Proprietary Information of

Windham Packaging, LLC

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Avocado Preliminary Shelf Life Study

Procedures:

Avocados were harvested on 10/14/17 from Mexico and shipped to Beacon Fruit & Produce Co., Chelsea, MA. 1 case of 48 avocados were picked up from Beacon Fruit & Produce Co. on 10/24/17 and brought to the laboratory at Windham Packaging, Windham, NH. The Control avocados were packaged in hot needle perforated bags (to simulate the open netting bags commonly used for avocados at retail) or in Hydro-Sure™ laser microperforated bags. Three avocados were placed in each bag. Avocados were stored in 40F until day 4, when they were placed in 50F. On day 6, avocados were moved to 68-70F and held at that temperature for the rest of the study. The avocados were removed from their bags on day 13 and held at 68-70 F. Quality was evaluated on days 0, 6, 9, 13, 15, 17, and 20. Package weights (g) were measured on days 0, 6, 9, 13, and 15. Firmness was measured using a penetrometer with a 6 mm tip on days 0, 6, 9, 13, 15, 17, 20. Firmness measurements were taken with both the peel on and off. Headspace measurements were taken on days 6, 9, 13. Taste tests were taken on days 6, 9, 13, 15, 17, 19, and 20. Taste tests evaluated texture, flavor, and aroma on a scale of 0-5: texture, 0=tough 5=creamy; flavor, 0=bland 5= grassy/nutty; aroma, 0= off-odor 2.5= no odor 5=grassy.

Results:

Headspace Analysis

Prolonged shelf life in avocados has been associated with reduced oxygen and increased carbon dioxide levels. The Control bags were perforated with hot needles, leaving ambient atmosphere (~21% O_2, ~0.1% CO_2) inside the package on days 6, 9, and 13. Hydro-Sure™ bags were specifically designed and perforated to maintain reduced O_2 and elevated CO_2 levels. O_2 levels in Hydro-Sure™ bags were 14.1, 6.7, and 7.7% on days 6, 9, and 13, respectively. CO_2 levels in Hydro-Sure™ bags were 8.5, 17.5, and 16.7% on days 6, 9, and 13, respectively.

Weight Loss

Avocado weights were measured throughout the study until day 15. On days 6-15, the Control avocados had significantly higher weight loss than the avocados packaged in Hydro-Sure™ bags. Avocados in the Control bags had 2.76, 5.47, 9.13, and 10.58% weight loss on days 6, 9, 13, and 15, respectively. Avocados in Hydro-Sure™ bags had 1.08, 2.64, 4.25, and 6.61% weight loss on days 6, 9, 13, and 15, respectively. Because the control bags were perforated with hot needles, there was no atmosphere control. Moisture loss occurred at a more rapid rate in the hot needle perforated bags than the avocados packed in Hydro-Sure™ bags.

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Days in Storage	Storage Temperature	Treatment	Weight (g)	Average Weight Loss (g)	Average Weight Loss (%)
0	40°F	Control	673.8		
		Hydro-Sure™	658.1		
6	Days 0-4: 40°F Days 5-6: 50°F	Control	652.5	18.50	2.76
		Hydro-Sure™	734.5	8.00	1.08
9	Days 6–13: 68-70°F in bag	Control	639.5	37.00	5.47
		Hydro-Sure™	626.5	17.00	2.64
13		Control	609.7	61.20	9.13
		Hydro-Sure™	619.1	27.42	4.25
15	Day 13-finish: 68-70°F in air	Control	601.5	71.13	10.58
		Hydro-Sure™	605.9	42.80	6.61

Figure 1: Average weight loss in Control avocados vs. avocados packaged in Hydro-Sure™ Bags

Color and Firmness

On days 0 and 6, all avocados had dark green exteriors and light green/yellow pulp. As the fruit ripened, the skin turned dark purple/brown. On day 9, the skin of the avocados packaged in Hydro-Sure™ bags remained green and the Control avocados began to turn purple and both Control and Hydro-Sure™ avocados had a green-yellow pulp. On day 13, the skin of the avocados packaged in Hydro-Sure™ bags remained green and the pulp stayed light green/yellow. The Control avocados' skin continued to turn purple/brown, and the pulp was a duller light/green yellow with small dark sports forming at the stem end of the fruit. On day 15, the Hydro-Sure™ avocados' exterior began to turn purple and the yellow/green color of the pulp started to fade. The Control fruit exterior was completely brown/purple and large brown sports had formed near the skin.

On days 17 and 19, the exterior of the Hydro-Sure™ avocados were dark brown/purple with some green and the pulp remained light green/yellow. The exterior of the Control avocados was dark brown and began to shrivel due to weight loss and the pulp was grayish/yellow/green with large and small dark spots throughout the fruit.

On day 20, the pulp of the Hydro-Sure™ was completely brown and the pulp was dull light green/yellow with no signs of rotting. In contrast, the exterior of the Control fruit was dark brown with coarse, light brown spots forming on the skin and the pulp was almost completely brown and rotted.

Firmness in avocados decreases as the fruit ripens and according to the literature, the fruit is fully ripe when firmness reaches 0.9 lb. Optimum firmness for consumption is between 0.99 and 1.51 lb. On day 0, unpeeled avocados had a firmness of 284.40 lbs. Throughout the study, avocados in both Control and Hydro-Sure™ bags had a steady decrease in firmness. Firmness of avocados in

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Control bags decreased at a more rapid rate than Hydro-Sure™ avocados. Firmness was slightly lower when the peels were removed for the measurements. Average firmness (peeled an unpeeled) in Hydro-Sure™ bags was measured at 30.7, 27.1, 19.2, 6.5, and 1.5lbs on days 6, 9, 13, 15, and 20, respectively. Average firmness of avocados in Control bags was significantly lower at 25.7, 2.1, 1.7, 1.4, and 0.94lbs on days 6, 9, 13, 15, and 20, respectively.

Avocados in Control bags ripened at a faster rate than those in Hydro-Sure™ bags, reaching optimal eating firmness between days 6 and 9. Because the firmness of the unpeeled Control fruit was 25.26 lbs on day 6 and 0.63 lbs on day 9, it is likely that the firmness reached optimum eating level around day 8 and did not stay there for long. The firmness of the unpeeled Hydro-Sure™ fruit was 4.92 on day 15, then dropped to 0.27 on day 20. The optimum eating firmness in Hydro-Sure™ avocados was likely achieved on day 17 or 18.

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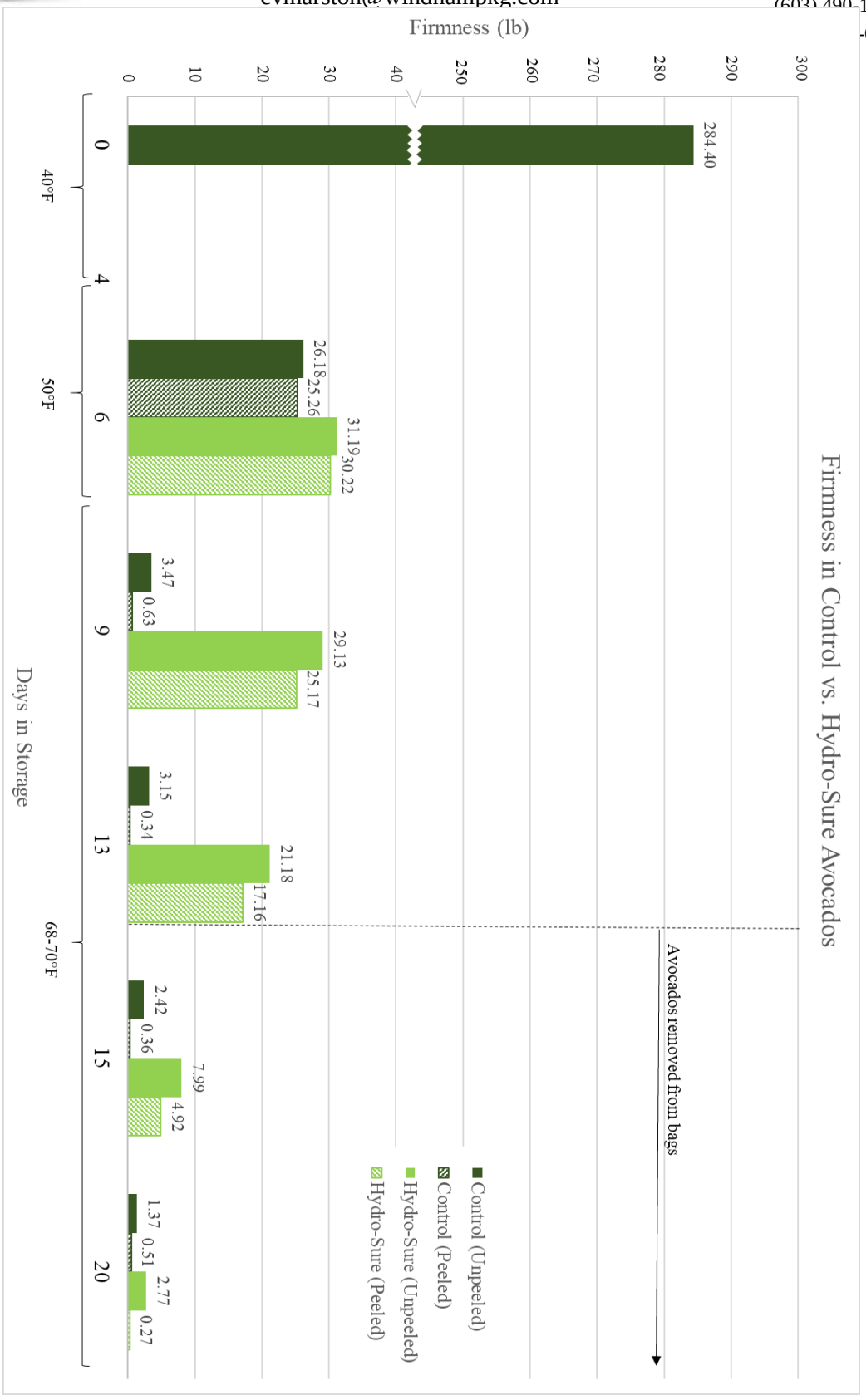

Figure 2: Firmness (lb) in avocados packaged in control (hot needle perforated) vs. Hydro-Sure™ bags

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Taste Tests

There was no significant difference in aroma between Control and Hydro-Sure™ avocados. Aroma decreased from day 6 until day 15, then increased on day 17 for both treatments. Aroma in Hydro-Sure™ avocados increased on day 19 and stayed the same on day 20. On day 6, Hydro-Sure™ avocados received a higher score (1) than Control avocados (0).

Control avocados had optimum texture ratings on days 9, 13, 15, and 17. Because of the modified atmosphere established inside the Hydro-Sure™ bags, ripening of these avocados, Hydro-Sure™ avocados did not reach optimum texture ratings until day 19. Texture scores in the Hydro-Sure™ avocados were rated 5 (optimum) on days 19 and 20, while Control avocados were not tested due to extreme decay.

Flavor scores were not significantly affected by packaging, except on day 9 where Hydro-Sure™ scored higher than Control avocados (Figure 2). However, the texture on Hydro-Sure™ avocados was not yet desirable at day 9, making it unlikely for the consumer to eat. By the time the Control avocados began to decay, the flavor ratings had not exceeded 3.5. On days 17, 19, and 20, the Hydro-Sure™ avocado flavor ratings were 3.75, 5, and 5, respectively.

Parameter	Days in Storage	Control	Hydro-Sure™
Aroma	6	4.5	4
	9	3.25	3.5
	13	3	2.5
	15	2.5	2.5
	17	3	3
	19	NT	4
	20	NT	4
Texture	6	0	1
	9	5	1.5
	13	5	2.5
	15	5	2
	17	5	3.25
	19	NT	5
	20	NT	5
Flavor	6	1.5	2
	9	3.5	2.5
	13	2.5	2.5
	15	3	3
	17	3.5	3.75
	19	NT	5
	20	NT	5

Figure 3: Taste test results in avocados packaged in control (hot needle perforated) vs. Hydro-Sure™ bags. On day 20, control avocados were not tasted due to extreme rotting. NT=not tested.

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Conclusions:

Avocados packaged in Control hot needle perforated bags ripened at a significantly faster rate than avocados packaged in Hydro-Sure™ bags. Control avocados were ripe before day 9 and their flavor peaked at a score of 3.5 (average). Signs of internal decay appeared in Control fruits on day 13, while Hydro-Sure™ fruit did not show any signs of internal rot at the end of the study (day 20).

Hydro-Sure™ packaging controlled the gas composition and moisture inside the bag, causing the avocados to ripen 2.5x more slowly than the control avocados packaged in hot needle perforated bags. In addition, Hydro-Sure™ packaging had a positive effect on flavor when the fruit developed full ripeness. Hydro-Sure™ packaging can be useful in controlling the ripening of avocados traveling long distances or remaining on retail shelves for extended periods.

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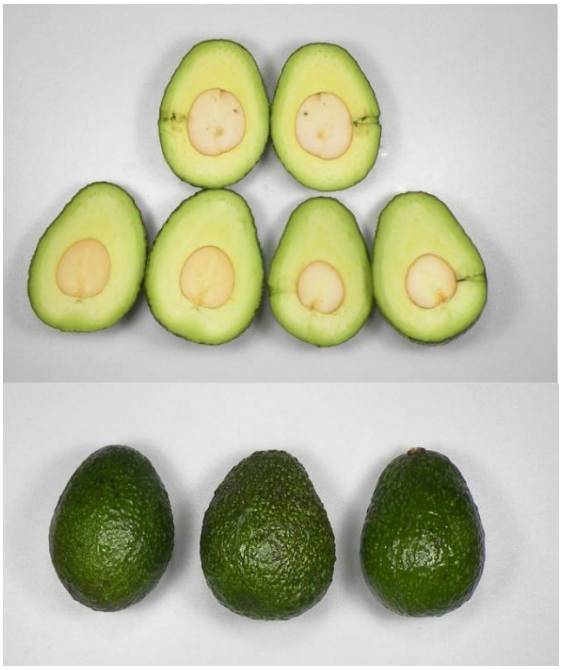

Figure 3. Control whole and cut avocados on Day 0.

Figure 4: Avocados packaged in Windham Packaging's Hydro-Sure^{TM} bag (left) and avocados packaged in control bag (right) after 13 days in storage. All avocados were packages in 40°F for 4 days + 50°F for 2 days + 68-70°F until day 20.

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Figure 5: Avocados packaged in Windham Packaging's Hydro-Sure™ bag (left) and avocados packaged in control bag (right) after 15 days in storage. All avocados were packages in 40°F for 4 days + 50°F for 2 days + 68-70°F until day 20.

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Figure 6: Avocados packaged in Windham Packaging's Hydro-Sure^{TM} bag (left) and avocados packaged in control bag (right) after 17 days in storage. All avocados were packages in 40°F for 4 days + 50°F for 2 days + 68-70°F until day 20.

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Figure 7: Avocados packaged in Windham Packaging's Hydro-Sure™ bag (left) and avocados packaged in control bag (right) after 19 days in storage. All avocados were packages in 40°F for 4 days + 50°F for 2 days + 68-70°F until day 20.

Figure 8: Avocados packaged in Windham Packaging's Hydro-Sure™ bag (left) and avocados packaged in control bag (right) after 20 days in storage. All avocados were packages in 40°F for 4 days + 50°F for 2 days + 68-70°F until day 20.