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Breeding tomatoes suitable for processing with triple disease resistance to tomato leaf curl disease, bacterial wilt and early blight

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ABSTRACT

India is the second largest producer of tomato with 11 per cent global share and cultivated on an estimated area of 0.76 million hectares with productivity of 24 tonnes per hectare. Less than 1% of the produce is processed when compared to 26% in other major producing countries. Of the estimated more than 41 million tonnes of tomato processed globally, only 130,000 tonnes were processed in India and domestic demand for processed tomato products is expanding at an estimated 30% annually. At present traditional fresh market tomato cultivars are being processed though such cultivars are unsuitable for processing. Processors in India are looking for high yielding tomato cultivars with high total soluble solids (5-6 º Brix), acidity not less than 0.4%, pH less than 4.5 and uniform red colour with a/b colour value of at least 2. In addition, firm fruited tomato cultivars with joint less pedicel (j2) which facilitate mechanical harvesting or rapid hand picking. ICAR-Indian Institute of Horticultural Research has recently developed two high yielding F_1 hybrids in tomato *viz:* Arka Apeksha and Arka Vishesh suitable for processing. On evaluation for three years, both the hybrids recorded good level of total soluble solids (4.5-5º Brix) and colour value of 2. Further, both the hybrids had high yield potential (80-90 tonnes / hectare) with triple disease resistance to tomato leaf curl disease, bacterial wilt and early blight. Arka Apeksha and Arka Vishesh were also bred with jointless pedicel making them suitable for mechanical harvesting. Our experimental studies on vine storability revealed that all the fruits were intact on plants even 110 days after transplanting in the main field facilitating once over harvest.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops cultivated in the world. It is used as salads and also cooked vegetable in the preparation of curries. Processed items such as tomato puree, ketchup, pickle, chutney, whole peeled tomatoes, and tomato powder are also consumed considerably. Tomatoes are also an important source of vitamins and minerals. They are an excellent source of phosphorus, iron and vitamin A, B and C (Cobley and Steele, 1976). They also contain small amounts of the B complex vitamins; thiamin, niacin and riboflavin (Naika *et al*., 2005). They are loaded in minerals, vitamins, essential amino acids, sugars and dietary fibers. Most importantly, tomatoes are rich in carotenoids, especially lycopene (Beecher, 1998). Lycopene and other flavonoids in tomato serve as good source of antioxidants (Agarwal and Rao, 2000). Tomato occupies 5.05 million hectares with a productivity of 37 t/ha in the world. In India it is cultivated in an estimated area of 0.81 million hectares with productivity of 25.3 t/ha (FAO STAT 2020). One of the major reasons for low productivity in India is due to prevalence of various biotic and abiotic stresses. White fly (*B. tabaci*) transmitted tomato leaf curl disease, bacterial wilt (*R. solanacearum*) and early blight (*A. solani*) cause economic yield losses in the major tomato growing areas of the country and elsewhere in the world (Lukyanenko, 1991). Though India is the second largest producer

of tomato with 11 % global share, less than 1% of the produce is processed when compared to 26% in other major producing countries Of the estimated more than 41 million tonnes of tomato processed globally, only 130,000 tonnes are processed in India and domestic demand for processed tomato products is expanding at an estimated 30% annually (Subramaniam, 2016). At present traditional fresh market tomato cultivars are being processed though such cultivars are unsuitable for processing. Processors in India are looking for high yielding tomato cultivars with high total soluble solids (5-6º Brix), acidity not less than 0.4%, pH less than 4.5 and uniform red colour with a/b colour value of at least 2 (Stevens and Rudich, 1978). In addition, firm fruited tomato cultivars with joint less pedicel (j2) which facilitate mechanical harvesting or rapid hand picking. Tomato breeding programme at ICAR-Indian Institute of Horticultural Research, Bengaluru has resulted in the development of high yielding dual purpose F_1 hybrids with triple disease resistance to tomato leaf curl disease (ToLCD), bacterial wilt (BW) and early blight (EB) suitable for both fresh market and processing.

MATERIALS AND METHODS

Development of triple disease resistant lines and F_1 hybrids

Back cross breeding method was adopted during 2005 to pool genes carrying resistance to ToLCD, BW and EB. An advanced breeding line IIHR-2202 (CLN-2123-Dc1F1-111-17-21-2-12) with combined resistance to ToLCD +BW received from The World Vegetable Center (WVC) was crossed with EB resistant line IIHR-1816 (NCEBR1). The resultant F_1 was backcrossed to IIHR-1816 and further advanced up to BC1F7 to develop seven advanced breeding lines with triple disease resistance to ToLCD+BW+EB (Fig. 1).

All the seven advanced breeding lines were resistant to ToLCD (*Ty 2*), BW and EB had high potential with good fruit quality attributes like deep red and firm fruits. All the seven lines were crossed with eight advanced breeding lines received from The World Vegetable Center, Taiwan in a line x tester design to develop 56 hybrids with triple disease resistance. Two hybrid combinations *viz.,* IIHR-2834 (TLBER-12-21-43-1) x IIHR-2833 (CLN-2498D) later named as Arka Rakshak and IIHR-2835 (TLBER-38-7-4-27) x IIHR-2832 (CLN-2498E) later named as Arka Samrat were resistant to ToLCD+BW+EB with high yield potential & excellent fruit quality attributes. Both Arka Rakshak and Arka Samrat were identified at Institute level for commercial cultivation during 2010 (Fig. 2).

IIHR-2202 (Combined resistant to ToLCV + BW) x IIHR-1816 (Moderately resistant to EB)
↓
F1 x IIHR-1816
↓
BC1F1
(Triple disease resistant recombinants selected underartificial conditions and advanced)
↓
BC1F7
(Seven advanced breeding lines *viz;* TLBER-7-12-15-28, 7-12-15-29, 7-4-11-29, 7-4-11-34, 38-7-4-27, 38-7-41-43 and 12-21-43-1 with triple resistance were selected)

Fig. 1 : Flow chart detailing the development of triple disease resistant tomato lines

RESULTS AND DISCUSSION

Development of dual purpose F_1 hybrids in tomato with triple disease resistance

Breeding for dual purpose tomato was initiated during 2016. Our aim was to develop high yielding triple disease resistant F_1 hybrids suitable for both fresh market and processing for year-round cultivation under open. Several hybrid combinations were attempted involving the triple disease resistant parent IIHR-2834 which had jointless (j2) pedicel which facilitates mechanical harvesting. IIHR-2834 was crossed with two advanced breeding lines *viz.,* IIHR-2918 (ToLCVRES4-F3-21-9-1) and IIHR-2917 (ToLCVRES4-F3-188-1-1) which were resistant to ToLCD (*Ty 3*) and BW and later named as Arka Apeksha (H-385) and Arka Vishesh (H-391) respectively (Fig. 3).

Performance of dual purpose F_1 hybrids: Arka Apeksha (H-385) and Arka Vishesh (H-391)

A total of eighteen F_1 hybrids including two hybrids *viz.,* H-385 (IIHR-2834 x IIHR-2918) and H-391 (IIHR-2834 x IIHR-2917) were evaluated for two years *viz.,* 2017 (rainy season), 2017-18 (winter

IIHR-2834

IIHR-2835

IIHR-2833

IIHR-2832

Arka Rakshak

Arka Samrat

Fig. 2 : Triple disease resistant F_1 hybrids developed at ICAR-IIHR

Arka Apeksha (H-385)

Arka Vishesh (H-391)

Fig. 3 : Arka Apeksha and Arka Vishesh dual purpose tomato F_1 hybrids

season) and 2018 (rainy season) and 2018-19 (winter season) respectively under open field conditions. Five commercial F_1 hybrids *viz.,* Arka Rakshak, Arka Samrat, Abhinava, Lakshmi and Shivam were also included as checks. During rainy season (2017), H-397 was the highest yielder followed by H-391 (94 t/ha), H-387 (84 t /ha) & H-385 (83 t /ha) (Table 1).

During winter season (2017-18), H-391 (44 t/ha) was the top yielder followed by H-387 (34 t/ha) and H-397 (33t/ha) (Table 2). During rainy season (2018), H-397 (51.88T/ha), H-387 (46t/ha), H-391 (28 t/ha) and H-385 (25 t/ha) (Table 3) were the top yielders among the processing type. During winter season (2018-19) both H-391 (31 t/ha) and H-385 (30t/ha) were also high yielders (Table 4).

Mean yield over all the seasons revealed that H-385 (46 t/ha) &H-391 (43 /ha) (Table 5) expressed high yield potential over the commercial dual purpose hybrid Abhinava (40 t/ha). Both these two hybrids also recorded average fruit weight of 70g-90g with high TSS (5^0Brix) and deep red firm fruits (8 kg/cm^2) which meet present day market demand. During rainy season (2018), both the hybrids *viz.,* H-385 and H-391 were triple disease resistant to ToLCD+BW+EB, whereas commercial hybrids expressed moderate resistance and susceptible reaction to ToLCD and BW (Table 6). Four season's data revealed that H-385 and H-391 had high yield potential & commercially acceptable fruit quality attributes with triple disease resistance to ToLCD, BW and EB. Pooled analysis for yield per hectare over three years confirmed yield stability of Arka Apeksha and Arka Vishesh (Table 7)

Table1 : Performance of tomato F_1 hybrids at ICAR-IIHR, Bengaluru (Rainy season, 2017)

Hybrid	Estima-ted yield (t/ha)	Average Fruit weight	No of fruit/ kg (g)	Fruit length (cm)	Fruit width (cm)	Pericarp thickness (cm)	TSS (^{0}Brix)	Fruit firmness (kg/cm^2)	No. of locules	Shelf Life (Days)	Fruit colour	Fruit shape
H-385	83.00	81.23	12.31	6.25	4.50	0.10	5.00	8.25	2.00	-	-	-
H-387	84.00	92.85	10.77	5.55	5.00	0.50	5.10	9.75	3.00	18	R	Sq. Round
H-391(Arka Vishesh)	93.17	101.11	9.89	5.90	5.00	0.75	5.50	7.00	3.00	19	R	Sq. Round
H-397	112.83	91.66	10.91	4.90	6.00	0.70	5.00	8.00	6.00	12	R	Obl-rd
H-423	52.50	95.24	10.50	6.10	5.50	0.55	4.70	8.25	3.00			
H-501	79.50	93.98	10.64	5.15	6.00	0.70	5.00	7.75	4.00	14	R	Obl-rd
H-502	89.50	80.45	12.43	4.35	5.80	0.65	4.00	8.25	4.00	-	-	-
H-504	72.25	95.15	10.51	5.10	5.90	0.50	4.80	6.75	6.00	-	-	-
H-505	74.67	101.42	9.86	5.10	6.00	0.60	5.00	9.50	4.00	-	-	-
H-506	98.33	113.38	8.82	5.15	6.60	0.90	4.10	6.75	5.00	13	R	Obl-rd
PH-1021	88.83	134.41	7.44	5.35	6.00	0.60	4.70	8.75	6.00	8	R	Obl-rd
PH-1025	89.00	127.23	7.86	5.75	6.00	0.70	5.10	7.25	6.00	9	R	Obl-rd
PH-6321	92.23	120.05	8.33	6.00	7.30	0.65	4.15	7.50	5.00	9	R	Obl-rd
Arka Rakshak	90.17	72.94	13.71	5.90	5.00	0.55	4.40	8.75	3.00	18	DR	Oval
Arka Samrat	103.33	89.93	11.12	5.10	6.20	0.80	4.90	9.00	4.00	19	DR	Obl-rd
Lakshmi	102.33	63.69	15.70	5.25	4.80	0.55	4.25	6.25	4.00	13	DR	Oblate
Shivam	99.83	86.43	11.57	4.65	5.65	0.50	4.80	6.75	5.00	13	DR	Oblate
Abhinav	88.33	90.91	11.00	5.50	4.60	0.60	4.35	8.25	2.00	13	DR	Oval
CD @5%	27.83	18.21	2.08	0.32	0.15	0.10	0.73	0.78	0.15			
CV (%)	19.17	8.21	11.07	2.30	0.95	5.25	5.47	3.70	2.26			

Table 2 : Performance of tomato F_1 hybrids at ICAR-IIHR, Bengaluru (Winter season, 2017-18)

Hybrid	Estimated yield (t/ha)	Average Fruit weight (g)	No of fruit/ kg	Fruit length (cm)	Fruit width (cm)	Pericarp thickness (cm)	TSS (^{0}Brix)	Fruit firmness (kg/cm^2)	No. of locules
H-385 (Arka Apeksha)	-	-	-	-	-	-	-	-	-
H-387	34.00	85.86	11.65	6.83	6.33	0.67	5.17	8.00	3.00
H-391 (Arka Vishesh)	43.67	89.56	11.17	7.17	6.17	0.90	4.83	7.17	2.00
H-397	33.33	105.30	9.50	6.33	7.17	0.77	5.17	7.17	4.00
H-423	-	-	-	-	-	-	-	-	-
H-501	16.08	125.00	8.00	6.50	7.67	0.97	5.20	7.00	6.00
H-502	24.83	109.01	9.17	6.67	7.33	0.70	4.83	7.50	5.00
H-504	-	-	-	-	-	-	-	-	-
H-505	34.33	97.64	10.24	5.17	6.17	0.67	5.00	9.00	3.00
H-506	34.83	105.30	9.50	5.17	6.33	0.50	5.00	6.00	4.00
PH-1021	29.17	120.37	8.31	6.00	6.67	0.63	5.17	8.33	4.00
PH-1025	32.33	132.28	7.56	7.00	7.50	0.70	4.83	8.00	4.00
PH-6321	38.17	112.04	8.93	6.67	6.77	0.73	5.17	8.00	3.00
Arka Rakshak	40.00	93.94	10.65	6.67	6.83	0.83	4.17	7.50	4.00
Arka Samrat	40.17	86.75	11.53	6.17	7.00	0.80	5.00	8.00	3.00
Lakshmi	39.83	88.38	11.31	6.83	6.17	0.83	5.00	8.00	2.00
Shivam	37.83	72.12	13.87	6.50	6.17	0.53	5.17	7.00	5.00
Abhinav	32.33	92.98	10.76	4.50	6.00	0.60	5.00	6.17	4.00
CD @5%	15.62	30.37	2.12	0.65	0.49	0.10	0.40	0.39	0.31
CV (%)	6.78	6.81	2.21	1.29	2.00	7.49	2.87	1.45	2.14

Table 3 : Performance of promising tomato hybrids during rainy season (2018-19)

Hybrid	Estimated yield (t/ha)	Average Fruit weight (g)	No of fruit/kg	Fruit length (cm)	Fruit width (cm)	Pericarp thickness (cm)	TSS (^{0}Brix)	Fruit firmness (kg/cm^2)	No. of locules
H-385 (Arka Apeksha)	24.67	66.67	15.67	5.63	5.27	0.70	5.00	8.20	3.33
H-387	46.09	100.00	10.00	5.03	4.90	0.70	4.33	8.17	3.00
H-391(Arka Vishesh)	28.07	68.70	14.67	5.33	5.60	0.97	4.83	9.17	3.00
H-397	51.88	81.20	12.33	4.93	6.30	0.97	4.17	6.63	6.00
H-423	22.67	83.33	12.00	6.20	5.30	0.80	5.17	7.37	3.00
H-501	21.04	120.37	8.33	5.33	6.03	0.87	5.00	6.50	5.00
H-502	2.81*	93.94	10.67	4.00	5.90	0.91	5.17	7.33	5.67
H-504	1.04*	91.41	11.00	4.03	4.90	0.47	5.73	6.50	5.00
H-505	9.79	96.97	10.33	4.50	4.80	0.50	4.77	8.33	4.33
H-506	22.19	100.67	10.00	5.23	6.23	0.77	4.23	6.17	6.00
PH-1021	27.60	120.37	8.33	5.03	6.20	0.57	5.37	7.50	5.00
PH-1025	17.81	120.37	8.33	5.23	5.90	0.30	4.60	8.17	5.00
PH-6321	40.63	116.67	8.67	5.17	6.03	0.60	5.10	10.33	5.00
Arka Rakshak	52.71	91.41	11.00	6.17	5.83	0.93	5.17	10.30	3.00
Arka Samrat	40.73	120.37	8.33	4.97	5.73	0.83	5.33	8.70	5.00
Lakshmi	4.38*	84.92	12.00	5.10	5.33	0.70	4.17	7.50	5.67
Shivam	25.52	81.20	12.33	3.93	6.00	0.53	5.23	7.67	6.00
Abhinav	25.83	103.70	9.67	6.10	4.87	0.90	4.50	8.50	2.00
CD@5%	18.50	15.12	2.17	0.31	0.45	0.18	0.79	0.48	0.42
CV (%)	9.30	0.96	2.45	0.46	3.12	2.82	0.65	1.99	1.26

Table 4 : Performance of tomato hybrids during winter season (2018-19)

Hybrid	Estimated yield (t/ha)	Fruit length (cm)	Fruit width (cm)	Pericarp thickness (cm)	TSS (^{0}B)	Fruit Firmness (kg/cm^2)	No of locules
H-385 (Arka Apeksha)	30.0	6.8	6.1	0.7	5.3	7.5	2.3
H-387	28.8	6.9	5.6	0.7	4.5	7.0	3
H-391 (Arka Vishesh)	31.4	6.5	5.6	0.7	4.7	6.6	2.7
H-423	28.9	7	5.6	0.7	4.4	7.3	3.3
H-501	24.8	5.5	7	0.4	4.8	6.0	5.3
H-502	28.1	4.5	6.7	0.6	5.4	5.7	5.7
H-504	28.6	4.2	5.8	0.5	5.5	6.1	5.0
H-505	26.1	5.8	6.8	0.7	5.3	6.9	5.7
H-506	28.0	5.3	6.5	0.8	4.6	6.9	5.3
PH-1021	28.3	5.4	5.8	0.5	5.4	7.7	5.7
PH-1025	25.3	6.6	7	0.5	5.2	5.9	6.3
PH-6321	32.3	5.7	5.7	0.6	5.5	6.0	6.3
Arka Abhed	28.9	5.4	6.1	0.7	5	6.7	6.0
Arka Rakshak	26.6	6.1	5.4	0.7	5.2	6.7	2.7
Arka Samrat	23.7	6.2	6.2	0.5	5.5	6.0	4.0
Lakshmi	22.9	4.4	5.8	0.5	5.8	5.8	4.0
Shivam	21.6	4.6	5.5	0.6	4.8	6.0	4.7
Abhinav	30.7	6.3	5.2	0.7	5	7.8	2.0
CD (P=0.05)	5.35	0.25	0.45	0.2	0.65	0.86	1.58
CV (%)	2.4	0.53	0.88	3.91	1.4	1.61	3.99

Table 5 : Mean Performance of selected tomato F_1 hybrids for yield and quality parameters

Hybrid	Estimated yield (t/ha)	AverageFruit wt (g)	TSS (^{0}Brix)	Fruit firmness (kg/cm^2)	% Increase in yield over Abhinav
H-385 (Arka Apeksha)	46.00	95.14	5.15	7.85	15
H-387	41.75	77.56	4.70	7.80	
H-391 (Arka Vishesh)	43.19	69.88	4.90	7.20	7.5
H-397	47.46	74.43	4.60	7.30	
H-423	31.20	82.96	4.40	6.90	
H-501	33.49	101.55	5.35	6.40	
H-502	33.83	83.76	5.10	6.90	
H-504	31.38	88.17	5.30	6.75	
H-505	33.80	94.95	4.75	7.90	
H-506	40.04	88.97	4.90	7.00	
PH-1021	36.92	108.80	5.15	7.05	
PH-1025	39.34	92.57	5.15	6.90	
PH-6321	42.96	88.12	4.90	7.65	
Arka Rakshak	43.78	72.07	4.90	7.80	
Arka Samrat	42.56	75.82	5.30	7.30	
Lakshmi	35.88	65.68	5.15	6.55	
Shivam	38.00	72.89	4.95	6.55	
Abhinav	39.77	72.88	4.80	7.70	

Table 6 : Reaction of tomato F_1 hybrids to ToLCBV, BW, EB and LB during rainy season (2018)

Hybrid	Reaction to ToLCBV Disease Severity Score		Disease Reaction	Bacterial wilt incidence (%)	Reaction to EB (PDI)	Reaction to LB (PDI)
	30dpi	60dpi				
H-385 (Arka Apeksha)	0.44±0.22	1.00±0.19	HR	2 (R)	05 (HR)	97 (HS)
H-387	0.67±0.19	0.89± 0.29	HR	2 (R)	10 (HR)	92 (HS)
H-391(Arka Vishesh)	0.33 ± 0.19	0.67± 0.00	HR	1 (R)	10 (HR)	100 (HS)
H-397	0.00± 0.00	0.44± 0.19	HR	0 (HR)	05 (HR)	0 (HR)
H-501	0.22 ± 0.11	0.44 ± 0.11	HR	0 (HR)	20 (R)	94 (HS)
H-506	0.22 ±0.11	0.67± 0.00	HR	2 (R)	15 (R)	92 (HS)
Arka Rakshak	1.78 ±0.11	2.44± 0.19	MR	6 (R)	15 (R)	100 (HS)
Arka Samrat	2.00 ±0.19	2.78± 0.19	MR	8 (R)	20 (R)	100 (HS)
Abhinava	1.11± 0.11	1.67 ± 0.19	MR	9 (R)	30 (MR)	98 (HS)
Lakshmi	0.67± 0.19	2.17 ± 0.11	MR	58 (HS)	30 (MR)	100 (HS)
Shivam	0.83± 0.19	3.00 ± 0.11	S	45 (S)	05 (HR)	93 (HS)
Punjab Chuhara	1.75± 0.09	4.00 ± 0.00	HS	-	-	-
CD@5%	0.652	0.650				14.11
CV %	36.32	22.32				6.89

Note: dpi= days of post inoculation, HR= Highly Resistant, MR= Moderately Resistant, R= Resistant, S= Susceptible and HS= Highly Susceptible

Table 7 : Pooled analysis for estimated yield per hectare

Hybrid	Yield (t/ha)		
	2017	2018	2019
H-385 (Arka Apeksha)	83.0	24.7	30.0
H-387	84.0	46.1	28.8
H-391 (Arka Vishesh)	93.2	28.1	31.4
H-397	112.8	51.9	28.9
H-423	52.5	22.7	28.9
H-501	79.5	21.0	24.8
H-502	89.5	2.8	28.1
H-504	72.3	1.0	28.6
H-505	74.7	9.8	26.1
H-506	98.3	22.2	28.0
H-1021	88.8	27.6	28.3
H-1025	89.0	17.8	25.3
H-6321	92.2	40.6	32.3
Arka Rakshak	90.2	52.7	26.6
Arka Samrat	103.3	40.7	23.7
Laxmi	102.3	4.4	22.9
Shivam	99.8	25.5	21.6
Abhinav	88.3	25.8	30.7
CD (P=0.05)		10.86	
CV (5%)		24.58	

Assessment of Arka Apeksha (H-385) and Arka Vishesh (H-391) for processing qualities

Processing qualities in fine pulp were estimated in Arka Apeksha and Arka Vishesh at ICAR-IIHR, Bengaluru. Both the hybrids exhibited higher values for TSS (>5^{0}Brix), lycopene (>12 mg/100g) and colour index (47) (Table 8). Processing qualities in tomato puree was also estimated in Arka Apeksha and Arka Vishesh. Arka Vishesh recorded the highest TSS (11.20^0 Brix) when compared to commercial puree marketed by popular processing Industries such as Dabur, Kisan and Morton (Table 9). Both the hybrids also exhibited higher values for lycopene (> 13 mg/100g). Higher values were also observed for TSS (>27^{0}Brix) & lycopene (>14 mg/100g) in tomato paste in both the hybrids (Arka Apeksha & Arka Vishesh) (Table 10). In order to assess the processing qualities and suitability of Arka Apeksha (H-385) and Arka Vishesh (H-391), fruit samples were supplied to four commercial processing industries located in the different states in the country *viz.,* Sahyadri Foods, Nashik, Maharashtra state, Sun-sip Foods, Srinivasapura, Karnataka State, Jadli Foods, Krishnagiri, Tamil Nadu State and Cremica Food Industries Ltd., Phillaur, Punjab State. Sahydri Foods analysed fruit samples of four entries *viz.,* Arka Apeksha, Arka Vishesh, Abhinav and Arka Ashish (a pure line selection from UC82B) for Hunter Lab colour value, lycopene, acidity, TSS, pH and total solids in the initial pulp and puree (Table 11). Colour value was more than 2 in the puree in all the samples. Arka Apeksha and Arka Vishesh recorded TSS 4^0 Brix and >12^0 Brix in the initial pulp and puree respectively which was slightly more than dual

Table 8 : Processing qualities attribute for fine pulp

Hybrid	TSS (°Brix)	Total Solids (%)	Juice Yield (%)	pH	Acidity (%)	Vit-C (mg/ 100g)	Lycop-ene (mg/ 100g)	Tomato Colour Index
Abhinav	5.68	7.54	74	4.2	0.38	27.84	10.26	44
H-397	5.66	6.86	67	4.1	0.33	17.52	12.19	45
Arka Vishesh (H-391)	5.40	6.60	70	4.3	0.54	15.83	12.97	47
Arka Apeksha (H-385)	5.33	6.88	74	4.2	0.54	20.15	13.41	47
H-387	5.00	7.26	74	4.1	0.52	13.85	11.95	47

Table 9 : Processing qualities- tomato puree

Hybrids	TSS (°Brix)	pH	Acidity (%)	Vit-C (mg/ 100g)	Lycopene (mg/ 100g)	Colour Value	Tomato Colour Index
Abhinav	10.2	4.1	0.66	36.56	11.90	0.99	42.18
H-397	10.80	4.1	0.67	22.26	13.91	1.20	45.65
Arka Vishesh (H-391)	11.20	4.1	0.83	28.75	13.03	1.36	47.21
Arka Apeksha (H-385)	8.80	4.1	0.81	27.54	13.41	1.28	47.99
H-387	10.33	4.0	0.72	24.06	13.38	1.34	50.46
Dabur old	9.8	3.9	0.59	13.42	14.02	1.21	45.22
Dabur new sample	10	3.8	0.60	14.66	13.92	-	-
Kisan	8.9	4.0	0.62	26.47	10.65	1.31	47.10
Morton	9.0	4.0	0.634	19.74	10.72	1.14	45.38

Table 10 : Processing qualities-tomato paste

Hybrid	TSS (°Brix)	Acidity (%)	Colour Value as per formula	Tomato Colour Index	Vitamin C (mg/ 100g)	Lycopene (mg/ 100g)	Tomato Colour Index
Abhinav	28.0	1.95	1.20	47.72	47.13	12.85	28.0
H-397	27.5	1.31	1.73	53.36	32.08	14.16	27.5
Arka Vishesh (H-391)	27.0	1.72	1.38	48.98	38.97	14.13	27.0
Arka Apeksha (H-385)	26.2	1.43	1.40	50.65	36.58	14.15	26.2
Indira	28.0	1.12	1.21	45.22	32.33	14.08	28.0

purpose commercial hybrid Abhinav and processing variety Aka Ashish. But Arka Ashish (476) recorded highest lycopene (C/2 scale) followed by Abhinav (473), Arka Apeksha (469) and Arka Vishesh (442). Acidity was less than 0.26 in Arka Ashish and Abhinav. pH was less than 4.3 in all the entries. Arka Apeksha recorded the highest total solids (86.35%) (Table 11) in the puree. Both Arka Apeksha and Arka Vishesh had acceptable processing qualities. Sun-sip foods analysed fruit samples in Arka Apeksha, Arka Vishesh and Abhinav for process time, Brix, acidity, pH, colour value and number. of pouches filled. All the parameters were on par with each other in the initial pulp and the final product, where as Arka Apeksha (2 hr 12 min) took less time compared to Arka Vishesh (2 h 25min) & Abhinav (2 h 27 min)

Table 11 : Processing quality parameters of selected hybrids

Parameter	H-391 (Arka Vishesh)				Abhinav				H-385 (Arka Apeksha)				Arka Ashish			
	Initial Pulp		12 brix puree		Initial Pulp		12 brix puree		Initial Pulp		12 brix puree		Initial Pulp		12 brix puree	
Hunter Lab colour value	On C/2 Scale	On D65/2 Scale	On C/2 Scale	On D65/2 Scale	On C/2 Scale	On D65/2 Scale	On C/2 Scale	On D65/2 Scale	On C/2 Scale	On D65/2 Scale	On C/2 Scale	On D65/2 Scale	On C/2 Scale	On D65/2 Scale	On C/2 Scale	On D65/2 Scale
L	32.92	31.27	23.74	23.1	32.38	31.15	24.3	23.5	32.75	30.54	23.65	22.77	32.77	31.12	23.17	22.37
a	34.36	31.45	27.89	26.47	34.04	31.85	30.86	29.18	33.26	30.05	29.48	28.16	34.09	31.91	30	28.4
b	16.75	15.3	13.55	12.18	15.7	14.19	14.16	12.96	17.25	15.33	13.64	12.6	17.03	15.37	13.7	12.49
a/b	2.052	2.055	2.058	2.173	2.169	2.244	2.179	2.251	1.928	1.96	2.162	2.234	2.002	2.076	2.189	2.273
Lycopene C/2	440	NA	442	NA	471	NA	473	NA	409	NA	469	NA	428	NA	476	NA
Brix	4	12.2	4	12	4	12.2	3.2	12.1								
Acidity	0.3	0.94	0.25	0.63	0.35	0.62	0.26	1.07								
pH	4.1	3.93	4.14	4.1	4.12	4.09	4.14	4.16								
Total Solids (%)	**95.22%**		**85.38%**		**94.76%**		**85.91%**		**95.15%**		**86.35%**		**96.13%**		**84.78%**	

Courtesy: Mr. Sachin, Sahyadri foods, Nashik, Maharashtra

Table 12 : Processing quality parameters of selected hybrids

Parameter	Arka Vishesh (H-391)		Arka Apeksha (H-385)		Abhinav	
Net fruit weight (kg)	6		5.85		6	
Process Time	2 Hrs 25 Min		2 Hrs 12 Min		2 Hrs 27 Min	
Readings	Initial	Final	Initial	Final	Initial	Final
Brix	4.05	12.12	4.28	12.21	4.41	12.31
Acidity %	0.28	0.89	0.28	0.85	0.31	0.89
pH	4.16	3.51	4.01	3.71	4.0	3.85
Colour-a/b	1.75	1.98	1.9	1.97	1.9	1.98
No of Pouches Filled	2 No's	2 No's	2 No's			

Courtesy: Mr. Hemanth, Sun-Sip foods, Srinivasapura, Karnataka

Table 13 : Physical, chemical, organoleptic analysis of fresh fruits

Parameter	Abhinav	Arka Vishesh (H-391)	Arka Apeksha (H-385)
T.S.S.	4.2°Brix	4.2°Brix	4.2°Brix
ACIDITY (% as C/A)	0.27%	0.33%	0.38%
SEEDS PERCENTAGE	VERY LESS	VERY LESS	VERY LESS
COLOUR	DEEP RED	DEEP RED	DEEP RED
TASTE	NATURAL & CHARACTERSTICS OF RIPE TOMATO	NATURAL & CHARACTERSTICS OF RIPE TOMATO	NATURAL & CHARACTERSTICS OF RIPE TOMATO
FLUSH	GOOD/DEEP RED	GOOD/DEEP RED	GOOD/DEEP RED
FLAVOR	TYPICAL RIPE TOMATO FLAVOR	TYPICAL RIPE TOMATO FLAVOR	TYPICAL RIPE TOMATO FLAVOR
APPEARANCE	SOUND & GOOD	SOUND & GOOD	SOUND & GOOD

Table 14 : Processing quality characteristics of Hybrids; Arka Vishesh (H-391) and Arka Apeksha (H-385)

Hybrid	T.S.S. (⁰Brix)	pH	Acidity (%)	Hunter color value on C2 illumination	Viscosity (30 sec.) BOSTWICK	Visual observation
Arka Vishesh(H-391)	4.05	4.39	0.36	L=32.56 a=35.37 b=16.67 ab=2.12	14.00	Less juicy, soft skin, less seed
	4.00	4.44	0.32	L=35.80 a=34.89 b=17.96 ab=1.94	14.00	
	3.94	4.42	0.35	L=30.19 a=34.45 b=16.16 ab=2.13	14.20	
Mean	4.00	4.41	0.34	a/b=2.06	14.00	
Arka Apeksha (H-385)	4.15	4.36	0.38	L=32.52 a=35.12 b=16.84 ab=2.09	12.00	Hard skin, less seed
	4.10	4.43	0.33	L=36.51 a=35.75 b=18.09 ab=1.98	12.50	
	4.05	4.42	0.35	L=32.94 a=35.87 b=17.43 ab=2.06	12.50	
Mean	4.1	4.4	0.35	a/b=2.04	12.33	

Courtesy: Cremica, Phillaur, Punjab

Table 15 : Processable characteristics for Arka Vishesh (H-391) and Aka Apeksha (H-385)

Parameter	H-391	H-385	Parameters desired by Processing Industry
TSS (degree ^{O}Brix)	4-4.6	4-4.7	4.2 or higher (Higher the better)
Colour value	1.98-2.12	1.96-2.09	> 1.95
Acidity (%)	0.32-0.36	0.34-0.38	<0.40
pH	4.21-4.41	4.12-4.40	< 4.40
Texture/ Firmness	4.09-5.41	4.05-4.30	> 4
Lycopene (mg/100g fresh weight)	8.5-10.5	11.12-11.42	>8.0
Lycopene in tomato paste (mg/100g fresh weight)	14.14	14.15	>14
Viscosity (Bostwick, cms/30 sec)	14-14.20	12-12.50	7-14

(Table 12). Jadli foods carried out physical, chemical and organoleptic analysis of fresh fruits. All the parameters in Arka Apeksha and Arka Vishesh were on par with commercial hybrid Abhinav (Table 13). Cremica analysed both Arka Apeksha and Arka Vishesh for TSS (4^{0}Brix), pH (4.4), acidity (0.35), colour value (>2) and viscosity (12-14) (Table 15).

CONCLUSION

Values obtained for all the parameters revealed that both the hybrids in Arka Apeksha and Arka Vishesh were suitable for processing. The processing qualities analysed by four commercial processing industries were in the acceptable range as desired by the processing industry in India. However, there is a need to breed tomato varieties / F_1 hybrids with higher TSS ($5.5\text{-}6^{0}$ Brix).

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