Divergent Selection for Polyphenol Oxidase and Grain Protein and their Impacts on White Salted Noodle, Bread and Agronomic Traits in Wheat

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Eating quality of Asian Noodles Judged by:

- Texture – varies by region and with individual.
- Color – consumers prefer stable, bright, creamy color.

Polyphenol Oxidase (PPO) affects Noodle Color:

- PPO enzyme activity related to time-dependent noodle color change (Baik et al., 1995: Martin et al., 2005).
- PPO enzyme concentrated in bran fraction.
- PPO enzyme activity increases with increased flour extraction rate.
- Low PPO activity desirable for best noodle brightness.

Genetic Control of PPO Activity:

- Genes on homoeologous group 2 chromosomes implicated (Jimenez and Dubcovsky, 1999)
- Quantitative trait loci (QTL) for kernel PPO identified 2A, 2D, 2B, 6B, 7D (Demeke et al., 2001; Raman et al., 2005)

Molecular Markers for Kernel PPO Genes:

- Full length sequences for *Ppo-A1* (2A) and *Ppo-D1* (2D) (He et al., 2007).
- Functional STS (Sequence Tagged Site) markers developed both genes.
- Markers can be used for marker assisted selection.

Other Factors Contribute to Noodle Darkening:

- Alkaline noodles continued to darken after PPO inhibited (Fuerst et al., 2006).
- Increased grain and/or flour protein leads to darker noodles.
  - Within a genotype (Baik et al., 1995; Habernicht et al., 2002).
  - Between genotypes (Davies and Berzonsky, 2003; Habernicht et al., 2002).

High Grain Protein Dilemma:

- Adds value.
- Better bread quality (loaf volume, water absorption).
- Detrimental to noodle quality.

Objectives

Determine the relative impact of *Ppo-A1* alleles and high vs low grain protein on noodles, bread and agronomic traits in segregating wheat populations.

White salted noodles low PPO (left) to high PPO ((right).

Materials and Methods:

Two Winter Wheat Populations:

- BigSky(Ppo-A1a)/BZ9W97-761(Ppo-A1b).
- GoldenSpike(Ppo-A1b)/MT9513(Ppo-A1b)//MTR99101(Ppo-A1a).
- Ppo-A1a (High PPO) Ppo-A1b (Low PPO).
- Parents fixed for *Ppo-D1*.

Divergent Selection Groups:

- ~300 F2:F3 and F3:F4 head rows.
- Measured Grain protein.
- PPO activity – 0 (light) to 5 (dark) (Anderson and Morris, 2001).
- Used means for divergent selection.

4 Selection groups (12 random lines per group):

- High PPO – High grain protein.
- High PPO – Low grain protein.
- Low PPO – High grain protein.
- Low PPO – Low grain protein.

Evaluation of Selection Groups:

- Randomized block split plot design 2 blocks.
- Populations (2) main plots.
- Entries (48 per population) subplots.
- 2 Locations.
- Measured Grain yield grain protein.

Ppo-A1 Genotyping and Re-selection:

- Used PPO18 STS marker for *Ppo-A1*.
- Select High and Low protein within *Ppo-A1* class.
- 4 selection groups (4 lines per group):
  - Ppo-A1a – High grain protein.
  - Ppo-A1a – Low grain protein.
  - Ppo-A1b – High grain protein.
  - Ppo-A1b – Low grain protein.

End Quality Evaluation:

- Kernel PPO activity (AACC method 22-85).
- Standard bread bake (AACC method 10-10B).
- White salted noodles.
  - Color L* (white-black) a* (red-green) b* (yellow-blue).
  - Texture – TA-XT2 Texture Analyzer.

Data Analysis:

- Mixed effects analysis of variance (PROX MIXED in SAS).
- Fixed effects = Environment Population *Ppo-A1* class Protein class.
- Random effects = Block Lines within *Ppo-A1* and Protein classes.
- Compared:
  - Ppo-A1 class means.
  - Protein class means.
  - Examined interactions.

Table 1. Means for kernel PPO, protein and grain yield for *Ppo-A1* allelic classes and high and low grain protein selection classes averaged over 2 populations 2 environments.

Effect	Kernel PPO	Grain protein	Grain yield
Ppo-A1 Class	ΔA_{475} min^{-1} g^{-1}	g kg^{-1}	kg ha^{-1}
Ppo-A1a	0.743	123	5006
Ppo-A1b	0.340	125	4997
P value	<0.01	0.24	0.94
Protein class			
High	0.505	132	4777
Low	0.577	115	5227
P value	0.01	<0.01	<0.01
CV%	23.7	7.8	10.2

Table 2. Means for flour and bread traits for *Ppo-A1* allelic classes and high and low grain protein selection classes averaged over 2 populations 2 environments.

Effect	Flour ash	Mix absorption	Loaf volume
Ppo-A1 class	g kg^{-1}	g kg^{-1}	mL
Ppo-A1a	4.28	624	999
Ppo-A1b	4.25	627	984
P value	0.65	0.46	0.75
Protein class			
High	4.32	639	1034
Low	4.20	611	949
P value	0.06	<0.01	<0.01
CV%	2.6	3.5	7.1

Table 3. Means for noodle color traits for *Ppo-A1* allelic classes and high and low grain protein selection classes averaged over 2 populations 2 environments.

Ppo-A1 class	L* 0h	L* 24h	L* (0-24h)
Ppo-A1a	86.5	77.5	9.0
Ppo-A1b	86.3	78.4	7.9
P value†	0.42	0.12	<0.01
Protein class			
High	85.7	76.8	9.0
Low	87.1	79.1	8.0
P value	<0.01	<0.01	0.01
CV%	1.1	2.1	9.7
Ppo-A1 class	a* 0	a* 24	a*(0-24h)
Ppo-A1a	0.082	0.639	-0.557
Ppo-A1b	0.176	1.081	-0.904
P value	0.14	<0.01	<0.01
Protein class			
High	0.239	1.097	-0.858
Low	0.019	0.623	-0.604
P value	<0.01	<0.01	<0.01
CV%	333.5	46.3	27.8
Ppo-A1 class	b* 0 h	b* 24h	b* (0-24h)
Ppo-A1a	17.76	24.24	-6.48
Ppo-A1b	18.12	25.75	-7.62
P value	0.43	0.01	<0.01
Protein class			
High	18.52	25.55	-7.03
Low	17.36	24.44	-7.08
P value	0.02	0.05	0.83
CV%	4.8	4.6	8.6

Table 4. Means for noodle texture traits for *Ppo-A1* allelic classes and high and low grain protein selection classes averaged over 2 populations 2 environments.

Effect	Springiness	Cohesiveness	Adhesiveness	Hardness
Ppo-A1 class				g
Ppo-A1a	0.914	0.549	-33.7	1033
Ppo-A1b	0.913	0.546	-33.0	1021
P value	0.92	0.57	0.52	0.31
Protein class				
High	0.917	0.554	-34.9	1044
Low	0.910	0.542	-31.8	1010
P value	0.04	0.01	0.01	0.01
CV%	2.0	3.2	16.4	6.0

Results:

- No evidence for *Ppo-A1* x Protein class interaction.
- No interactions with populations.

Table 1.

- *Ppo-A1a* differed from *Ppo-A1b* by 40 ΔA_{475} min^{-1} g^{-1}.
- High and Low protein groups differed by 17 g^{-1} kg^{-1}.
- High protein group reduced yield 8.6%.

Table 2.

- High protein group had increased water absorption and loaf volume.
- *Ppo-A1* did not affect bread.

Table 3.

- *Ppo-A1a* had > change (0-24h) in L* (darker) than *Ppo-A1b*.
- High protein < L* 0h and 24h and > change (0-24h) in L* than Low protein.
- *Ppo-A1* allelic class difference = Protein class difference (15 g kg-1) for change in L* (0-24h).
- *Ppo-A1b* gave > a* (24h) (more red) and > change in a* (0-24h) than *Ppo-A1a*.
- High protein class gave > a* and > change (0-24h) in a* than Low protein class.
- *Ppo-A1b* class gave > b* (24h) (more yellow) and > change in b* (0-24h) than *Ppo-A1a* class.
- High protein class gave > b* (0 and 24h) than Low protein class.

Table 4.

- Protein class affected noodle texture. High protein more firm.
- *Ppo-A1* class did not affect noodle texture.

Conclusions:

- High protein gave higher loaf volume and firmer noodles.
- Both *PpoA1* and protein affected noodle color profile.
- *Ppo-A1* class = 15 g kg-1 protein difference on change in noodle brightness.
- *Ppo-A1* class and Protein effects were additive.

Selected References:

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