Project Title: Mitigating WA 38 greasiness and related quality defects

Report Type: Final Project Report

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Item	2022	2023	2024
Salaries	$54,000.00	$56,160.00	$58,406.00
Benefits	$20,050.00	$20,852.00	$21,686.00
Wages			
Benefits			
RCA Room Rental			
Shipping			
Supplies	$4,000.00	$1,000.00	
Travel			
Plot Fees			
Miscellaneous			
Total	$78,050.00	$78,012.00	$80,092.00

Footnotes: Salaries: Research personnel to carry out field and laboratory work, fruit evaluations and data analyses in years 1, 2, and 3. Benefits: $20,050, $20,852, and $21,686 are requested for benefits tied to the research personnel.
Supplies: Supply costs of $4,000 in year 1 and $1,000 in year 2 are requested to pay for supplies for fruit quality evaluation

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Item	(Type year of project start date here)	(Type year start date of year 2 here if relevant)	(Type year start date of year 3 here if relevant)
Salaries			
Benefits			
Wages			
Benefits			
RCA Room Rental			
Shipping			
Supplies	$3,000.00	$3,000.00	$3,000.00
Travel	$3,000.00	$3,000.00	$3,000.00
Plot Fees			
Miscellaneous			
Total	$6,000.00	$6,000.00	$6,000.00

Footnotes: Supplies: Supply costs of $4,000 in year 1 and $1,000 in year 2 are requested to pay for supplies for fruit quality evaluation. Travel: $3,000 is requested in years 1, 2, and 3, respectively, for associated travel for Dr. Anne Plotto.

Project Title: Mitigating WA 38 greasiness and related quality defects

Peel greasiness has been the most prominent issue during the first years following the commercial launch of WA 38 (Torres & Gomez, 2020; Hedges and Torres, 2021). This is a common phenomenon on apples and can develop while the fruit is on the tree or during the cold chain. Some of the factors involved in skin greasiness are genetic differences between cultivars, tree age, growing environment (seasonal variation), storage environment (temperature, atmosphere, relative humidity), length of storage, and fruit maturity (Yang et al., 2017). The objectives of this project were:

1. Further, define harvest maturity guidelines limiting greasiness in the cold chain.
2. Establish ethylene mitigation protocols that reduce greasiness for both conventional and organic production.
3. Determine the limitations of wax/detergent for mitigating greasiness in the post-storage cold chain.
4. Identify and determine protocols for mitigating off-flavors associated with greasiness.

Significant Findings:

1. Maturity progression varied between growing sites and seasons. The starch degradation rate was temperature-dependent during the growing season. Warmer weather led to higher rates of starch degradation and greater dispersion of starch indexes at harvest.
2. Overall, skin greasiness was more related to fruit maturity and cooler weather during the last part of the growing season than just tree age.
3. There was a higher incidence (and severity) of greasiness in fruit from air storage compared to that stored in controlled atmosphere (CA; 2.5% O_2, 1.5% CO_2), but more consistently on that from H2 (1 week after commercial harvest). In all cases, greasiness increased once in the simulated shelf-life period (7 days at 68°F).
4. Retain® reduced greasiness incidence and severity postharvest up to 4 months, but not during 'shelf-life' once fruit was removed from cold storage. In general, the earlier the applications (14 and 21 days before harvest), the more effective control of skin greasiness was achieved.
5. Although 1-MCP formulations were able to delayed ripening, they had inconsistent effects over skin greasiness.
6. All detergents tested were able to remove skin greasiness effectively, and all coatings continued to control greasiness during the cold chain.
7. The off-flavor, described as bitterness, was mostly detected in the flesh of the unexposed section of the fruit, and linked with a higher ratio of aroma compounds typical of unripe apples over the ripe ones. Following the harvest recommendations and avoiding the harvest of immature fruit should be able to minimize it.

Results

Objective 1: Further define harvest maturity guidelines, limiting greasiness in the cold chain. Maturity progression was evaluated weekly starting at 4 weeks before commercial harvest. Following each harvest, fruit was stored 33°F in air or in a controlled atmosphere (2.5% O_2, 1.5% CO_2). Fruit quality (ripeness, skin greasiness, and physiological disorders) was evaluated monthly for 6 months. Skin greasiness was rated using a 4-point subjective scale, rubbing the fruit against the hand, and rated as (0) no greasiness to (3) severe greasiness.

Maturity was different in fruit from different locations and growing seasons, with ethylene production, starch index, and chlorophyll degradation (DA meter) reflecting these differences. Figure 1 shows the frequency of SI values in fruit harvested commercially and one week later. In 2022, the warmest year, there was a greater dispersion of SI values with no differences between the two harvests in fruit from both locations (Mattawa and Quincy), compared to the other seasons.
Skin greasiness was site-dependent; the warmest site (Mattawa) had, in general, less greasy fruit at harvest than the cooler site (Quincy) (Fig. 2). In both orchards, there was a higher incidence of greasiness in the later harvest, emphasizing the role of harvest maturity in this defect.
As in the previous seasons, in 2024-2025, CA storage reduced fruit softening (~0.8 lb), ethylene production, and background color change (I_{AD} values) compared to air storage (Table 1). Overall, throughout all growing seasons, skin greasiness incidence and severity were lower in fruit stored in CA compared to those in air. In addition, greasiness increased during the 'shelf-life' period (7 days at 68ºF). Fig. 3 shows the results from the 2024/2025 storage season.

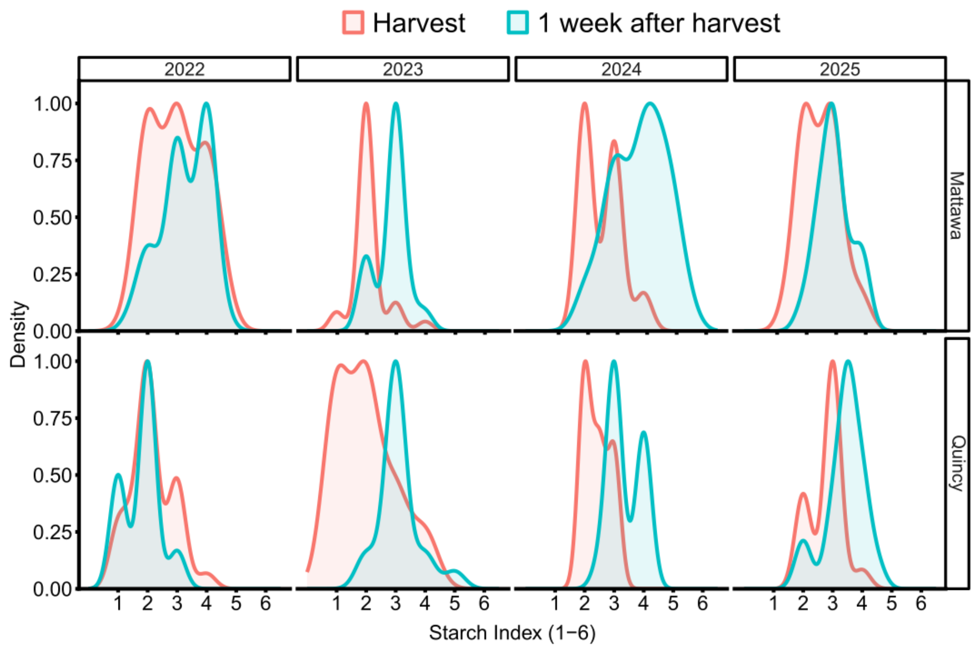

Figure 1. Density plots from the starch index of fruit from Mattawa and Quincy in 2022, 2023, 2024, and 2025 at commercial harvest and one week later (1 week after harvest, wah) or up to three weeks later (2024). Overlap shapes show no differences in the starch degradation population in fruit sampled at each timepoint.

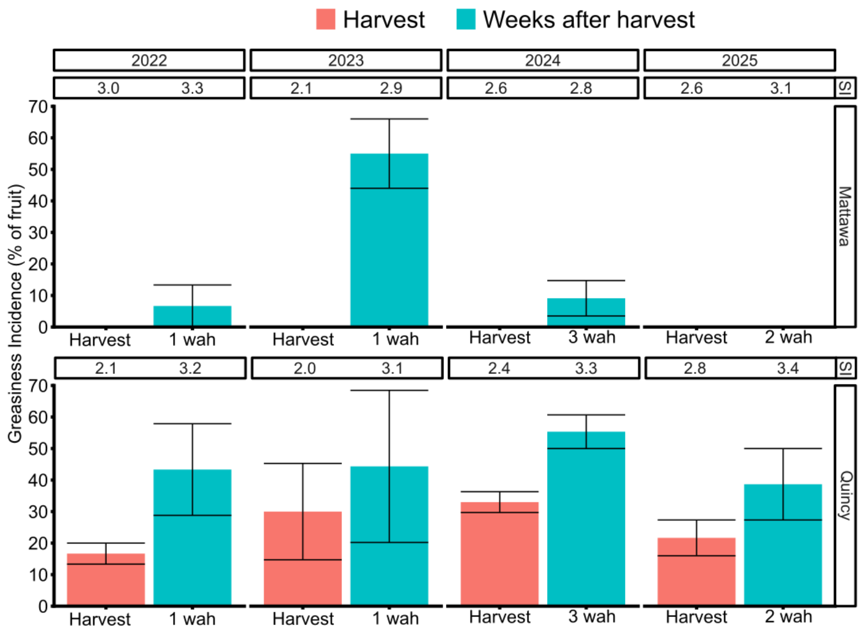

Figure 2. Bar plots of greasiness incidence (average) from Mattawa and Quincy in 2022, 2023, 2024, and 2025 at commercial harvest and up to 3 weeks later (week after harvest). Bars present the standard error. The average starch indexes at each harvest point are shown on top of each column.

Table 1. Relative ripeness and greasiness (average values) during air and CA storage at 33°F during the 2024-2025 season.

	Harvest	Storage Eval.	Firmness (lb)		Backg. Color (1-4)		I_{AD} (0-2.2)		SI (1-6)		Ethylene (ppm)	
			RA	CA	RA	CA	RA	CA	RA	CA	RA	CA
Mattawa	H1	1mo+1d	18.7	19	3.4	3.4	0.4	0.3	4.2	3.9	17.8	15.3
		2mo+1d	17.7	18.1	4	4	0.3	0.3	5	4.8	38.7	18.8*
		3mo+1d	17.1*	19	3.9	3.9	0.2*	0.3	5.8	5.7	55.1	12.6*
		4mo+1d	18.2	17.0*	4	4	0.2*	0.3	6	6	54.9	14.1*
		5mo+1d	16.7	16.5	4	4	0.2*	0.3	6	6	48.9	11.9*
		6mo+1d	16.7*	17.9	4	3.8	0.2*	0.3	6	6	15.7	7.1*
	H2	1mo+1d	17.2	16.0*	4	4	0.3	0.3	4.8*	5.8	22.5	23.7
		2mo+1d	16.6	16.5	4	4	0.2	0.3	5.9	5.7*	31.3	21.1*
		3mo+1d	16.7	16.9	4	4	0.2*	0.3	5.9	5.8*	44.5	24.8*
		4mo+1d	16.2	16	4	4	0.7*	0.9	6	6	54.6	15.7*
		5mo+1d	16.5*	17.5	4	3.9	0.2*	1.1	6	6	39.8	12.9*
		6mo+1d	15.9	16.5	4	4	0.2	0.2	6	6	29.1	14.3*
Quincy	H1	1mo+1d	19.2	19	2.2	2.2	0.9	0.8	4.2	4	16	0.3*
		2mo+1d	19.2	19.5	2.9	2.7	1	1	5.1	5.1	47	19.0*
		3mo+1d	18.2*	19.5	3.3	3.2	0.7*	0.9	5.6	5.7	70.3	8.0*
		4mo+1d	17.5*	19.4	3.2*	3.6	0.8	0.9	5.9	5.9	80.7	10.3*
		5mo+1d	17.2*	18.4	3.3	3.5	0.8	0.7	6	6	63.7	10.7*
		6mo+1d	16.7*	19.6	3.6	3.5	0.8	0.8	6	6	71.1	12.3*
	H2	1mo+1d	18.4	18	3.6	3.8	0.8	0.7	3.9	4.2	48	48.8
		2mo+1d	18.2	18.6	3.3	3.6	0.8	0.8	5.3	5.0*	54.7	15.4*

3mo+1d	18.1*	19.1	3.9	3.7	0.5*	0.8	5.8	5.8	72.7	11.6*
4mo+1d	17.2*	18.5	3.9	3.6*	0.2*	0.3	6	6	77.3	9.0*
5mo+1d	17.9*	20.9	3.4	3.1*	0.6	0.3*	6	6	42.3	11.2*
6mo+1d	17.1*	18.4	3.9	4	0.7	0.8	6	6	44.2	9.6*

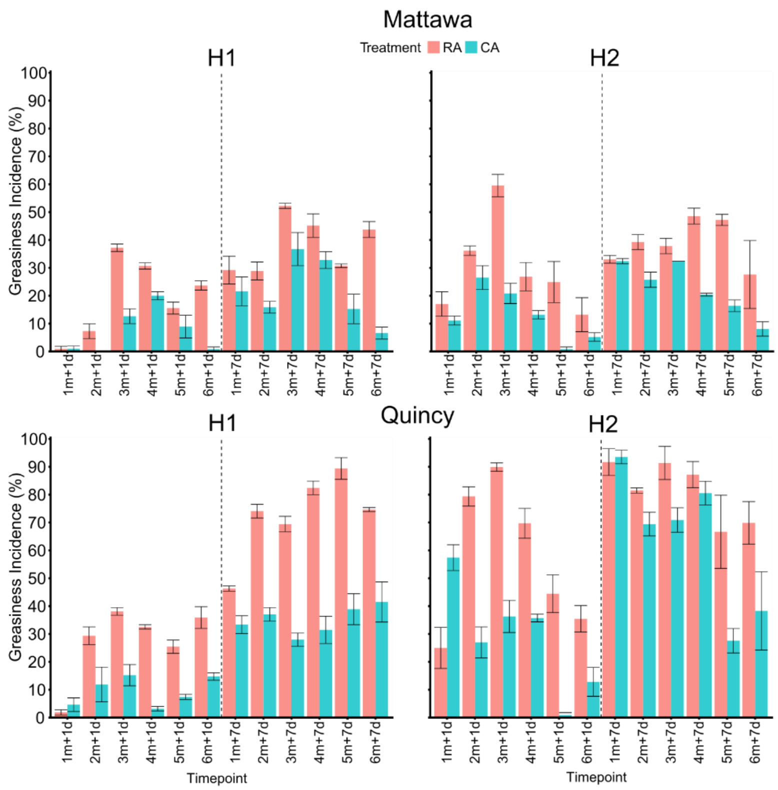

Figure 3. Bar plots of greasiness incidence (average) from Mattawa and Quincy in the 2024 season up to 6 months in storage (RA or CA) plus 1 or 7 days at room temperature (20 ºC). Bars present the standard error.

Objective 2: Establish ethylene mitigation protocols that reduce greasiness for both conventional and organic production.

Table 2 shows treatments applied in 2022, 2023, 2024 and 2025. Preharvest application of Retain®, either at half or full rate, suppressed ethylene production and delayed the starch degradation at harvest (Table 3 shows results for 2024/2025). Fruit greasiness was present at the time of the first application (2 weeks before harvest) in 2023. In 2024, it appeared in the UTC one week after commercial harvest. In 2025, no greasiness at the time of harvest was detected in any of the treatments.

There were no differences between treatments in ethylene production or starch degradation postharvest (Table 3 shows results for 2024/2025). All Retain® reduced greasiness incidence and severity after 1 day at 68ºF. The effect disappeared after 7 days at 68ºF and 4 months of storage (Table 3 shows results for 2024/2025).

As in 2022, in 2023, Harvista™, either applied at a single (1x) or double (2x) rate, was not able to reduce ethylene production nor affect the starch degradation pattern on the fruit compared to the UTC. Nevertheless, in 2023 Harvista™ 2x was able to better retain firmness after 4 months of air storage (Table 4). Harvista™ 1x plus SF was able to retain flesh firmness for up to 12 months of storage (+3.0 lb than UTC and Harvista™ 1x). No differences in skin greasiness between treatments were observed at harvest. Ethylene production was suppressed using Harvista™ 1x plus SF (T5) and UTC plus SF (T4) for up to 8 months plus 7 days at 68ºF. Similar results were found in 2024. Skin greasiness severity was reduced by Harvista™ 1x plus SF treatment in 2023. This did not occur in the 2024 season (Table 3).

Table 2. PGR treatments (rate and time of application) during the 2023, 2024, and 2025 seasons.

Year	Treat.	Material/a.i.	Rate	Timing	Others
2022	T1	Untreated control (UTC)	NA	NA	• Orchard location: Zillah, WA • Sylcoat (0.1% OSi) added to Retain® applications. • Two harvests: At the time of UTC (commercial), and 1 week later.
	T2	AVG (ReTain®)	Full rate (24 oz/acre)	7 DBH	
	T3	ReTain®	Half-rate (12 oz/acre)	7 DBH	
2023	T1	Untreated control (UTC)	NA	NA	
	T2	ReTain®	Full rate (24 oz/acre)	21 DBH	
	T3	ReTain®	Full rate (24 oz/acre)	14 DBH	
	T4	ReTain®	Full rate (24 oz/acre)	7 DBH	
2024 & 2025	T1	Untreated control (UTC)	NA	NA	
	T2	ReTain®	Full rate (12 oz/acre)	14 DBH	
	T3	ReTain®	Half rate (24 oz/acre)	14 DBH	
	T4	ReTain®	Full rate (24 oz/acre)	7 DBH	
2022 & 2023	T1	UTC			• Orchard location: Royal City, WA • Two harvests: At the time of UTC (commercial), and 1 week later. • Only harvest 1 for SF treats.
	T2	1-MCP (Harvista™ 1.3 SC) (1x)	Full dose	14 DBH	
	T3	Harvista™ (2x)	Full dose	14 & 7 DBH	
	T4	UTC plus 1-MCP (SmartFresh™; SF)	100 ppm	At harvest	
	T5	Harvista™ 1x plus SF	T2 plus SF (100 ppm)	At harvest	
2024 & 2025	T1	UTC			
	T2	UTC plus 1-MCP (SmartFresh™; SF)	100 ppm	At harvest	

AVG: Aminoethoxyvinyglicine; 1-MCP: 1-methylcyclopropene; DBH: Days before harvest

Table 3. Fruit maturity (starch index, SI, flesh firmness, internal ethylene concentration, IEC, titratable acidity) and greasiness incidence and severity (low) during storage at 33ºF of WA 38 apples treated with AVG (Retain®). Season 2024/2025.

	Eval.	Treat.	SI (1-6)	Firmness (lb)		IEC (ppm)		Titratable Acidity (% malic acid)		Greasiness: Incidence (% fruit)		Greasiness: Low Greasiness (% fruit)	
				+1d	+7d	+1d	+7d	+1d	+7d	+1d	+7d	+1d	+7d
H1	Harv.	UTC[Y]	2.2	18.6	-	0.9 b[z]	-	0.6	-	0.0	-	0.0	-
		T2	2.3	18.1	-	1.4 c	-	0.6	-	0.0	-	0.0	-
		T3	2.4	18.1	-	0.6 a	-	0.6	-	0.0	-	0.0	-
		T4	2.5	18.0	-	0.4 a	-	0.5	-	0.0	-	0.0	-
	4 m	UTC	6.0	16.8 c	15.4 a	43.7 b	159.3 c	0.4	0.4	46.0	61.1 b[x]	42.2 b	40.2
		T2	6.0	16.4 a	15.2 a	56.5 c	148.2 b	0.4	0.4	38.8	66.7 a	33.0 b	39.8
		T3	6.0	16.6 b	16.1 b	35.2 a	94.0 a	0.4	0.3	35.5	54.8 b	34.8 c	45.2
		T4	6.0	17.0 c	15.8 b	37.3 a	150.4 b	0.4	0.4	42.9	73.7 a	36.8 a	32.6
	8 m	UTC	6.0	15.6 a	15.1	15.9 b	201.9 c	0.3	0.2	29.4	62.0 a	25.4	50.9

		T2	6.0	16.3 b	14.9	11.8 a	167.9 b	0.2	0.2	29.4	64.8 a	28.1	47.9
		T3	6.0	15.8 a	15.4	10.1 a	145.9 a	0.3	0.2	14.3	30.6 b	12.2	26.3
		T4	6.0	15.5 a	15.9	15.1 b	151.3 a	0.3	0.2	23.8	39.8 b	20.2	30.4
		UTC	3.8 b	17.4	-	2.2 b	-	0.5		0.0	-	0.0	-
	Harv.	T2	2.8 ab	17.4	-	0.8 a	-	0.6		0.0	-	0.0	-
		T3	2.6 a	18.6	-	0.8 a	-	0.6		0.0	-	0.0	-
		T4	3.3 b	17.7	-	1.6 b	-	0.6		0.0	-	0.0	-
		UTC	6.0	16.3 b	15.3	46.8 b	181.9 c	0.3	0.3	25.6 a	55.6 a	24.0	41.1
H2	4 m	T2	6.0	15.7 a	15.2	45.5 b	153.2 b	0.4	0.3	26.9 a	51.8 a	24.2	40.1
		T3	6.0	15.4 a	15.2	36.0 a	136.3 a	0.3	0.3	19.0 b	34.4 b	18.4	29.8
		T4	6.0	16.3 b	15.1	38.8 a	182.9 c	0.3	0.3	17.6 b	27.9 b	17.1	25.6
		UTC	6.0	16.0 b	14.8	10.2 b	155.6 b	0.2	0.2	14.6	21.6	14.1	19.3
	8 m	T2	6.0	15.2 a	14.5	5.8 a	160.6 c	0.3	0.2	19.0	27.1	18.6	24.2
		T3	6.0	15.6 ab	14.7	8.2 ab	131.3 a	0.3	0.2	7.7	27.7	7.7	26.5
		T4	6.0	15.3 a	14.6	6.7 a	160.0 c	0.2	0.2	10.3	34.1	10.3	29.1

[Y] UTC= Untreated Control

[Z] ANOVA (P≤0.05). Different letters indicate significant differences between treatments within timepoints (Tukey, P≤0.05).

[x] Kruskal-Wallis (P≤0.05). Different letters indicate significant differences between treatments within timepoints (Dunn Test, P≤0.05).

Table 4. Fruit maturity (starch index, SI, flesh firmness, internal ethylene concentration, IEC, titratable acidity) and greasiness incidence and severity (low) during storage at 33ºF of WA 38 apples treated with 1-MCP (SmartFresh (SF)). 2024/2025 season.

	Eval	Treat.	SI (1-6)	Firmness (lb)		IEC (ppm)		Titratable Acidity (% malic acid)		Greasiness			
										Incidence (% fruit)		Low Greasiness (% fruit)	
				+1d	+7d	+1d	+7d	+1d	+7d	+1d	+7d	+1d	+7d
H1	Harvest		2.8	18.8	-	1.2	-	0.6	-	0.0	-	0.0	-
	4 m	T1	6.0	18.8 *[z]	18.2*	48.6	119.8	0.3*	0.3	23.0	40.5*[x]	68.2	37.0
		T2	6.0	20.5	20.5	18.4*	99.5	0.5	0.4	21.4	24.6	68.6	50.5
	8 m	T1	6.0	18.0	17.3	8.0	106.8	0.2	0.2	13.9	26.8	86.1	67.7
		T2	6.0	18.4	18.2	11.1	100.4	0.2	0.2	35.4*	59.0*	29.5*	21.4*
	12 m	T1	6.0	16.7*	16.2*	15.6	86.7	0.1*	0.2	10.2	18.4	60.3*	67.4
		T2	6.0	17.7	17.2	8.7*	38.3*	0.2	0.2	9.7	18.1	90.3	61.9
H2	Harvest		2.6	19.3	-	2.4	-	0.6	-	0.0	-	0.0	-
	4 m	T1	6.0	19.5	17.1*	29.6	95.1	0.4	0.3*	25.9*	47.2*	57.9*	30.7*
		T2	6.0	19.8	19.5	4.5*	9.7*	0.4	0.4	13.2	33.3	86.8	61.4
	8 m	T1	6.0	17.4*	16.0*	7.9*	94.6	0.2	0.2*	0.0	25	0.0*	58.8

	T2	6.0	19.3	18.5	16.1	60.1	0.2	0.3	18.6*	29.8	77.9	59.5
12 m	T1	6.0	16.2*	14.4*	3.6*	106.3	0.2	0.1*	14.7	21.2	77.1	73.9
	T2	6.0	19.8	19.1	17.1	101.6	0.2	0.2	18.3	24.7	70.9	65.2

[Z] ANOVA (P≤0.05). Asterisks indicate significant differences between treatments within timepoint.
[x] Kruskal-Wallis (P≤0.05). Different letters indicate significant differences between treatments within timepoints (Dunn Test, P≤0.05).

Objective 3: Determine the limitations of wax/detergent for mitigating greasiness in the post-storage cold chain.
Experiments done in 2022 and 2023 are shown in Table 5. For the coating trials, fruit was cleaned with Epi-Clean (60 s), dried in air, and coated with the different formulations (Table 5).
In general, all detergent treatments were able to remove the greasiness on the fruit for up to 7 days at 68ºF regardless of the initial amount of greasiness in 2022, and up to 1 day in 2023 (Fig. 4). All coatings tested in all trials were able to maintain grease-free fruit for up to 21 days at RT plus 30 days in cold storage plus 21 additional days at RT (Fig. 5).

Table 5. Detergent and coating treatments in the 2022 and 2023 seasons.

Year	Fruit condition	Product	Treat.	Material	Rate	Application Time
2022	Low greasiness High greasiness	Detergents	1	UTC (Water)	NA	30 s
			2	Acidex Duo	25 ml / L	30 & 60 s
			3	Epi-Clean	25 ml / L	30 & 60 s
	Low greasiness	Coatings	1	UTC	NA	-
			2	PrimaFresh 360 HS	0.4 g /fruit	30 s
			3	Shield-Brite AP-450	0.4 g /fruit	30 s
			4	Xedasol	0.4 g /fruit	30 s
2023	High greasiness	Detergents	1	UTC (Water)	NA	30 s
			2	Acidex Duo	25 ml / L	30 & 60 s
			3	Epi-Clean	25 ml / L	30 & 60 s
		Coatings	1	UTC	NA	-
			2	PrimaFresh 360 HS	0.4 g /fruit	30 s
			3	Shield-Brite AP-450	0.4 g /fruit	30 s
			4	Xedasol	0.4 g /fruit	30 s

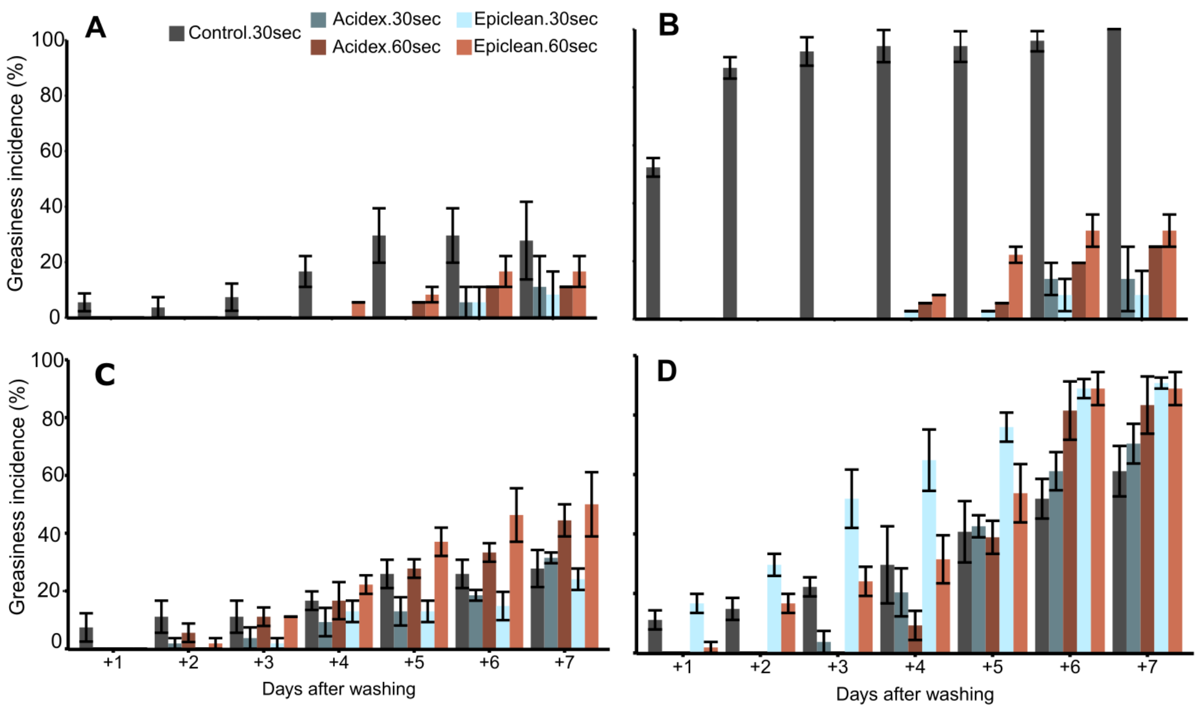

Fig. 4. Greasiness incidence (% fruit) in WA 38 apples in 2022 (A: Low greasiness lot; B: High greasiness lot) and 2023 (C: Trial 1; D: Trial 2). All fruits were stored at 33 ºF and evaluated for up to 7 days at 68 ºF after washing with different detergent treatments (Mean ± Standard Error).

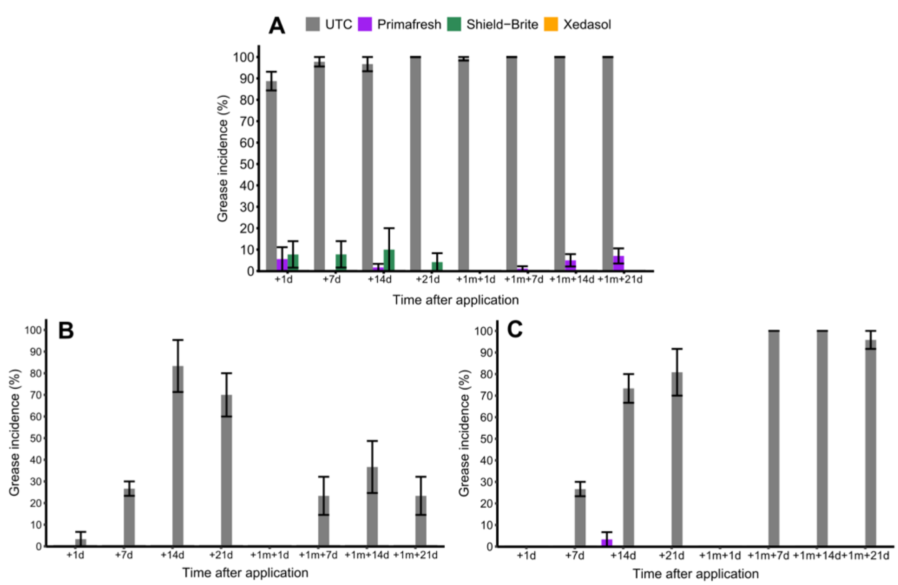

Fig 5. Greasiness incidence (% fruit) in WA 38 apples in 2022 (A) in fruit with low greasiness and evaluated up to 21 days at 68ºF after coating treatments, and after 1 month in cold storage (33ºF) and up to 21 days at 68ºF; and in 2023 stored for 6 months (B) or 10 months (C) for up to 21 days at 68ºF with or without 1 month of air storage (33 ºF) after the coating treatment.

Objective 4: Identify and determine protocols for mitigating off-flavors associated with greasiness.

In 2022, fruit sampled from long-term CA lots where the off-flavor was identified were used for an *ad hoc* taste panel of individuals accustomed to apples to identify the "bitter" off-flavor as well as hypothetical off-flavor components. Apples (n=160) were sampled in sections representing quarters of the fruit (stem/calyx end; sun-facing/shaded) (n=320 in total). Apple samples (peel separated from the flesh) were rated for eating quality, and the adjacent peel/cortex flash was frozen in LN_2 and stored at -80 ^oC until processing and instrumental analysis. Samples were rated as "bitter", "musty", "chemical", "medicinal", "metallic", "tingly", "astringent", or an "after taste", all descriptors of the off-flavor determined by panelists during training. The aroma profile was analyzed using gas chromatography/mass spectrometry to allow for a snapshot of the aroma, approaching a direct comparison of the profile and the panelists' experience. Data were analyzed using statistical approaches that identified the presence, nature, and associated aroma components linked with those samples identified as imparting an off-flavor.
Off-flavor was identified in at-least one sample given to each panelist. Bitter samples were often detected in the same fruit as samples that were not considered bitter. While peel typically produces the highest levels of aroma, bitterness was more commonly associated with cortex tissue (Fig. 3), the shade side of the apple (>60%), and the shoulder and calix-end sections.
The aroma profile was compared with off-flavor detected by the sensory panel. Off-flavor was determined as a positive response to any of the following descriptors as they could all be considered descriptors of the off-flavor according to the sensory panel survey: "Bitter", "chemical", "medicinal", "metallic", "tingly", "astringent", or "after taste" (Fig. 6). The aroma profile (35 natural aroma chemicals) was consistent among samples from the same apple, but links with off-flavor were not obvious until whole apples were categorized according to presence of off-flavor. An apple was considered if off-flavor was detected in 50% or more of the comprising cortex or peel samples. This more clearly revealed associations with aroma chemicals linked with unripe apples, especially more "cut grass" and less ripe apple aroma chemicals (Fig. 7). This classification was even more apparent when projected using the ratio of 2-methylpropyl acetate, an aroma note associated with apples that were considered "good" overall, to one that was associated with "bad" flavored fruit, 2-hexenyl acetate. Consequently, once these associations were confirmed using this binary categorization, we could follow levels of these and related aroma compounds back to compare them with sensory classifications of individual samples, finding that links between the limited set of aroma compounds and sensory classification still held true.
Subsequent work should focus on determining any associations among phenotype, unripe aroma notes, and harvest maturity to resolve whether harvesting maturity impacts consumers' experience of off-flavors. Rather than any single chemical causing the off-flavor, it is possible that another significant factor, such as maturity, is impacting flavor consumer perception of bitterness such as a pre-association between that attribute and green, grassy aroma notes.

No bitterness or off flavor was detected in fruit from any of the previous experiments (Objectives 1, 2, and 3) performed during 2023, 2024, and 2025.

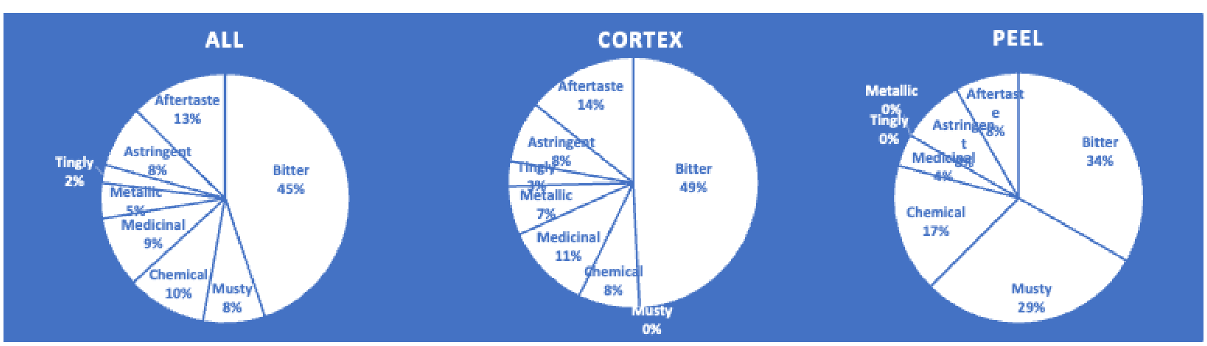

Fig. 6. Descriptors of taste found by the trained panel. Values indicate % of samples (n=320) in each descriptor.

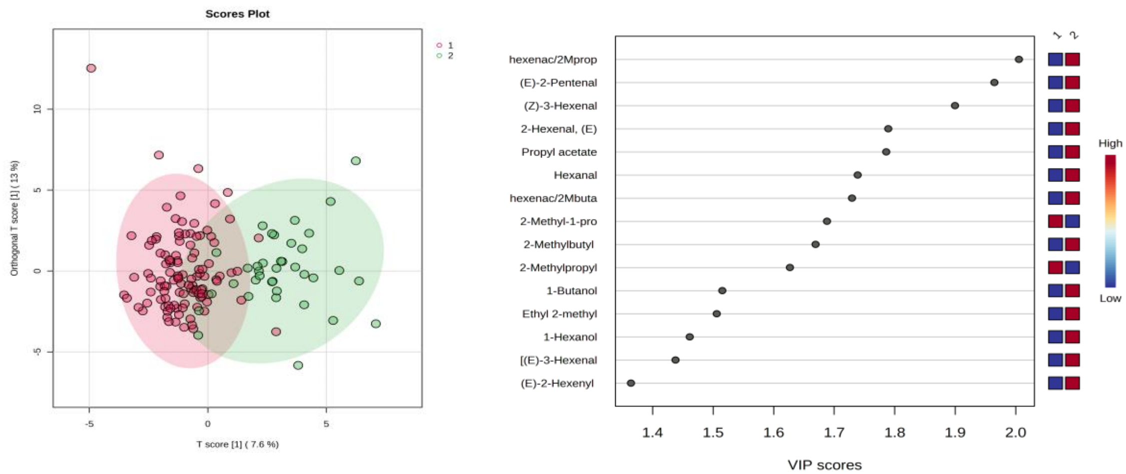

Fig. 7. Flesh tissue samples (left) from WA 38 apples were identified by a sensory panel as having off-flavor (green) or not (red). This indicates that the aroma profile, as a whole, is different between apples considered to have an off-flavor and those with no issue. It also reveals that there are one or more aroma components related to this difference. Natural aroma chemicals (right) that are most associated with off-flavored samples include those typically most abundant in unripe or immature apples, while those prominent in samples considered good are typically more prominent in ripe apple aroma profile. The ratio of unripe to ripe aroma components are also high in this list, further highlighting the relationship between unripe aroma and perceived off-flavor.

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EXECUTIVE SUMMARY

Project Title: Mitigating WA 38 greasiness and related quality defects

Keywords: apple, cosmic crip, fruit quality, Retain, Harvista, Smartfresh, coating, maturity indexes

Abstract:

Skin greasiness remains a key postharvest challenge for WA 38 apples, particularly during long-term storage and marketing. This project evaluated how harvest maturity, growing conditions, and postharvest practices influence greasiness development and related quality defects, including off-flavors, with the goal of identifying practical strategies growers can apply throughout the cold chain. Results showed that fruit maturity at harvest is a major driver of greasiness risk. Starch breakdown

progressed differently among sites and seasons, largely due to temperature differences during the growing season. Warmer conditions led to faster starch degradation and greater variability in maturity at harvest, increasing the risk of greasiness. In contrast, cooler temperatures late in the season were associated with higher greasiness development.
Storage conditions also influenced greasiness development. Fruit stored in regular air developed more greasiness than fruit stored under controlled atmosphere (CA). In all storage regimes, greasiness increased once fruit were removed from cold storage and placed into shelf-life conditions (7 days at 68°F).
Ethylene management before and after harvest played an important role too. Retain® applications reduced greasiness at harvest and during cold storage for up to four months, with earlier applications (14–21 days before harvest) provided a better control. However, Retain® did not prevent greasiness development once fruit were removed from cold storage. Among postharvest treatments, a single application of Harvista™ combined with SmartFresh (SF) or SF alone reduced greasiness incidence during storage.
During packaging, detergent washes were able to eliminate greasiness for 1–7 days before the reappearance of greasiness, while coatings helped maintain control during the cold chain, but neither approach fully prevented greasiness during shelf life.
An off-flavor described as “bitterness” was most often detected in immature fruit and was linked to aroma profiles typical of unripe apples. Following recommended harvest maturity guidelines and avoiding immature fruit is the most effective way to reduce this off-flavor risk.

PROJECT OUTCOMES

- **Refined harvest maturity guidelines** confirmed that fruit maturity at harvest is the primary factor influencing WA 38 greasiness and off-flavor risk. Cooler late-season conditions increased greasiness, reinforcing the need for careful, block-specific harvest timing.
- **Validated ethylene-management tools** showed that early preharvest Retain® applications (14–21 days before harvest) reduced greasiness during cold storage, while only Harvista™ (1x) combined with SmartFresh consistently reduced greasiness severity postharvest across storage conditions.
- **Defined storage and handling impacts** demonstrated higher greasiness incidence in regular air storage compared to CA, with greasiness increasing during shelf-life in all cases.
- **Established practical limits of post-storage interventions**, with detergents providing only short-term greasiness removal (1–3 days) and coatings offering extended but incomplete control during the cold chain.
- **Identified the source of off-flavors**, linking bitterness primarily to immature fruit and unripe aroma profiles, and confirming that proper harvest maturity is the most effective mitigation strategy.