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Research Article

Physicochemical properties of five different tomato cultivars of Meghalaya, India and their suitability in food processing

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Abstract

Data on physical and chemical properties of agro-food materials are valuable because they are needed as input to models predicting the quality and product behavior. The correlation between laboratory test processes (such as blanching, dehydration, etc.) and the physicochemical qualities of tomato varieties will contribute to develop an optimal solution for processing and product quality. The physicochemical characteristics of tomato fruits from five different cultivars grown at the orchard of ICAR Research Complex for North Eastern Hill (NEH) region, Umiam, Meghalaya, India, were studied. The result showed that *Solam Garima* has the highest titratable acidity, ascorbic acid and reducing sugar amongst the five cultivars. The *Pau-2374* cultivar has the highest total solids, total soluble solids (TSS) and lycopene content. The seed, skin and other fibrous residual wastes is highest in *VR-415*, but lowest in *Pau-2374*. *Sel-2* can be used in canning industry as it has the maximum firmness and mineral content. The maximum average fruit weight, total sugars and peak sugar:acid ratio was found in *Sel-3*. Even after blanching, *Pau-2374* possessed the highest total solids, TSS and lycopene content, and *Solam Garima* contained the highest titratable acidity and firmness. Dried pulp of *Solam Garima* was able to retain the highest content of titratable acidity, ascorbic acid and total sugar, indicating its suitability for making dehydrated tomato products (flakes, powders, chips, etc). However, the dried pulp of *Sel-2* showed the highest ash content and sugar:acid ratio, and the dried pulp of the *Pau-2374* cultivar had the maximum lycopene content, inferring their good consumer acceptance in the market. The results showed that these five cultivars of Meghalaya have considerable number of attributes (i.e. physicochemical characteristics), required to be processed by food industries and hence can be recommended to breeders for cultivation.

Keywords: physico-chemical qualities*, Sel-2, Sel-3, Solam Garima, VR-415, Pau-2374,* ascorbic acid, lycopene.

Introduction

Although a clear definition of quality for agricultural products does not exist, it could be described as the group of characteristics that consumers wish to find in the product. The processing industries demand concrete specifications from its providers which affects the demanded quality. Since most quality factors are related to physicochemical properties, it is possible to develop quality evaluation methods based on these properties, in most of the cases. Data on physical properties of agro-food materials are valuable because they are needed as input to models, predicting the quality and behaviour of products in processing.

Although cultivar (cv.) is probably the most important factor affecting the quality of processed tomato products, other major parameters are tomato maturity, growing location and climate, and processing conditions. Tomato is one of the most important vegetable crops in Meghalaya supporting the livelihood and improving the economic life of many tomato growers in the state. It is often called "poor man's orange" because they are good source of vitamins, particularly vitamin A and C. It is also a rich source of natural lycopene, a carotenoid possessing anti-oxidative activity [5]. Fresh tomatoes and its processed products are highly refreshing and appetizing. It finds wide application in day-to-day use for making curries, soups, salads, tomato cocktail, etc. Processed tomatoes are used for making tomato juice, tomato powder, pickles or fermented tomatoes, tomato flakes, chips, ketchup, puree, sauce, paste, etc.

Tomato is a perennial**,** often grown outdoors in temperate climates as an annual crop. Tomatoes are grown in sandy to heavy clay soils. Well drained soils, like sandy or red loam is ideal. The optimum temperature required for its cultivation is 15-27ºC. It can withstand drought fairly but does not do well in heavy rainfall areas. However, it is grown in high hills of Meghalaya from February to June (spring-summer), while in mid and low hills, two crops can be raised; one from February to June and another from September to December. The summer crop fetches good price.

The demand of tomato in the country is increasing day-by-day with the increase in population and its preference for tomato. Growing consumer interest in the product both as a fresh fruit and processed product has considerably broadened its market opportunities. Tomato has a limited shelf life at ambient conditions and is highly perishable. Moreover, fresh fruit is not available in all parts of the country throughout the year at uniform price. These growing market opportunities have, however, necessitated that tomatoes be accessible in a more convenient format and thus led to the development of technologies for the preservation and sale of the product especially in a dry format. Now-a-days, the nutrient content is another important factor that impacts on the consumers' choice for preserved products. Processing has tremendous impact on the retention of nutrients and their availability in the body. Processing of tomatoes to a puree or paste is an added value, as it frees lycopene from the tomato matrix, thus enhancing its bioavailability [2].

Drying of fruit and vegetables is one of the oldest methods of preservation. Generally there is no microbial proliferation in dried vegetables containing 5-7% moisture. So, dried vegetables can be stored for long period. The reduction in mass and volume during drying also improves the efficiency of packaging, sorting and transportation. The dried tomato flakes have considerable market potential, but tomato powder has higher consumer acceptability. The tomato powder can be reconstituted into juice or used as a starting material for the preparation of products like sauce, ketchup, chutney, etc. It can also be used as a flavouring agent/nutrient supplement in good mixes, baby food, health food, etc.

The design of appropriate product, its quality and its associated machinery for mechanizing the processing of tomato, requires knowledge of the physical and chemical properties of the fruits. Bajaj *et al.* [9] worked on "Analysis of important chemical constituents of different varieties of tomato" and have shown the suitability for processing of different varieties with respect to their different physicochemical characters. Saimbhi *et al.* [40] also investigated physicochemical characters of seventeen exotic varieties of tomato, grown at the Vegetable Research Area, Ludhiana, and have shown their suitability for processing. Thus the present study was undertaken to evaluate different varieties of tomatoes grown at the orchard of ICAR Research Complex for North Eastern Hill (NEH) region, Umiam, Meghalaya, suitable for processing. This investigation was also undertaken to study the ascorbic acid and lycopene retention in different tomato varieties of Meghalaya as affected by blanching (pre-drying treatment) and dehydration.

Materials and Methods

Materials

The investigation includes 5 varieties of tomato grown at the ICAR Research Complex for North Eastern Hill (NEH) region, Umiam, Meghalaya during May-June, 2009. All the chemicals used were of analytical grade.

Ripe tomato varieties cv. *Sel-2, Sel-3, Solam Garima, VR-415* and *Pau-2374* were procured from the orchard. These were washed under running water to remove the adhering impurities. Fruit of similar size, shape and free from injury were selected for the experiment.

Pre-drying treatment

Blanching

The ripe tomatoes were scalded in boiling water to facilitate the complete inactivation of the enzymes (polyphenol oxidase and peroxidases) and also for easy removal of the skin manually by means of a pointed knife. The blanched tomatoes were peeled and then macerated to form pulp. The seeds and other residues were removed manually. The pulp of each variety was then dried in a simple cabinet dryer.

Drying

In order to determine the influence of blanching and dehydration, tomato varieties were dried in a cabinet dryer, after blanching and the changes in their physicochemical properties were evaluated.

The pulp from each variety, were spread evenly over the trays in single layer, having a thickness of 2-3cm. The dehydration experiments were conducted in 2 replications at 60°±2°C for 6 hours, till dry, non-sticky products were obtained. The moisture loss was recorded at particular intervals by a digital balance of ±0.05g accuracy. Initial and bone dried weights were used to calculate the initial moisture content, which was expressed as gram water/ gram dry matter.

Storage

Drying of pulp resulted in the formation of slabs having soft gel-like texture, which were similar to fruit leathers. The dehydrated product prepared from different tomato varieties, were stored in desiccators for 6-7 hours to avoid moisture absorption, and finally these were packed in LDPE (low density polyethylene) 200 guages (17 cm x 14 cm) pouches. The product was stored at ambient temperature (20-35°C).

Quality evaluation
Un-blanched and water-blanched tomato and the obtained dehydrated product of each cultivar were analyzed for physical and chemical properties, using AOAC methods [1]. Three replicate samples of three fruits per cultivar were crushed in a mortar using a pestle and then subjected to analysis. Likewise, the dried product was also crushed in a mortar using a pestle and then subjected to homogenization in a laboratory blender at high speed for 1 min. The homogenates were filtered and then subjected to analysis.

Physical analysis
Five fruit of each variety were randomly selected and the average fruit weights, locules number, pericarp thickness and fruit density were recorded. The mean value was evaluated as described by Adedeji *et al*. [2]. Fruit weight was recorded by an electronic balance (with an accuracy of 0.01g). The pericarp thickness and diameter of the fruit were measured using vernier caliper along the longitudinal (stem to blossom end) and cross-sectional axis (transverse diameter).Volume occupied by the test fruit was measured by determining the volume of water displaced by the fruit. The seed-skin-fibre content in tomato fruits were determined by separating them and the pulp yield was measured.

Colour of tomatoes and dried products were measured by Hunter color difference meter (Color Quest XE, Hunter Lab), calibrated with a white tile. “L” represents the lightness index (“0” for black to “100” for white), “a” represents greenness and redness (“+100” for red and “-80” for blue) while “b” represents for yellowness and blueness (“+70” for yellow and “-80” for blue). Three replications of each of the five tomato varieties were analyzed in triplicate.

Firmness of tomatoes was measured using 35 mm. aluminum probe with a TA.XT.Plus Texture Analyser (Stable Micro Systems, SMSP). Three replications of each of the five tomato varieties were analyzed in triplicate.

Chemical analysis
Total soluble solids (TSS) of the resulting clear juice samples were determined by bench-top Palette digital refractometer (ATAGO) and the result was expressed in percentage after temperature correction. Moisture content of the fruits was determined by keeping the samples in a thermostatically controlled electric oven at $105\pm1^{o}C$ for 2 hr [1]. Total solids were obtained from the dry solids remaining in the moisture-content determination. Total ash content was determined by taking 10 grams sample and heated in muffle furnace at $600°\pm2°C$ for 3 hours [35]. The titratable acidity was estimated by titrating 5 ml of sample against 0.1N NaOH solution using phenolphthalein as an indicator. The acidity was calculated and expressed as percent anhydrous citric acid [1]. Ascorbic acid content was determined by using 2,6-dichlorophenol indophenols dye method [35].

Lycopene estimation was done by using AOAC method [1]. 5-10g sample was repeatedly extracted with acetone until the residue became colourless. The acetone extract was transferred to a separating funnel containing 10-15ml. petroleum ether and then 5% sodium sulphate solution was added. The lower acetone phase was repeatedly extracted with petroleum ether similarly, until it became colourless. The upper petroleum ether extract was pooled and its volume was made upto 50ml. with petroleum ether. Diluted an aliquot to 50ml. with petroleum ether and the colour was measured in a 1 cm. cell at 503nm in spectrophotometer (Systronics UV-VIS double beam spectrophotometer 2201) using petroleum ether as blank. The results are reported as-

Table 1. Physicochemical characteristics of tomato cultivars

Properties		*Solam Garima*	*VR-415*	*Pau-2374*	*Sel-2*	*Sel-3*
Appearance		**Oval, medium**	**Round, medium**	**Round, medium**	**Oval, nipple-shaped**	**Oval, large**
Average fruit weight (g)		49.6±0.04	59.1±2.10	51.1±0.07	44.0±1.02	64.0±0.02
Length	Longitudinal, L (mm)	40.194±0.12	46.716±0.09	47.164±0.12	43.730±0.25	57.602±0.07
	Transversal, T (mm)	44.578±0.31	47.154±0.17	42.672±0.23	40.750±0.13	44.834±0.03
Pulp (%)		54.62±0.08	59.48±0.56	56.34±0.29	50.77±0.51	64.51±0.37
Shape index (L/T)		0.9017	0.9907	1.1053	1.0731	1.2848
TSS, °Brix (%)		4.8±0.29	3.6±0.06	5.4±0.10	4.3±0.15	4.4±0.27
Total solids (%)		5.3±0.31	4.1±0.71	5.9±1.6	4.8±0.01	4.9±0.05
Moisture content, (% dry basis)		1780.05±6.97	2594.33±8.51	1211.05±7.62	1390.54±4.11	1453.16±3.39
Titratable acidity (% citric acid)		0.8216± 1.61	0.4536±2.01	0.6192±0.83	0.3867±1.01	0.3560±0.09
Ascorbic acid (mg/100g)		21.5385±1.39	15.873±2.97	19.375±2.51	12.688±1.57	18.532±1.99
% Reducing sugars		4.38±0.59	3.91±0.71	4.00±0.89	3.72±0.36	3.90±0.28
% Total sugars		6.98±0.48	4.84±0.68	6.23±1.78	4.90±0.68	7.10±1.28
Lycopene (mg/100g)		1.668±0.15	1.492±0.37	2.7898±0.39	1.8911±0.23	1.9785±0.17
Firmness (kg/sq.mm)		2.6680±0.01	3.1803±0.03	2.1988±0.13	3.7029±0.10	2.4751±0.02
Volume of fruit (ml)		33.6±0.58	48±0.71	35±0.12	28.9±0.26	47.5±0.39
Total ash content (%)		17.7658±0.58	10.7680±0.39	10.2979±0.21	19.1377±0.18	11.2462±0.12
Pericarp thickness (mm)		5.4±1.02	6.4±0.71	5.2±0.39	7.2±0.12	5.6±1.93
Locules (Nos.)		2.3±0.38	2.7±0.24	2.2±0.41	2.0±0.17	3.0±0.31
TSS/Acid ratio		5.84	7.93	8.72	11.120	12.360
Sugar/Acid ratio		8.496	10.670	10.061	12.671	19.944
Yield of dehydrated tomato product (% wt basis)		9.09±0.37	6.48± 0.76	9.75±0.53	8.57±0.44	6.65±0.13
Seeds, skin, fibres & other residual portion (% wt basis)		24.56±1.32	35.49±1.08	14.34±2.10	29.14±0.76	17.11±0.72

$$\textbf{mg of lycopene per 100g sample} = \frac{\textbf{3.1206 x OD of sample x vol. made up x dilution x 100}}{\textbf{1 x wt. of sample x 1000}}$$

Reducing sugars and total sugars were determined by the methods described by Ranganna [35] with slight modifications. To a known quantity of sample (10ml or 10g), 10ml of 45% lead acetate solution was added and after 10-20 minutes, 5g potassium oxalate was mixed. The content was filtered through Whatman No. 41 filter paper and the volume of the filtrate was made upto 100ml with water. 75ml of this filtrate was titrated against Fehling's solutions A & B (5ml each). The remaining 25 ml filtrate is mixed with 5ml conc. HCl and kept overnight. It is then neutralized with 10% NaOH solution using phenolphthalein as an indicator. The volume of this pink coloured solution was made upto 75ml and then titrated against Fehling's solutions A & B (5ml each).

$$\textbf{\% reducing sugars} = \frac{\textbf{0.05 x volume made up x 100}}{\textbf{1}^{\textbf{st}}\textbf{ titre value x wt. or vol. of sample}}$$

$$\textbf{\% total sugar (as invert sugars)} = \frac{\textbf{0.05 x vol. made up initially x vol. made up after neutralization x100}}{\textbf{2}^{\textbf{nd}}\textbf{ titre value x wt. or vol. of sample initially taken x 25}}$$

% sucrose = (% total sugar as invert sugars - % reducing sugars) x 0.95

% total sugar = % reducing sugars + % sucrose

Statistical analysis

Data represents means of triplicates (n=3) for physicochemical parameters and means of 5 values in case of physical characteristics. The values of standard deviation are also calculated for each parameter. The mean value was evaluated as described by Adedeji *et al*. [2]. Correlation coefficients were calculated using Pearson's technique for important parameters in different cultivars.

Results and Discussion

The dimensions of the tomatoes are presented in Table 1. Wide variations were found in the physicochemical characteristics of these five varieties of tomato. Variations in physicochemical attributes of these tomato varieties after blanching and dehydration are shown in Table 2 and 3, respectively. Similar variations were also found by Bajaj *et al.* [9] and Saimbhi *et al.* [40].

Average fruit weight varied widely among the investigated cultivars (Table 1). The *Sel-3* cultivar had higher weight than the others followed by the *VR-415* cultivar. *Sel-2* had the lowest fruit weight. The *Sel-3* cultivar had the highest pulp yield of 64.51%, followed by the *VR-415* cultivar with approximately 59.48% of pulp yield. The pulp yields of the other cultivars were *Pau-2374, Solam Garima* and *Sel-2* for 56.34%, 54.62% and 50.77%, respectively. The highest fruit-yielding cultivar would be of great interest to tomato growers [2]. However, the yield of dehydrated product (by weight basis) varied between 9.75% and 6.48%, with the highest value in *Pau-2374*. Percentage seed-skin-fiber content by weight ranged between 35.49% and 14.34%, with *VR-415* and *Pau-2374* having the highest and the lowest values, respectively. To the processor, cultivars with lower skin and seed content are preferable as these are removed during processing, thereby constituting a loss.

Shape index

Appearances of the test samples are given in the Table 1. The shape of the fruits varied from spherical to pear-like. There was a distinct difference in the longitudinal and transverse dimensions of *Sel-2, Sel-3, Solam Garima, VR-415* and *Pau-2374.* The *Sel-3* cultivar has the highest longitudinal diameters followed by *Pau-2374. VR-415* has the highest transverse diameter. According to Padda *et al.* [30], tomato varieties with shape index around 1 are round, 1.1 to 1.2 are oval whereas; with shape index 1.4 or more are pear shaped. Pear-shaped varieties are suitable for canning because its spherical shape will make it more amenable to design consideration parameters than the other nonconventional shapes.

Number of locules

The varieties having higher number of locules are more juicy and suitable for table purpose [30]. Pear shaped varieties have less number of locules [41]. The locule number mainly varied from 2 in *Sel-2* to 3 in *Sel-3* (Table 1).

Blanching

Blanching prior to drying or dehydration is required to inactivate peroxidase activity, protect colour, texture and nutrients. It also reduces drying time, renders undesirable enzymes inactive, expels air from the tissues and helps to retain minerals and acids [27, 15, 36].

Blanching time needed in boiling water for complete in activation of the enzymes was 7 min for *Pau-2374*, 8 min for *Sel-3*, 4 min for *Solam Garima*, 5 min for *Sel-2* and 2 min for *VR-415*. This variation in blanching time may be due to the difference in size, texture and composition of the tomatoes [22].

Moisture content

Among the 5 varieties, un-blanched *VR-415* had the highest moisture content of 2594.33% (dry basis) (Table 1), but it was highest in blanched *Sel-3* (3823.08% dry basis) (Table 2) and finally, dried *VR-415* had the lowest moisture level (30.21% dry basis) (Table 3). This can be attributed to different water uptake capacity, texture, composition of the varieties and blanching time. Blanching increases moisture level. So, blanched samples with higher moisture content than the untreated samples were subjected to drying. Moisture content decreases due to high loss of moisture at higher temperature.

Firmness

Firmness is the most relevant property in quality characterization of the tomatoes processed in the canning industry, in particular, of canned whole tomatoes. Firmness and skin resistance are the most relevant properties in quality characterization of the tomatoes processed in the canning industry. It is related to ripeness rate and the tomato susceptibility to damage during harvesting and processing. Ripe fruits are often soft and break easily because of a lack of firmness. Even when they have a high organoleptic quality, canning industries process them as triturated tomato with a lower price than whole peeled tomatoes [2]. Hot water blanching produced softer tomatoes and their firmness decreased [4]. For canning, *Sel-2* is suitable, as it has the highest firmness value, followed by *VR-415* (Table 1). However, blanched sample of the *Solam Garima* cultivar showed maximum firmness, followed by *Sel-2* (Table 2).

Pericarp thickness

Higher is the pericarp thickness; better is the firmness of fruit [41]. *Sel-2* is suitable for canning, as it has the highest pericarp thickness.

Total solids and total soluble solids (TSS)

The soluble solids content is one of the most important quality parameters in processing tomato. 50–65% of soluble solids contents are sugars, glucose and fructose, and their amount and proportion influence the organoleptic quality of tomatoes [2]. The remaining soluble solids are mainly citric and malic acids, lipids and other components in low concentrations. In the present investigation, percentage total solids ranged from 5.9% to 4.1%, with the *Pau-2374* cultivar having the highest values. The total solids content has implications for processing. It suggests that the *Pau-2374* cultivar would require a smaller quantity of tomatoes to obtain a certain level of quality in production of products such as purees and pastes, thus reducing the cost of the product.

The TSS content is important criterion in determining the suitability of varieties for processing. High TSS is desirable to yield higher recovery of processed products. Guold *et al.* [19] worked on tomatoes for canning and formulated that for varieties suitable for processing, TSS content should be more than 5%.

TSS content of un-blanched samples was more than that of blanched ones, due to leaching loss of soluble solids during blanching. Guerrant *et al*. [18] proved the decreasing trend of TSS with increasing blanching time. The dried tomato products have higher TSS due to moisture loss and concentration effect.

Table 2. Physicochemical parameters[*] of tomato cultivars after blanching

Properties	Tomato cultivars				
	Solam Garima	***VR-415***	***Pau-2374***	***Sel-2***	***Sel-3***
Lycopene (mg/100g)	2.1595±0.06	2.0846±0.02	2.9396±0.01	2.8446±0.02	2.6088±0.13
Titratable acidity (% citric acid)	0.5408±0.09	0.14336±0.05	0.3926±0.02	0.1228±0.01	0.1395±0.08
Ascorbic acid (mg/100g)	19.0476±0.48	12.708±0.51	15.873±0.66	9.5238±0.61	12.698±0.54
TSS, °Brix (%)	4.6±0.8	3.5±0.95	5.3±0.83	4.2±0.81	4.2±1.07
Total solids	5.1±1.32	4.0±0.51	5.8±0.36	4.7±0.65	4.9±0.11
Moisture content (% dry basis)	2225.58±3.51	2677.78±2.77	2841.18±1.03	2470.86±3.37	3823.08±4.97
Total ash content (%)	18.4819±1.18	11.9430±1.46	10.6175±1.29	19.5422±1.14	12.1546±1.55
Firmness (kg/sq.mm)	0.6325±0.44	0.3402±0.19	0.4427±0.23	0.5619±0.26	0.2685±0.07

[*]values are mean± standard deviation of triplicate samples (n=3)

Titratable acidity: According to Guold and Berry [19], a tomato variety for processing should have acid contents ranging from 0.35% to 0.55%. Titratable acidity for the five cultivars was almost similar; however, Solam Garima was the most acidic (Table 1). High acid values are required for best flavor and it is mainly because of the presence of citric and malic acids [2]. The present data indicates that the *Solam Garima* and *Pau-2374* cultivars as having higher acid values than *VR-415, Sel-2* and *Sel-3* cultivars, which implies better flavor. Acids present in foods not only improve the palatability of many fruit products but also influence their nutritive value by playing a significant role in the maintenance of acid–base balance in the body. The acids influence the flavor, brightness of color, stability, consistency and keeping quality of the product. In addition, acidity of the tomato juice greatly influences the processing time and temperature of the product [2].

In the present experiment, acidity of un-blanched samples was higher than that of blanched samples. Some workers believe that decrease in acidity is caused by the leaching loss of acids during blanching. But, Mosha and Gagel [27], Cruess [15], Raul *et al.* [36] showed that blanching helps to retain acids. Again, acidity increased after drying, similar to the postulations of Kikon [23] found in dehydrated apples and Sagar *et al.* [39] in mango powder. During drying, increase in acidity is mainly attributed to the increased moisture loss from the sample with corresponding increase in temperature (Table 3). At still higher temperatures, sugar level decreases and evidently acidity increases.

TSS/Acid ratio

Saimbhi *et al.* [40] showed that the ratio of TSS/acid determines the taste and flavour of the varieties. Low TSS/acid ratio makes the variety acidic and unsuitable for table purpose. *Sel-3* has the highest TSS/Acid ratio of 12.360 and *Solam Garima* had the lowest ratio (Table 1).

Total ash content

Typical values were reported for ash content (Table 1). Although there were not much differences among the cultivars studied, it is worthy to note that the *Sel-2* and *Solam Garima* cultivars had higher values than *Sel-3, VR-415* and *Pau-2374*. This implies higher mineral constituents in the *Sel-2* and *Solam Garima* cultivars [2].

Sel-2 was found to be having the highest ash content after blanching and dehydration (Table 2 and 3), followed by that of *Solam Garima*. A slight decrease in total ash content was noticed when blanched samples were dried. This might be owing to the reaction of acids with basic minerals at higher temperatures. On the other hand, total ash content increased after blanching (Table 2). This may be because of leaching of soluble solids and concentration of minerals at different blanching time [27, 15, 36].

Sugars

The content of reducing sugars among the cultivars was almost similar. Values ranged between 4.38% and 3.72%. It is interesting to note that *Solam Garima* and *Pau-2374* were higher in reducing sugars than the *VR-415, Sel-3* and *Sel-2* cultivars. Among the unblanched samples, reducing sugar was highest in *Solam Garima* and total sugars in *Sel-3* (Table 1), but in dried blanched samples, reducing sugar is highest in *VR-415* and total sugar in *Solam Garima* (Table 3). This might be because of different level of leaching loss in different blanching time. Reducing sugars increased because of more rapid hydrolysis of polysaccharides and their subsequent conversion to reducing sugars at higher temperatures. Similar trend has been observed by Sagar *et al*. [39] in mango powder. Total sugar content also increased after drying due to moisture loss and concentration effect. This result is in compliance with the findings of Khurdiya *et al.* [22], where the total sugar content also increases after dehydration of Ber fruit. However, this hike in total sugar level is not very high, which might be because of inversion of sugars, Maillard reaction and leaching loss. This assumption is also validated by the results obtained from mango fruit bar study, conducted by Nanjundaswamy *et al.* [29]. Chawla and Ranote [14] also found an increase in total sugar content in dehydrated watermelon products.

Sugar/Acid ratio

Adedeji *et al.* [2] reported that high sugar and high acid contents are required for best flavor (i.e., sweetness, sourness and overall flavor intensity) in tomatoes. The peak sugar:acid ratio was found in unblanched *Sel-3* (19.994) (Table 1), so fresh *Sel-3* is expected to have high consumer acceptability and can be used for fresh-cut produce and salads. In dried tomato products, both acid and sugar content increases compared to their unblanched sample. So, this ratio also increases and was found highest in dried *Sel-2* i.e. 63.466, but not in dried *Sel-3* (Table 3). This can be due to Maillard reaction, hydrolysis of polysaccharides in *Sel-3* at higher temperature.

Ascorbic content

The vitamin C content varied among the cultivars. The *Solam Garima* cultivar had the highest vitamin C content of 21.54 mg/100g, followed by *Pau-2374* (19.375mg/100g), which in-turn is closely followed by *Sel-3* having a value of 18.532 mg/100g. The *Sel-2* cultivar had the least, with a value of 12.688 mg/100g (Table 1). Vitamin C is a very heat- labile component and its retention is affected by thermal processing. So, the decreasing trend of ascorbic acid content in blanched and dehydrated tomatoes is ascribed to heat labile nature of this vitamin (Table 2 and 3). Because tomato is mainly consumed in the processed form, using a cultivar with high vitamin C content is preferable. This experiment shows that, in *Solam Garima*, ascorbic acid decreased from 21.5385 mg/100g to 11.121 mg/100g after dehydration. So, there was a reduction of 48.37% in ascorbic acid. Likewise, the reduction of ascorbic acid in *Sel-3* and *Pau-2374* during dehydration was 45.44% and 59.86%, respectively. Therefore, *Sel-3* and *Solam Garima* have better ascorbic acid retention capacity during processing.

Table 3. Physicochemical parameters[*] of tomato cultivars after cabinet drying.

Properties	Tomato cultivars				
	Solam Garima	*VR-415*	*Pau-2374*	*Sel-2*	*Sel-3*
Lycopene (mg/100g)	2.925±1.35	2.2285±1.27	4.603±1.4	3.7179±0.17	2.710±0.08
Titratable acidity (% citric acid)	0.989±0.04	0.64±0.02	0.876±0.03	0.427±0.03	0.5012±0.02
Ascorbic acid (mg/100g)	11.121±1.56	8.5185±0.8	7.7778±0.84	6.5203±1.43	10.1111±1.19
Moisture content (% dry basis)	41.35±4.3	30.21±3.5	34.05±2.7	30.89±2.3	38.89±3.3
Total ash content (%)	13.7864±1.76	8.8833±2.03	9.7384±1.94	15.9677±1.39	10.9725±1.37
% Reducing sugars	12.8±0.99	19.3±1.07	11.4±1.53	12.7±0.71	10.6±0.80
% Total sugars	31.8±0.66	30.4±0.54	23.4±0.38	27.1±1.05	25.7±0.05
Sugar/Acid ratio	32.154	47.5	26.712	63.466	51.276

[*]values are mean± standard deviation of triplicate samples (n=3)

Lycopene

Edwards and Lee [16] reported the changes in the concentration of various carotenoids in carrots and peas during canning. The tomato changes in colour during different stages of its maturity and ripening i.e., from green to pale white, then yellow and finally red. The yellow colour is owing to the presence of carotene. The red colour appears when the lycopene is formed in the fibres. Lycopene is responsible for the attractive red colour of the fruit and its products. Therefore, growers should select varieties with the brightest, most red and yellow color because those are the most influential characteristics behind consumer acceptance.

The difference in lycopene content among the various cultivars was negligible. Among the 5 varieties, lycopene content was found to be highest in un-blanched and blanched *Pau-2374* (2.7898 mg/100g and 2.9396 mg/100g, respectively) (Table 1 and 2), but it was highest in dried *Sel-2* (3.7179 mg/100g) (Table 3). So, it can be attributed to thermal degradation of lycopene of *Pau-2374* at higher temperature. Several workers have shown leaching losses to be responsible for increase in carotenoids content during processing [10, 6, 7]. In this study, apparent increase in lycopene, as a result of blanching operation, occurred may be due to leaching loss of water soluble antioxidant compounds like ascorbic acid, bioflavonoids and other polyphenolic compounds. High temperature treatments either stabilize or very slightly reduce the lycopene content of the fruit [19].

Arya *et al.* [6] and Sharma *et al.* [42] found that carotenoids are relatively more stable in blanched carrots than un-blanched dried sample. They also proved that dehydration methods employed did not significantly influence the rate of degradation of carotenoids in blanched cabinet-dried carrots. However, the apparent increase in lycopene after drying can be attributed to the loss of water from the pulp and the remaining lycopene got concentrated in the dried product.

Table 4. Hunter Color parameters* of tomato cultivars

Samples	Hunter -Color Parameters	Varieties of tomatoes				
		Solam Garima	***VR-415***	***Pau-2374***	***Sel-2***	***Sel-3***
Un-blanched tomato	L	38.1675±2.9	40.62±3.5	39.4275±1.4	47.82±2.3	43.697±1.6
	a	12.0375±1.5	8.1±2.3	7.7625±1.8	15.96±1.9	11.5±3.2
	b	15.525±1.3	15.36±0.6	14.4575±0.9	21.70±0.6	19.457±1.9
Hot water-blanched tomato (Whole)	L	36.04±1.6	39.60±1.7	36.34±1.7	37.55±2.3	35.295±2.3
	a	12.95±2.2	8.74±3.9	7.83±3.9	13.56±2.8	11.77±2.7
	b	14.33±1.0	15.83±1.1	6.065±1.1	14.96±1.0	8.38±0.4
Pulp from blanched tomato	L	31.87±2.5	29.18±3.1	28.56±1.6	55.78±2.7	41.82±1.8
	a	15.30±1.7	11.42±2.4	8.19± 1.2	14.82±2.1	12.405±3.5
	b	1.49±0.9	4.54±0.8	3.22±0.9	-5.62±0.08	-1.08±0.5
Dried tomato product	L	22.29±3.7	23.89±2.5	21.98±1.9	26.73±1.1	22.85±2.6
	a	17.37±2.3	15.98±1.8	10.87±3.3	15.72±1.9	12.49±2.9
	b	0.18±0.02	0.36±0.05	-0.79±0.03	-0.67±0.3	0.65±0.4

*values are mean± standard deviation of triplicate samples (n=3)

In the present study, blanching resulted in overall increase of lycopene content. In *Pau-2374*, blanching increased lycopene by 5.37% and it rose by 64.99% during drying. Similarly, in *Sel-2*, lycopene level increased by 50.42% after blanching and 96.59% after drying. This increment in lycopene during blanching of *VR-415, Sel-3* and *Solam Garima* were 39.72%, 31.82% and 29.47%, respectively and their corresponding increase of this carotenoid content after dehydration were 49.36%, 36.97% and 75.36%, respectively.

Thus, it can be inferred that blanching conditions for *Sel-2*, used in this experiment, was most efficient in retaining lycopene in its blanched sample, and hence, a consequent increase in the lycopene content of dehydrated sample of *Sel-2*, was also observed.

Fruit colour

Tomato colour is associated with ripeness rate and is used to determine the harvesting time [2]. During drying, Hunter "+a" value increases mainly due to moisture loss, leaching loss and concentration effect in dried products (Table 4). Among the unblanched and blanched whole fruit, the "+a" value was highest in *Sel-2* whereas, among the pulp and dried product, it was highest in *Solam Garima*. This might be due to thermal degradation of some carotenoids in *Sel-2* at higher temperature. It can also be attributed to the fact that Maillard reactions, caramelisation of sugars during heating might have increased the "a" values in dried products of *Solam Garima***.** It is interesting to note that, the increase in red colour in the pulp of blanched sample is higher than the corresponding whole blanched sample. It is probably due to the increased extraction of the carotenoids from the ruptured tomato tissue during processing. Because of similar reason, Panalaks and Murray [32] also reported increase in carotenoids of 52% and 72% on cooking and canning of carrots, respectively.

The correlation coefficients shown in Table 5, 6, 7, 8 and 9, clearly depict the relationship between tomato cultivars and their physicochemical properties. For instance, in all the investigated cultivars, lycopene showed the highest correlation with Hunter "a" value (>0.9), followed by titratable acidity and least with ascorbic acid (<0.9). This indicates that as lycopene content increases, Hunter "a" value i.e. redness also increases and consecutively, ascorbic acid decreases during processing. This occurs because thermal processing either stabilizes or very slightly reduces the lycopene content of the fruit [16, 17], whereas ascorbic acid being a heat-labile substance, suffers from deep degradation with thermal treatment. Likewise, titratable acidity increases from fresh to dried product due to concentration effect of acids. However, variations from this usual trend have been observed in Sel-2 (Table 8) and Sel-3 (Table 9) cultivars. This again confirms that different cultivars from same region or environment have different physicochemical properties. So, further studies need to be undertaken to explain the reasons behind such variations of same parameter in different cultivar, to correlate sensory evaluation of dried tomato product of different cultivars against the instrumental analysis, and to determine optimum processing parameter of each cultivar for consumer preference.

Table 5. Pearson's correlation coefficient for physicochemical properties of *Solam Garima*

	Lycopene	Titratable acidity	Ascorbic acid	Hunter "a" value
Lycopene	1	0.226676	-0.98602	0.968017
Titratable acidity		1	-0.62189	0.247546
Ascorbic acid			1	-0.91268
Hunter "a" value				1

Table 6. Pearson's correlation coefficient for physicochemical properties of *VR-415*

	Lycopene	Titratable acidity	Ascorbic acid	Hunter "a" value
Lycopene	1	0.042378	-0.91371	0.909454
Titratable acidity		1	-0.44473	0.453973
Ascorbic acid			1	-0.99995
Hunter "a" value				1

Table 7. Pearson's correlation coefficient for physicochemical properties of *Pau-2374*

	Lycopene	Titratable acidity	Ascorbic acid	Hunter "a" value
Lycopene	1	0.846171	-0.97495	0.998609
Titratable acidity		1	-0.70644	0.816893
Ascorbic acid			1	-0.98532
Hunter "a" value				1

Table 8. Pearson's correlation coefficient for physicochemical properties of *Sel-2*

	Lycopene	Titratable acidity	Ascorbic acid	Hunter "a" value
Lycopene	1	0.096763	-0.99995	0.22443
Titratable acidity		1	-0.10701	0.9482
Ascorbic acid			1	0.214383
Hunter "a" value				1

Table 9. Pearson's correlation coefficient for physicochemical properties of *Sel-3*

	Lycopene	Titratable acidity	Ascorbic acid	Hunter "a" value
Lycopene	1	0.014688	-0.98446	0.998726
Titratable acidity		1	-0.19006	-0.03578
Ascorbic acid			1	-0.97434
Hunter "a" value				1

Conclusions

The physicochemical characteristics of five different tomato cultivars grown in the orchard of ICAR Research complex, Meghalaya, were compared and their suitability for processing was determined. In order to determine the influence of blanching and dehydration, tomato varieties were dried in cabinet dryer, after blanching and the changes in their physico-chemical properties were evaluated in laboratory. Wide variations were found in the physico-chemical characteristics of 5 varieties of tomato. *Solam Garima* has the highest titratable acidity, ascorbic acid and reducing sugar amongst the five cultivars. The *Pau-2374* cultivar has the highest total solids, total soluble solids (TSS) and lycopene content. The seed, skin and other fibrous residual wastes is highest in *VR-415*, but lowest in *Pau-2374*. *Sel-2* can be used in canning industry as it has the maximum firmness and mineral content. The maximum average fruit weight, total sugars and peak sugar:acid ratio was found in *Sel-3*. After blanching, it was found that *Pau-2374* possessed the highest total solids, TSS and lycopene content, and *Solam Garima* contained the highest titratable acidity and firmness. Dried pulp of *Solam Garima* was able to retain the highest content of titratable acidity, ascorbic acid and total sugar, indicating its suitability for making dehydrated tomato products (flakes, powders, chips, etc). However, the dried pulp of *Sel-2* showed the highest ash content and sugar:acid ratio, and the dried pulp of the *Pau-2374* cultivar had the maximum lycopene content, inferring their good consumer acceptance in the market. Critical examination of the various characteristics of these tomato varieties shows that *Pau-2374, Solam Garima, Sel-2 and Sel-3* can prove to be useful for processing. All these varieties are equally important for one or more of their attributes. Also, two or more of these varieties can be amalgamated to obtain the desired effect, according to our requirement, during processing and in final product. Thus, these cultivars are recommended for deliberate cultivation. This genetic resource presents tremendous potential to breeders.

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