FINAL PROJECT REPORT **YEAR**: 18 months of 18

WTFRC Project Number: AP-17-108

Project Title: 'WA38' fruit size and dry matter for fruit quality/consumer preference

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Item	2017	2018
Salaries	24,000	24,960
Benefits	8,597	8,941
Equipment[¥]	6,000	
Supplies		
Travel	6,500	6,500
Miscellaneous[1]	36,350	38,350
Plot Fees	5,000	5,000
Total	**86,447**	**83,751**

Footnotes:
[1] WSU sensory evaluation facility fees
[¥] Originally, we requested funds for an Amilon starch meter. Instead, in December 2017 our Minolta color meter broke and Konica Minolta would no longer service it. We asked permission from Mike Willet to use the equipment money to buy a new Minolta Colorimeter CR-400 (no request of increase in current year budget).

RECAP ORIGINAL OBJECTIVES

1. ***Identify the distribution of fruit size and dry matter in both a young (1st crop in 2018) and a mature orchard (4th crop in 2017 and 5th crop in 2018).***
2. ***Correlate fruit quality parameters of selected fruit categories (by size and dry matter) to consumer preference.***

SIGNIFICANT FINDINGS

1. ***Identify the distribution of fruit size and dry matter in both a young (1st crop in 2018) and a mature orchard (4th crop in 2017 and 5th crop in 2018).***
    - Using a non-destructive predictive model, dry matter was estimated at harvest in 2017 and 2018 among young (1st crop 2018) and mature (4th crop 2017 and 5th crop 2018) orchards. 2018 production showed a tendency toward higher dry matter classes than the 2017 fruit distribution.
    - Younger orchards generally produced larger proportions of higher dry matter fruits than the more mature orchard.
    - WA38 non-destructive dry matter prediction model (created in 2017 and adopted across the whole project) reported an increase in mean absolute error of its performance when utilized in 2018 on young orchard with very high dry matter apples.
2. ***Correlate fruit quality parameters of selected fruit categories (by size and dry matter) to consumer preference.***
    - Mature crop (5th crop) produced apples with lower firmness, soluble solid content (SSC), titratable acidity (TA), I_{AD} and lower starch index than 1st and 2nd cropping orchards (young) both at +1.5 M and + 5.5 months of after harvest 2018.
    - Firmness, I_{AD} and starch index decreased linearly with the increase of apple size (from Small to Extra-large) with the larger apples being softer, with lower I_{AD} and starch index.
    - The four different apple sizes at +1.5M after harvest 2018 did not statistically differ in terms of soluble solid content (SSC) nor for titratable acidity.
    - The top 3 WA38 attributes that contribute the most to the overall liking are, in order, apple flavor, sweetness and sourness
    - WA38 apples with dry matter between 14.00% and 16.99% were always preferred by consumers if compared to dry matter classes 17.00% to 18.99% in the Medium and Large sizes.
    - Consumers are more inclined to pay higher prices for WA38 apples coming from mature orchards and Large in size.

METHODS

1. ***Identify the distribution of fruit size and dry matter in both a young (1st crop in 2018) and a mature orchard (4th crop in 2017 and 5th crop in 2018).***

Non-Destructive Dry Matter Prediction Model

Procedure described in 2017 continuing report.

At-Harvest Size and Dry Matter Distribution of Young and Mature Orchards (2017-2018)

To examine dry matter distribution as a response to orchard age, rootstock, and fruit size, four orchards were evaluated non-destructively for predicted dry matter at-harvest using the model previously described in year 1 report. In 2017, the 4th crop (mature) of Sunrise Orchard (SRO, WA38 on G41 and M9-NIC29 rootstocks) was harvested. In 2018, Sunrise WA38 block (5th crop) was again harvested with the addition of a Granny Smith on M9-T337 top-worked with WA38 in 2016 (2018 being its 1st crop). Additionally, two new commercial WA38 orchards trained to spindle– one budded on G41 (Freepons-Prosser) and the other on M9-NIC29 (Quincy) – were harvested as their 1st

cropping in 2018. Representative Fancy and Extra Fancy subsamples of fruit from each orchard were selected for dry matter prediction and sorted in to size classes under the following classifications: Small = 70-75 mm or ~113-88 apples/box (U.S. apple box equivalent to 19 kg apples), Medium = 80 mm or ~80-72/box, Large = 85-95 mm or ~64-<48/box, and Extra-Large = 100+mm or < 48/box. Fruit 65 mm or smaller (163/case) were not considered marketable fruit for the purpose of this study.

Fruit Sorting for Quality and Consumer Testing

Following predicted dry matter and fruit size classification, apples from the 2017 Sunrise Orchard harvest were divided in to low (13.00 – 13.99%), moderate (14.00 – 14.99%), and high (15.00-15.99 %) predicted dry matter categories and Small (70-75mm), Medium (80mm), and Large (85-95mm) fruit size categories. From these categories, fruit were randomly assigned in equal proportion to either instrument fruit quality evaluation or consumer testing groups, and within these groups, either split in a 1 or 5-months post-harvest evaluation period. Fruit were stored at 32°F under regular atmosphere conditions until quality evaluation and consumer testing (carried out contemporarily).

Dry matter predicted at 2018 harvest was higher than dry matter at harvest 2017, so we modified the classification with "very high" dry matter classes (i.e. 16.00-16.99%, 17.00-17.99%, 18.00-18.99% predicted dry matter). Combinations of orchard age-size-predicted dry matter apples were sorted in to evaluation periods as done in 2017. Not all class combinations were available in sufficient amounts for both quality and consumer evaluation, and in these scenarios (e.g. low dry matter in Large fruit), instrumental quality was prioritized over consumer evaluation both at +1.5 month after harvest (November 2018) and + 5.5 month of storage (March 2019). Additionally, at-harvest sorting classes used for 2017 harvest of Sunrise Orchard (low, mid, high dry matter) needed to be enlarges to accommodate 2018 harvests as substantial portions of fruit belonged to groups outside these classes. Complete data analysis was finalized after the last consumer test in March 2019 and reported below in the results session.

2. ***Correlate fruit quality parameters of selected fruit categories (by size and dry matter) to consumer preference.***

Instrumental Fruit Quality

Fruit quality was assessed 1- and 5-months post-harvest on the basis of red blushed overcolor (%), maximum red and background color (CR-300 Colorimeter, Konica Minolta, Toyko, Japan), I_{AD} (Sinteleia, Italy) firmness (Digi-Test2, Mohr, Richland, WA, USA), soluble solids concentration (°Brix, PAL-1, Atago, Bellevue, WA, USA), starch index (1 to 6 WTFRC scale), actual dry matter (%), titratable acidity (% Malic Acid), and pH, among others both in 2017 and 2018.

Consumer Panels

For the first year, WA38 apples were received on November 15th, 2017 and March 26th, 2018 for consumer evaluation at 1- and 5-months post-harvest, respectively, and placed in 38°F storage at the WSU School of Food Science in Pullman, WA. Fruit from regular cold storage were brought up to room temperature 24 hours before analysis, washed in cool water and dried with paper towels. Apples were cut into equal 1/8 parts with the seed core removed and placed on a white paper plate. From this samples, consumers were asked about their acceptance of the apple slice appearance, aroma, firmness, crunchiness, juiciness, sweetness, sourness, apple flavor and overall liking using a 9-point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much and 9=like extremely). For each period of evaluation, consumers anonymously tested up to 5 sliced fruit samples a day for each day of testing until all combinations of rootstock, fruit size, and predicted dry matter were exhausted. 94 consumers participated in the 1-month, and 97 for the 5-month post-harvest evaluation – a total of 1,965 responses.

In the second year (2018) we ended up with 29 combinations of rootstock-orchard age-fruit size and DM class to compare after 1.5 M after harvest and offer to the panelists across 6 days of sensory analysis. We worked with 3 teams of panelists, each team was coming to taste fruit for two days in a row then the second team was taking over and then the third one (panelists number in each team: 102, 101, 99). Each panel team tasted apples coming from young and mature orchards within one rootstock. To verified that the judgmental capacity of each team was not significant different across days, we introduced an internal control (not done in 2017 panel test) of Honeycrisp apples harvested in 2018 from the same farm where WA38 mature (5th crop) block is planted (Sunrise Rock, Island) to be tasted every other day across the 6 days of panel. Another reason to introduce a highly appreciated variety in the trail was to see how the different combinations of WA38 sorted by DM and size scored in comparison to Honeycrisp in terms of overall liking. Statistical analysis of the responses for Honeycrisp samples across the 3 teams presented only slice appearance as the only one attribute barely significant; given the lack of differences across the other attributes, we felt comfortable compiling the data and making comparisons across all apples across 6 days (29 combinations and 3 controls). In addition, also the ballot was modified in 2018 integrating a series of 3 "willingness to pay" dichotomous questions in order to identify which price is the most appropriate for the consumers based on the eating experience ($1.21/lb, $2.23/lb or $3.25/lb). In March 2019, the same procedure was repeated offering to the panelist WA38 apples from 23 combinations after 5.5 M of RA cold storage plus 6M stored organic Honeycrisp as internal control across the 6 days. Numbers of panelists in the three teams in March 2019 were 96, 98, 101 for a total of 2,486 responses (including Honeycrisp control).

RESULTS & DISCUSSION

1. ***Identify the distribution of fruit size and dry matter in both a young (1st crop in 2018) and a mature orchard (4th crop in 2017 and 5th crop in 2018).***

At-Harvest Size and Dry Matter Distribution of Young and Mature Orchards (2017-2018)

Figure 1 illustrates the predicted 2018 dry matter distribution among dry matter classes (each DM class covers 1% DM increase). We sampled 4477 apples in 2018 and 1360 apples in 2017 (mature 4th crop SRO for trees budded on G41 and Nic29). Younger orchards produced larger proportions of higher dry matter fruits relative to the more mature orchard. This is due to their low cropping densities in 2018 as well as from being of first cropping maturity, increasing the allocation of dry matter on a per-fruit basis despite the high vigor of this cultivar. The large proportion of high dry matter fruits in the first cropping year is likely transitory and will even out as the orchard matures. 2018 production showed a tendency toward higher dry matter classes than the 2017 fruit distribution. Dry matter shifts among fruit sizes and rootstocks and

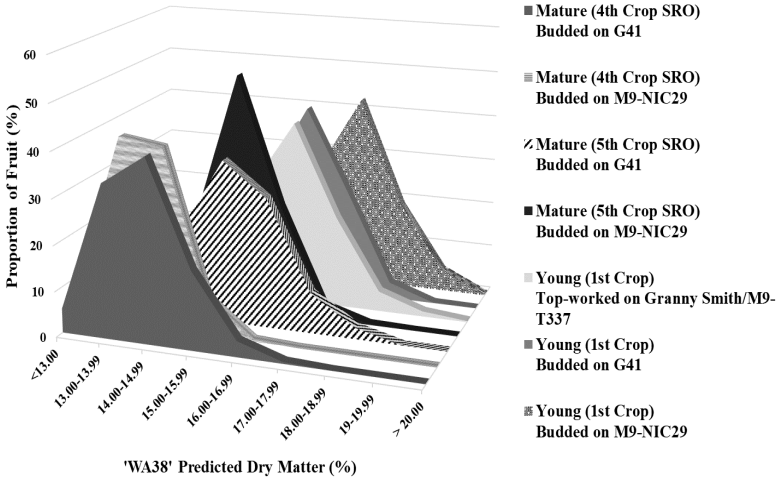

Figure 1: *Predicted dry matter (%) distribution among 'WA38' orchards both mature (SRO) and young as determined at-harvest using Felix F-750 Produce Quality Meter at harvest 2017 (4th crop SRO) and 2018 (5th crop SRO and 1st Crop elsewhere).*

orchards will follow the crop load and the age of the orchards. Fruit weight (as proxy for fruit size) and dry matter are linearly related, but this relationship varies among cropping years and rootstocks (data shown in previous report).

2. ***Correlate fruit quality parameters of selected fruit categories (by size and dry matter) to consumer preference.***

Instrumental Fruit Quality

Comparing WA38 apples for fruit quality based on orchard and cropping age revealed significant differences both at +1.5 M after harvest 2018 (corresponding to the same period when the first WA38 apples sale hit the markets in 2019) and at +5.5 M after storage in March 2019.

Mature vs Young orchards

Mature crop (5th crop in SRO) produced apples with lower firmness, soluble solid content (SSC), titratable acidity (TA), I_{AD} and lower starch index than 1st and 2nd cropping orchards both +1.5 M after harvest (Figure 2) and after 5.5 months of storage (data not shown). First and second cropping of young orchards were characterized by apples with high firmness, high acidity and SSC > 16% with an average starch index of 5.3 in the 1-to-6 scale.

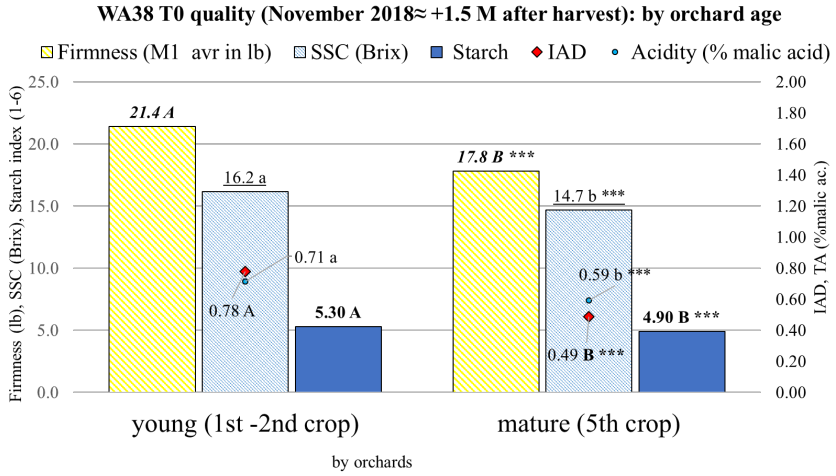

*Figure 2: Average values for instrumental quality +1.5 month post-harvest including average firmness (lb), soluble solids content (°Brix), I_{AD}, Starch index and titratable acidity among fruit from young (1st and 2nd crop) and mature (5th crop) orchards. Significant difference in means indicated by different letters via SNK. * = P < 0.05, ** = P < 0.01, *** = P < 0.001.*

Fruit size

Another way to look at the instrumental fruit quality data is by apple size. In Figure 3, the main quality differences between apples of the different sizes - from Small (70-75mm=113-88apples/box) to Extra-Large (100-105+=<48 apples/box) - are highlighted for T0 assessment (+1.5 M after harvest). Firmness, I_{AD} and starch index decreased linearly from Small to Extra-Large with the larger apples being softer (> 3 lb softer in firmness than size Small), higher level of chlorophyll degreening (lower I_{AD}) and lower starch index (avr. 4.7 out of 6). It is worth noting that the four different apple sizes at +1.5M after harvest did not statistically differ for soluble solid content (SSC) ranging from 15.5 to 14.9 °Brix, nor for titratable acidity (0.67 to 0.61 % malic acid; Figure 3). After 5.5 months of storage (data not shown), while all four fruit sizes reached already the complete starch degradation (starch index 6 out of 6), firmness was measured higher in Small fruit than in larger fruit and Extra-Large apples showed the lowest SSC (statistically different from Small and Medium fruit SSC) and lowest titratable acidity. Interesting to report that the dry matter (by destructive method) at T0 and T1 was not significantly different between the four sizes ranging from 16.2 to 16.5% and from 15.3 to 16.5%, respectively in the two time points of assessment. When analyzing dry matter values from the non-destructive readings by Felix F750 on all fruit available (other than a subset of fruit assessed by the destructive method) - after 5.5 months of storage- it emerged that the Extra-Large

fruit had a significant lower dry matter average value than the Small, Medium and Large fruit probably due to a dilution effect (data not shown).

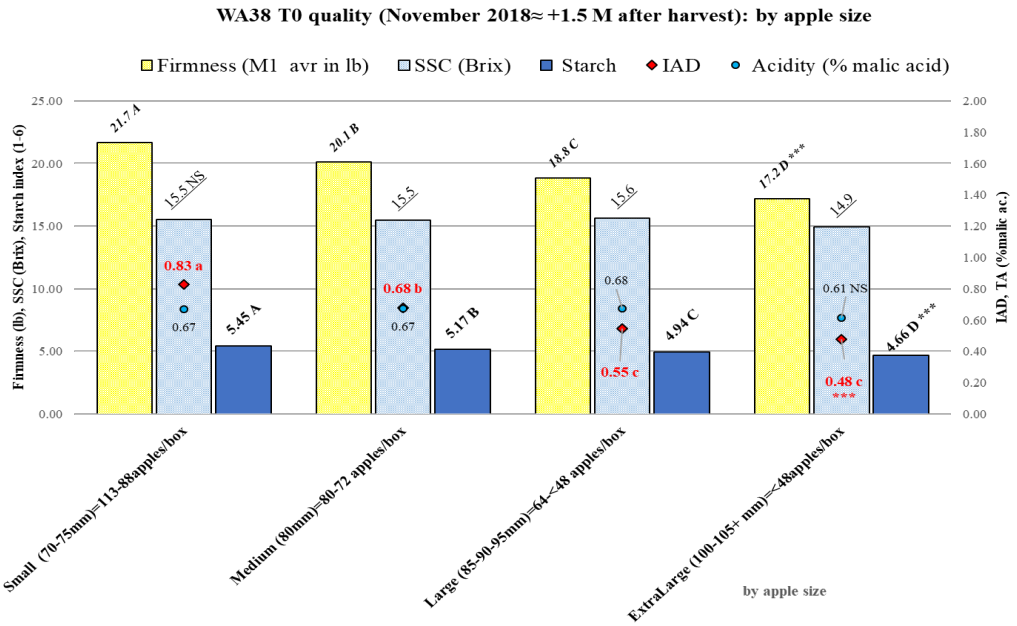

*Figure 3: Average values for instrumental quality +1.5 month post-harvest including average firmness (lb), soluble solids content (°Brix), I_{AD}, Starch index and titratable acidity: comparison among apples of four different sizes from Small to Extra-large accordingly to the sorting method described above. Significant difference in means indicated by different letters via SNK. * = P < 0.05, ** = P < 0.01, *** = P < 0.001.*

Dry matter categories

In the comparison between dry matter levels (from 12.00-12.99% to 19.00-19.99%, with 0.99% increment per each class) within each of the orchard age groups (interaction orchard age x dry matter classes, regardless of apple sizes; Table 1), relevant differences in fruit quality emerged at T0 and T1 assessments. After 1.5 M after harvest, apples harvested from both mature and young orchards showed higher firmness with dry matter increase [ranging in the young crop from 21 lb for low DM (13.00-13.99%) to 24.2 lb for very-high DM (19.00-19.99%)]. Regarding SSC in mature orchard (1.5 M after harvest), fruit in the classes between 13.00-13.99% to 18.00-18.99% reported fluctuating but statistically comparable values, while apples in class 12.00-12.99% showed lower SSC (SSC range across the 7 dry matter classes from 11.7°Brix to 16.8°Brix). On the other hand, within the young orchard production (+1.5 M after harvest), the SSC range was shifted toward higher values with apples belonging to 19.00-19.99% DM class reaching 18.2°Brix, while apples from 13.00-13.99% reported 13.1°Brix (Table 1). The difference in SSC between those extreme classes is 5°Brix and consumers can clearly perceive it. In both mature and young crops (Table 1), apples with higher dry matter (>16.00%) tend also to have higher titratable acidity and lower starch index in comparison to low DM classes (<13.99%).

Fruit quality assessment at T1 (+5.5 M after storage in March 2019) reported the same trend described above for T0. The only differences are that Red overcolor and starch index did not show statistically significant difference across the DM classes within each of the crop age while firmness, SSC and TA increased with the increase of DM% of the apple (data not shown). We believe that the fruit quality data related to +1.5 M after harvest are more interesting for the reader since they represent the status of the apples approximately around the period of the year when WA38 will be sold.

*Table 1: Comparison between dry matter classes of WA38 apples within each cropping age: average values for main parameters of instrumental quality +1.5 month post-harvest (T0 assessment). Parameters listed are average fruit weight (g), I_{AD}, Red overcolor %, firmness (lb), soluble solids content (°Brix), Starch index, dry matter % and titratable acidity. Significant difference in means indicated by different letters via SNK. * = P < 0.05, ** = P < 0.01, *** = P < 0.001. Areas shaded in grey represent combinations of cropping age x DM classes not present in the experiment.*

T0 quality (harvest 2018)-cropping (age)	WA38 Dry matter (DM) classes sorted by NIR spectroscopy	Weight (g)		I_{AD}		Red overcolor (%)		Firmness (lb)		SSC (°Brix)		Starch (1-6 scale)		destructive DM (%)		Titratable Acidity (% malic acid)	
young (1st -2nd crop)	12.00-12.99 %																
	13.00-13.99 %	161	B	1.15	A	96		21.05	C	13.08	G	6.00	A	13.77	G	0.63	CD
	14.00-14.99 %	225	A	0.62	C	94		19.26	D	13.89	F	5.90	A	14.85	F	0.56	D
	15.00-15.99 %	255	A	0.75	BC	92		20.21	CD	14.90	E	5.59	B	16.08	E	0.66	CD
	16.00-16.99 %	261	A	0.73	BC	93		21.19	C	16.12	D	5.28	C	17.01	D	0.71	BC
	17.00-17.99 %	260	A	0.81	BC	93		21.82	BC	16.89	C	5.20	C	17.78	C	0.74	ABC
	18.00-18.99 %	244	A	0.84	BC	93		22.88	B	17.44	B	4.79	D	18.64	B	0.83	A
	19.00-19.99 %	230	A	1.02	AB	90		24.19	A	18.18	A	5.01	CD	19.62	A	0.80	AB
	Sign.	***		***		NS		***		***		***		***		***	
mature (5th crop)	12.00-12.99 %	172	C	0.72	A	83	B	17.75	C	11.74	B	5.94	A	12.37	G	0.56	B
	13.00-13.99 %	245	B	0.62	AB	91	A	17.38	C	13.03	AB	5.79	A	13.68	F	0.54	B
	14.00-14.99 %	281	B	0.48	BC	94	A	17.11	C	13.52	AB	5.23	B	14.22	E	0.55	B
	15.00-15.99 %	328	A	0.44	C	94	A	17.26	C	14.16	AB	4.83	C	15.10	D	0.57	B
	16.00-16.99 %	341	A	0.44	C	95	A	18.07	C	16.37	A	4.58	D	16.35	C	0.61	B
	17.00-17.99 %	337	A	0.48	BC	95	A	19.06	B	15.77	AB	4.43	D	17.40	B	0.67	AB
	18.00-18.99 %	344	A	0.65	A	95	A	21.15	A	16.76	A	4.07	E	18.37	A	0.74	A
	19.00-19.99 %																
	Sign.	***		***		***		***		***		***		***		***	

Consumer Panels (+1.5 M and 5.5 M after harvest)

Sensory analyses carried out both at T0 and T1 time points, contemporarily to the instrumental fruit quality assessments, revealed meaningful differences in consumer perception of WA38 apples in comparison to Honeycrisp, introduced in year 2 only as internal control.

Mature vs young orchards

Comparing WA38 apples from mature orchard to young orchard (age of cropping) and to Honeycrisp control at +1.5 M after harvest, it appeared clear that apples produced from mature orchard scored the highest values (in a hedonistic scale 1 to 9) for many of the attributes tested, such as slice appearance, firmness, crunchiness, juiciness, sweetness, sourness, apple flavor and overall liking (score 7.2 out of 9.0). Mature WA38 apples were different from WA38 apples cropped in young orchard for the overall liking score (for young cropping 6.5 out of 9.0), while Honeycrisp with an overall liking of 6.9 placed in between mature and young cropping (data not shown). Honeycrisp control apples scored lower than WA38 mature apples for slice appearance, firmness, crunchiness, juiciness, sweetness, sourness, apple flavor and overall liking at +1.5 M after harvest, while they resulted similar for sweetness and sourness. In general, aroma, whole apple appearance (size and shape) and overall apple color did not reported significant differences in the way consumers perceived WA38 mature, young and Honeycrisp apples (data not shown). In addition, the consumer test carried out in March 2019 (+5.5 M after harvest) confirmed the previous results where WA38 apples from mature orchard were preferred in comparison to WA38 from young orchard and Honeycrisp control. After long storage, Honeycrisp apples reported the lowest overall liking and showed to be statistically different from WA38 from mature blocks with scores equal to 5.9 and 7.0 respectively; apples from young orchard registered an intermediate liking between mature crop of WA38 and Honeycrisp, equal to 6.3 (data not shown). Honeycrisp at the same time of tasting (March 2019) showed lowest scores for sweetness, sourness, apple flavor and overall appearance in comparison to mature and young WA38 apples.

Fruit size

Analyzing sensory results (at +1.5 M after harvest) by comparing fruit by size we can highlight other relevant differences (Figure 4). The only attribute among the three sizes provided for panel test (Small, Medium and Large) and Honeycrisp control that was not differently perceived by consumers in November 2018 was aroma (Figure 4), with scores always higher than 6.5 (out of 9.0). Same

results reported for March 2019 consumer test; aroma was not perceived differently across sizes and control. The smallest WA38 apples (113-88 apples/box) emerged as the least preferred in November 2018, firstly for their appearances, considering together whole apple appearance (size and shape) and overall apple color, and then for all the other attributes (Figure 4). The overall liking by consumers scored WA38 Large (64-<48 apples/box) apples as the first preferred followed by Honeycrisp (control), WA38 Medium apples and as least favorite WA38 Small fruit (Figure 4).

After 5.5 M of storage (March 2019), the least preferred for the whole fruit appearance and apple flavor was Honeycrisp control. Small WA38 fruit scored low also at this time point and in particular resulted similar to Honeycrisp as overall liking, sweetness and sourness. Once again, Large WA38 apples were the favorite overall due to high scores for apple flavor, sourness, sweetness and juiciness (data not shown). In terms of whole fruit appearance, the Medium WA38 apples were endorsed, reaching scores above 7 (and significantly higher than the Large WA38 fruit).

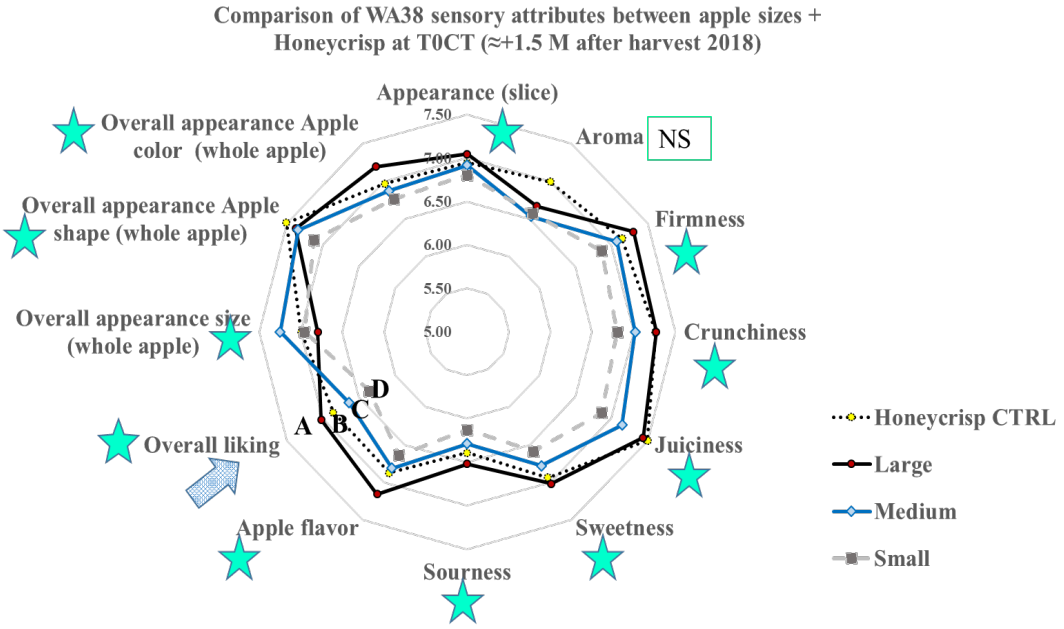

Figure 4: Spider net chart representing the scores collected from sensory analyses from consumers approximately +1.5 month post-harvest 2018 (November 2018) when comparing the three apple sizes (Small, Medium and large) with Honeycrisp control. Stars close to attributes (11 stars out of 12 attributes) identify significant difference from statistical analysis (for P < 0.01 or P < 0.001). Only overall liking presents SNK discrimination letters. Size categories: Small (70-75 mm) =113-88 apples/box, Medium (80 mm) =80-72 apples/box, Large (85-90-95+ mm)= 64-<48 apples/box.

Dry matter categories

Comparing the five dry matter levels in trial regardless of the cropping age, size and rootstock just fewer differences appeared at +1.5 M after harvest. While apples sorted in to DM categories did not differ for whole apple color and size, nor aroma, sweetness, sourness and apple flavor, though they were diversely perceived for firmness, crunchiness, juiciness, whole apple shape and overall liking. WA38 apples above 17% DM reported a lower overall liking than WA38 apples from 14.00 to 15.99%. This judgement reflected the lower scores recorded for firmness, crunchiness, juiciness preferences in the WA38 apples > 17% DM (data not shown). Consumer's opinion data during March 2019 panel test reported a decrease in overall liking with the increase in DM in WA38 apples (ranging from 6.9 to 5.9), in particular the highest scores were assigned to WA38 apples in 14.00-14.99%, 15.00-15.99% and 16.00-16.99% and the lowest to Honeycrisp, while WA38 17.00-17.99% and 18.00-18.99% scored in between them (6.2-6.3). Juiciness, crunchiness and sweetness preferences decreased with the increase of dry matter in the fruit (data not shown).

Focusing on the overall consumer liking at +1.5 M after harvest as interaction of apple sizes x dry matter categories, a clear discrimination about consumer preference between combinations under evaluation appeared clear (Figure 5). The average overall liking for control Honeycrisp apples resulted 6.85 (out of a 9-point scale) and Small size WA38 apples (from 14.00% to 17.9% DM) scored lower than the control value (average 6.34) with no difference across the four DM categories within the small size, while medium size WA38 apples reported values very similar to the Honeycrisp control in the 14.00 to 16.99% DM categories (with a maximum avr. score of 6.8). Furthermore, Large size WA39 fruit overpassed the control value reaching avr scores above 7 for 14.00% to 16.99% DM classes (Figure 5). We can conclude that at 1.5 M after harvest, the consumer preferred Large apples with a dry matter between 14.00% and 16.99% and that higher dry matter categories (>17.00%) are less desired (Figure 5), probably due to the high firmness and lower juiciness in the bite.

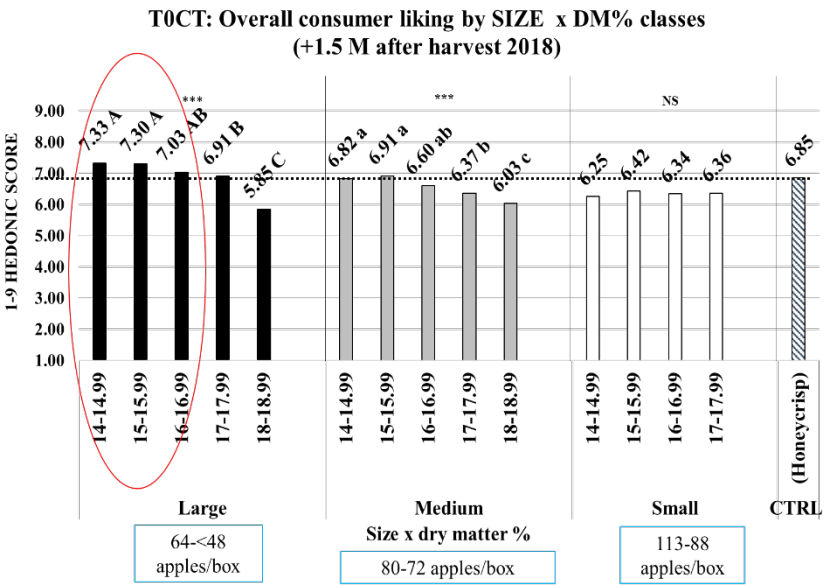

*Figure 5: Column chart representing the consumer overall liking scores from sensory analyses at +1.5 month post-harvest 2018 (November 2018) when comparing the dry matter classes within each of the three apple sizes (Small, Medium and large) and Honeycrisp control. Significant difference in means with each size class are indicated by different letters via SNK. * = P < 0.05, ** = P < 0.01, *** = P < 0.001.*

After long storage (about 5.5 M after harvest 2018), a lot more combinations of WA38 size and dry matter classes showed to be superior in overall liking than Honeycrisp control (data not shown). Small WA38 fruit, regardless of the dry matter class, scored 6 (average) for overall liking, while Medium and Large WA38 apples reported average scores equal to 6.4 and 6.7 respectively (HC scored 5.9). Moreover, WA38 apples with dry matter between 14.00% and 16.99% were always preferred if compared to dry matter classes 17.00% to 18.99% in the Medium and Large sizes (data not shown).

Correlation analysis

For both consumer panels run on fruit harvested in 2018 (at +1.5 and +5.5 M after harvest), a correlation analysis showed that the top 3 WA38 attributes that contribute the most to the overall liking of this new variety are, in order: apple flavor, sweetness and sourness (Table 2). On the other hand, whole apple size, whole apple color and aroma seemed to contribute the least to the overall consumer liking of WA38 apples (Table 2).

Willingness-to-pay (WTP)

Regarding the consumers' willingness to pay to purchase WA38 fruit after 1.5M from harvest, we noticed that consumers tend to be more inclined to buy mature WA38 apples with a higher price ≥ $2.23/lb (45.5%) versus young fruit (35.0%; data not shown). Moreover, the Large WA38 fruit reported the same proportion of consumer willing to pay a higher price as for Honeycrisp; 42% of the consumers are prone to pay ≥ $2.23/lb to buy those fruit (while 58% will buy for prices < $2.23/lb). A lower percentage of consumers (only 20%) are willing to pay higher tiers of price (≥ $2.23/lb) for WA38 apples in the highest dry matter category (18.00-18.99% DM), while this

proportion doubled (42%) when WA38 apples judged belonged to the 14-14.99% DM category (data not shown). In general, after long storage (+5.5 M after harvest 2018, March 2019), a slight decrease in the proportion of consumer willing to pay premium prices was noticed, but the same trends as at +1.5 M after harvest were confirmed (Figure 6). Consumers are more inclined to pay higher prices for WA38 apples coming from mature orchards and Large in size.

*Table 2: Correlation analysis between all the sensory attributes tested on WA38 apples for consumer preference and the overall liking on November 2018 and March 2019 respectively +1.5 M after harvest 2018 and +5.5 M after harvest in storage. Higher is the correlation coefficient, stronger is the correlation between the two parameters. Significant *** = P < 0.001.*

Pearson Correlation Coefficients, N = 3223 T0CT November 2018 Prob > |r| under H0: Rho=0										
	Appearance	Aroma	Firmness	Crunchiness	Juiciness	Sweetness	Sourness	Apple Flavor	WholeSize	WholeColor
Overall	0.40823	0.35741	0.59576	0.62261	0.67533	0.78884	0.72414	0.82871	0.23492	0.33545
Overall liking	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Pearson Correlation Coefficients, N = 2486 T1CT March2019 Prob > |r| under H0: Rho=0										
	Appearance	Aroma	Firmness	Crunchiness	Juiciness	Sweetness	Sourness	Apple Flavor	WholeSize	WholeColor
Overall	0.42308	0.3875	0.62548	0.65292	0.67674	0.77721	0.7101	0.8515	0.28345	0.36527
Overall liking	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

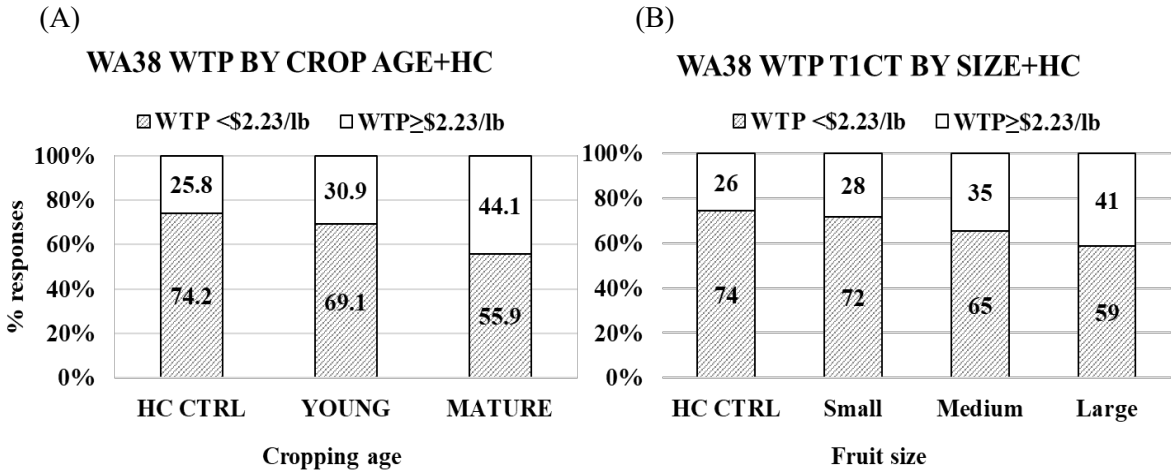

Figure 6: Willingness to pay (WTP) WA38 fruit based on cropping age (A) and fruit size (B) at +5.5 month post-harvest 2018 (March 2019): results are presented as proportion (%) of answers for the lower tier of prices (<$2.23/lb) and the highest (≥$2.23/lb). Inside each comparison Honeycrisp control (HC CTRL) is reported as reference.

EXECUTIVE SUMMARY

Project title: 'WA38' fruit size and dry matter for fruit quality/consumer preference
Key words: at-harvest sorting, sensory analysis, overall liking

Abstract:
Presorting WA38 apples at harvest by size and predicted dry matter allowed to identify differences in fruit quality and consumer preferences. Consumers overall preferred Large and Medium apples with dry matter <17%. Higher proportion of consumers is willing to pay higher prices (≥$2.23/lb) for WA38 apples from mature orchard.

PROJECT OUTCOMES (Presentations):

- **Musacchi S.:** "Report activity year 2017". Oral presentation by Musacchi S. at the Endowment Advisory Committee meeting (EAC) on 03/13/2018.
- **Musacchi S., Evans K., Ross C. and Serra S.:** "WA38' fruit size and dry matter for fruit quality/consumer preference". Oral presentation by Musacchi S. at the Cosmic Crisp® Quality Standards Sub-committee meeting on 07/24/2018.
- **Musacchi S., Evans K., Ross C. and Serra S.:** "WA38' fruit size and dry matter for fruit quality/consumer preference". Oral presentation by Musacchi S. at the Cosmic Crisp® Quality Standards Sub-committee meeting on 12/10/2018.
- **Musacchi S., Evans K., Ross C. and Serra S.:** "WA38' fruit size and dry matter for fruit quality/consumer preference". Oral presentation by Musacchi S. at the Cosmic Crisp® Quality Standards Sub-committee meeting on 02/28/2019.
- **Musacchi S.:** "Report activity year 2018". Oral presentation by Musacchi S. at the Endowment Advisory Committee meeting (EAC) on 03/11/2019.
- **Musacchi S., Evans K., Ross C. and Serra S.:** "WA38' fruit size and dry matter for fruit quality/consumer preference". Oral presentation by Musacchi S. at the Washington State Tree Fruit Association (WSTFA) annual meeting 2019 on 12/11/2019.

SUMMERY OF FINDINGS

- In 2018, production showed a tendency toward higher dry matter classes than the 2017 fruit distribution. Younger orchards generally produced larger proportions of higher dry matter fruits relative to the more mature orchard.
- Mature orchards (5th crop) produced apples with lower firmness, soluble solid content, titratable acidity, I_{AD} and lower starch index than 1st and 2nd cropping orchards (young) both at +1.5 M and + 5.5 months of after harvest 2018.
- Firmness, I_{AD} and starch index decreased linearly with the increase of apple size with the larger apples being softer, with lower I_{AD} and starch index. At +1.5M after harvest 2018, no statistical differences for SSC and titratable acidity were found across the four apple sizes.
- The top three WA38 attributes that contributed the most to the overall liking were: apple flavor, sweetness and sourness.
- WA38 DM 14.00% -16.99% apples were always preferred by consumers if compared to dry matter classes >17.00% in the Medium and Large sizes.
- Consumers are more inclined to pay higher prices for WA38 apples coming from mature orchards and Large in size.

FUTURE DIRECTIONS

- Further explore consumer preference in relation to optimal harvest time for WA38 to maximize internal quality and minimize production losses.