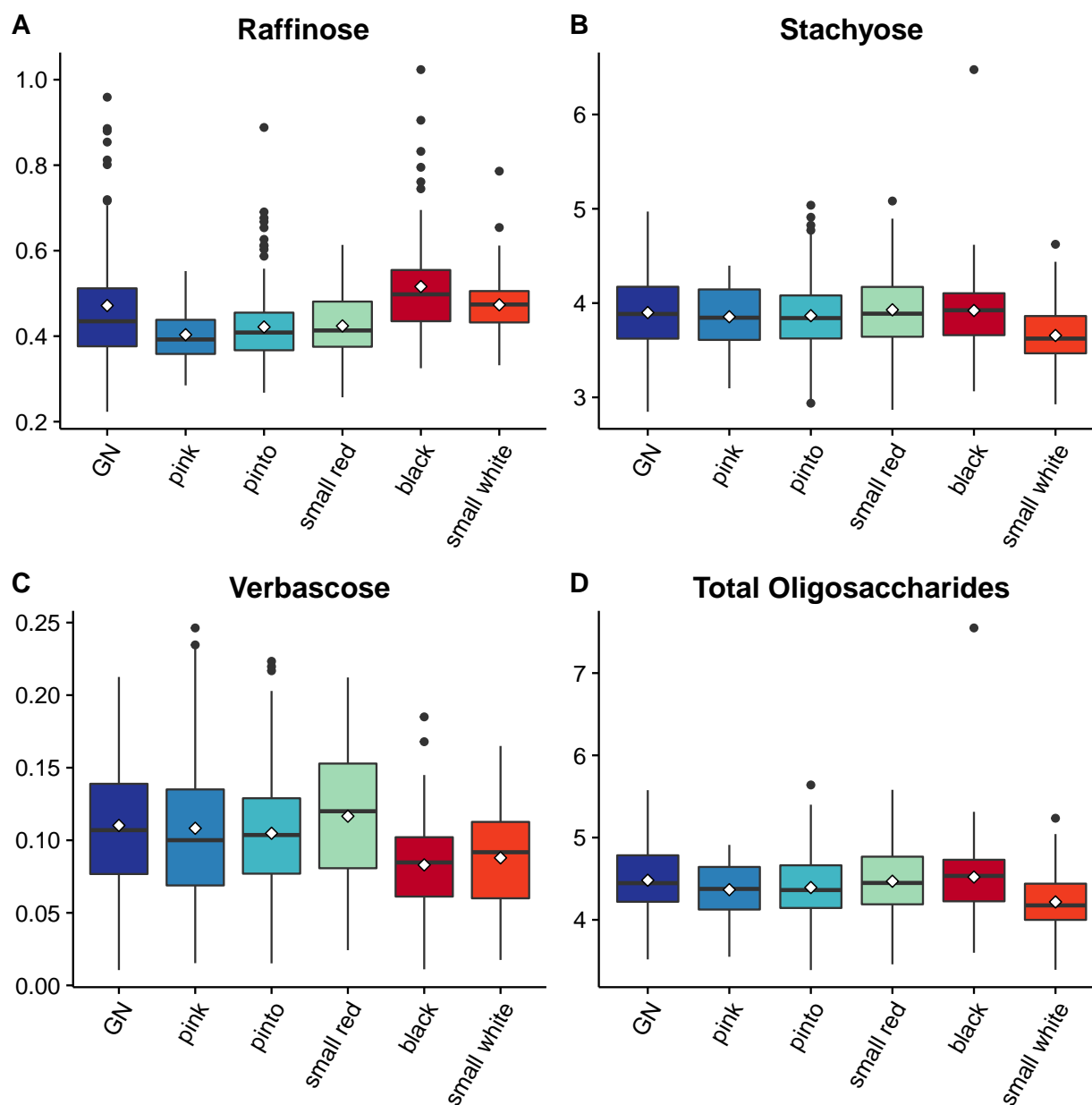


Figure 1: Oligosaccharide content in common bean by marketclass (A) Raffinose, (B) Stachyose, (C) Verbascose, and (D) total oligosaccharides (= Raff + Stach + Verb). Blue boxes (GN, pink, pinto, small red) belong to race Durango, red boxes (black, small white) belong to race Mesoamerica.

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	Raffinose	Stachyose	Verbascose	Total Oligosaccharides
black	0.516 a	3.921 b	0.08 a	4.52 b
GN	0.472 bc	3.899 b	0.11 c	4.48 b
pink	0.403 a	3.855 ab	0.11 bc	4.37 ab
pinto	0.421 a	3.866 b	0.1 c	4.39 b
small red	0.424 ab	3.928 b	0.12 c	4.47 b
small white	0.473 c	3.656 a	0.09 ab	4.22 a

Table 18: Raffinose outliers.

	Entry	mktclass	race	Rep	value
17	92BG-7	black	mesoamerican	1	0.795
31	A-55	black	mesoamerican	1	0.745
32	A-55	black	mesoamerican	2	0.832
255	Domino	black	mesoamerican	1	0.761
325	I9365-31	black	mesoamerican	1	1.024
424	ND021717	black	mesoamerican	2	0.905
843	CDC Crocus	GN	durango	1	0.812
844	CDC Crocus	GN	durango	2	0.886
1012	Matterhorn	GN	durango	2	0.801
1053	NE1-09-20	GN	durango	1	0.880
1054	NE1-09-20	GN	durango	2	0.959
1081	NE1-09-9	GN	durango	1	0.854
1082	NE1-09-9	GN	durango	2	0.719
1543	92US-1006	pinto	durango	1	0.603
1544	92US-1006	pinto	durango	2	0.626
1599	AC Island	pinto	durango	1	0.691
1893	Frontier	pinto	durango	1	0.668
2118	Maverick	pinto	durango	2	0.612
2229	NE2-09-1	pinto	durango	1	0.612
2230	NE2-09-1	pinto	durango	2	0.888
2243	NE2-09-10	pinto	durango	1	0.654
2453	Quincy	pinto	durango	1	0.677
3266	AC Polaris	small white	mesoamerican	2	0.786
3405	F07-004-9-1	small white	mesoamerican	1	0.654



Table 19: Stachyose outliers.

	Entry	mktclass	race	Rep	value
428	ND021717	black	mesoamerican	2	6.476
1673	Arapaho	pinto	durango	1	4.826
2009	IP08-2	pinto	durango	1	4.772
2317	NW-410	pinto	durango	1	4.910
2485	San Juan	pinto	durango	1	5.038
2891	Centa Pupil	small red	durango	1	5.083
3451	HY4181	small white	mesoamerican	1	4.624

Table 20: Verbascose outliers.

	Entry	mktclass	race	Rep	value
293	F04-2801-4-1-2	black	mesoamerican	1	0.19
434	ND021717	black	mesoamerican	2	0.17
1414	ROG 312	pink	durango	2	0.25
1665	Apache	pinto	durango	1	0.22
1805	CDCWM-2	pinto	durango	1	0.22
2030	Jackpot	pinto	durango	2	0.22

Table 21: Total oligosaccharides outliers.

	Entry	mktclass	race	Rep	value
432	ND021717	black	mesoamerican	2	7.55
2489	San Juan	pinto	durango	1	5.64
3455	HY4181	small white	mesoamerican	1	5.24

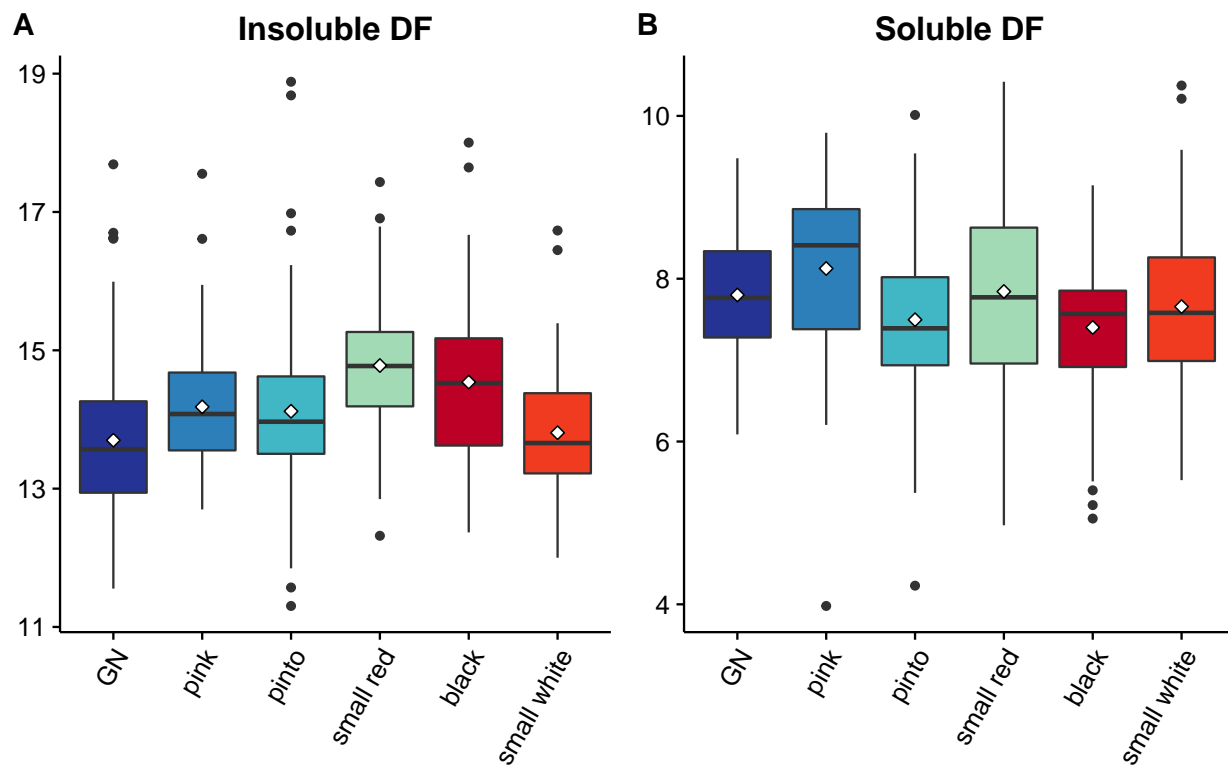


Figure 2: (A) Soluble and (B) insoluble dietary fiber in common bean by marketclass. Blue boxes (GN, pink, pinto, small red) belong to race Durango, red boxes (black, small white) belong to race Mesoamerica.

Table 22: 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 c	7.4 a
GN	13.7 a	7.8 ab
pink	14.18 abc	8.13 b
pinto	14.12 b	7.5 a
small red	14.78 c	7.84 ab
small white	13.81 ab	7.66 ab

Table 23: IDF outliers.

	Entry	mktclass	race	Rep	value
197	CDC Jet	black	mesoamerican	1	17.64
449	PR0443-151	black	mesoamerican	1	18.00
631	ABC-Wei hing	GN	durango	1	17.69
645	AC Resolute	GN	durango	1	16.63
995	Marquis	GN	durango	1	16.70
1051	NE1-09-20	GN	durango	1	16.61
1261	CDC Camino	pink	durango	1	16.61
1415	Roza	pink	durango	1	17.55
1555	ABCP-15	pinto	durango	1	16.98
1625	AC Pintoba	pinto	durango	1	11.57
1626	AC Pintoba	pinto	durango	2	11.30
1765	CDC Pinnacle	pinto	durango	1	18.69
2129	Max	pinto	durango	1	16.73
2591	TARS-VCI-4B	pinto	durango	1	18.88
3095	Rojo Chiquito	small red	durango	1	17.43
3123	SR7-3	small red	durango	1	12.32
3544	Medalist	small white	mesoamerican	2	16.45
3614	Nautica	small white	mesoamerican	2	16.73

Table 24: SDF outliers.

	Entry	mktclass	race	Rep	value
5	115M (Black Rhino)	black	mesoamerican	1	5.22
188	CDC Espresso	black	mesoamerican	2	5.40
327	I9365-31	black	mesoamerican	1	5.05
1336	I9365-5	pink	durango	2	3.98
2008	IP08-2	pinto	durango	2	10.01
2595	TARS-VCI-4B	pinto	durango	1	4.23
3911	Voyager	small white	mesoamerican	1	10.21
3912	Voyager	small white	mesoamerican	2	10.37

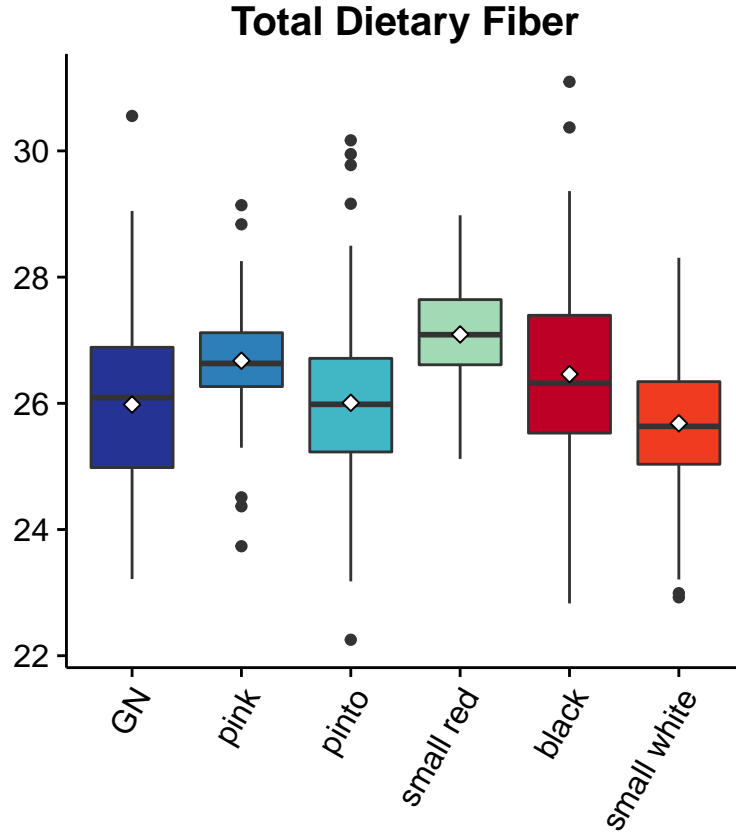


Figure 3: Total Dietary Fiber content in common bean by marketclass. Blue boxes (GN, pink, pinto, small red) belong to race Durango, red boxes (black, small white) belong to race Mesoamerica.

Table 25: 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
GN	25.98 ab
pink	26.67 cd
pinto	26.01 ab
small red	27.09 d
small white	25.68 a

Table 26: Total DF outliers.

	Entry	mktclass	race	Rep	value
430	ND021717	black	mesoamerican	2	30.37
457	PR0443-151	black	mesoamerican	1	31.10
653	AC Resolute	GN	durango	1	30.55
1326	I9365-25	pink	durango	2	24.51
1339	I9365-5	pink	durango	1	23.74
1340	I9365-5	pink	durango	2	24.37
1423	Roza	pink	durango	1	28.84
1507	USWA-61	pink	durango	1	29.14
1634	AC Pintoba	pinto	durango	2	22.25
1773	CDC Pinnacle	pinto	durango	1	29.78
2011	IP08-2	pinto	durango	1	30.17
2012	IP08-2	pinto	durango	2	29.95
2137	Max	pinto	durango	1	29.16
3650	Neptune	small white	mesoamerican	2	22.99
3860	T9905	small white	mesoamerican	2	22.93

– Lineplots

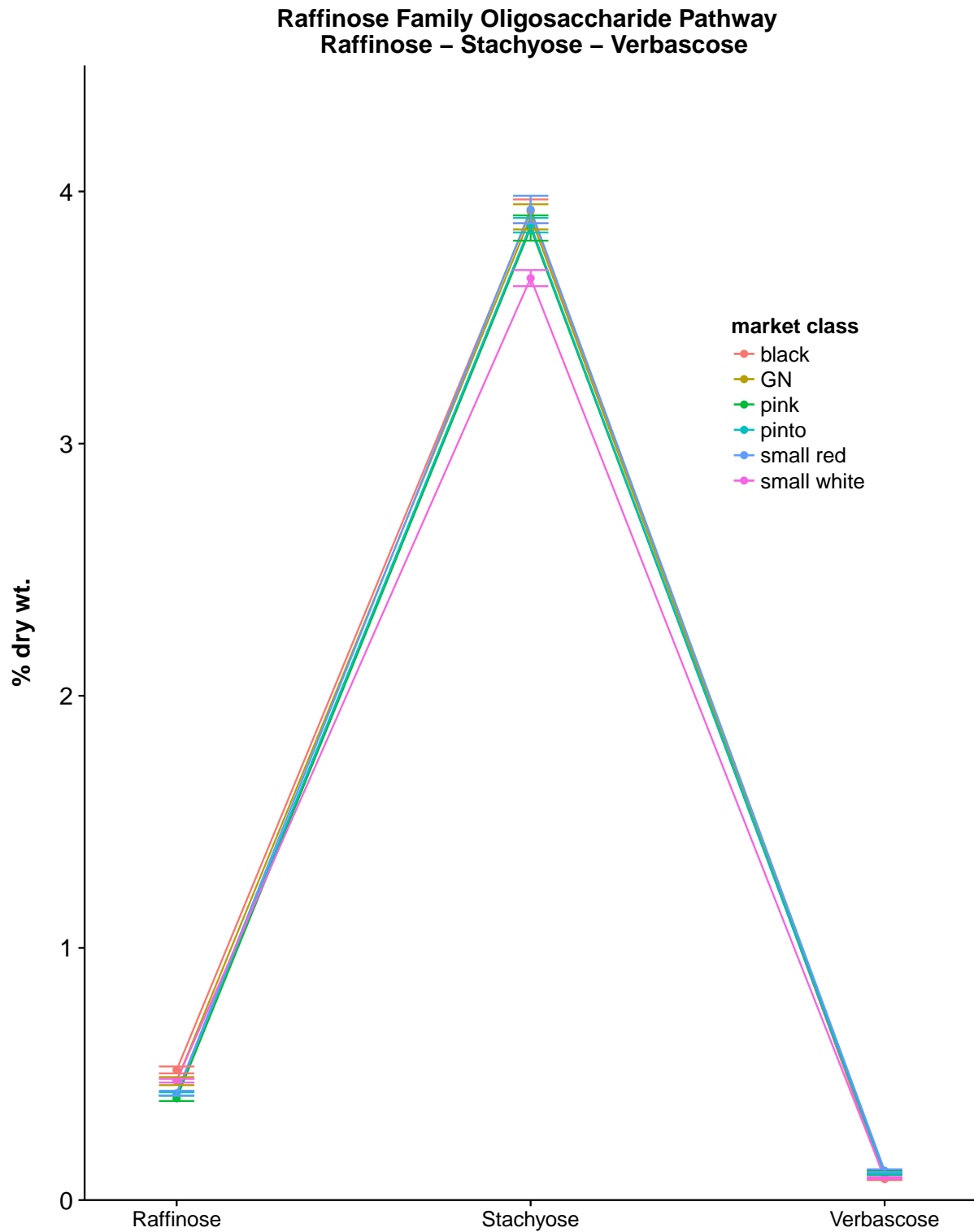


Figure 4: Mean content of each oligosaccharide along the Raffinose Oligosaccharide Family pathway.

## Results: Race

### – Boxplots

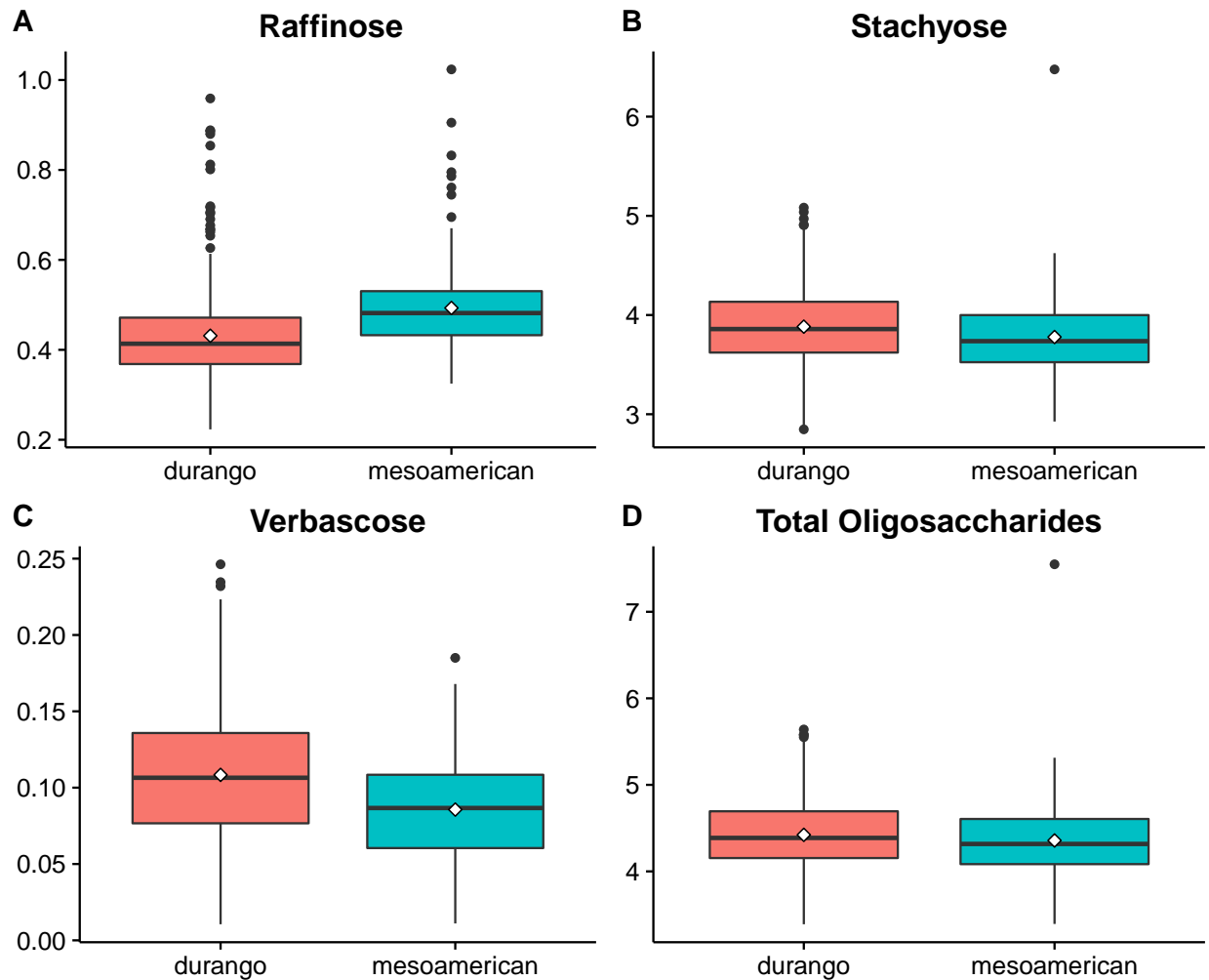


Figure 5: Oligosaccharide content in common bean by race (A) Raffinose, (B) Stachyose, (C) Verbascose, and (D) total oligosaccharides (= Raff + Stach + Verb).

Table 27: Mean fiber component content by race. Values with different letters differ significantly between races ( $p < 0.05$ ).

Race	Verbascose	Raffinose	Stachyose	Total Oligosaccharides
Durango	0.431 a	3.88 b	0.108 b	4.42 a
Mesoamerican	0.493 b	3.78 a	0.086 a	4.36 a

Table 28: Raffinose outliers.

	Entry	mktclass	race	Rep	value
17	92BG-7	black	mesoamerican	1	0.795
31	A-55	black	mesoamerican	1	0.745
32	A-55	black	mesoamerican	2	0.832
200	CDC Jet	black	mesoamerican	2	0.695
255	Domino	black	mesoamerican	1	0.761
325	I9365-31	black	mesoamerican	1	1.024
424	ND021717	black	mesoamerican	2	0.905
843	CDC Crocus	GN	durango	1	0.812
844	CDC Crocus	GN	durango	2	0.886
858	CDC Nordic	GN	durango	2	0.662
871	Emerson	GN	durango	1	0.668
955	GN9-4	GN	durango	1	0.703
956	GN9-4	GN	durango	2	0.706
1012	Matterhorn	GN	durango	2	0.801
1026	NE1-09-13	GN	durango	2	0.716
1053	NE1-09-20	GN	durango	1	0.880
1054	NE1-09-20	GN	durango	2	0.959
1081	NE1-09-9	GN	durango	1	0.854
1082	NE1-09-9	GN	durango	2	0.719
1599	AC Island	pinto	durango	1	0.691
1893	Frontier	pinto	durango	1	0.668
2230	NE2-09-1	pinto	durango	2	0.888
2243	NE2-09-10	pinto	durango	1	0.654
2453	Quincy	pinto	durango	1	0.677
3266	AC Polaris	small white	mesoamerican	2	0.786

Table 29: Stachyose outliers.

	Entry	mktclass	race	Rep	value
428	ND021717	black	mesoamerican	2	6.476
651	AC Resolute	GN	durango	1	4.971
917	GN Star	GN	durango	1	4.906
1085	NE1-09-9	GN	durango	1	2.847
2317	NW-410	pinto	durango	1	4.910
2485	San Juan	pinto	durango	1	5.038
2891	Centa Pupil	small red	durango	1	5.083



Table 30: Verbascope outliers.

	Entry	mktclass	race	Rep	value
293	F04-2801-4-1-2	black	mesoamerican	1	0.19
1357	Pink Floyd	pink	durango	1	0.23
1358	Pink Floyd	pink	durango	2	0.23
1414	ROG 312	pink	durango	2	0.25

Table 31: Total oligosaccharides outliers.

	Entry	mktclass	race	Rep	value
432	ND021717	black	mesoamerican	2	7.55
655	AC Resolute	GN	durango	1	5.58
921	GN Star	GN	durango	1	5.55
2489	San Juan	pinto	durango	1	5.64
2895	Centa Pupil	small red	durango	1	5.58

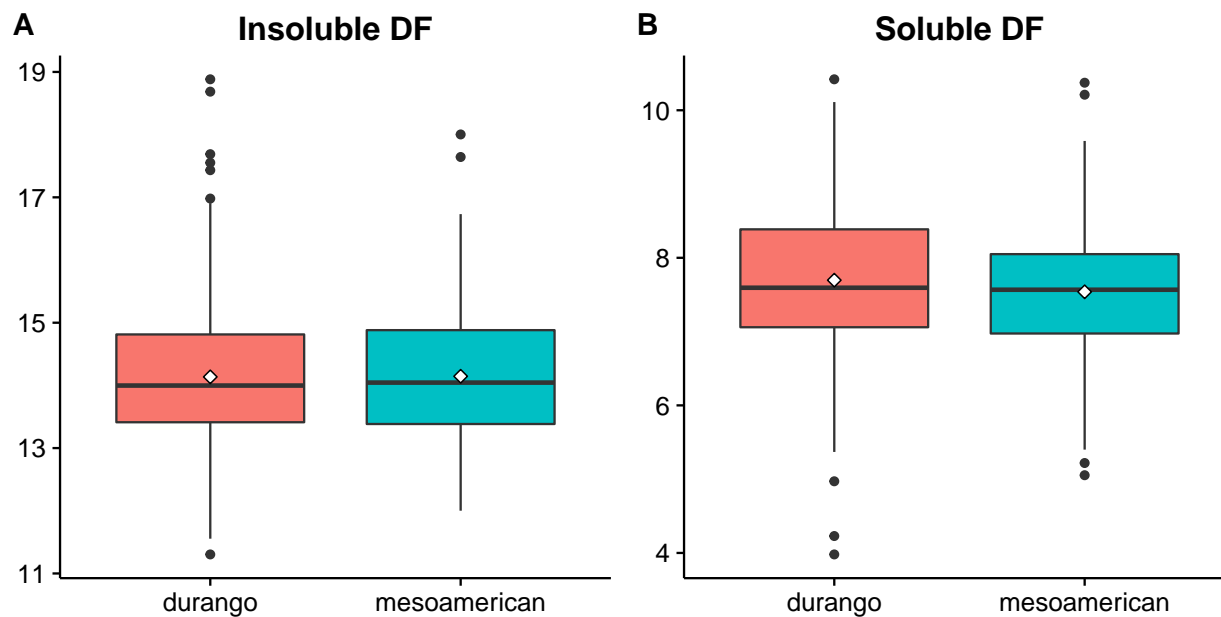


Figure 6: (A) Soluble and (B) insoluble dietary fiber in common bean by race,

Table 32: Mean fiber component content by race. Values with different letters differ significantly between races ( $p < 0.05$ ).

Race	Insoluble DF	Soluble DF
Durango	14.14 a	7.7 a
Mesoamerican	14.15 a	7.54 a

Table 33: IDF outliers.

	Entry	mktclass	race	Rep	value
197	CDC Jet	black	mesoamerican	1	17.64
449	PR0443-151	black	mesoamerican	1	18.00
631	ABC-Weihing	GN	durango	1	17.69
1415	Roza	pink	durango	1	17.55
1555	ABCP-15	pinto	durango	1	16.98
1626	AC Pintoba	pinto	durango	2	11.30
1765	CDC Pinnacle	pinto	durango	1	18.69
2591	TARS-VCI-4B	pinto	durango	1	18.88
3095	Rojo Chiquito	small red	durango	1	17.43

Table 34: SDF outliers.

	Entry	mktclass	race	Rep	value
5	115M (Black Rhino)	black	mesoamerican	1	5.22
327	I9365-31	black	mesoamerican	1	5.05
1336	I9365-5	pink	durango	2	3.98
2595	TARS-VCI-4B	pinto	durango	1	4.23
2889	Centa Pupil	small red	durango	1	4.97
3127	SR7-3	small red	durango	1	10.42
3911	Voyager	small white	mesoamerican	1	10.21
3912	Voyager	small white	mesoamerican	2	10.37

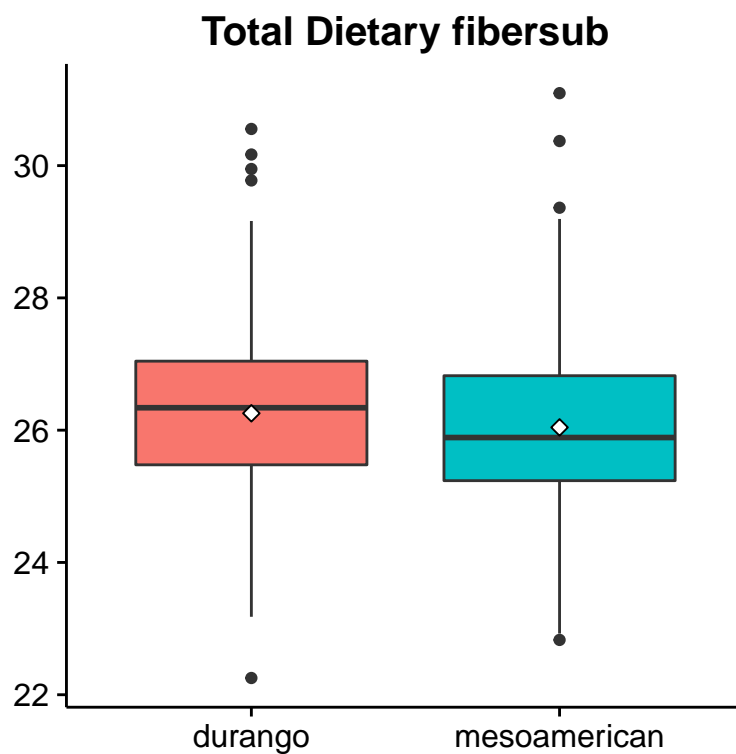


Figure 7: Total Dietary Fiber content inn common bean by race

Table 35: Mean total dietary fiber content by race. Values with different letters differ significantly between races ( $p < 0.05$ ).

Race	Total DF
Durango	26.26 a
Mesoamerican	26.04 a

Table 36: Total DF outliers.

	Entry	mktclass	race	Rep	value
430	ND021717	black	mesoamerican	2	30.37
457	PR0443-151	black	mesoamerican	1	31.10
653	AC Resolute	GN	durango	1	30.55
1326	I9365-25	pink	durango	2	24.51
1339	I9365-5	pink	durango	1	23.74
1340	I9365-5	pink	durango	2	24.37
1423	Roza	pink	durango	1	28.84
1507	USWA-61	pink	durango	1	29.14
1634	AC Pintoba	pinto	durango	2	22.25
1773	CDC Pinnacle	pinto	durango	1	29.78
2011	IP08-2	pinto	durango	1	30.17
2012	IP08-2	pinto	durango	2	29.95
2137	Max	pinto	durango	1	29.16
3650	Neptune	small white	mesoamerican	2	22.99
3860	T9905	small white	mesoamerican	2	22.93

– Lineplots

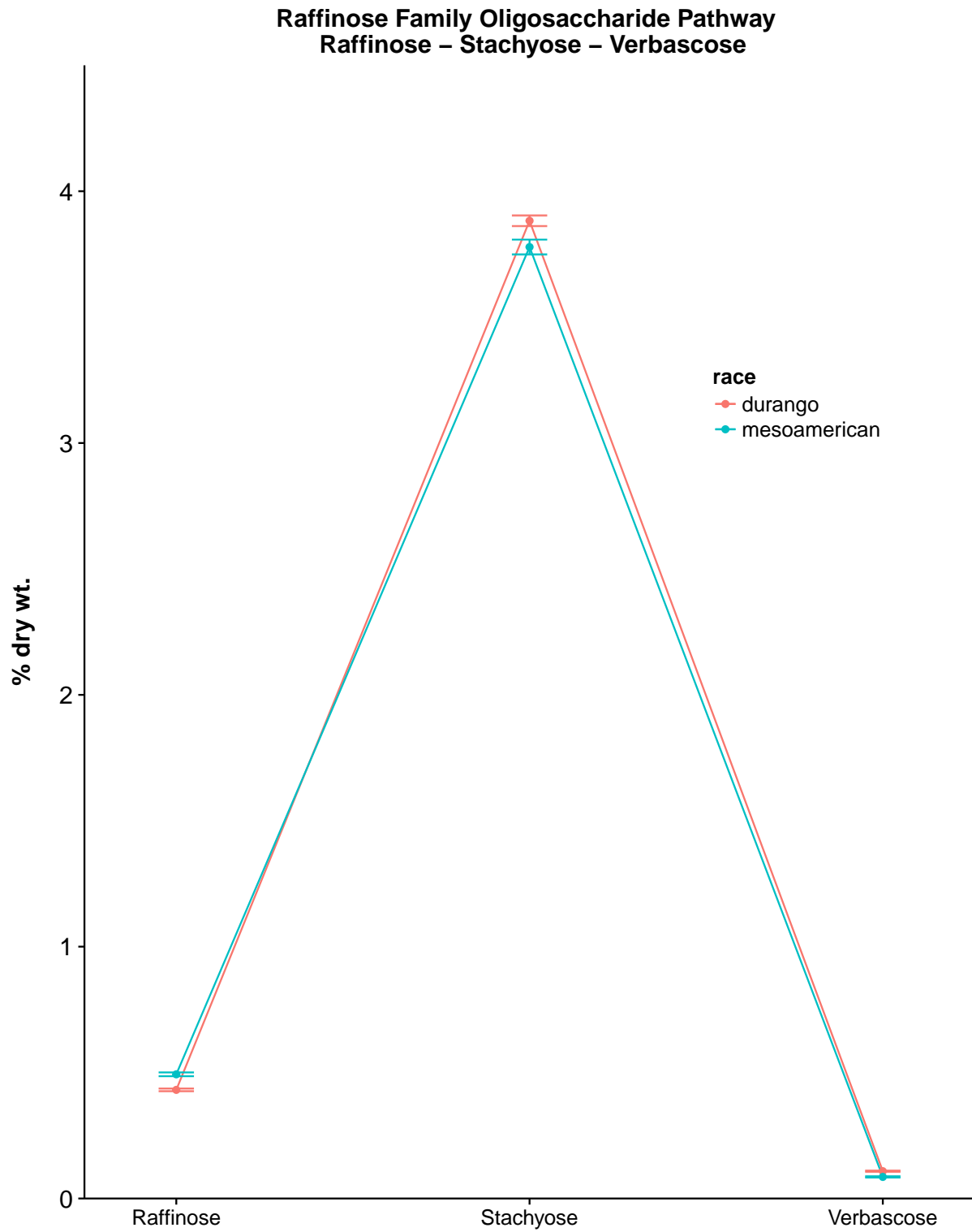


Figure 8: Mean content of each oligosaccharide along the Raffinose Oligosaccharide Family pathway.

## Statistical Methods

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

### – *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.

Table 37: ANOVA table testing raffinose.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	0.0151	0.0151	1.5233	0.2177
race	1	0.4591	0.4591	46.3238	0.0000
race:mktclass	4	0.2757	0.0689	6.9549	0.0000
Residuals	543	5.3811	0.0099	NA	NA

Table 38: ANOVA table testing stachyose.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	3.7460	3.7460	24.9411	0.0000
race	1	1.3092	1.3092	8.7167	0.0033
race:mktclass	4	3.3367	0.8342	5.5541	0.0002
Residuals	543	81.5546	0.1502	NA	NA

Table 39: ANOVA table testing verbascose.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	0.0104	0.0104	6.4660	0.0113
race	1	0.0622	0.0622	38.7633	0.0000
race:mktclass	4	0.0077	0.0019	1.1986	0.3104
Residuals	543	0.8714	0.0016	NA	NA

Table 40: ANOVA table testing total oligosaccharides.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	3.8277	3.8277	21.9484	0.000
race	1	0.5127	0.5127	2.9401	0.087

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
race:mktclass	4	4.7805	1.1951	6.8530	0.000
Residuals	543	94.6963	0.1744	NA	NA

Table 41: ANOVA table testing insoluble DF.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	7.9048	7.9048	6.8884	0.0089
race	1	0.0113	0.0113	0.0098	0.9211
race:mktclass	4	65.1238	16.2810	14.1875	0.0000
Residuals	543	623.1227	1.1476	NA	NA

Table 42: ANOVA table testing soluble DF.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	0.3447	0.3447	0.4002	0.5272
race	1	2.9956	2.9956	3.4782	0.0627
race:mktclass	4	20.5153	5.1288	5.9552	0.0001
Residuals	543	467.6525	0.8612	NA	NA

Table 43: ANOVA table testing total DF.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	1	17.4799	17.4799	12.0355	0.0006
race	1	5.4790	5.4790	3.7725	0.0526
race:mktclass	4	94.2225	23.5556	16.2189	0.0000
Residuals	543	788.6314	1.4524	NA	NA

## – *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.



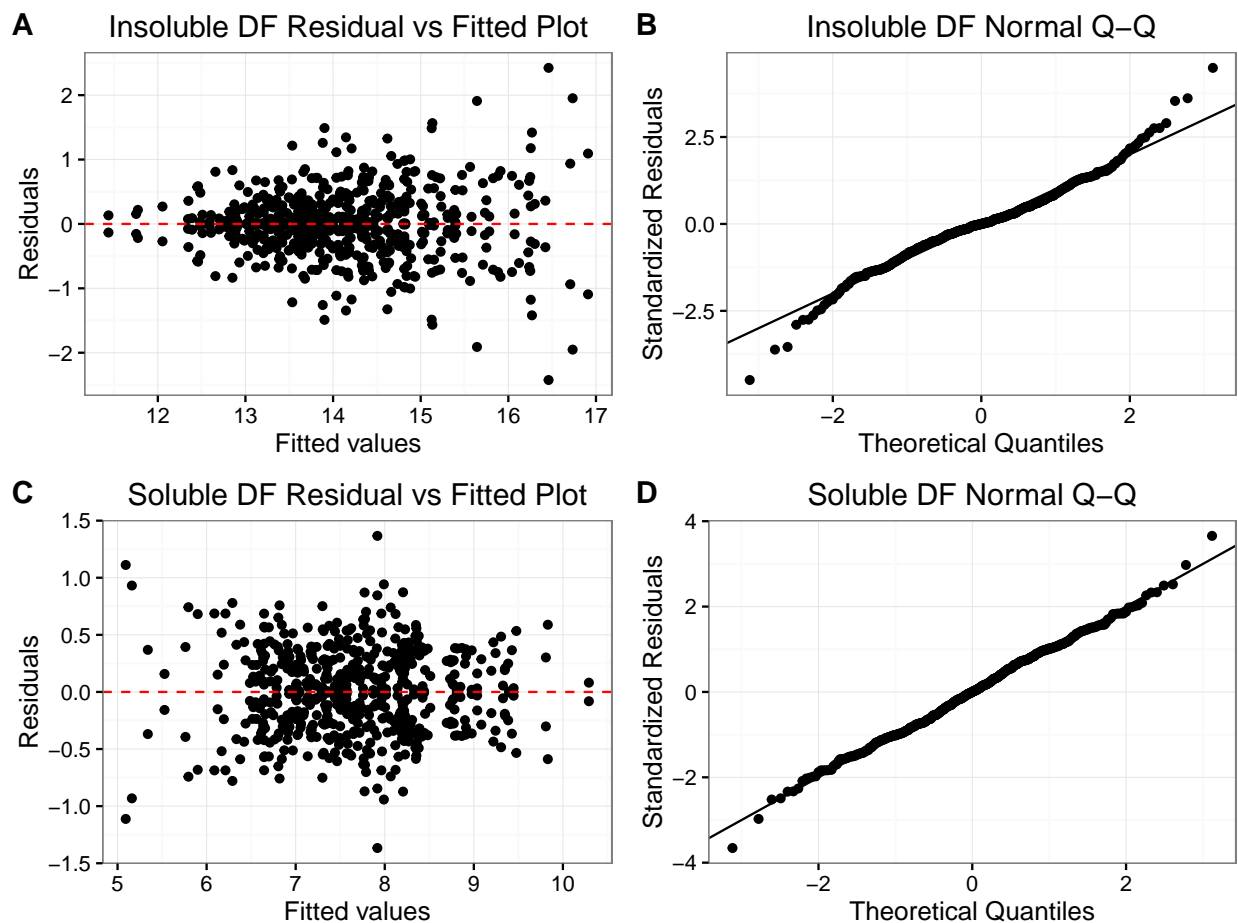


Figure 9: Residual versus fitted and q-q plots of insoluble and soluble DF. The insoluble DF plots look to reveal non-homogeneity of variance, but both the log and square root transformations did not improve it enough to warrant transforming the data.

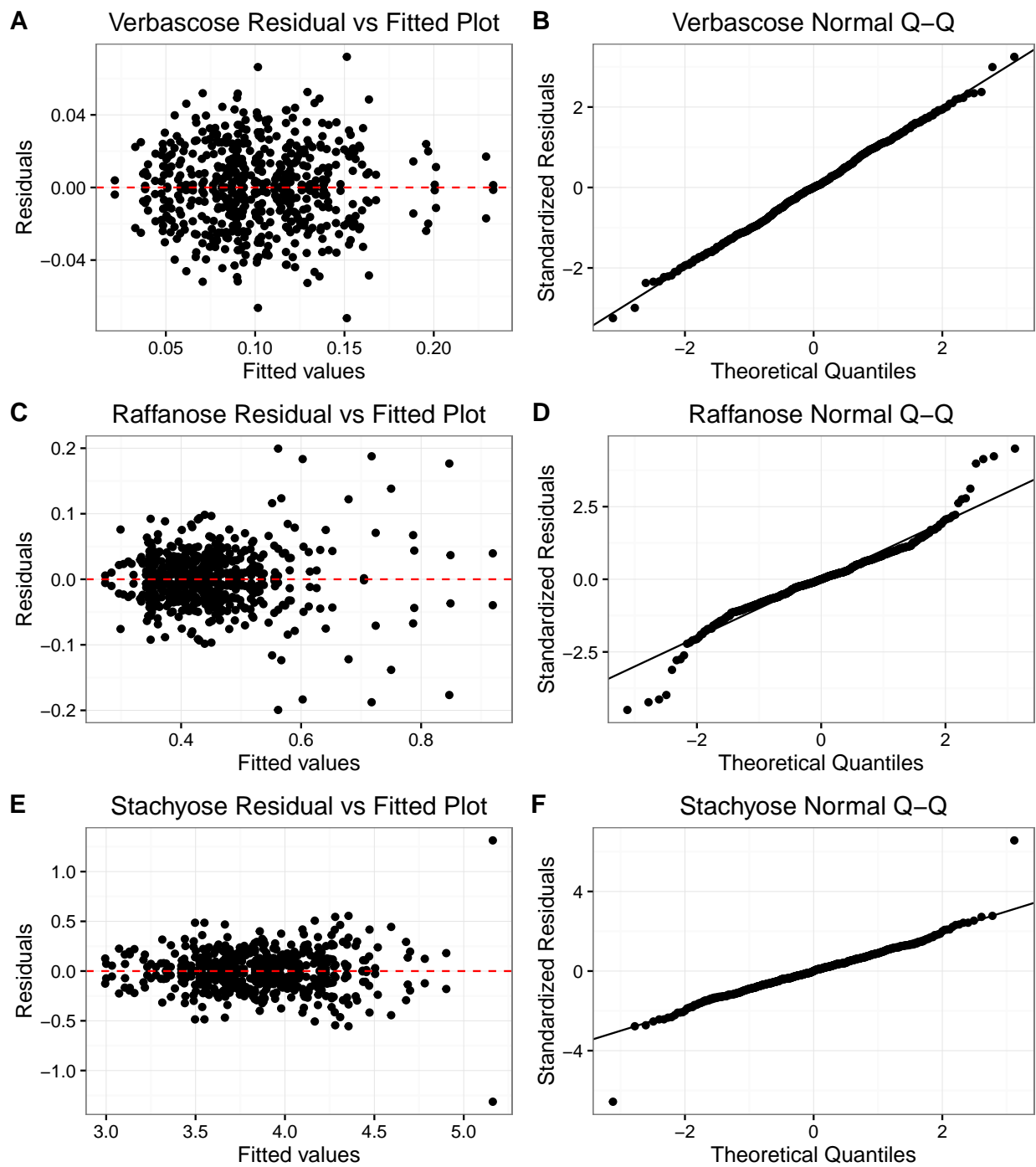


Figure 10: Residual versus fitted and q-q plots of verbascose, raffinose, and stachyose. The raffinose plots look to reveal non-homogeneity of variance, but both the log and square root transformations did not improve it enough to warrant transforming the data.

## – *Pairwise Comparisons*

Tukey adjusted pairwise comparisons were made between each market class and each race for each fiber component using the TukeyHSD function. 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)
```

## GxE Analysis

54 of the 275 entries grown in Fort Collins, CO in 2015 were also grown in North Dakota. All entries originated from the Middle American gene pool and were further subdivided into two races and six market classes. Beans were assayed for fiber components to determine effects of g, e, and gxe.

Race	Market Class	No. Entries
Durango		<b>93</b>
	GN	21.5
	pink	11
	pinto	45.5
	small red	15
Mesoamerican		<b>44.5</b>
	black	20.5
	small white	24