

Abstract:

FruitGard® has proven itself to be an effective antimicrobial for spoilage pathogens on all produce surfaces. Microorganisms can bloom during transport causing waste of product and resources. SGE, LLC (SGE), ran a full-scale trial to evaluate FruitGard® interventions in shipping containers of plantains and pineapples to prevent mold in transit and to increase shelf life post transit. SGE used FruitGard® Wipeout and Maintenance pouches to create a custom release (of total fumigant dose and timed release over the shipping cycle) intervention for each produce type. This test showed statistically significant reductions in mold development on crownless and whole pineapples during shipment and for up to three weeks in cold storage, 40 F. The test also showed similar outcomes for plantains. FruitGard® pouches were a convenient way to deploy the fumigant in shipping containers and the intervention was proven to be safe for container re-entry at the port of entry.

Experimental Design:

Plantains and pineapples were treated in forced air cooled shipping containers and compared to control non-treated containers shipped at the same time. Containers originated in Columbia (plantains) and Costa Rica (pineapples) and landed at the same port on the NE US coast. The shipping time was 2 weeks for pineapples and 4 weeks for plantains. Approximately 960 cases of pineapples (22,750 Kg.) and 960 cases of plantains (22,750 Kg.) were treated in separate containers. Plantains were placed in vented corrugated boxes roughly 50 lbs of fruit per box. Twenty pallets, 48 boxes/pallet, were loaded in both the treated and control shipping containers. Pineapples were placed in vented corrugated boxes and combinations of whole and crownless fruit were placed in the container. Whole fruit boxes contained 6 fruit per box and crownless boxes contained 8 fruit per box. In the control container 17 pallets of whole fruit and 3 pallets of crownless fruit were dispersed evenly in the container. In the treatment container 14 pallets of whole fruit were placed in combination with 6 pallets of crownless fruit. Three pallets of crownless fruit in the treated and control containers had one layer of boxed pineapples inoculated with penicillium at the crown - approximately 18 boxes per container. Inoculated fruits were done to ensure a measure of decay pressure. The fruit were arranged evenly throughout the container, Figure 1.

FruitGard® treatment was designed to release a high burst of fumigant over the first 12 hours and then maintain a low background level during transport. For convenience FruitGard® dual pouches, Figure 2, were activated and placed at the back end of the container on top of the palletized fruit right before the container was closed and placarded.

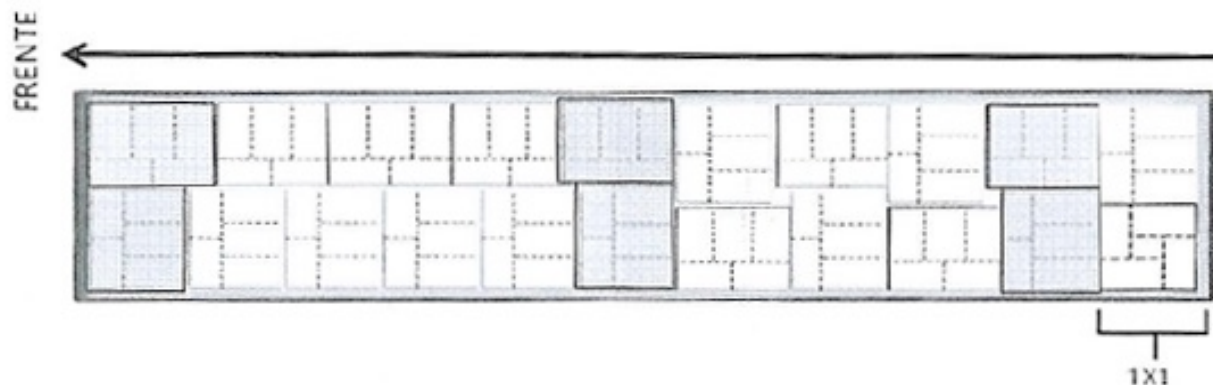


Figure 1: Pineapple Container Layout
Note: shaded areas indicate crownless pallet placement



Figure 2: SGE Wipeout and Maintenance Pouches

Upon arrival treated containers were tested for residual fumigant gas concentrations using Morphtec safety badges, Dräger tubes (0.1 ppm sensitivity) and a handheld gas sensor. Untreated containers were also checked as a negative control. **Neither control nor treated containers showed any residual headspace FruitGard® fumigant which confirmed worker safety protocols.**

Boxes of pineapples and plantains were gathered from treated and untreated containers. The boxes were sent by refrigerated truck to a local analytical laboratory. At the laboratory the boxed fruit was held in a walk-in cooler at 40 F. Evaluations of stored fruit took place over a 3 week period; after 3 weeks the produce was too ripe to draw effective comparisons.

A rating scale of 1 to 10 was developed for crownless pineapples examining the exposed crown and whole pineapples were evaluated based on the basil end on a scale of 1-5 – See Appendix A. No rating scale was developed for plantains since the fruit was relatively free of mold on arrival

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and the sample set was too small. Pictures of the fruit are provided as evidence of the treatment impact – see Appendix B. Each pineapple in a box was given a rating by an individual reviewer. Three reviewers rated each piece of fruit according to the scales – See Appendix C crownless and Appendix C whole data.

Results / Conclusions:

Table 1 shows the average weekly ratings for the pineapple groups. In all cases the treated crownless fruit had better overall quality ratings than untreated fruit. The differences between the sets narrowed the longer the fruit was stored. Treated whole fruit were not significantly different from controls until week three at which point the treated fruit had better quality assessments. The data sets, control versus treated, were compared for statistical significance. Table 2 shows the critical t ratio and the calculated t ratios for each material. There was a strong statistical significance between the controls and treated for both inoculated and non-inoculated crownless fruit over the entire three week holding period. Treated whole fruit were not significantly different until week three at which point mold started to develop on the untreated controls.

Table 1: Average Rating Numbers for Pineapple Groups

Week	Control			Week	Treated		
	Inoculated Crownless	STD	Data Points		Inoculated Treated Crownless	STD	Data Points
1	6.02	1.42	121	1	4.72	1.60	121
2	6.87	1.49	121	2	6.01	1.50	121
3	8.59	1.35	121	3	7.59	1.68	121
	Crownless	STD	Data Points		Treated Crownless	STD	Data Points
1	5.99	1.92	121	1	3.64	1.85	121
2	7.27	2.01	121	2	4.83	2.15	121
3	8.95	1.36	121	3	7.45	1.86	121
	Whole	STD	Data Points		Treated Whole	STD	Data Points
1	1.39	0.66	66	1	1.45	0.71	66
2	2.19	1.5	66	2	1.72	1.06	66
3	4.38	2.56	66	3	2.94	1.66	66

Table 2: t Ratios for Pineapple treatments; critical t Ratio 2.5758 @ P = 0.005

Pineapple Type	Degrees of Freedom	Week	t Ratio	Statistical Difference
Inoculated Crownless	120	1	6.6569	Yes
	120	2	4.4558	Yes
	120	3	5.0828	Yes
Crownless	120	1	9.6551	Yes
	120	2	9.0815	Yes
	120	3	7.1313	Yes
Whole	65	1	-0.4990	No
	65	2	2.0530	No
	65	3	3.8051	Yes

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The plantains showed similar behavior to the pineapples. Controls showed early development of white mold at the cut tips while treated fruit showed significantly less – see Appendix B. The mold continued to develop during storage and over the three week period the differences between controls and treated were more substantial. Unfortunately, there were not enough plantain samples to do a statistical comparison.

FruitGard® interventions were shown to retard mold development on pineapples and plantains in shipment and subsequent cold storage. Differences between controls and treated fruit in transit were statistically significant. **FruitGard® dual pouches provided a convenient method of treatment in shipping that ensured proper treatment and safety.** The use of FruitGard® did not negatively impact the fruit e.g. discoloration, odor changes. A customized solution using Wipeout and Maintenance release products was developed for this customer showing the versatility of designed release products.

Appendix A: Rating Scales for Pineapples



Crownless Scale 1



Crownless Scale 2



Crownless Scale 3



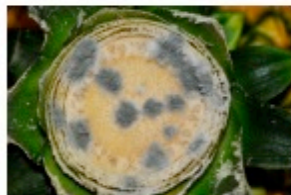
Crownless Scale 4



Crownless Scale 5



Crownless Scale 6



Crownless Scale 7



Crownless Scale 8

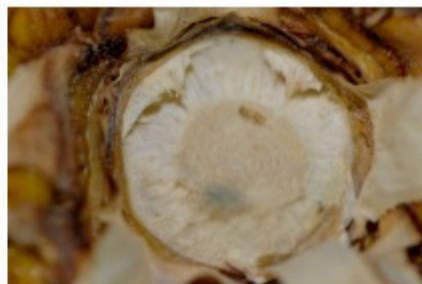


Crownless Scale 9

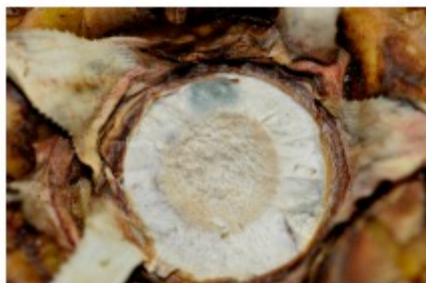
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Basil Scale 1



Basil scale 2



Basil Scale 3



Basil Scale 5

Appendix B: Plantain Observations

Plantains – Storage day 14



CIO2-1



Control-1



CIO2-2



Control-2



CIO2-3



Control-3



CIO2-4



Control-4

Plantains Storage Day 21



CI02-1



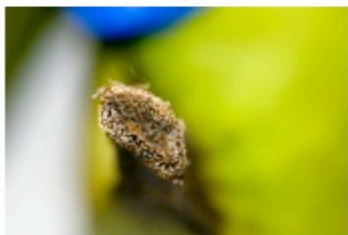
Control-1



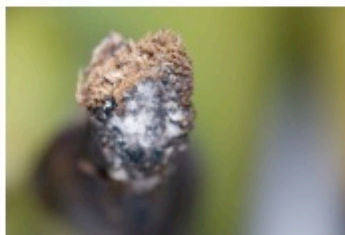
CI02-2



Control-2



CI02-3



Control-3



CI02-4



Control-4

Box	Code	Pineapples 1 thru 11												AVE	Std Dev
1	14	10	9	9	10	9	10	10	10	9	9	9	9.45	0.52	
2	14	9	9	10	10	10	10	9	9	10	10	10	9.64	0.50	
3	14	10	10	9	10	10	9	10	8	10	10	10	9.64	0.67	
4	2	6	9	9	8	9	10	9	10	9	8	10	8.82	1.17	
5	2	9	9	8	7	10	10	7	10	9	10	10	9.00	1.18	
6	88	9	9	9	10	9	9	8	10	8	9	10	9.09	0.70	
7	2	9	10	8	10	10	2	9	10	5	6	5	7.64	2.73	
8	22	10	9	9	7	9	9	8	8	9	9	8	8.64	0.81	
9	14	8	8	5	10	9	10	10	8	8	9	10	8.64	1.50	
														8.95	1.36

Box	Code	Pineapples 1 thru 11										AVE	Std Dev
1	16	9	9	5	9	10	9	9	10	10	9	8.91	1.38
2	16	8	8	10	9	9	9	7	8	7	7	8.18	0.98
3	2	3	1	3	4	5	5	5	7	2	7	4.18	1.89
4	10	8	7	9	9	8	10	9	10	8	7	8.45	1.04
5	2	8	5	9	9	9	10	8	9	8	9	8.45	1.29
6	10	7	8	7	2	9	8	7	7	7	7	6.91	1.76
7	2	7	7	3	8	7	8	7	8	8	8	7.09	1.45
8	10	8	6	7	6	6	8	7	5	6	7	6.91	1.38
9	10	7	8	6	7	6	6	9	10	9	5	7.45	1.63
10	16	8	8	7	8	7	8	6	8	9	9	7.91	0.94
												7.45	1.86

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Whole Control

Day 7

Box	Code	Pineapples 1 thru 6						AVE	Std Dev
1	4	1	1	1	1	1	1	1.00	0.00
2	32	1	1	1	1	1	2	1.17	0.41
3		1	1	1	1	1	1	1.00	0.00
4		1	3	2	1	1	3	1.83	0.98
5		1	1	1	1			1.00	0.00
6		1	2	1	1	2	1	1.33	0.52
7		2	2	2	1	3	2	2.00	0.63
8		1	2	2	1	1	1	1.33	0.52
9		1	1	3	1	3	2	1.83	0.98
10		2	3	1	1	2	1	1.67	0.82
11		1	1	1	1	1	1	1.00	0.00
								1.39	0.66

Whole Control

Day 14

Box	Code	Pineapples 1 thru 6						AVE	Std Dev
1	4	1	1	1	2	1	1	1.17	0.41
2	32	1	1	1	1	1	1	1.00	0.00
3		1	1	3	1	1	1	1.33	0.82
4		1	5	2	2	2	2	2.33	1.37
5		1	1	1	1			1.00	0.00
6		3	4	3	2	5	1	3.00	1.41
7		5	4	4	2	5	4	4.00	1.10
8		1	2	1	1	2	1	1.33	0.52
9		3	4	1	2	6	2	3.00	1.79
10		3	4	1	2	6	2	3.00	1.79
11		1	6	2	3	2	1	2.50	1.87
								2.19	1.50

Whole Control

Day 21

Box	Code	Pineapples 1 thru 6						AVE	Std Dev	Observations on Rind
1	4	6	2	3	6	5	2	4.00	1.90	No Mold
2	32	2	5	1	1	1	1	1.83	1.60	No Mold
3		1	5	1	5	1	2	2.50	1.97	Some Green Mold
4		1	7	3	3	2	3	3.17	2.04	No Mold
5		3	4	7	2			4.00	2.16	Slight Green Mold
6		7	8	7	8	9	8	7.83	0.75	Green Mold
7		8	9	7	7	6	7	7.33	1.03	Covered Green Mold
8		3	2	2	1	3	3	2.33	0.82	Slight Green Mold
9		2	5	4	4	1	2	3.00	1.55	Slight Green Mold
10		5	8	9	5	6	7	6.67	1.63	Slight Green Mold
11		4	3	6	6	9	4	5.33	2.16	Slight Green Mold
								4.38	2.56	

FruitGard® Dual Pouch Mold Intervention Shipping Study: Pineapples and Plantains

Whole ClO2

Day 7

Box	Code	Pineapples 1 thru 6						AVE	Std Dev
1	3	1	1	2	2	2	1	1.50	0.55
2	15	1	2	1	1	2	1	1.33	0.52
3	11 M	1	1	1	1	1	2	1.17	0.41
4	6 B	1	1	1	2	2	2	1.50	0.55
5	9 T	2	1	1	1			1.25	0.50
6	15 B	1	1	1	1	1	1	1.00	0.00
7	15 B	1	1	1	2	2	1	1.33	0.52
8	11 T	2	1	1	2	3	2	1.83	0.75
9	15 M	2	1	1	2	5	1	2.00	1.55
10	9 T	1	1	2	3	1	1	1.50	0.84
11	15 M	2	1	2	1	1	2	1.50	0.55
								1.45	0.71

Whole ClO2

Day 14

Box	Code	Pineapples 1 thru 6						AVE	Std Dev
1	3	1	1	2	2	2	1	1.50	0.55
2	15	1	2	2	2	1	1	1.50	0.55
3	11 M	1	1	1	2	3	4	2.00	1.26
4	6 B	1	1	1	1	2	1	1.17	0.41
5	9 T	6	2	2	1			2.75	2.22
6	15 B	1	1	1	1	1	1	1.00	0.00
7	15 B	1	1	1	1	1	1	1.00	0.00
8	11 T	1	2	2	2	3	3	2.17	0.75
9	15 M	2	1	1	2	5	2	2.17	1.47
10	9 T	1	2	2	5	2	2	2.33	1.37
11	15 M	3	1	1	2	2	1	1.67	0.82
								1.72	1.06

Whole ClO2

Day 21

Box	Code	Pineapples 1 thru 6						AVE	Std Dev	Observations on Rind
1	3	1	4	2	3	2	1	2.17	1.17	Slight White Mold
2	15	2	1	3	6	3	1	2.67	1.86	No Mold
3	11 M	5	3	2	2	2	1	2.50	1.38	Slight White Mold
4	6 B	2	2	1	5	2	4	2.67	1.51	No Mold
5	9 T	3	5	3	7			4.50	1.91	No Mold
6	15 B	2	1	2	3	1	1	1.67	0.82	Slight White Mold
7	15 B	2	2	1	2	3	2	2.00	0.63	Green Mold
8	11 T	6	5	4	3	5	3	4.33	1.21	White Mold
9	15 M	2	5	4	3	2	3	3.17	1.17	Very soft, White Mold
10	9 T	3	8	7	4	5	4	5.17	1.94	Slight White Mold
11	15 M	2	2	3	2	1	2	2.00	0.63	No Mold
								2.94	1.66	