FACTORS AFFECTING TOMATO SOLIDS

PRESENTATION AVAILABLE ON OUR WEBSITE:

WWW.TOMATOSOLUTIONS.CA

DR. J.A. DICK AND A.A. DICK
MARCH 2, 2018
TOMATO DAY, LEAMINGTON, ONTARIO, CANADA
TOMATO PULP
--MEASURABLE FACTORS--

LYCOPENE

WIS ↔ NTSS
EYE APPEAL

TOMATO JUICE, SAUCE, ETC.
--CONSUMER PERCEPTION--

CONSISTENCY  ↔  FLAVOR
% SOLUBLE SOLIDS FOR A TYPICAL PROCESSOR
ONTARIO, CANADA, 2013 - 2017

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOWEST GROWER</td>
<td>4.0</td>
<td>4.0</td>
<td>4.3</td>
<td>4.0</td>
<td>4.4</td>
</tr>
<tr>
<td>HIGHEST GROWER</td>
<td>4.6</td>
<td>4.4</td>
<td>5.0</td>
<td>4.6</td>
<td>5.0</td>
</tr>
<tr>
<td>AVERAGE OF ALL GROWERS</td>
<td>4.3</td>
<td>4.2</td>
<td>4.5</td>
<td>4.3</td>
<td>4.9</td>
</tr>
</tbody>
</table>

AVERAGE DIFFERENCE BETWEEN LOWEST & HIGHEST GROWER = 0.6
DIFFERENCE FROM LOWEST TO HIGHEST YEAR = 0.7
<table>
<thead>
<tr>
<th>COMPONENTS OF A PROCESSING TOMATO</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLUBLE SOLIDS (°BRIX, NTSS)</td>
<td>4.37</td>
</tr>
<tr>
<td>WATER INSOLUBLE SOLIDS (WIS)</td>
<td>1.44</td>
</tr>
<tr>
<td><em>(WIS here includes ~0.25% seeds &amp; skin)</em></td>
<td></td>
</tr>
<tr>
<td>TOTAL SOLIDS (TS) = % DRY WEIGHT OF PULP</td>
<td>5.81</td>
</tr>
<tr>
<td>WATER</td>
<td>94.19</td>
</tr>
</tbody>
</table>

*NOTE: ACTUAL WIS~1.19% (1.44-0.25)
TOMATO PULP COMPOSITION FOR 26°BRIX PASTE

- 83.2% Removed as water by evaporation
- 11.0% Water retained in tomato paste
- 4.37% Soluble solids
- 1.19% Water insoluble solids (0.01% lycopene)

WIS
SOLUBLE SOLIDS
RETAINED WATER
REMOVED WATER
TOMATO PULP SEPARATED BY FILTRATION

TOMATO PULP WITH WATER INSOLUBLE SOLIDS (WIS)

TOMATO SERUM WITH SOLUBLE SOLIDS

01 31 2018
WATER INSOLUBLE SOLIDS (WIS) ARE A VERY IMPORTANT COMPONENT OF TOMATO PULP

- 58% CELLULOSE & HEMICELLULOSE, AND 42% PECTIN

- WIS GENERALLY ONLY 1% OF PULP (VARIABLE)

- LYCOPENE INSOLUBLE IN WATER ≈ 0.01% (80-125 mg/Kg)

- PECTIN CAN BE DEGRADED BY ENZYMES (IN FIELD, PROCESSING)

- CONSISTENCY INCREASES AS WIS:TOTAL SOLIDS INCREASES
WIS CONCENTRATED IN SUB-EPIDERMAL LAYER

- LAYER REMOVED BY LYE PEELING
- 20-30 % OF TOMATO WEIGHT
- VERY HIGH IN WIS, LYCOPENE (OVER HALF OF TOTAL?)
- LYE PEEL WASTE UNUSABLE
- WASTE IS USABLE IF STEAM PEELED
<table>
<thead>
<tr>
<th>COMPONENTS OF SOLUBLE SOLIDS (NTSS, BRIX)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRUCTOSE – A REDUCING SUGAR (59% OF SUGAR)</td>
<td>1.48</td>
</tr>
<tr>
<td>GLUCOSE – A REDUCING SUGAR (41% OF SUGAR)</td>
<td>1.02</td>
</tr>
<tr>
<td>TOTAL REDUCING SUGAR</td>
<td>2.50</td>
</tr>
<tr>
<td>TITRATABLE ACIDITY (CITRIC &amp; MALIC)</td>
<td>0.47</td>
</tr>
<tr>
<td>TOTAL SOLUBLE SUGAR AND ACIDS</td>
<td>2.97</td>
</tr>
<tr>
<td>RESIDUAL SOLUBLE COMPONENTS (PECTINS, MINERAL SALTS ESPECIALLY POTASSIUM)</td>
<td>1.40</td>
</tr>
<tr>
<td>TOTAL SOLUBLE COMPONENTS</td>
<td>4.37</td>
</tr>
</tbody>
</table>
MEASURING SOLUBLE SOLIDS

METHOD 1

- CENTRIFUGE PULP TO OBTAIN CLEAR LIQUID
- DRY THIS AND CALCULATE % SOLUBLE SOLIDS
- ALSO CAN DO TOTAL SOLIDS, THEN CALCULATE WIS BY SUBTRACTING SOLUBLE SOLIDS
- VERY ACCURATE, BUT TIME CONSUMING AND COSTLY
MEASURING SOLUBLE SOLIDS, CONT’D

METHOD 2

- USE A DIGITAL REFRACTOMETER

- PLACE A SAMPLE OF CLEAR LIQUID (FILTERED OR CENTRIFUGED) ON LENS, PRESS BUTTON AND RECORD READING

- FAST, EASY, BUT NOT AS ACCURATE
### Refractometer Readings for Different Substances

<table>
<thead>
<tr>
<th>Solution</th>
<th>% by Weight</th>
<th>Refractometer Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dextrose (Pure Sugar)</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Potassium Chloride</td>
<td>5.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Citric Acid</td>
<td>5.0</td>
<td>4.4</td>
</tr>
<tr>
<td>Certo (Sugar, Fumaric Acid, Pectin)</td>
<td>5.0</td>
<td>4.9</td>
</tr>
<tr>
<td>Simulated Solution</td>
<td>5.0</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Note: Simulated solution consisted of 2.86% dextrose (sugar), 0.538% citric acid, 0.801% potassium chloride, and 0.801% Certo (sugar, fumaric acid, and pectin in undisclosed amounts) - this solution would be similar to tomato pulp.
DIGITAL REFRACTOMETER

SAMPLE ➔

4.9 %

PR-32α (Brix 0–32%)
VALUE OF SOLUBLE SOLIDS

- COMPLEX FLAVOR CHEMICALS
- ACIDS AND SUGARS
  - FOR SUGAR/ACID FLAVOR BALANCE
  - PRESERVATION AND FOOD SAFETY

BUT, -ADDS NO LYCOPENE
  - ADDS NO WIS (VISCOSITY/CONSISTENCY)
WHY MEASURE SOLUBLE SOLIDS?

- PASTE PRODUCTION CONCENTRATES PULP TO °26 BRIX SO HIGH INITIAL °BRIX = LESS PULP NEEDED

- 26/4.3 = 6.05 CONCENTRATION RATIO
- 26/4.8 = 5.42 CONCENTRATION RATIO
- 6.05/5.42 = 1.116
- COSTS 11.6% MORE TO MAKE PASTE WITH LOW °BRIX TOMATOES

- BUT.... COLOR AND WIS MUST ALSO INCREASE TO MAINTAIN PASTE COLOR AND VISCOSITY
QUALITY FACTORS FOR TOMATO PASTE

- **VISCOSITY** – DEPENDS ON WATER INSOLUBLE SOLIDS (WIS) and PECTIN = 1.19% OF PULP

- **LYCOPENE FOR COLOR**
  - 0.01% OF PULP (80-125 mg/kg)
  - 10 LB/acre FOR A 50 TON/acre CROP

- **SOLUBLE SOLIDS** – FLAVOR AND ACIDITY
  = 4.37% OF PULP
CRITERIA FOR ASSESSING PASTE QUALITY

- PASTE IS DILUTED TO 12 °BRIX

- COLOR IS MEASURED ON THE HUNTER a/b SCALE - SHOULD BE 1.8 OR ABOVE

- VISCOSITY (CONSISTENCY) IS MEASURED WITH THE BOSTWICK CONSISTOMETER - VISCOSITY REQUIREMENTS MAY VARY DEPENDING ON PRODUCT FORMULATION
BOSTWICK CONSISTOMETER
CONSISTOMETER CELL LOADED PRIOR TO TRIPPING
INGREDIENTS: TOMATO PUREE (WATER, TOMATO PASTE), WATER, SALT, CITRIC ACID, SPICE, COTTONSEED OIL, FLAVOUR.
PASTA SAUCE

- CRUSHED TOMATOES
- GLUCOSE FRUCTOSE (SUBSTITUTES FOR SOLUBLE SOLIDS)
- CORN STARCH (THICKENER – SUBSTITUTES FOR WIS)

5.5 CM
HUNTER COLORIMETER

TOMATO SAUCE

\[ \frac{a}{b} = 1.83 \]
PASTA
SAUCE

a/b = 1.54
LYCOPENE IMPORTANCE IN TOMATO PRODUCTS

- ARTIFICIAL COLOR CANNOT BE ADDED TO SUBSTITUTE FOR LYCOPENE
- DEPENDING ON THE PRODUCT, (EG. PASTA SAUCE) SUGAR AND THICKENING AGENTS CAN BE ADDED TO SUBSTITUTE FOR SS AND WIS
- FOR EXAMPLE, KETCHUP ADDS SUGAR BUT NO THICKENING AGENT TO DILUTED PASTE (DEPENDS ON WIS & LYCOPENE)
BANANA KETCHUP WITHOUT ANY TOMATO SOLIDS - LOOKS AND TASTES SIMILAR TO TOMATO KETCHUP DUE TO SUGAR, VINEGAR, SPICE, AND ARTIFICIAL COLOR
IMPORTANT RELATIONSHIPS

- IF °BRIX OF RAW PRODUCT INCREASES WITHOUT AN INCREASE IN WIS, VISCOSITY OF PASTE WILL BE REDUCED

- IF °BRIX OF RAW PRODUCT INCREASES WITHOUT AN INCREASE IN LYCOPENE, PASTE COULD HAVE POOR COLOR (LESS THAN a/b RATIO OF 1.8 @ 12 °BRIX)
CULTIVAR SELECTION CRITERIA FOR THE AUSTRALIAN PROCESSING TOMATO INDUSTRY

<table>
<thead>
<tr>
<th>PASTE</th>
<th>PEELING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) VISCOSITY (WIS)</td>
<td>1) PEELABILITY – EASY SKIN REMOVAL</td>
</tr>
<tr>
<td>2) COLOR (LYCOPENE)</td>
<td>2) °BRIX – 5.0 CONSIDERED EXCELLENT</td>
</tr>
<tr>
<td>3) pH</td>
<td>3) COLOR – NO YELLOW SHOULDER</td>
</tr>
<tr>
<td>4) EARLINESS</td>
<td>4) pH – CITRIC ACID BAD FOR FLAVOR</td>
</tr>
<tr>
<td>5) °BRIX</td>
<td>5) FLAVOR – FULL TOMATO FLAVOR</td>
</tr>
</tbody>
</table>

➢ WANT HIGH °BRIX, BUT THIS CAN REDUCE VISCOSITY.
“HARD TO GET HIGH VISCOSITY PASTE WITH HIGH °BRIX FRUIT”
BIOLOGY OF SOLIDS PRODUCTION IN TOMATOES

LEAVES → SUCROSE

CONVERTED TO STARCH & WIS IN TOMATO

RIPENING →

FRUCTOSE
GLUCOSE
ACIDS
OTHER SOLUBLES (PECTINS)

SOURCES

SINK

SINK

SINK
SOURCE – SINK RELATIONSHIP

➢ ASSUMING A FULL CANOPY OF FOLIAGE, HIGHER FRUIT LOAD (YIELD) RESULTS IN LOWER °BRIX

➢ REDUCTION OF °BRIX BY HIGH FRUIT LOADS CAN INDUCE YELLOW SHOULDER DISORDER (YSD)

➢ EXCESS N MAKES LEAVES AN UNPRODUCTIVE SINK

➢ INFLUENCED BY VARIETY AND CULTURAL CONDITIONS
RELATIVE DISTRIBUTION OF SOLIDS IN TOMATO FRUIT

- **SUCROSE** (Leaves)
  - STARCH (Fruit)
    - Insoluble Solids
      - Less Variable
    - Soluble Solids
      - More Variable
  - Cell Structure (Cellulose, etc.)
  - Cell Contents (Sugars, Acids, etc.)
AGRONOMIC PRACTICES TO IMPROVE PASTE RECOVERY FROM RAW PRODUCT

1) USE HYBRIDS WITH HIGHER SOLUBLE SOLIDS PROVIDING WIS (VISCOSITY) AND COLOR ALSO INCREASE

2) PRACTICES THAT ENHANCE OR MAINTAIN PHOTOSYNTHETIC EFFICIENCY OF LEAVES (RISKS REDUCTION IN VISCOSITY)

3) HARVEST ON TIME TO PREVENT LOSS OF SOLIDS

4) PRACTICES THAT RESTRICT WATER AVAILABILITY TO ROOTS (RISKS REDUCED YIELD)
1

TOMATO HYBRID DIFFERENCES AFFECTING PASTE QUALITY

(USING TOMATO SOLUTIONS DATA)
VISCOSITY (SECONDS) – 2016/2017 (CORRELATES WITH WIS)

HIGH VISCOSITY

LOW VISCOSITY

H5108  H3406  CC337  TSH26  TSH34

8.8  12  10.2  12.9  11.6
FUTURE HYBRID DEVELOPMENT
(FROM ACTUAL DATA)

<table>
<thead>
<tr>
<th></th>
<th>% SOLUBLE SOLIDS</th>
<th>VISCOSITY (SEC)</th>
<th>LYCOPENE (mg/KG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPICAL HYBRID</td>
<td>5.1</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>HYBRID-TSX</td>
<td>5.7</td>
<td>14.9</td>
<td>116.3</td>
</tr>
</tbody>
</table>
BREEDING CONSIDERATIONS:

- SELECTION FOR RESISTANCE TO YELLOW SHOULDER DISORDER (YSD) FOR HIGH PEEL QUALITY USUALLY ASSOCIATED WITH HIGHER SOLUBLE SOLIDS

- HIGHER VISCOSITY ASSOCIATED WITH THICK WALLS AND FIRMNESS, ALSO NEEDED FOR PEEL QUALITY

- HIGHER LYCOPENE ENHANCES VISUAL QUALITY FOR BOTH PASTE AND PEEL PRODUCT
BREEDING CHALLENGES:

- SELECTION FOR HIGH YIELD ASSOCIATED WITH DECREASED °BRIX AND YELLOW SHOULDER (POOR PEEL QUALITY)

- SELECTION FOR VERY HIGH °BRIX CAN CAUSE BLOSSOM END ROT & HIGH MOULD COUNTS
FACTORS AFFECTING BREEDING FOR HIGHER BRIX

1) HIGHER RATIO OF LEAVES TO FRUIT
   - MORE SUGAR FOR LESS FRUIT = HIGHER °BRIX

2) ROOT SYSTEM RESTRICTED IN ABILITY TO ABSORB AND TRANSLOCATE WATER TO FRUIT
   - CONCENTRATES SOLIDS IN FRUIT
   - LESS CALCIUM TRANSLOCATED TO FRUIT
     = HIGHER INCIDENCE OF BLOSSOM END ROT
BREEDING OPPORTUNITIES:

- INCREASED LYCOPENE USING “OLD GOLD CRIMSON” (OGC)

- INCREASED FIRMNESS AND VISCOSITY USING:
  - FRUIT WITH THICKER FIRMER WALLS (MULTIGENIC INHERITANCE)
  - SINGLE GENES WITH SPECIFIC EFFECTS ON WIS

IMPROVED FRUIT FIRMNESS ESSENTIAL FOR HARVESTING AND PROCESSING, AND ENHANCES HOLDABILITY IN FIELD.
INCREASING LYCOPENE CONTENT

- CONVENTIONAL SELECTION FOR BETTER PEELED COLOR IS ASSOCIATED WITH HIGHER LYCOPENE AND SOLUBLE SOLIDS

- THIS MULTIGENIC IMPROVEMENT IN COLOR MAY BE DEPENDENT ON HIGHER SOLIDS (+ 0.30 %)

- THE CRIMSON GENE (OGC) CAN INCREASE LYCOPENE BY 18% COMPARED TO LOW SOLIDS HYBRIDS & IS PHOTOSYNTHETICALLY EFFICIENT WITH NO IMPACT ON YIELD

- BOTH HIGHER SOLIDS GENETICS AND THE CRIMSON GENE SHOULD BE USED FOR THE BEST PEEL AND PASTE COLOR
LYCOPENE VS HUNTER a/b RATIO FOR COLOR TOMATO SOLUTIONS PLOTS, 2016

HIGH COLOR (TSH40/TSH42) OGC

MEDIUM COLOR (TSH26/TSH34)

LOW COLOR (5108/3406)

$R^2 = 0.89$
PRODUCTION PRACTICES TO ENHANCE OR MAINTAIN PHOTOSYNTHETIC EFFICIENCY (PROBABLY RELATIVELY MINOR EFFECTS)

1) CONTROL FOLIAR FUNGAL DISEASES (MOST GROWERS HAVE A GOOD PROGRAM)

2) INCREASE OR MAINTAIN SOIL K @200 PPM - VERY IMPORTANT FOR PEEL PRODUCT

3) BALANCED N/K RATIOS (NO EXCESSIVE FOLIAGE)
**EFFECT OF FUNGICIDES ON LATE BLIGHT RESISTANT HYBRIDS**  
**HARVESTED 109 DAYS FROM PLANTING**  
**AVERAGE OF 9 HYBRIDS - TOMATO SOLUTIONS PLOTS - 2017**

<table>
<thead>
<tr>
<th></th>
<th>YIELD (T/AC)</th>
<th>°BRIX</th>
<th>VISCOSITY (SECONDS)</th>
<th>LYCOPENE mg/Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT SPRAYED</td>
<td>39.8</td>
<td>5.7</td>
<td>8.6</td>
<td>114</td>
</tr>
<tr>
<td>SPRAYED</td>
<td>44.8</td>
<td>6.0</td>
<td>10.4</td>
<td>114</td>
</tr>
<tr>
<td>IMPROVEMENT</td>
<td>+12%</td>
<td>+5%</td>
<td>+21%*</td>
<td>0%</td>
</tr>
</tbody>
</table>

* UNSPRAYED PLOTS WERE OVER-RIPE, SO PECTINS WERE LOWER
TYPICAL LATE BLIGHT RESISTANT HYBRID

NO SPRAY

SPRAYED

NO ETHREL
PRODUCTION PRACTICES TO PREVENT LOSS OF SOLIDS ONCE PRODUCED

- SOLIDS CAN BE LOST AFTER PEAK RIPENESS

- ACIDITY DECREASES $\rightarrow$ pH INCREASES $\rightarrow$ SPROUTS

- PECTINS DEGRADED $\rightarrow$ SOFT FRUIT $\rightarrow$ VISCOSITY $\downarrow$

- PLANTING AND HARVESTING SCHEDULE ESSENTIAL -- OFTEN DISRUPTED BY WEATHER
PRODUCTION PRACTICES TO RESTRICT WATER AVAILABILITY TO ROOTS

- DROUGHT PRONE SAND AND CLAY SOIL → HIGHER °BRIX

- **BUT**, LACK OF ADEQUATE MOISTURE CAN RESULT IN BLOSSOM END ROT CAUSING HIGH MOULD COUNTS IN JUICE & PASTE

- EXCESSIVE FOLIAGE PRODUCTION DUE TO FERTIGATION OR IRRIGATION MAY DIVERT SOLIDS FROM FRUIT TO LEAVES

- EXTENSIVE RESEARCH IN CALIFORNIA SHOWS THAT °BRIX IS REDUCED AS YIELDS ARE INCREASED BY IRRIGATION
“BRIX VERSUS YIELD RELATIONSHIP”

- ARTICLE PUBLISHED IN THE CALIFORNIA TOMATO GROWER
- 5 PAGES LONG
- DETAILS INVERSE RELATIONSHIP
- READ THE COMPLETE ARTICLE AT:

WWW.TOMATOLAND.COM/DOCUMENTS/182.PDF
FACTORS CAUSING DIFFERENCES IN SS AMONG FIELDS (OBSERVATIONAL/SPECULATIVE)

- SOIL COMPACTION – RESTRICTED WATER UPTAKE
- EXCESSIVE N APPLICATION – LEAVES BECOME SINK
- FOLIAR DISEASES (BACTERIAL SPOT)
- POOR ROTATION $\rightarrow$ ROOT DISEASES $\rightarrow$ POOR WATER UPTAKE
- LOW POTASSIUM LEVELS
- SOIL TYPE – WATER HOLDING CAPACITY POOR
FACTORS BEYOND YOUR CONTROL

- RAINFALL
- SOLAR RADIATION
- TEMPERATURE
- DISEASE

→ YEAR TO YEAR VARIABILITY IN SOLUBLE SOLIDS
- ACCOUNTS FOR OVER HALF OF TOTAL VARIABILITY
WORST = WET, CLOUDY, COLD + LEAF DISEASES
→ BUT, WIS WILL NOT VARY AS MUCH
SUMMARY

1) SS IMPORTANT FOR FLAVOR AND ACIDITY
2) WIS AND LYCOPENE IMPORTANT FOR RECOVERY
   WHEN RE-CONSTITUTED (AS SAUCE, ETC)
3) RESTRICTED WATER UPTAKE WILL INCREASE SS
   AS WELL AS WIS, IMPROVING PASTE RECOVERY
4) HIGHER SUGAR PRODUCTION IN LEAVES WILL
   INCREASE SS, BUT LESS FOR WIS (LOW VISCOSITY)
5) LYCOPENE INFLUENCED BY HYBRID & MATURITY
MOST TOMATO PROCESSORS IN ONTARIO (AND EASTERN U.S.) HAVE A HIGH PRIORITY FOR PRODUCING PEELED TOMATOES

THE SAME FACTORS THAT RESULT IN HIGH PEEL RECOVERY WILL ALSO ENHANCE PASTE RECOVERY & QUALITY
REFERENCES AND SOURCES


REFERENCES AND SOURCES, CONT’D


Evaluation of Processing Tomatoes From Two Consecutive Growing Seasons: Quality Attributes, Peelability and Yield.

Potassium requirements for maximum yield and fruit quality of processing tomato. Hartz, Miyao, Mullen, Cahn, Valencia, and Brittan.

Estimation of certain chemical constituents of fruits of selected tomato genotypes grown in Turkey. Turhan and Seniz.

Quality of processing tomato fruit from four bloom dates in relation to optimal harvest timing. Renquist & Reid. (1998) New Zealand Journal of Crop and Horticultural Science, 26:2, 161-168,

And many other research reports and papers.