TOMATO ATTRIBUTES AND THEIR CORRELATION TO PEELABILITY AND PRODUCT YIELD

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Abstract

Although tomato paste research has received significant attention, relatively little effort has been addressed to optimization of value-added whole peel and diced tomato processing. Our laboratory has conducted research evaluating tomato attributes which may be indices of peelability and product yield.
Eleven tomato varieties were harvested at USDA stage 4 (pink), USDA stage 6 (red) and red plus either 1, 2 or 3 weeks time. Maturity was established by tagging either flowers or pink fruit. Fruit was evaluated for physical attributes, texture, paste quality, peelability and product yield. Physical attributes measured included color, density, height, weight, width, shoulder height, stem scar diameter, locule number and gel state, seed number and weight, pericarp wall thickness and red layer thickness. Paste quality was determined using a microwave hot break procedure and evaluation of raw and cooked color, Bostwick, pH, °Brix, titratable acidity and serum viscosity. Tomatoes were exposed to steam, vacuum and mechanical peel eliminators and then percent peelability and product yield were calculated. Firmness of raw and peeled diced tomatoes was measured using a Kramer shear cell.
Discriminant analysis was used to determine which subsets of physical attributes correlated to desirable levels of peelability and product yield. A model equation was developed using four physical attributes, e.g. width, stem scar diameter, pericarp thickness and red layer thickness. Use of the model allowed for prediction of “paste” vs. “whole peel/dice” group allocation with 90% accuracy in pilot scale studies. The model is currently being tested at the commercial scale with California processors.

1. Introduction

Tomato paste research has been a focus of concentration at both the university and industry levels for many years and there is a great deal of accumulated knowledge. The University of California continues to conduct research every year related to the evaluation of new tomato varieties, with emphasis on yield and paste attributes. The diced tomato market received increasing attention in 1980’s and 1990’s, with greater demand for higher value salsa, pizza and spaghetti sauces and other formulated products. At the outset, little was known about breeding and processing requirements for efficient peel removal while maintaining high yields of superior quality products. There was, and still is, a lack of uniformity in what is sold as “diced” tomatoes, not to mention crushed, sliced, etc. Higher value whole peel, diced and crushed products allow for greater margins, but measurable attributes for determining whether raw materials meet specifications for these products have not been established. Processors are faced with making decisions on whether to send loads to paste or dice without reliable indicators of product performance.

Since 1994, the California League of Food Processors has funded a project in our laboratory that focuses on diced tomatoes. The first step in producing superior quality, higher value tomato products is the use of appropriate raw materials. During the 1994-1996 seasons we evaluated the effects of variety and maturity on ease of peeling and yield of whole peel and diced tomatoes. Physical attributes of tomatoes were determined and correlation between peelability and product yield were established. The model was tested at commercial facilities during the 1998 and 1999 seasons, and these findings will also be discussed. A summary of project activities from 1994 to 1999 is as follows:

1994-95	•Established methods for evaluation of peelability, initial results obtained
	•Developed "standard" method for steam peeling all varieties
1995-96	•Standard peeling procedures utilized
	•Evaluated seven varieties @ 3 maturity stages (pink, red, red + 2 wks)
	•Determined physical attributes, paste quality, peelability, product yield
1996-97	•Studied ten varieties @ 3 maturities (red, red + 2 wks and red + 3 wks)
	•Determined physical attributes, paste quality, peelability, product yield
1997-98	•Correlated physical attributes with paste quality and peelability/ yield
	•Conducted discriminant analysis to develop predictive model
1998-99	•Tested model at commercial tomato facilities and UC Davis

Results of this project, and the development of a model for directing tomatoes to paste vs. whole peel and dice production are summarized in this paper.

2. Materials and Methods

2.1. Raw Materials

During the 1994 season, tomatoes were hand harvested from Yolo county grower fields (in central California) at the red maturity stage (USDA stage 6). Forty five kg lots of red tomatoes were picked from the second or third truss of plants randomly selected by walking down rows in the commercial field. Varieties of interest were chosen by the California League of Food Processors' Tomato Research Committee and included Alta, Brigade, Ferry Morse (FM) 6203, Peto Nema 512 and Orsetti Halley 3155.

In the 1995 and 1996 seasons, it was desirable to control fruit maturity therefore tomatoes were planted in replicate blocks at the UC Davis Vegetable Crops Experiment Station. In 1995, second set clusters with a target number of open flowers were tagged in seven varieties on the same day. Maturation was closely monitored and fruit was hand harvested from tagged clusters at the pink, red (generally 5-7 days after pink) and overripe (red stage + 2 wk) stages. Harvest order was determined by typical days to harvest for each variety studied. Varieties selected for evaluation in 1995 included Brigade, FM 9208, Heinz 8892, Heinz 3044, LaRossa, Nema 512 & Orsetti Halley 3155.

It was observed during the 1995 season that some fruit abortion may have occurred due to mishandling during flower tagging, therefore during the 1996 season maturity was established by tagging individual fruit in the second or third truss of the plant at the pink stage. During the 1996 season, tomatoes were hand harvested at the red, red + 2 wk and red + 3 wk stages. Varieties evaluated in 1996 included Brigade, FM 9208, Heinz 3044, Heinz 8892, Heinz 9280, Hypeel 45, LaRossa, Orsetti Halley 3155, Orsetti 8066 and Sun 6117.

2.2. Fruit Preparation and Physical Attribute Analysis

Following harvesting, tomatoes were transported to the Food Processing Facility of the Dept. of Food Science and Technology at UC Davis. Tomatoes were washed in a series of solutions: tap water with detergent, tap water rinse, tap water containing 100 ppm chlorine, tap water rinse, 2 deionized water rinses. Following washing, tomatoes were dried and sorted visually. Fruit which had yellow eye, were under or overripe, sunburned, insect damaged, rotten or visually bruised were eliminated from the study. Thirty fruit were randomly selected for physical attribute characterization; the remaining fruit were used for processing evaluation. Of the 30 fruit, 20 were used for firmness determination and other physical attributes were measured on the remaining 10 fruit.

Physical attributes evaluated during the 1994, 1995 and 1996 seasons varied somewhat, with attributes added or removed in later years depending on apparent relevance. Attributes determined in each season are listed below, followed by a brief description of the procedure:

1994 weight, height, shoulder height, density, color at stem end, equator, blossom end, firmness (whole fruit deformation)

1995 weight, height, width, shoulder height, density, color at stem end, equator and blossom end, firmness (shear press and puncture on raw and cooked dice), stem scar diameter, pericarp thickness, red layer thickness, locular gel state and weight, number of seeds

1996 weight, height, width, shoulder height, density, color at equator, stem scar diameter, pericarp thickness, red layer thickness, number of locules, locule weight, flesh weight, shape, number of cracks at stem scar, internal color

Weight of each fruit was measured using a top-loading balance. Height and width (at widest point) were measured using digital calipers. Shoulder height was defined as the distance from the bottom of the stem scar to a ruler placed across the top of the tomato, and was measured using digital calipers. Density was defined as the ratio of weight and volume of each fruit [g/ml]. The volume of each fruit was determined by submerging the tomato in water (25°C) and weighing the volume of water displaced by the fruit. One g of water was assumed to be equivalent to 1 ml of water. External color (L*a*b and hue) of the fruit was measured using a Minolta colorimeter. Three measurements were taken at the stem end, equator and blossom end of each fruit. Shape and number of cracks were specified in 1996. Following these measurements on the whole fruit, tomatoes were cut in half and additional physical attributes were determined.

The internal color of the tomato was determined in 1996 by measuring the color of the radial arms four times in different locations. Pericarp thickness and the red layer thickness were measured using digital calipers. All measurements were repeated three times in different randomly chosen locations around the fruit circumference. Locular gel was removed using a spoon, the state identified as solid, gel-like or liquid, and weighed. Number of locules was determined in 1996 and number of seeds were counted in 1995. Flesh weight was determined by difference (whole fruit wt. – locular gel wt.).

2.3. Peelability and Whole Peel and Dice Product Evaluation

In order to establish a standard procedure for evaluating peelability of tomatoes, a number of potential objective peeling methods were evaluated in 1994. These included:

1. boiling water + room temp water spray
2. boiling water + 1 min ice water dip
3. boiling water + vacuum (20”)
4. steam blanch + vacuum (20”)
5. freeze exterior + boiling water dip
6. steam exposure (15 psig/250°F) + vacuum (20”)

In order to determine degree of peelability, the following procedures were compared:

1. ease of slipping peel off when tomato held in hand at blossom end
2. ease of “sloughing” peel off at stem scar w/ thumb
3. appearance of physical crack in peel

In 1994, a number of evaluations were made on the fruit following exposure to one of the peeling methods listed above. These included the time required to achieve a crack around 50% of fruit circumference (stem scar to blossom end) in 80% or more of the test batch (20 fruit), peeled tomato yield (w/w), dice yield (w/w), yield of both wet and dry peel (w/w) and peelability index (% fruit with 50% crack).

During the 1995 and 1996 season, a standard peeling procedure was utilized based on results obtained during the 1994 season. This involved exposing 3 to 6 replicate batches of 20 fruit to 15 psig steam (250°F) for 1 min, 15 sec followed by 22” vacuum. Prior to processing, the number of fruit and total batch weight were determined.

Following the steam + vacuum treatment, tomatoes were passed over mechanical disc and pinch rollers. Peelability class was evaluated after steam + vacuum exposure, and after passing over mechanical rollers. A subjective classification (Table 1) was established and fruit in classes 1-3 were defined as unpeeled, while those in classes 4 + 5 were peeled.

In addition, peel index (square inches peel remaining on tomatoes), whole peel yield (w/w) and dice yield (w/w) were obtained. Whole peel yield was determined on peeled tomatoes (classes 4 + 5) only, following which tomatoes were diced to 1/2" using an Urschel 'Sterling' vegetable cutter and drained for 60 sec on a screen, then weighed.

Firmness was determined using Kramer shear press and puncture tests on raw and cooked diced tomatoes. Raw tomatoes were hand peeled prior to dicing. For the Kramer test, triplicate 200 g samples were evaluated by filling the sample cell loosely. Force in compression required to deform the sample by 90% was measured. The test speed was 1.0 mm/sec and results were given in newtons. For the puncture test, individual pericarp discs were removed using a cork borer and a 3 mm puncture probe was used to measure force required to deform 90%.

2.4. Paste Analysis

Tomato paste evaluation was carried out in the 1995 and 1996 seasons. Duplicate 1300g lots of tomatoes were microwaved, weight was adjusted with water, cooled and pulped and finished using a lab pulper with a 0.033 inch screen, according to the standard tomato variety evaluation procedure. Juice samples were evaluated for Bostwick flow and color was measured using and Agtron E-5M and a Gardner (L*, a*, b* and hue) on the dearated pulp. °Brix, pH, titratable acidity and serum viscosity were also measured.

3. Results

Results will be discussed on a year-by-year basis from 1994-1997, because goals for each processing season were slightly different.

3.1. 1994-95 Tomato season

3.1.1. Establishment of a standard method for peelability evaluation

One of the primary objectives during the 1994 season was establishment of a method for evaluating peelability. In terms of the 6 methods evaluated, the most desirable in terms of ease of use, practicality and time required to perform test were the following:
- boiling water + 1 min ice water dip
- steam exposure (15 psig/250°F) + vacuum (20")

After conferring with members of the Tomato Research Committee, it was agreed that the steam exposure + vacuum method was most similar to commercial applications, therefore this was established as the standard method. Evaluation of peelability was felt to be least subjective and most reproducible when appearance of a physical crack in peel was utilized. These results were the basis on which evaluation was carried out during the 1995 and 1996 seasons, and the 5 point peelability class system was developed.

3.1.2. Physical attributes

Comparisons were made between physical attributes evaluated in the 5 varieties. The following results were obtained:
•No significant difference (nsd) in width, weight or density
•Halley 3155 significantly <u>longer</u> than other four varieties
•Brigade significantly lowest in <u>shoulder ht</u>., FM 6203 highest, nsd between other three
•Alta most uniformly <u>red</u>, Halley 3155 and Brigade ripened slowest
•Brigade slightly <u>firmer</u>, Halley 3155 most variable

3.1.3. Peelability and whole peel and dice product yield

Processing results may be summarized as follows:
•Halley 3155 and Brigade slightly higher peeled tomato yield and lowest in dry peel yield
•Halley 3155 and FM 6203 highest dice yield
•Halley 3155, FM 6203 & Brigade highest peelability

Comparisons between the five varieties evaluated suggested that Halley 3155, Brigade and FM 6203 would make the best peeling and value-added variety contributions. Nema 512 and Alta did not perform well as peeling varieties.

3.2. 1995-1996 Tomato season

The effects of both maturity and variety on peelability and product (paste, whole peel and dice) yield were the focus of research during the 1995-96 and 1996-97 projects. Maturity played a significant role in the quality of all tomato products. In particular:
• Paste quality declined with maturity (°Brix, Bostwick, serum viscosity, pH & T.A.)
• Firmness declined with increasing maturity
• Peelability and dice yield increased with maturity

3.2.1. Paste analysis

Three varieties performed fairly well in the seven paste quality attributes measured, e.g. °Brix, Bostwick, serum viscosity, pH, T.A, Agtron color and Gardner color. These were Heinz 8892 (with exception of pH), Nema 512 (with exception of °Brix) and Heinz 3044 (with exception of °Brix and T.A.). In terms of °Brix alone, Halley 3155 and Heinz 8892 were superior. If one were to focus solely on Bostwick and/or serum viscosity, however, the best varieties would appear to be Heinz 8892, Nema 512 and Heinz 3044.

Maturity significantly affected paste quality, with less mature fruit demonstrating more desirable attributes and red or red + 2 wk fruit showing a decline in quality with maturity. This is illustrated in particular by looking at changes in °Brix, Bostwick and serum viscosity. Acidity levels, as indicated by both pH and T.A., decrease between the pink, red and red + 2 wk stages. Color was relatively stable after the red stage, or changes were not discriminated by the Agtron or Gardner color measurements.

3.2.2. Peelability and whole peel and dice product yield

Firmness was greatest in Heinz 8892 and Nema 512 fruit and lowest in the Heinz 3044 variety. Maturity was again a significant factor, with firmness generally declining with maturity. The best overall varieties for peelability, whole peel and dice yield were Brigade and FM 9208, followed by Halley 3155 and LaRossa. FM 9208 was the easiest to peel. Whole peel and dice yield were highest in Halley 3155 and FM 9208, followed by Brigade and LaRossa. Varieties Heinz 8892, Heinz 3044 and Nema 512 were difficult to peel and therefore yielded less product. Cooked dice yields were highest in Halley 3155 and Brigade, indicating that these varieties were best able to maintain textural integrity through a processing step. Increasing maturity significantly affected peelability, with more mature fruit peeling more readily. However, there is a tradeoff between increased peelability and loss in firmness that must be evaluated. The best multi-use varieties, for either paste or whole peel/dice processing, were Halley 3155 and LaRossa.

3.3. 1996-1997 Tomato Season

Results from 1996-97 confirmed that maturity plays a significant role in product quality. As true in the previous year, the following were noted:

• Paste quality declined with maturity (°Brix, Bostwick, serum viscosity, pH and T.A.)
• Firmness declined with increasing maturity
• Peelability & dice yield increased with maturity

Some of the varieties evaluated in 1996-97 were new, but six (Brigade, FM 9208, Halley 3155, Heinz 3044, Heinz 8892 and LaRoss) were the same both years. Varieties were compared as discussed for 1995-96 and the following conclusions were reached.

Best paste varieties:	H 8892, LaRossa
Best dice varieties:	Brigade, Hypeel 45, Sun 6117
Best multi-use varieties:	Halley 3155

Comparing both years, Heinz 8892 was highly ranked as a paste variety in both years while Halley 3155 was noted as the best multi-use variety both years.

3.4. Statistical analysis

Analysis of variance was carried out on all the 1995-96 and 1996-97 data to determine whether significant differences existed between varieties and maturities. Fisher's Least Square Difference (LSD) was used to compare varieties if interaction and variety F values were significant. Therefore the following were done:

- compared variety means at each maturity
- compared maturity levels for each variety

3.4.1. Statistical analysis of 1995-96 tomato season data

Significant differences existed between varieties in all paste attributes, all peelability attributes except peel index and all physical attributes (Table 2). In addition, significant differences existed between maturities in all paste attributes and most physical attributes (except width, locule gel wt. and # seeds) but in no peelability/dice attributes.

3.4.2. Statistical analysis of 1996-97 tomato season data

As found in the previous year, significant differences existed between varieties in all paste attributes and all physical attributes, but only in the % dice yield of the peelability attributes (Table 3). Similar to 1995-96 also, significant differences existed between maturities in all paste attributes and most physical attributes (except weight and # locules) but in no peelability/dice attributes. Based on analysis of variance results, it appears that variety plays more of a role in peelability/dice attributes than maturity.

3.4.3. Correlations of physical attributes to paste quality, peelability and product yield

It was desirable to try to correlate physical attributes, which may be measured quickly and used as indices, with paste, whole peel and dice quality and peelability. In this regard, it may be possible to utilize a limited number of physical attributes to direct loads. Results of correlations for the 1995-96 and 1996-97 seasons were as follows:

• <u>1995 Season</u>

Paste quality correlations

- Bostwick and wall thickness
- serum viscosity and wall thickness
- °Brix with height, width, locular gel weight, shoulder ht., stem scar diameter and texture

Peelability/dice correlations

- Pericarp wall thickness and % peeled, % whole peel and % dice yields
- Raw texture and % peeled, % whole peel

•Density and cooked dice texture

•1996 Season:

Paste quality correlations

- •Bostwick and height, stem scar diameter and raw texture (puncture)
- •serum viscosity and raw texture (both puncture and Kramer)
- •°Brix with height, # locules and wall thickness.

Peelability/dice correlations

- •Pericarp weight (%) and % peeled, % whole peel yield
- •Red layer thickness and % peeled, % whole peel and % dice yield
- •Raw texture and % peeled, % whole peel and % dice yield
- •Density and %peeled

In general, correlations obtained in 1996 were not as strong as those found in the 1995 season. Although useful, simple correlations may not tell the whole story. In situations where attributes which define "good paste" or "good dice" may be complex, e.g. there may be a synergistic effect of more than one attribute, it may be difficult to assign a one to one correlation of one physical attribute to product quality. Therefore, it is necessary to go one step further and carry out "discriminant analysis" which uses two or three subsets independent attributes and correlates these to specific product groups.

3.4.4. Discriminant Analysis

Discriminant analysis produces equations which are used with a set of independent variables (such as physical attributes) to assign observations to known groups. It can be useful in assigning future samples (e.g. incoming tomato loads), for which group membership is not known, to one of the groups. Groups are defined based on specific values of the most important 2-3 measurable parameters. We established 2 groups, "good dice" and "poor dice" and based on values for each group, incoming loads would be sent to the whole peel/dice line or paste line.

There is little published data on what values of % peeled, % whole peel yield and % dice are desirable, so we used average values from the 1995 and 1996 data sets. The average values obtained were 65.3% peeled, 46.0% whole peel and 32.6% dice yield; tomatoes with values above these were considered to be good candidates for whole peel and dice products. For the 1995 and 1996 season data, we used ANOVA to compare groups for each of the independent variables (physical attributes) evaluated in both years. No significant group differences were found. However, we then used discriminant analysis to evaluate whether subsets of physical attributes correlated to groups.

It was determined that significant variables related to the good dice group were the following: width, stem scar diameter, wall thickness and red layer thickness. Equations were established using the values in Table 4 to predict good dice vs. poor dice grouping.

Good dice= -177.154+ width (8.999) + stem scar (-11.393) + wall (-3.762) + red (10.737)

Poor dice= -182.614+ width (9.672) + stem scar (-13.885) + wall (-6.968) + red (16.716)

Of the 41 samples evaluated in 1995 and 1996, use of these equations led to appropriate group classification 90% of the time. The physical attributes deemed to be of importance in the discriminant analysis model are relatively easy to measure using digital calipers. We typically evaluate a sample lot of 10 tomatoes, which requires approximately 15 minutes.

Use of this model and the good dice and poor dice equations is currently being investigated in collaboration with the California tomato processing industry. Preliminary results indicate some success, but varietal factors may play a strong role. Research continues to determine a simple means of discriminating tomatoes destined for paste vs. value-added whole peel and dice products.

Tables

1. Subjective definitions of tomato peelability classes

Class	Definition
1	No cracks, or cracks which are less than half-way down the side of the fruit.
2	Cracks reaching from the stem scar to the blossom end or even further; peel tightly attached to the fruit
3	Cracks as in class 3, but peel is loosened, and more than 50 % of all peel is still attached to the fruit
4	As class 3, but less than 50 % of all peel is still attached to the fruit
5	Peel is not attached to fruit anymore or is just attached to the stem scar / blossom end

2. Significant differences in paste quality, peelability, product yield and physical attributes in tomatoes evaluated in 1995-1996.

Significant Differences Between	Paste Quality	Peelability and Whole Peel or Dice Product Yield	Physical Attributes
Tomato Variety	°Brix, pH, Bostwick, T.A., Agtron, L*, a*, b* and serum viscosity	% unpeeled, % peeled, % whole peel yield, % dice yield	weight, height, width, density, shoulder height, stem scar diameter, wall thickness, red layer thickness, locule gel wt., # seeds, differential volume, raw texture, % drained weight, and color of top, middle & bottom of tomato
Tomato Maturity	°Brix, pH, Bostwick, T.A., Agtron, L*, a*, b* and serum viscosity	none	weight, height, density, stem scar diameter, wall thickness, red layer thickness, differential volume, raw texture, % drained weight, and color of top, middle and bottom of tomato

3. Significant differences in paste quality, peelability, product yield and physical attributes in tomatoes evaluated in 1996-1997.

Significant Differences Between	Paste Quality	Peelability and Whole Peel or Dice Product Yield	Physical Attributes
Tomato Variety	°Brix, pH, Bostwick, T.A., Agtron, LED, L*, a*, b*, USDA color and serum viscosity	% dice yield	weight, height, width, density, shoulder height, stem scar diameter, # locules, % locule weight, % pericarp, % pericarp flesh yield, wall thickness, red layer thickness
Tomato Maturity	°Brix, pH, Bostwick, T.A., Agtron, LED, L*, a*, b*, USDA color and serum viscosity	none	height, width, density, shoulder height, stem scar diameter, % locule weight, % pericarp, % pericarp flesh yield, wall thickness, red layer thickness

4. Discriminant functions for good dice and poor dice model equations

	Good Dice	Poor Dice
Constant	-177.154	-182.614
Width	8.999	9.672
Stem Scar	-11.393	-13.885
Wall Thickness	-3.762	-6.968
Red Layer Thickness	10.737	16.716