FINAL PROJECT REPORT

Project Title: Sensory and consumer acceptance of advanced apple breeding selections

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Total Project Funding: $87,155

Budget History:

Item	Year 1: 2010	Year 2: 2011	Year 3: 2012
Salaries[1]	22,014	22,895	24,542
Benefits[2]	1,881	1,956	1,897
Equipment			
Supplies[3]	4,000	4,000	4,000
Travel			
Plot Fees			
Miscellaneous			
Total	$27,865	$28,851	$30,439

Footnotes:
1 Salaries: One MS graduate student was supported by this research (9 month salary)
2 Benefits: includes health insurance and medical aid
3 Supplies: includes chemical reagents, sensory panels supplies (consumables consisting of paper plates, towels, cuspidors, forks, plastic wrap, tape, saltines, photo copies, participation incentives).

ORIGINAL OBJECTIVES:
The overall objective of this study was to study newly developed Washington State apple selections and characterize the sensory properties of these new selections. The sensory properties of these apple selections were then related to consumer acceptance. Specific objectives were to:
1) Profile new apple selections using trained panelists. Working with Dr. Kate Evans, we identified promising apple selections ready to move to the next phase of development. Panelists were trained to describe important sensory properties of apples. The trained panel then developed sensory profiles for each of the new apple selections.
2) Consumer panel evaluation of new selections of Washington State apples. Consumers evaluated each apple selection for their liking of various sensory attributes.

SIGNIFICANT FINDINGS:
In **2010**, a series of commercial apple varieties were profiled in order to establish baseline profiles for these apples.
- Fuji – high perceived sweetness, apple flavor, firmness
- Gala – moderate sweetness, high firmness
- Honeycrisp – high crispness, moderate sweetness, high apple flavor
- Pink Lady – moderate sweetness, sourness, apple flavor
- Granny Smith – high sourness, astringency and firmness; low sweetness
- The analytical measures of crispness, firmness and mealiness (using the DigiTest), sweetness (percent soluble solids), sourness (titratable acidity) supported the results found by the trained panel.

In **2011**, the apple selections that were evaluated varied in their sensory properties and consumer acceptance based on apple selection, pick date and growing site. Specifically:
- WA5 (Brewster Pick 2), WA5 (Quincy Pick1) and Honeycrisp were rated highly by the trained panel for texture attributes and were highly acceptable by a consumer panel.
- For WA5 (Brewster), harvest time had a significant impact on texture attributes, with Pick2 being significantly higher in texture intensity. Consumers found significant differences in texture attributes and overall acceptance (Pick 2 higher).
- Growing location also influenced consumer acceptance with WA5 (Pick1); apples grown in Quincy had higher acceptance for crispness and firmness compared to those grown in Brewster.
- Honeycrisp (Pick2) was highly rated for sensory attributes as evaluated by the trained panel, but had low mealiness and astringency.
- WSU7 (Quincy, Pick1 and 2) were high in juiciness and firmness, moderately high in sweetness, high in sourness and high in apple flavor intensity as evaluated by the trained panel.
- For WSU7 (Quincy), harvest time had a significant impact only on juiciness acceptance, with Pick2 having a higher juiciness acceptance compared to Pick1.

In **2012**, apple selections were profiled by trained panelists and consumers.
- Spring 2012: WA2 and WA38 were compared in a pairwise comparison to Gala in a consumer test in Spokane. Consumers (n=120) at River Park Square (shopping center in Spokane WA) were asked which of the two apples they preferred for the attributes of appearance, taste/flavor and texture and to indicate the sample they preferred overall. Consumers significantly preferred WA2 over Gala for all attributes. WA38 was also compared to Gala in the consumer testing in Spokane WA. Results showed that consumers significantly preferred WA38 to Gala based on appearance and texture. Consumers (n=100) in Pullman WA identified WA2 fruit as having greater overall acceptance compared to Gala ,

with acceptance of firmness, crispness and juiciness being statistically significant. Consumers in Pullman WA also found WA38 to be more acceptable based on texture attributes and overall acceptance.

- Spring 2012: Trained panelists evaluated 8 apple selections (Gala as the control), with several of the apple selections being stored under different storage conditions: Jazz (MCP +/-), WA38 (MCP +/-), WA2 (RA/CA), WSU19 (MCP) and Ambrosia (MCP). Some differences were observed due to the application of MCP during storage. Gala rated lower in many sensory attributes compared to the other apples. Pullman consumer panel (n=100) evaluation of these apples showed that WA2 (RA, CA), Jazz+MCP and WSU19 (MCP), WA38 (MCP) were rated highly for overall acceptance. Ambrosia, Gala and Jazz (-MCP) were liked less by the consumers.

- Fall 2012: Consumers (n=80) and trained panelists evaluated 8 Phase 2 apple selections (Gala as the control). On Day 1, significant differences in overall acceptance of the apple selections were found, with WSU 52 being liked significantly more overall than WSU 61 and the Gala control. A similar pattern was found for apple flavor intensity, with WSU 52 being liked significantly more than WSU 50, WSU 61 and the Gala control. The acceptance of the taste attributes of sweetness and sourness also differed among apples. The sweetness and sourness of WSU 52 was liked more than these same attributes in Gala. For the texture attributes, WSU 64 and WSU 50 were liked the most for firmness, crispness and juiciness, while WSU 61 and Gala were liked the least for these texture attributes. On Day 2, WSU 81, WSU 92, WSU 82, WSU 65 and Gala (control) were evaluated. Fewer differences were noted. Apple flavor intensity differed among apples, with the Gala apple being the lowest in liking (as observed in Day 1). Gala was also lower in acceptance based on the attributes of juiciness and sweetness.

- Fall 2012: Trained panelists evaluated the following selections: WSU 50, WSU 52, WSU 61, WSU 64, WSU 65, WSU 81, WSU 82, WSU 92, and Gala. WSU 82 was the sweetest selection and only significantly differed from WSU 52 and WSU 50, which were the two least sweet. Unlike with sweetness, there was a high variation between apples in terms of sourness. WSU 92 was the most sour variety and significantly differed from the four least sour varieties, WSU 61, WSU 82, Gala, and WSU 81. WSU 64 was the highest in apple flavor and only significantly differed from Gala. WSU 50 had the highest crispness intensity and Gala had the lowest. Gala was also significantly different from WSU 50, WSU 65, WSU 92, and WSU 64 for crispness. WSU 64, WSU 50, WSU 92, and WSU 65 were the most firm varieties. All varieties had at least medium levels of juiciness, with WSU 50 being the highest, and WSU 81 and Gala being the lowest.

RESULTS AND DISCUSSION:

Spring 2012
Methods:
Apples: The selections included in this study were selected in collaboration with the WTFRC: Jazz (MCP +/-), WA38 (MCP +/-), WA2 (RA/CA), WSU19 (MCP), Ambrosia (MCP) and Gala (CA+MCP). In order to minimize the effects of environment, all the fruit was sourced from the breeding program Phase 3 orchards in Quincy and nearby commercial orchards by the WTFRC staff. The samples were delivered to Pullman one week prior to the consumer and trained panel assessment and stored in a cold room at 37F until needed. A chain of custody document was completed for each sample. Fruit from each sample were also tested by the WABP lab in Wenatchee prior to assessment.

Trained Panel Evaluations: The trained panel was composed of 10 individuals. The panelists were trained over 15 hours using techniques described by Meilgaard et al. (1999). The apple attributes were selected using reported literature and previous studies performed in our lab. Panelists were trained to recognize apple flavor (sweetness, sourness, apple flavor intensity and astringency) and texture (firmness, crispness, juiciness and mealiness).   Evaluations took place in individual sensory booths equipped with laptop computers for recording data. Following training sessions, apple selections were presented to each panelist for evaluation in replicate. Panelists were presented with 1/8 of the apple under study. The apple selections were randomly presented to the panelists at room temperature and under white lighting conditions. Panelists were asked to indicate the intensity of the apple attributes described above. Results were collected using Compusense 5.0 software (Guelph, ON) and analyzed using ANOVA and Tukey's HSD.

Consumer Panel Evaluation: Consumer evaluations were conducted in two sites: Pullman WA (February 21 and 23 2012) and Spokane WA (March 3 2012) in River Park Square, a popular shopping center located downtown Spokane. For all consumer panels, consumers were recruited using advertising, posters and e-mail. In Pullman, evaluations took place in individual sensory booths equipped with laptop computers. Consumers (n=100) were presented with 1/8 apple of the apple selections. Honeycrisp and Gala were presented as controls. Consumers indicated their overall acceptance and the acceptability of flavor (sweetness, sourness, and apple flavor intensity) and texture (firmness, crispness, and juiciness) attributes for each apple selection. All attributes were evaluated by the panel using a 7-point scale (1 = dislike very much, 7 = like very much). Results were collected and analyzed as described above. Due to the number of samples, two days of consumer evaluations were conducted. On Day 1, consumers evaluated WSU19(-MCP), Ambrosia(+MCP), WA2 (CA), Jazz(+MCP) and Gala (+MCP control). On Day 2, consumers evaluated WA38(+/-MCP), WA2(RA), Jazz(-MCP) and Gala (+MCP control).

In Spokane, consumers (n=120) were presented with two pairs of apple samples: WA2 (CA/-MCP) and Gala(+MCP control)and WA38 (CA/-MCP) and Gala(+MCP control). For each pair of samples, consumers were asked which of the two apples they preferred for the attributes of appearance, taste/flavor and texture and to indicate the sample they preferred overall. They were presented with a slice of apple for tasting but were also shown a whole apple in order to judge appearance. In both Pullman and Spokane, consumers were from diverse ethnic backgrounds and ranged from 18 to 70 with approximately 38% of subjects under the age of 35. Approximately 60% of subjects were female and the majority of consumers ate apples at least once to several times a week and grew up in the Northwest U.S.A.

<u>Results</u>
Consumer Panel Evaluations: In the Spokane consumer testing, consumers preferred WA2 over Gala for all attributes (Table 1). When comparing WA38 to Gala, consumers significantly preferred WA38 based on appearance and texture (p<0.05).

Table 1. Consumer scores indicating the preferred sample in a pair comparing WA 2 (CA/-MCP) to Gala (CA/+MCP). Data represent 120 consumer responses with * p<0.05.

	Number of consumers preferring each sample		
	WA 2	Gala	Total
Overall	88*	32	120
Appearance	85*	34	119
Taste/Flavor	82*	38	120
Texture	88*	32	120

In the Pullman WA consumer testing, 100 consumers were asked to score different attributes on a 7-point hedonic scale on a number of different apples including the same samples of WA 2 (CA/-MCP) and Gala (CA/+MCP). Once again, WA2 fruit had a greater overall acceptance compared to Gala and was preferred for all attributes, with firmness, crispness and juiciness being statistically significant (Table 2).

All of the apple selections were evaluated by consumer panels in Pullman WA. Due to the number of samples, two consumer panels on two separate days were conducted.

Day One   The separation of the different apple selections based on specific attributes is shown in Table 2. Based on overall acceptance, the Gala control was rated the lowest compared to the other apple selections. Based on texture, WA2CA and Jazz+MCP were more accepted by consumers for firmness, with Gala (CA/+MCP) being the least accepted. A similar trend was observed for crispness while for juiciness, the WSU19-MCP and the Gala (CA/+MCP) apples were rated the lowest in acceptance.   Based on sourness, results showed that the apple selections of WSU19-MCP, WA2CA and Jazz+ MCP were the most accepted with similar results found for sweetness acceptance.

Day Two   The separation of the different apple selections evaluated by the consumers on Day 2 is shown in Table 3. Based on overall acceptance, the WA2 (RA) and WA38 (+MCP) apples were the most accepted by the consumers. A similar pattern was observed for acceptance of apple flavor intensity. For texture attributes, Gala (CA/+MCP) was the least accepted based on firmness, as observed with the Day 1 apples. Gala (CA/+MCP) was also least accepted for crispness and juiciness, again results that were observed when comparing Gala (CA/+MCP) to the Day 1 apple selections. Regarding acceptance of sweetness, the most accepted apples were WA38(-MCP) and WA2(RA).

Table 2. Mean separation (Tukey's HSD) for consumer (n=100) acceptance of sensory attributes of five apple selections on Day 1 using a 7-pt hedonic scale (with 1= dislike very much and 7=like very much). Within each attribute, different letters indicate a significant differences (p<0.05).

Apple attributes	WSU 19 -MCP	Ambrosia +MCP	WA 2CA	Gala (CA/+MCP)	Jazz+MCP
Overall acceptance	5.6a	5.3ab	5.6a	5.1 b	5.3ab
Apple flavor intensity	5.3a	4.6 b	5.2ab	4.7 b	5.0ab
Firmness	5.4 c	5.6bc	6.1a	4.9 d	5.9ab
Crispiness	5.7a	6.0ab	6.2a	5.1 c	6.0ab
Juiciness	5.2 c	5.7ab	6.1a	5.3 bc	6.0a
Sweetness	5.7a	5.2 b	5.4ab	5.1 b	5.3ab
Sourness	5.2a	4.4 c	5.1ab	4.6 bc	4.8abc

Table 3. Mean separation (Tukey's HSD) for consumer (n=100) acceptance of sensory attributes of five apple selections on Day 2 using a 7-pt hedonic scale (with 1= dislike very much and 7=like very much). Within each attribute, different letters indicate a significant differences (p<0.05).

Apple attributes	WA38+MCP	WA38-MCP	WA2RA	Gala(CA/+MCP)	Jazz-MCP
Overall acceptance	5.1 c	5.7ab	6.0a	5.0 c	5.2 bc
Apple flavor intensity	4.8 b	5.5a	5.7a	4.5b	4.7 b
Firmness	5.9a	6.0a	6.1a	4.8 b	5.8a
Crispiness	6.1ab	6.2ab	6.3a	5.0 c	6.0 b
Juiciness	5.9ab	6.1a	6.1a	5.1 c	5.6 b
Sweetness	4.9 b	5.5a	5.8a	4.9 b	5.0 b
Sourness	4.4 c	5.1ab	5.3a	4.6a	4.6 c

Trained Panel Evaluations: The intensities of several of the sensory attributes evaluated by the trained panelists are shown in the following figures. For sourness, Ambrosia was found to be the least intense. For the texture attributes of crispness, firmness and juiciness, Gala was the least intense.
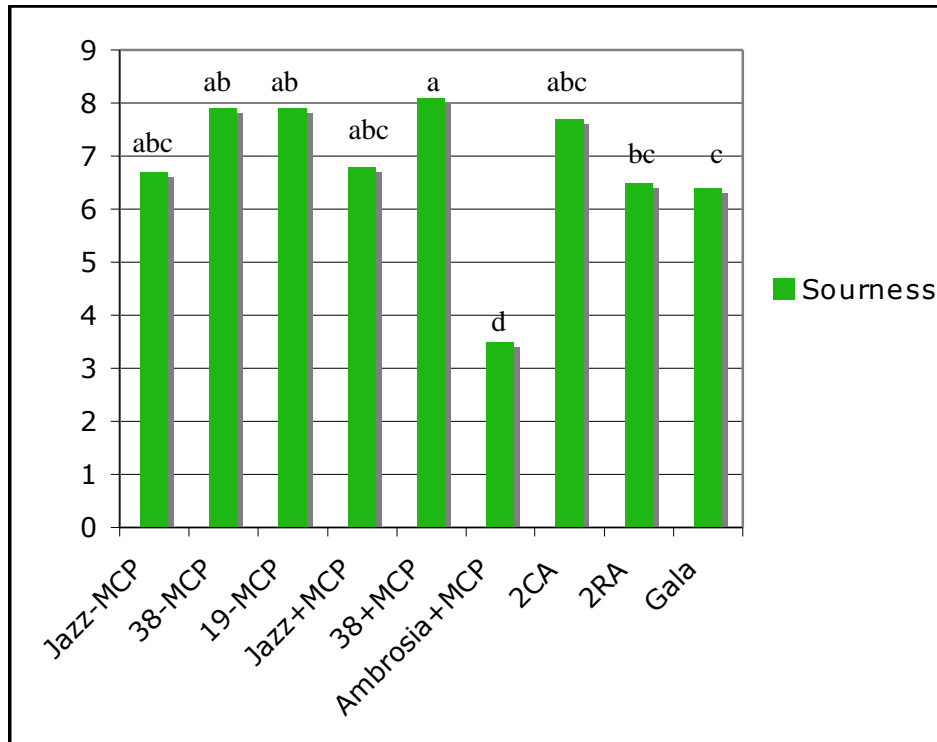

Figure 1. Separation of the 9 apples as evaluated by the trained panelists for sourness intensity (n=13).
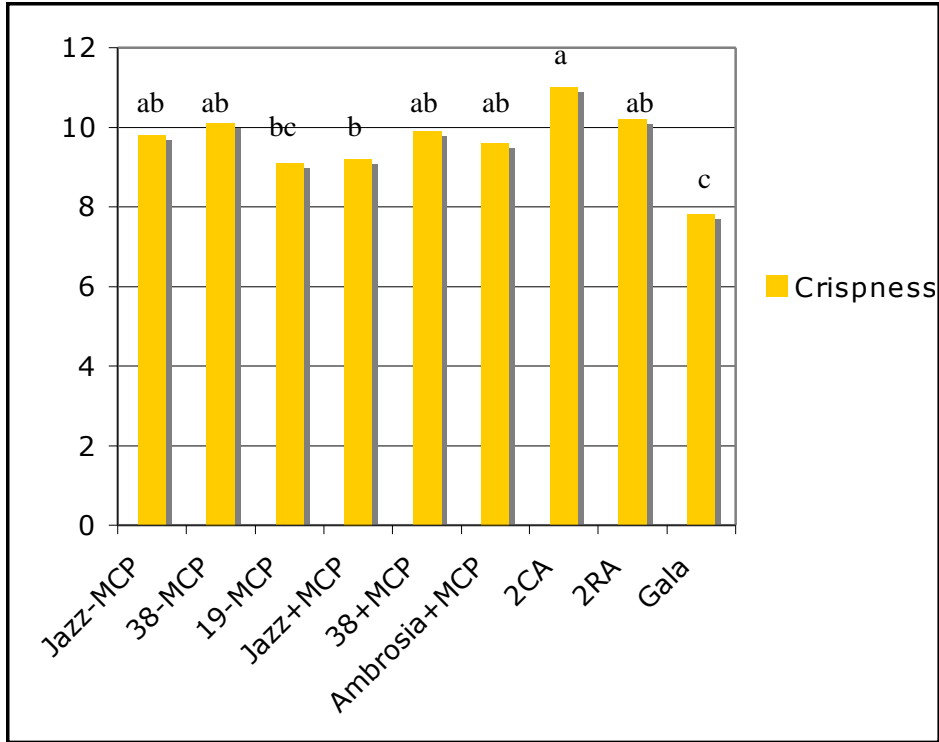
Figure 2. Separation of the 9 apples as evaluated by the trained panelists for crispness intensity (n=13).
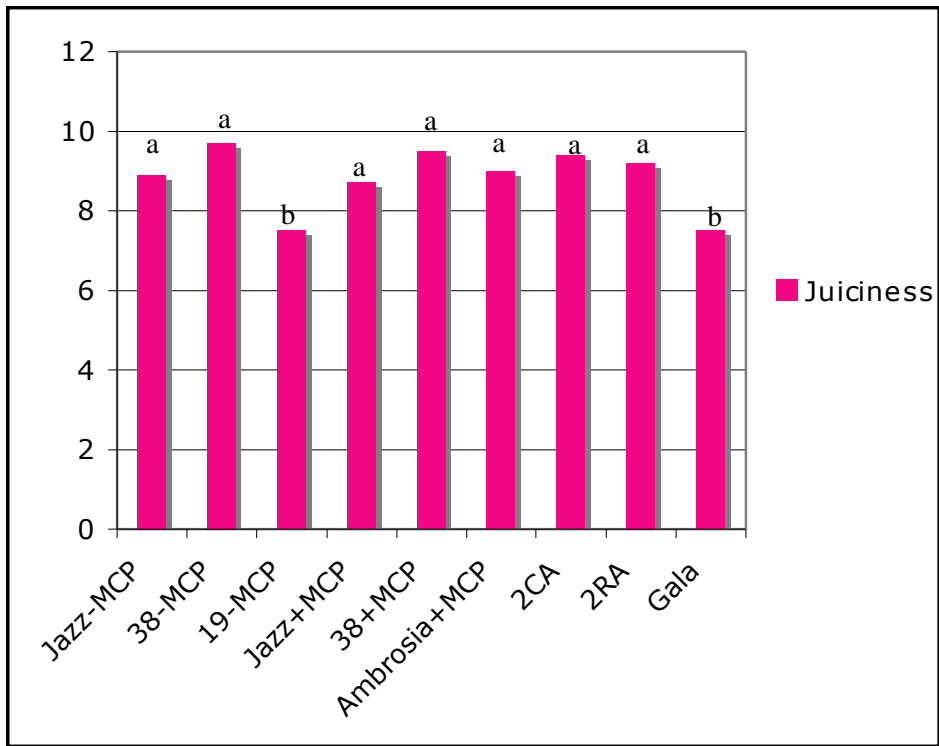

Figure 3. Separation of the 9 apples as evaluated by the trained panelists for juiciness intensity (n=13).
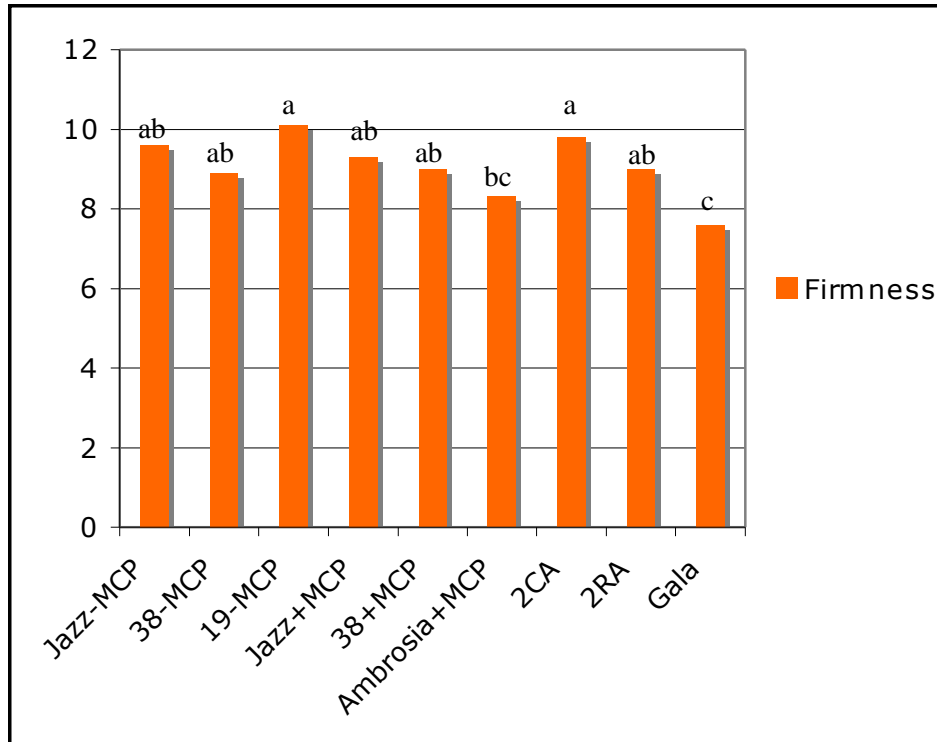
Figure 4. Separation of the 9 apples as evaluated by the trained panelists for firmness intensity (n=13).

Fall 2012
The methods used in Fall 2012 were similar to those in Spring 2012. The Phase 2 apple selections evaluated were: WSU 50, WSU 52, WSU 61, WSU 64, WSU 65, WSU 81, WSU 82, WSU 92, and Gala. The consumer panels differed in that that they were only conducted in Pullman. For the consumer panels, on Day 1, 80 consumers were presented with WSU 52, WSU 64, WSU 50, WSU 61 and Gala (control). On Day 2, 80 consumers were presented with WSU 81, WSU 92, WSU 82, WSU 65 and Gala (control). The Gala control apples were supplied by the WTFRC.

Consumer Panel Evaluations: On Day 1, significant differences in overall acceptance of the apple selections was noted (Table 4). WSU52 was liked significantly more overall than WSU 61 and the Gala control but with similar overall liking as WSU64 and WSU50. A similar pattern was found for apple flavor intensity, with WSU52 being liked significantly more than WSU50, WSU61 and the Gala control. The acceptance of the taste attributes of sweetness and sourness also differed among apples. The sweetness and sourness of WSU52 was liked more than these same attributes in Gala. For the texture attributes, WSU64 and WSU50 were liked the most for firmness, crispness and juiciness, while WSU61 and Gala were liked the least for these texture attributes. Compared to Day 1, the apples evaluated on Day 2 did not show as many differences (Table 5). No significant differences were noted among apples for overall acceptance, firmness, crispness, or sourness. Apple flavor intensity did differ among apples, with the Gala apple being the lowest in liking (as observed in Day 1). As also seen in Day 1, Gala was lower in acceptance based on the attributes of juiciness and sweetness.

Table 4. Mean separation (Tukey's HSD) for consumer (n=80) acceptance of sensory attributes of five apple selections on Day 1 using a 7-pt hedonic scale (with 1= dislike very much and 7=like very much). Within each attribute, different letters indicate a significant differences (p<0.05).

Apple attributes	WSU 52	WSU 64	WSU 50	WSU 61	Gala (control)
Overall acceptance	5.7a	5.5ab	5.5ab	5.0b	5.0b
Apple flavor intensity	5.8a	5.3ab	5.2b	5.1b	4.5c
Firmness	5.6ab	5.8a	5.9a	4.7c	5.2b
Crispiness	5.9ab	6.1a	6.1a	4.9c	5.5b
Juiciness	6.1a	5.8ab	5.7ab	5.5bc	5.2c
Sweetness	5.6a	5.4a	5.4a	5.3ab	4.9b
Sourness	5.3a	4.8ab	5.2a	4.9a	4.3b

Table 5. Mean separation (Tukey's HSD) for consumer (n=80) acceptance of sensory attributes of five apple selections on Day 2 using a 7-pt hedonic scale (with 1= dislike very much and 7=like very much). Within each attribute, different letters indicate a significant differences (p<0.05).

Apple attributes	WSU 65	WSU 92	WSU 81	WSU 82	Gala (control)
Overall acceptance	5.4	5.5	5.6	5.5	5.2
Apple flavor intensity	5.4a	5.3ab	5.4a	5.0ab	4.8b
Firmness	5.7	5.7	5.4	5.4	5.6
Crispiness	6.1	5.9	5.7	5.7	5.9
Juiciness	6.0a	5.8ab	5.9ab	6.0a	5.5b
Sweetness	5.3ab	5.2ab	5.5a	5.4ab	5.0b
Sourness	5.0	4.8	5.0	4.6	4.8

Trained Panel Evaluations: WSU82 was the sweetest selection and only significantly differed from WSU52 and WSU50, which were the two least sweet selections. Unlike with sweetness, there was a high variation among apple selections in terms of sourness (Figure 5). WSU92 was the most sour and significantly differed from the four least sour selections, WSU61, WSU82, Gala, and WSU81. All the apple selections had low intensities and little variation for astringency. WSU52 was the most astringent, with a mean intensity of 5.6, and significantly differed from the three least astringent selections, Gala, WSU65, and WSU81. There was also little variation between apples in terms of apple flavor intensity. WSU64 the highest in apple flavor and only significantly differed from Gala. All the texture attributes were found to have medium to medium-high intensities except for mealiness, which exhibited low intensity in all apple selections. WSU50 had the highest crispness intensity and Gala had the lowest crispness intensity (Figure 6). Gala was also significantly different from WSU50, WSU65, WSU92, and WSU64 for crispness. WSU64, WSU50, WSU92, and WSU65 were the most firm selections and did not significantly differ from each other (Figure 7); however, they were significantly different from the rest of the selections. All selections had at least medium levels of juiciness (Figure 8), with WSU50 being the highest, with a mean of 10.6 intensity, which significantly differed from WSU81 and Gala, the two least juicy selections. The mealiest selection was WSU81 and the least mealy selection was WSU50.
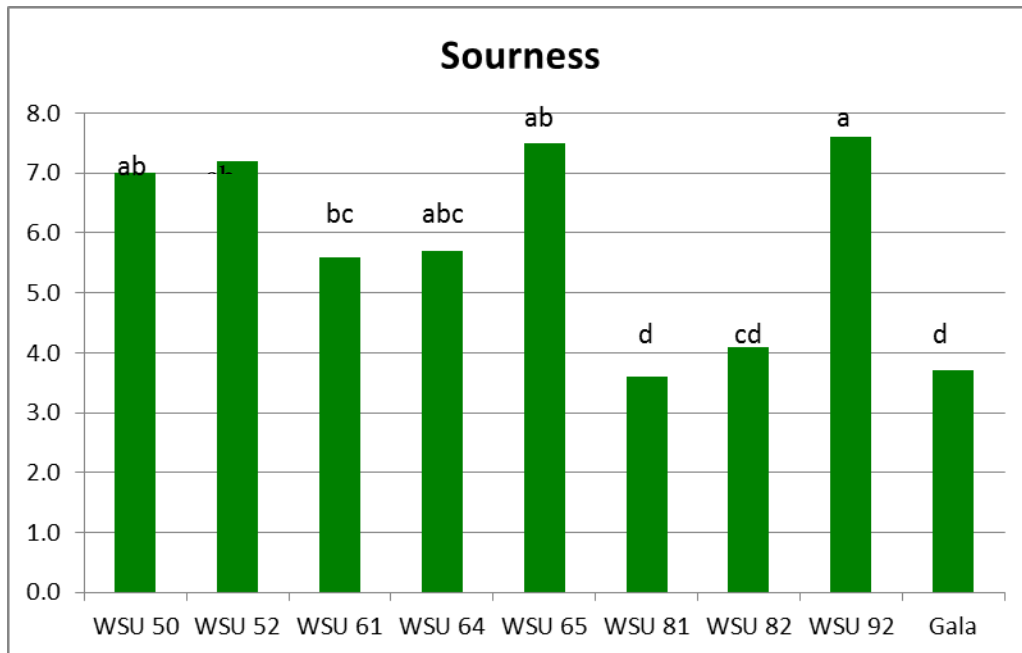
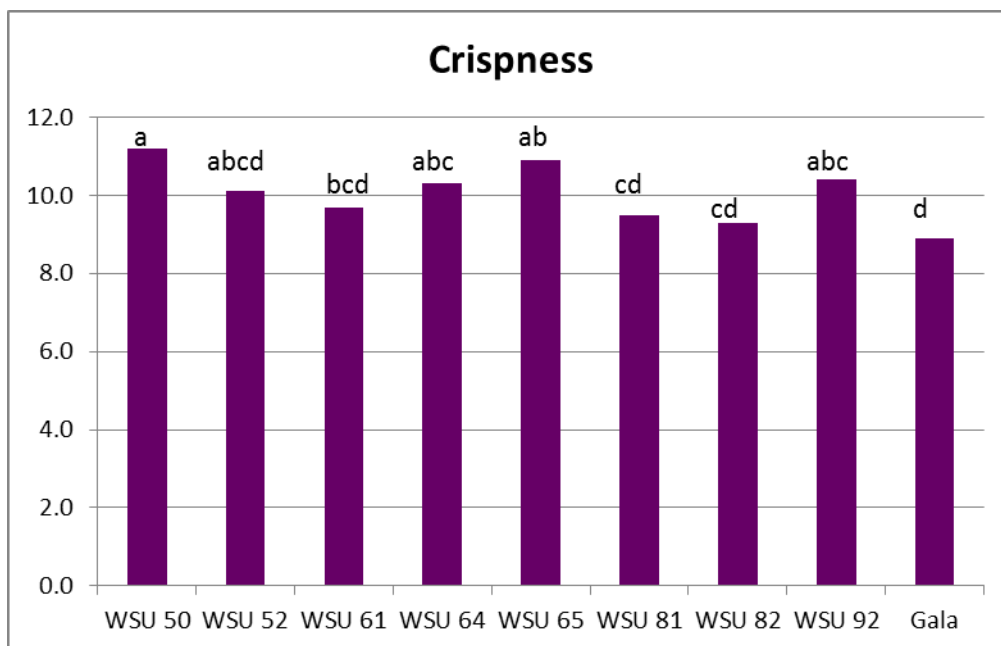**Figure 5.** Separation of the 9 apples as evaluated by the trained panelists for sourness intensity (n=10).

Figure 6. Separation of the 9 apples as evaluated by the trained panelists for crispness intensity (n=10).

Figure 7. Separation of the 9 apples as evaluated by the trained panelists for firmness intensity (n=10).
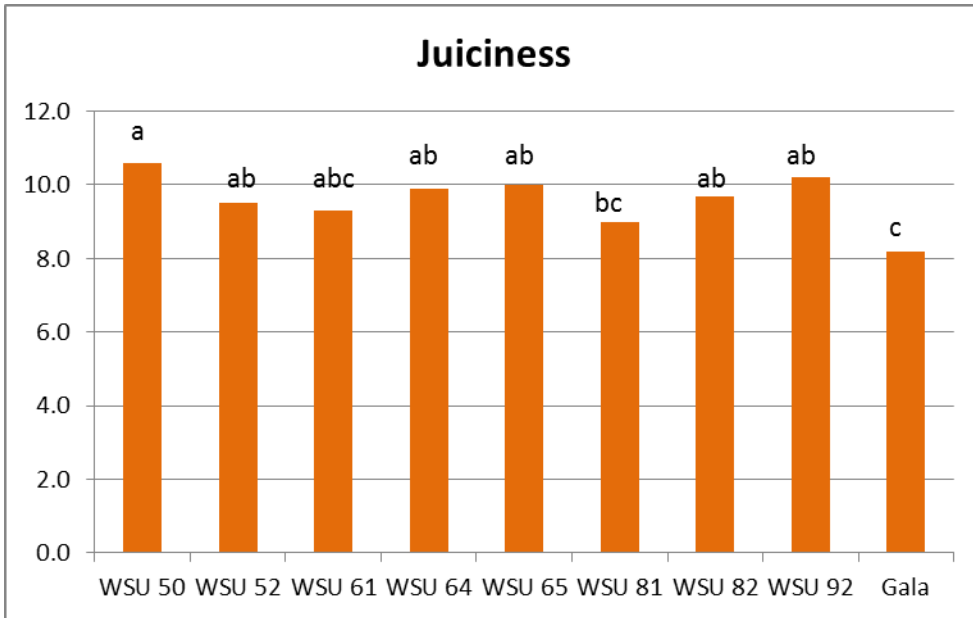

Figure 8. Separation of the 9 apples as evaluated by the trained panelists for juiciness (n=10).

EXECUTIVE SUMMARY
Significant Progress and Future Directions
The fruit industry is going through a transformation in which the consumer is given more consideration than in the past. Consequently, greater pressure has been placed on breeders and growers to develop new apple cultivars that meet the needs of the consumers. To gather consumer acceptability information, as well as detailed characterizations of the apples, sensory evaluation of new apple selections is required.

This project characterized new apple selections developed by the Washington State University Apple Breeding Program (WABP). These selections showed promise for commercialization based on the preliminary evaluation by the breeding team. However, in order to aid decisions regarding the commercialization of an advanced selection from the breeding program, further formal sensory evaluation studies were conducted on the fruit. The first step was to characterize the sensory properties of the apples using a trained sensory panel. To determine consumer acceptability, thus helping with future commercial success, the apple selections were also evaluated by consumer panels to determine the acceptance of various sensory attributes of the apples including texture, flavor, taste and appearance. These results have assisted the WABP and the WTFRC in identifying which apple selection should be recommended for commercialization and provided some information regarding the optimum storage regime required.

This project built upon several years of previous collaborative research in which researchers at the WSU sensory evaluation facility (Pullman) worked with apple breeders at the WSU Tree Fruit Research & Extension Center (Wenatchee) to perform sensory evaluation of promising apple selections. The sensory and consumer data on the advanced and elite selections from the WABP provided useful feedback to the breeding team, confirming decisions about which selection or selections to take forward for release and commercialization.

Summary of Findings:
- Established a baseline profile of five commercially available apple selections.
- Described specific sensory differences in apple selections due to pick date and growing site. For some apples, an earlier pick date maintained the sensory quality of the apples, which corresponded to a high consumer acceptance. However, for other apples such as WSU7 (Quincy), harvest time had a significant impact only on juiciness acceptance, with Pick2 having a higher juiciness acceptance compared to Pick1.
- Growing location influenced sensory properties. For example, WA5 grown in Quincy had higher consumer acceptance for crispness and firmness compared to those grown in Brewster.
- WA2 and WA38 were compared to Gala in consumer tests in Spokane and Pullman WA. Results showed that WA2 fruit was significantly preferred over Gala for appearance, taste/flavor and texture by consumers at River Park Square (shopping center in Spokane WA). WA38 was also compared to Gala in consumer testing in Spokane WA. Results showed that consumers significantly preferred WA38 to Gala based on appearance and texture. Similar results were found in Pullman WA consumer tests which found WA2 and WA38 to be more acceptable than Gala based on texture attributes and overall acceptance.
- Trained panelists evaluated 8 apple selections (Gala as the control), with several of the apple selections being stored under different storage conditions. Results showed the effect of the presence of 1-MCP on the sensory properties of some selections and varieties.
- Early testing shows that WSU64, WSU50 (high crispness and juiciness) and WSU81 are promising new selections based on their acceptance of sensory properties.
- Three years of consumer and trained panel sensory evaluation studies confirm that overall acceptance of the apple is related primarily to its texture attributes, followed by flavor.