EFFECT OF TOMATO FRUIT SIZE ON LYE PEEL LOSSES

TOMATO SOLUTIONS

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SUMMARY

Lye peel recovery data was used to mathematically calculate the depth of peel and flesh removal when the optimal combination of time, concentration, and temperature are used to effectively remove peel without excessive flesh removal. This information was then used to calculate theoretical lye peel losses due to fruit weight and shape. Peel losses were shown to increase exponentially as fruit weight decreases. As well, more elongated fruit had higher lye peel losses. These losses are directly related to the surface area of the fruit. As fruit size increases, there is a direct economic benefit from reduced lye peel losses, as well as a corresponding reduction in lye peeling and waste disposal costs.

INTRODUCTION

The major factor determining whole peel recovery when lye peeling tomatoes is the complete loss of the skin and flesh removed during lye peeling. This is correlated with surface area of each fruit. The relationship between fruit size and surface area is non-linear, so smaller size fruit have a proportionately greater surface area than larger fruit, and hence a higher percentage of lye peel loss.

Depth of peel removal coupled with the surface area determines total lye peel loss. Minimizing the depth of peel removal by using only the optimum combination of exposure time, lye concentration, and temperature will result in the lowest lye peel losses for a given fruit size. Using larger sized fruit, overall surface area can be reduced, and lye peel loss will be further minimized. Fruit size going into the peeler is controlled by three factors: size grading, variety, and environmental conditions such as moisture availability in production fields.

In our lye peeling work, weight of skin and peel removed during lye peeling is recorded, and from this, depth of peel removal can be mathematically calculated. This data can then be used to calculate lye peel loss for various fruit sizes and shapes. It is important to know what losses could be in order to make good decisions regarding variety selection.

If peeled colour and firmness are good, along with other quality factors such as stem scar size, then a larger fruit size with a corresponding improvement in peeled recovery would be very advantageous. Calculation of the costs of using fruit of various sizes assists in making good decisions when choosing tomato hybrids for commercial use.

PURPOSE

To determine theoretical losses due to lye peeling for a range of tomato fruit sizes with various shapes, ranging from perfectly round, to oval, to very elongated, and potential cost savings from using larger fruit.

METHODS

Using actual lye peeling data, the depth of peel removal in an optimized system was determined by using the lye peel loss and mathematical methods to determine the depth of peel and flesh removal. Peeling depth was estimated to be 0.118 cm (1.18 mm). The following assumptions were made to calculate the peel losses for fruit weights from 20 grams to 150 grams.

-round fruit
-1 gram of fruit weight = 1 cubic cm.
-depth of peel and flesh removal = 0.118 cm (1.18 mm)

Formulae

volume of a sphere = $4/3*3.1416r^3$ (where r = radius of the fruit, or ½ the diameter)
surface of a sphere = $4*3.1416r^2$

An additional calculation was made using a depth of 2.0 mm which may occur due to excessive peel exposure times, or excessive lye concentrations. These losses may be more typical of some factory lye peeling systems set up to handle a wide range of situations. Sometimes, excessive amounts of peel and flesh can be removed leading to lower recovery.

Calculations were also made for elongated fruit assuming the stem scar end and blossom end are both perfectly hemi-spherical. These calculations were only made for 40g, 50g, 60g, and 70 gram fruit, and for height:width ratios of 1.5 (plum shaped), 2.0 (San Marzano shape), and 2.5 (very elongated).

RESULTS

CHART ILLUSTRATING EFFECT OF FRUIT SIZE
ON PERCENT THEORETICAL PEEL LOSS AT A DEPTH OF 1.18 MM
IN AN OPTIMIZED LYE PEELING SYSTEM

ROUND FRUIT WEIGHT (G)	r (radius) cm	DIAMETER (CM)	DIAMETER (INCHES)	depth of peel removal (cm)	surface area (cm^2)	volume removed (cc^3) (=grams)	% Peel Loss
20	1.68417	3.36834	1.33	0.1180783	35.64	4.21	21.04
25	1.81422	3.62844	1.43	0.1180783	41.36	4.88	19.54
30	1.9279	3.8558	1.52	0.1180783	46.71	5.52	18.38
35	2.02955	4.0591	1.60	0.1180783	51.76	6.11	17.46
40	2.12193	4.24386	1.67	0.1180783	56.58	6.68	16.70
45	2.20689	4.41378	1.74	0.1180783	61.20	7.23	16.06
50	2.28539	4.57078	1.80	0.1180783	65.63	7.75	15.50
55	2.35956	4.71912	1.86	0.1180783	69.96	8.26	15.02
60	2.42900	4.858	1.91	0.1180783	74.14	8.75	14.59
65	2.49468	4.98936	1.96	0.1180783	78.21	9.23	14.21
70	2.55707	5.11414	2.01	0.1180783	82.17	9.70	13.86
75	2.61656	5.23312	2.06	0.1180783	86.03	10.16	13.55
80	2.67346	5.34692	2.11	0.1180783	89.82	10.61	13.26
85	2.72804	5.45608	2.15	0.1180783	93.52	11.04	12.99
90	2.78051	5.56102	2.19	0.1180783	97.15	11.47	12.75
95	2.83108	5.66216	2.23	0.1180783	100.72	11.89	12.52
100	2.8799	5.7598	2.27	0.1180783	104.22	12.31	12.31
105	2.92712	5.85424	2.30	0.1180783	107.67	12.71	12.11
110	2.97286	5.94572	2.34	0.1180783	111.06	13.11	11.92
115	3.01724	6.03448	2.38	0.1180783	114.40	13.51	11.75
120	3.06035	6.1207	2.41	0.1180783	117.69	13.90	11.58
125	3.10228	6.20456	2.44	0.1180783	120.94	14.28	11.42
150	3.29666	6.59332	2.60	0.1180783	136.57	16.13	10.75

** DEPTH OF PEEL REMOVAL BASED ON ACTUAL PEELING DATA FOR THIS SAMPLE

CHART ILLUSTRATING EFFECT OF FRUIT SIZE
ON PERCENT THEORETICAL PEEL LOSS AT A DEPTH OF 2.0 MM
IN A NON-OPTIMIZED (AGGRESSIVE) LYE PEELING SYSTEM

WEIGHT OF ROUND FRUIT (G)	r (radius) cm	DIAMETER (CM)	DIAMETER (INCHES)	depth of peel removal (cm)	surface area (cm^2)	volume removed (cc^3) (=grams)	% Peel Loss
20	1.68417	3.36834	1.33	0.2	35.64	7.13	35.64
25	1.81422	3.62844	1.43	0.2	41.36	8.27	33.09
30	1.9279	3.8558	1.52	0.2	46.71	9.34	31.14
35	2.02955	4.0591	1.60	0.2	51.76	10.35	29.58
40	2.12193	4.24386	1.67	0.2	56.58	11.32	28.29
45	2.20689	4.41378	1.74	0.2	61.20	12.24	27.20
50	2.28539	4.57078	1.80	0.2	65.63	13.13	26.25
55	2.35956	4.71912	1.86	0.2	69.96	13.99	25.44
60	2.42900	4.858	1.91	0.2	74.14	14.83	24.71
65	2.49468	4.98936	1.96	0.2	78.21	15.64	24.06
70	2.55707	5.11414	2.01	0.2	82.17	16.43	23.48
75	2.61656	5.23312	2.06	0.2	86.03	17.21	22.94
80	2.67346	5.34692	2.11	0.2	89.82	17.96	22.45
85	2.72804	5.45608	2.15	0.2	93.52	18.70	22.01
90	2.78051	5.56102	2.19	0.2	97.15	19.43	21.59
95	2.83108	5.66216	2.23	0.2	100.72	20.14	21.20
100	2.8799	5.7598	2.27	0.2	104.22	20.84	20.84
105	2.92712	5.85424	2.30	0.2	107.67	21.53	20.51
110	2.97286	5.94572	2.34	0.2	111.06	22.21	20.19
115	3.01724	6.03448	2.38	0.2	114.40	22.88	19.90
120	3.06035	6.1207	2.41	0.2	117.69	23.54	19.62
125	3.10228	6.20456	2.44	0.2	120.94	24.19	19.35
150	3.29666	6.59332	2.60	0.2	136.57	27.31	18.21

H:W RATIO	% PEEL LOSS AT PEELING DEPTH OF 1.18 mm (OPTIMAL)			
	40 GRAMFRUIT	50 GRAM FRUIT	60 GRAM FRUIT	70 GRAM FRUIT
1.0 (ROUND)	16.70	15.50	14.59	13.86
1.5 (PLUM)	17.25	16.01	15.07	14.31
2.0 (SAN MARZANO)	18.13	16.83	15.84	15.04
2.5 (VERY ELONGATED)	19.02	17.66	16.62	15.79

H:W RATIO	% PEEL LOSS AT PEELING DEPTH OF 2.0 mm (AGGRESSIVE)			
	40 GRAM FRUIT	50 GRAM FRUIT	60 GRAM FRUIT	70 GRAM FRUIT
1.0 (ROUND)	28.29	26.25	24.71	23.47
1.5 (PLUM)	29.21	27.11	25.52	24.24
2.0 (SAN MARZANO)	30.70	28.50	26.83	25.47
2.5 (VERY ELONGATED)	32.22	29.91	28.15	26.74

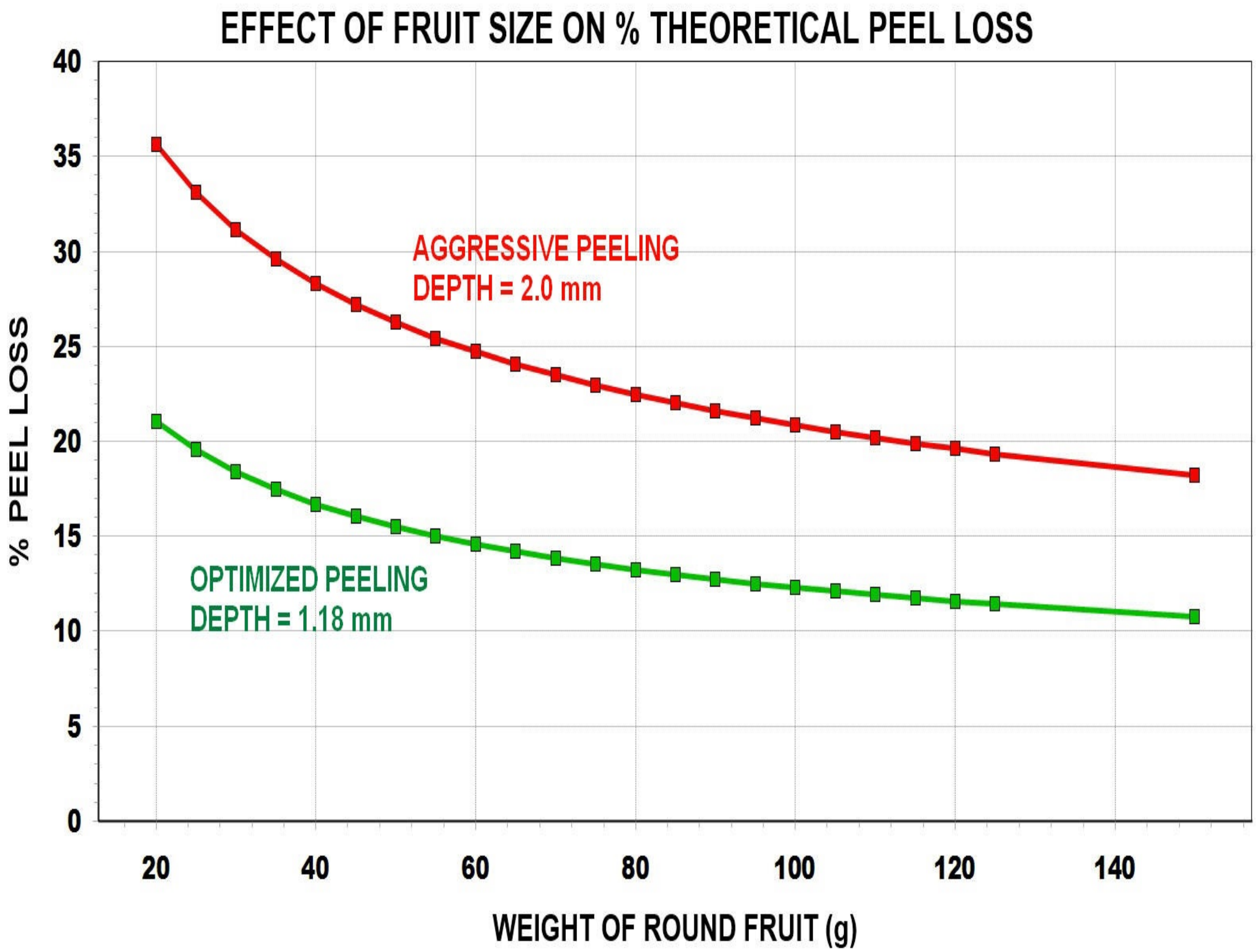
HEIGHT:WIDTH RATIO = 1.0 (DIGITALLY MODIFIED FROM CC337)

HEIGHT:WIDTH RATIO = 1.5 (CC337 VARIETY)

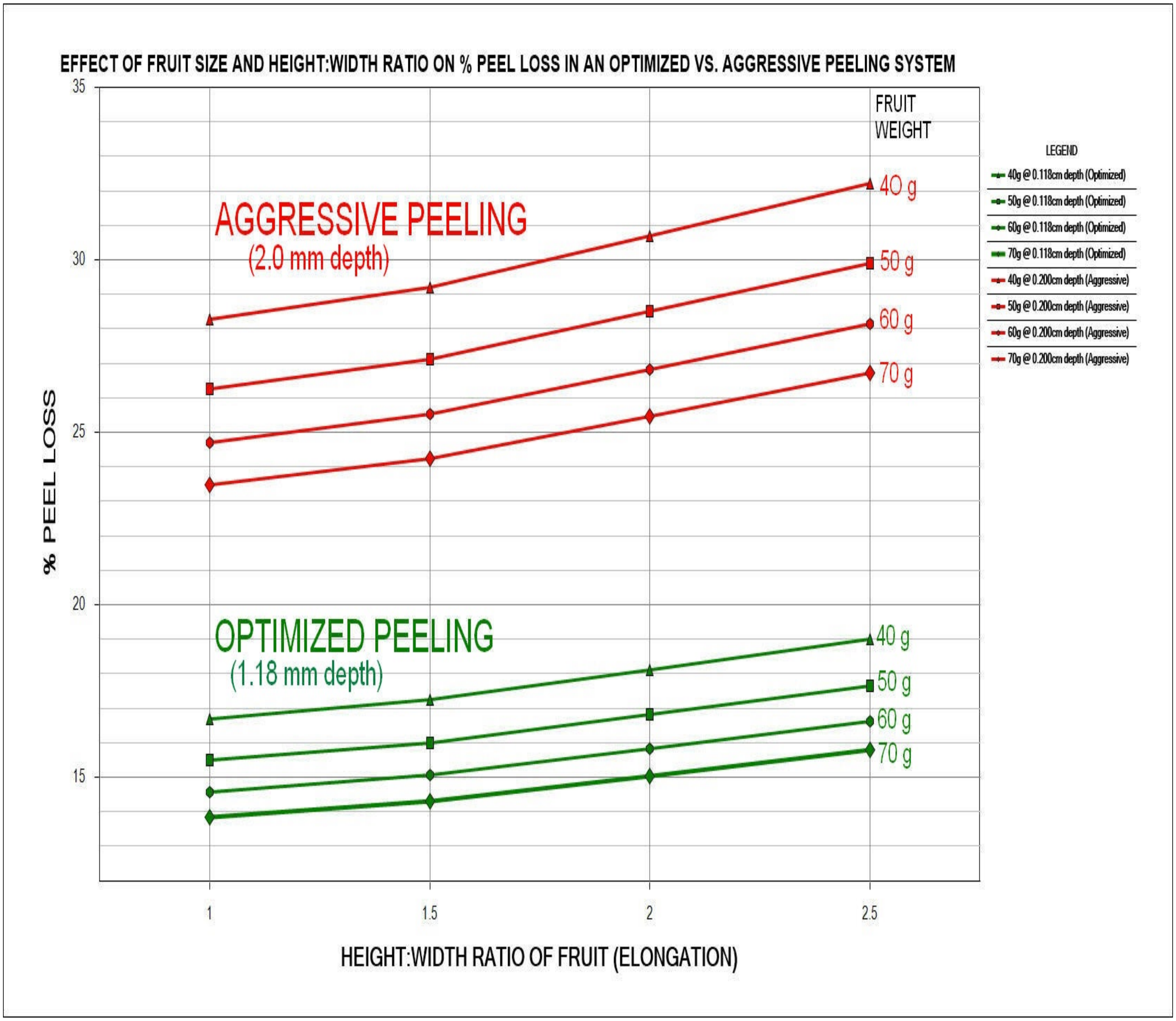
HEIGHT:WIDTH RATIO = 2.0 (DIGITALLY MODIFIED FROM CC337)

HEIGHT:WIDTH RATIO = 2.5 (DIGITALLY MODIFIED FROM CC337)

GRAPH SHOWING EFFECT OF FRUIT SIZE ON % THEORETICAL PEEL LOSS FOR PERFECTLY ROUND TOMATOES



NOTE: As shown above, as the weight (size) of fruit increases, peel losses decrease significantly. Losses are directly related to the depth of peel and flesh removal, and a small absolute change in peeling depth can drastically decrease peeled recovery.



EFFECT OF FRUIT SIZE AND HEIGHT:WIDTH RATIO ON % PEEL LOSS IN AN OPTIMIZED VS. AGGRESSIVE PEELING SYSTEM
% PEEL LOSS
35
30
25
20
15
FRUIT WEIGHT
AGGRESSIVE PEELING
(2.0 mm depth)
40 g
50 g
60 g
70 g
OPTIMIZED PEELING
(1.18 mm depth)
40 g
50 g
60 g
70 g
1
1.5
2
2.5
HEIGHT:WIDTH RATIO OF FRUIT (ELONGATION)
LEGEND
40g @ 0.118cm depth (Optimized)
50g @ 0.118cm depth (Optimized)
60g @ 0.118cm depth (Optimized)
70g @ 0.118cm depth (Optimized)
40g @ 0.200cm depth (Aggressive)
50g @ 0.200cm depth (Aggressive)
60g @ 0.200cm depth (Aggressive)
70g @ 0.200cm depth (Aggressive)

DISCUSSION

As the graphs show, the greatest peeling losses occur with small fruit where a relatively small change in fruit size (weight) results in a proportionately greater peel loss compared to the same change in larger fruit sizes. For instance, in the optimized lye peel system, a 50 gram fruit results in a 15.5% peel loss, compared to a 16.7% peel loss for a 40 gram fruit, and a 14.59% peel loss for a 60 gram fruit. This is an increase of 1.2% peel loss in the smaller fruit, and a decrease of 0.91% in the larger fruit.

As the depth of peel and flesh removal increases (non-optimized lye peel system), losses become much higher. Using the same example as above, losses in the 40 gram fruit are 2.04% higher than for a 50 gram fruit and losses are decreased by 1.54% in the 60 gram fruit. In the aggressive lye peeling system, the loss for a 50 gram fruit is estimated to be 26.25% which is probably close to commercial experience.

In 2013, the average fruit weight of CC337 was the lowest of any hybrid tested at 43 grams. Losses under an aggressive system with perfect non-cracked fruit would be estimated at 27.64%. TSH33 with a larger fruit weight of 58 grams would have an estimated loss of 25.00%. The difference is 2.64% lower lye peel loss with TSH33 due to fruit size alone.

To calculate the impact on profitability, the fact that retained tomato material is on the peeled fruit which have the highest commercial value must be considered. If peeling 60,000 tons, retaining 2.64% of this would be equivalent to 1584 tons at a value of $103.75/ton (2013 prices) for a total retained value of $164,340. The actual value would be much higher since the retained tomato solids are going into whole pack, and the cost of peeling etc to get this additional tonnage is reduced. In fact, at a loss of 27.64%, an additional 2,189 tons would have to be peeled to result in the 1584 tons of retained peeled product with the larger fruit size. This 2,189 tons would have to be purchased at a cost of $227,109.75. This is closer to the true value of the larger fruit size but still does not take into account the cost of the extra lye peeling, waste disposal, and the fact that the tomato solids are going into a much higher priced final product than sauce, crushed or paste. With larger fruit sizes such as the 81 gram TSH32, lye peel losses would be 5.28% lower than for the small fruited CC337, or exactly double the reduction with TSH33.

Another factor determining peel recovery is the shape or amount of elongation of the fruit. These types can be categorized in height:width (H:W) ratios. A distinct plum shape fruit would have an H:W ratio of 1.5 while a San Marzano type might be in the range of 2.0 to 2.5. Our calculations showed that the amount of peel loss increased as the H:W ratio increased. This is fairly significant as 60 gram fruit with a H:W ratio of 1.5 results in 0.48% more peel loss than perfectly round fruit.

Other factors are also important in optimizing peeled recovery such as firmness and resistance to cracking. If the skin on the fruit is cracked due to mechanical forces (machine harvest and handling) prior to lye exposure, peel losses would probably be much higher, but we have no data on this. We intend to compare cracked and non-cracked fruit of the same size to determine relative peel losses and recovery this fall (2014). The amount of cracked fruit is related to fruit firmness, shape, and weight, as well as other factors such as skin elasticity.

As fruit size increases, the amount of cracked fruit due to handling can increase due to the higher impact force generated by the higher fruit weight. A very firm fruit will not deform as much on impact so that the stress on the skin is minimized. If fruit size is increased there needs to be a concurrent improvement in firmness to avoid an increase in the percentage of cracked fruit.

We still do not know the extent to which cracked fruit would increase lye peel loss. It could be that there is extra loss just in the small area of the crack and this may not drastically impact peeling loss. Most of the fruit crack during lye peeling exposure, exposing a considerable area of the fruit surface to the corrosive activity of the lye solution. Obviously, these factors need to be examined in detail.

The shape of the tomato has a large influence on the amount of cracked fruit, with highly elongated fruit very resistant to impact cracking. This can be seen most clearly with the San Marzano types such as TSH24 and TSH35. The narrower locular area inside the elongated tomatoes probably reduces the amount of compression on impact, resulting in less skin distortion and breakage. If cracked fruit are found to significantly increase peel losses, the reduction in cracked fruit generally found with more elongated fruit might counteract the increased peel loss due to the elongated shape.

In the plum shaped hybrids, a similar factor likely operates, in that hybrids with thick fruit walls, and reduced locular area are firmer and therefore more resistant to impact cracking. A larger number of locules resulting from more cross walls reinforcing the outer fruit walls can also improve firmness and reduce cracking.

As previously mentioned, we hope to conduct some lye peel tests in the fall of 2014 to determine the importance of skin cracks on lye peel losses.

REFERENCES (all available on the internet)

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