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STUDIES ON THE PRODUCTION AND STORAGE OF TOMATO JUICE

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Abstract. Four tomato cultivars, viz., Lyallpur selected, Marion, Roma and Peshawar local were taken up for the production and storage studies on tomato juice. Effect of storage on various physicochemical characteristics, e.g. ascorbic acid, total acidity, pH, total soluble solids, viscosity, settling, organoleptic evaluation, etc. were investigated. Cultivar Lyallpur selected proved to be most suitable for juice production and storage under the conditions specified in the text. Calculations on the cost of production of tomato juice indicated the economic feasibility of this project.

Tomato juice is an excellent source of vitamins A and C among processed foods available to consumers in many developed countries. Jayadeviah *et al.*[1] named tomatoes a cheap source of vitamins A and C. Tomato fruit has also been labelled as an apple for the poor. Jabbar and Hujjatullah reported[2] that N.W.F.P. tomatoes contained 93.5% moisture, 52.0 mg/100 g ascorbic acid, while Spanish tomatoes have been reported[3] to contain 94.16% moisture, 2.51% reducing sugars and 23.0 mg/100 g ascorbic acid.

It has been reported[4] that processing of tomato juice resulted in decreased ascorbic acid, a little but measurable loss in carotene; while acidity and total sugars remained almost unchanged.[5] Studies on the effect of storage temperature on vitamin C retention have revealed[6,7] that high storage temperatures were undesirable. Nutting *et al.*[8] observed that tomato products containing 5.6–6.8% solids changed less in flavour and colour, and lost less ascorbic acid when stored at 100°F.

Likewise, many investigations on tomato products have been carried out in other countries, but almost nothing has been done to see the suitability of Pakistani tomato cultivars for processing and subsequent storage. Therefore, some of the promising tomato cultivars grown in N.W.F.P. were tested for their amenability to juice production and their suitability for the storage of processed juice. Moreover, economics of juice production was also studied as it would not be advisable to produce processed tomato juice at a price which is beyond the purchasing capacity of an average consumer.

Materials and Methods

Suitability of Tomato Cultivars for Juice Production. Four tomato cultivars viz. Lyallpur selected (L. selected), Marion, Roma and Peshawar local (P. local) were acquired from the Agricultural Research Institute, Tarnab. The tomatoes were harvested at a redripe maturity, transported to PCSIR Laboratories, Peshawar, and processed as follows :

Fresh tomatoes were washed, steam-blanched for 5 min and passed through a pulper using sieve No. 26 (dia of holes 0.023 in). Sodium chloride (2%) was added to the juice, filled in sterilized bottles, crown corcked, processed in boiling water for 10 min, cooled and stored at ambient temperature for further investigations. The following analyses were carried out on fresh weight basis:

(i) Fresh tomatoes were analysed for moisture content,[9] ascorbic acid,[10] and total acidity.

(ii) Processed juice was analysed for ascorbic acid, total acidity, pH (Beckman model 96), degree of Brix (Abbe refractometer) and viscosity (viscometer model SB 434).

(iii) The processed juice during storage was analysed for ascorbic acid, viscosity, degree of Brix, total acidity, pH and settling of juice, during various intervals up to storage time of 270 days. Organoleptic evaluations for desirable tomato colour of processed juice were also carried out during storage. These experiments were repeated during second season.

Economics of the Tomato Juice Production. The data regarding prices of fresh tomatoes were collected from the local vegetable market. The prices were taken at fortnightly intervals and 24 observations were recorded starting from June 1, 1971. The results are presented in Fig. 1. Although there would be a change in prices of fresh tomatoes year after year, the factor would be compensated by a proportional increase in the prices of the tomato products. Hence these calculations are applicable even to varying prices:

(a) Calculations of the Cost of Production of Tomato Juice:

(i) Price of 20 kg fresh tomatoes (as purchased on 1st June, Table 1)	Rs. 3.08
(ii) Amount of juice recovered from 20 kg fresh tomatoes	19.40 kg
(iii) Price of 19.40 kg tomato juice	Rs. 3.08
(iv) Overhead charges including labour, steam, electricity, depreciation of equipment, preserva-	

tive (Table salt etc.) @ 50% 1.54
(v) Cost of packaging materials (64 bottles of 300 g capacity each @ Rs. 0.25) 16.00
(vi) Total cost of production of 64 bottles juice (iii+iv+v) 20.62
(vii) Cost of production of one bottle juice of 300 g capacity 0.32
(viii) Cost of production of one kg juice packed in 300 g capacity bottles 1.06

(b) Statistical Analysis[11]

S.E. $= \sqrt{7.5283/23 \times 24} = 0.11$ '
t at 5% level $= 0.11 \times 2.069 = 0.228$
t at 1% level $= 0.11 \times 2.807 = 0.309$
(i) Confidence limits of average price at 5% level $= 1.13 \pm 0.228 = 0.902$ to 1.358.
(ii) Confidence limits of average price at 1% level $= 1.13 \pm 0.309 = 0.821$ to 1.439.
(iii) Calculated price of one kg bottled tomato juice = Rs. 1.06.

TABLE 1. PRICE SCHEDULE AND STATISTICAL ANALYSIS OF PRICES OF TOMATOES DURING THE 1970–1971.

Date	Month	X*	$X-\bar{X}$	$(X-\bar{X})^2$
1st	June	0·15	—0·98	0·9604
15th	June	0·24	—0·89	0·7921
1st	July	1·19	0·06	0·0036
15th	July	1·39	0·26	0·0676
1st	August	1·58	0·45	0·2025
15th	August	1·76	0·63	0·3969
1st	September	2·35	1·22	1·4884
15th	September	1·21	0·08	0·0064
1st	Oct.	1·19	0·06	0·0036
15th	Oct.	0·99	—0·14	0·0196
1st	Nov.	0·99	—0·14	0·0196
15th	Nov.	0·79	—0·34	0·1156
1st	Dec.	0·99	—0·14	0·0196
15th	Dec.	0·79	—0·34	0·1156
1st	Jan.	0·66	—0·47	0·2209
15th	Jan.	0·79	—0·34	0·1156
1st	Feb.	0·59	—0·54	0·2916
15th	Feb.	0·79	—0·34	0·1156
1st	March	0·99	—0·14	0·0196
15th	March	1·96	0·83	0·6889
1st	April	2·38	1·25	1·5625
15th	April	1·56	0·43	0·1849
1st	May	1·17	0·04	0·0016
15th	May	0·79	—0·34	0·1156
$\Sigma X = 27·25$		$\bar{X} = 1·13$	$\Sigma (X-\bar{X})^2 = 7·5283$	

X* price of one kg tomatoes in Rupees

Results and Discussion

Physicochemical Characteristics of Tomato Juice
Ascorbic Acid. Ascorbic acid content of L. selected, Marion, Roma and P. local tomato fruits were 41.5, 52.8, 39.5 and 47.6 mg/100 g respectively; however, after processing these values were lowered to 33.8, 45.9, 34.6 and 39.6 mg/100 g respectively.

Ascorbic acid content of tomato juice decreased during storage at room temperature, in agreement with the observations of Kattan *et. al.*[12] Major portion (60–70%) of this loss occurred during first 60-days of storage (Table 2); thereafter it was lost at a diminishing rate up to a storage time of 270 days. During the last few intervals of storage (from 180 to 270 days), a negligible loss of ascorbic acid was observed. The difference in per cent retention of ascorbic acid in the juice of various tomato cultivars was clearly observed only after 120-days storage (Table 2). The highest amount of ascorbic acid was retained by the juice of cultivar L. selected, while the lowest retention was recorded in P. local. Ascorbic acid retention of L. selected, Marion, Roma and P. local was 26.25, 25.40, 22.35 and 22.12% respectively, when analysed after a storage time of 270 days. In fresh tomatoes and freshly processed juice the highest amount of ascorbic acid was found in the variety Marion (fresh fruit, 52.80 mg/100 g, freshly processed juice, 45.92 mg/100 g). Therefore, it follows that higher ascorbic acid retention in the juice of variety L. selected up to a storage-time of 270 days may be attributed to its varietal characteristics, because all the four cultivars were processed and stored under the identical conditions.

Total Soluble Solids (TSS). Total soluble-solids content of juice of all the four cultivars was almost similar, when analysed just after processing. TSS of all the samples increased during storage. Cultivar Marion recorded maximum increase (2.0°Brix) while the minimum increase was observed in cultivar Roma (1.3°Brix), when analysed after a storage time of 270 days. This increase in TSS may be attributed to the solubilization of juice constituents during storage (Table 3). However, Kattan *et. al.*[12] reported a decrease in TSS of tomato juice stored at various temperatures. This may probably be possible, if the juice is improperly processed and the sugars or other soluble solids are broken up. However, Kattan *et al.*[12] did not analyse the juice for sugars or other individual soluble solids to have an experimental proof of this phenomenon.

pH and Titratable Acidity. At the start of the experiment pH of the juice of cultivars L. selected, Marion, Roma and P. local were 4.25, 4.29, 4.37 and 4.31 respectively. These values decreased by 0.09, 0.11, 0.17 and 0.11 respectively, after a storage time of 270 days, and total acidity increased gradually during the same storage time from 0.04 to 0.08% (Table 2). The decrease in pH and rise in total acidity may probably be due to the degradation of the pectic substances and the formation of free uronic acids.[13] However, minor variations in pH and acidity might be due to the varietal characteristics of tomatoes.

TABLE 2. EFFECT OF VARIETY AND LENGTH OF STORAGE ON ASCORBIC ACID RETENTION, TOTAL ACIDITY AND pH OF TOMATO JUICE.

Season	Storage time (Days)	Ascorbic acid retention (%)				Total acidity (%)				pH			
		L. selected	Marion	Roma	P. local	L. selected	Marion	Roma	P. local	L. selected	Marion	Roma	P. local
First													
	0	100·0	100·0	100·0	100·0	0·36	0·39	0·38	0·33	4·25	4·29	4·37	4·31
	30	60·2	46·0	59·0	56·2	0·36	0·36	0·36	0·34	4·25	4·28	4·36	4·30
	60	47·1	36·5	45·0	40·6	0·36	0·39	0·36	0·36	4·22	4·27	4·35	4·30
	90	34·3	28·1	32·9	29·5	0·37	0·39	0·38	0·38	4·21	4·25	4·32	4·28
	120	29·3	25·7	28·6	25·0	0·38	0·41	0·39	0·39	4·20	4·22	4·32	4·24
	150	28·6	23·8	27·5	24·4	0·39	0·43	0·38	0·39	4·21	4·24	4·30	4·22
	180	27·7	23·0	25·7	22·5	0·41	0·41	0·41	0·38	4·18	4·22	4·25	4·21
	210	27·4	23·0	25·7	22·5	0·41	0·41	0·41	0·41	4·18	4·20	4·22	4·20
	240	26·5	22·8	25·5	22·3	0·43	0·42	0·41	0·42	4·15	4·19	4·23	4·20
	270	26·3	22·4	25·4	22·1	0·42	0·42	0·42	0·43	4·16	4·16	4·20	4·20
Second													
	0	100·0	100·0	100·0	100·0	0·38	0·37	0·37	0·36	4·30	4·29	4·32	4·33
	30	62·1	51·1	58·7	55·3	0·38	0·38	0·38	0·36	4·31	4·26	4·32	4·31
	60	46·1	38·9	45·0	42·2	0·38	0·39	0·40	0·38	4·30	4·26	4·31	4·30
	90	38·3	30·1	34·4	30·5	0·39	0·39	0·40	0·39	4·29	4·25	4·30	4·30
	120	30·6	26·3	29·0	25·1	0·39	0·40	0·41	0·39	4·29	4·22	4·29	4·28
	150	29·0	22·9	27·8	23·8	0·40	0·41	0·41	0·39	4·28	4·20	4·29	4·22
	180	28·2	22·6	25·8	22·7	0·40	0·42	0·42	0·40	4·27	4·20	4·29	4·21
	210	27·6	22·1	25·4	22·4	0·41	0·42	0·42	0·42	4·27	4·20	4·26	4·20
	240	27·4	21·9	25·3	22·1	0·42	0·43	0·42	0·42	4·22	4·20	4·22	4·19
	270	27·1	21·8	24·9	21·9	0·42	0·43	0·43	0·42	4·20	4·20	4·21	4·20

Viscosity (*Engler's Units, E.U.*). Viscosity of the juice samples was determined after a storage period of 30 days. Juice of cultivar P. local showed the highest viscosity (4.68 E.U.), whereas cultivar Marion had the minimum viscosity (3.00 E.U.). These values gradually decreased in all cases. After a storage period of 270 days the decreases for Roma, P. local, Marion and L. selected were 1.35, 0.88, 0.65 and 0.49 E.U. respectively (Table 3). It was reported[14] that consistency of tomato juice depended upon the quantity, shape and degree of subdivision of the cell walls present as well as their pectin content. It was also reported[15] that viscosity of the juice was decreased with enzymic activities, while Luh and Daoud[16] observed that pectinesterase activity was increased with red-ripe maturity. Hence, L. selected and Marion cultivars might have comparatively lesser amounts of these pectin degrading enzymes. Miers *et al.*[17] observed that pectic enzyme activity was inhibited at low pH. The juices of L. slected and Marion cultivars remained viscous during storage as compared to other cultivars due to comparatively lower pH of their juices. Foda and McCollum[15] reported that the loss of consistency was due to hydrolysis and other types of degradation of the polymeric components present in the juice. Stier *et al.*[18] also associated the decrease of tomato juice viscosity to the depolymerization of pectic substances but intensity of this phenomenon vary with variety and more specifically with the stage of maturity at the time of harvesting.

Settling of Juice. The data reported in Table 3 represent a comparative statement of settling position in the juice of various tomato cultivars up to a storage time of 270 days. Serum separation observed after 30-days storage was not increased with the advancement of storage time. Therefore, with the length of storage, the settling was not increased. About 95% of the samples of all the four cultivars showed settling, the average of which is reported in Table 3. Cultivar L. selected recorded the minimum amount of settling (1.52 cm), whereas samples from the other three cultivars showed similar, but higher amount of settling than L. selected. Kattan *et al.*[12] reported that by increasing the size of screen openings, separation of clear serum could be minimized. Robinson *et al.*[19] observed that settling increased with increase in suspended solids and decreased with rupture of intact cells by homogenization. It has also been reported [19] that pectin content did not directly affect the degree of settling.

Organoleptic Evaluations. Processed tomato juice was organoleptically evaluated for its colour. The result of these tests showed that after 30-days storage the juice of L. selected had much better colour as compared to other three cultivars. The order of preference of the other three was : Marion > P. local > Roma. This order of preference remained unchanged up to a storage time of 270 days. Results of the present investigation agree with observations of Tenov *et al.*[20] that Roma retained good colour on processing. However, the colour deteriorated considerably during storage.

Economics of the Production of Tomato Juice. The cost of production of one kg. processed tomato juice has been calculated as Rs. 1.06 provided the juice is produced during the first week of June, when there is glut of this fruit in the market. The calculated value (Rs. 1.06) falls within the price range of fresh tomatoes as observed from 15th October to 1st March and 15th May to 15th June (Table 1). The average price of 24 observations, plotted in Fig. 1, comes to be Rs. 1.13. Thus, the calculated price of one kg processed juice, i.e. Rs. 1.06, falls within the confidence limits of average price both at 5 and 1% levels. These observations indicate that the difference

TABLE 3. EFFECT OF VARIETY AND LENGTH OF STORAGE ON TOTAL SOLUBLE SOLIDS, VISCOSITY AND SETTLING OF TOMATO JUICE.

Season	Storage Time (Days)	TSS°(Brix)				Viscosity (Engler's units)				Settling (cm)+			
		L. selected	Marion	Roma	P. local	L. selected	Marion	Roma	P. local	L. selected	Marion	Roma	P. local
First													
	0	6·6	6·4	6·8	6·5	*	*	*	*	—	—	—	—
	30	6·7	6·4	7·0	6·7	3·64	3·00	4·40	4·68	1·52	2·54	2·67	2·54
	60	7·2	7·0	7·4	7·2	3·48	2·88	4·25	4·63	1·52	2·67	2·67	2·54
	90	7·4	7·5	7·6	7·6	3·35	2·75	3·95	4·47	1·66	2·67	2·67	2·67
	120	7·7	8·0	7·8	7·9	3·25	2·50	3·75	4·39	1·66	2·67	2·79	2·67
	150	7·8	8·2	8·0	7·9	3·20	2·55	3·35	4·03	1·66	2·54	2·79	2·41
	180	7·8	8·4	8·0	8·0	3·20	2·40	3·40	4·10	1·52	2·54	2·67	2·67
	210	7·9	8·4	8·0	8·0	3·15	2·38	3·30	4·00	1·66	2·67	2·67	2·67
	240	7·9	8·4	8·1	8·0	3·15	2·44	3·15	3·78	1·66	2·67	2·67	2·67
	270	8·0	8·4	8·1	8·1	3·15	2·35	3·05	3·80	1·66	2·67	2·67	2·67
Second													
	0	6·5	6·5	7·0	6·5	3·60	3·10	4·48	4·60	—	—	—	—
	30	6·5	6·6	7·1	6·6	3·51	2·85	4·45	4·52	1·66	2·41	2·54	2·54
	60	6·8	7·0	7·2	7·1	3·44	2·75	4·40	4·40	1·66	2·54	2·54	2·67
	90	6·9	7·1	7·2	7·4	3·35	2·60	4·28	4·35	1·52	2·54	2·54	2·54
	120	7·3	7·4	7·4	7·5	3·30	2·50	4·05	4·05	1·52	2·54	2·54	2·54
	150	7·4	7·6	7·7	7·7	3·25	2·45	3·90	4·15	1·78	2·54	2·54	2·67
	180	7·7	7·9	7·6	7·9	3·20	2·35	3·75	3·90	1·66	2·67	2·41	2·54
	210	7·7	8·2	7·7	8·0	3·15	2·45	3·55	3·85	1·66	2·67	2·54	2·67
	240	7·8	8·4	8·0	8·1	3·15	2·40	3·40	3·80	1·66	2·54	2·54	2·67
	270	8·0	8·5	8·0	8·1	3·10	2·40	3·25	3·75	1·66	2·67	2·67	2·67

* Readings on viscosity could not be taken at 0–days storage due to unavoidable circumstances; † Average of five readings.

between the average price of fresh tomatoes and the calculated price of bottled juice is statistically insignificant. Therefore, processing of tomato juice is economically feasible. Moreover, production of tomato juice is economically feasible. Moreover, production of tomato juice not only ensures utilization of surplus tomatoes at the time of glut, which otherwise would have resulted in wastage of this valuable food, but would also make it possible for the consumer to purchase the juice of this fruit at reasonable prices throughout the year.

Conclusion

Storage analyses of tomato juice showed that cultivar L. selected was the most suitable one for processing and storage of juice as far as ascorbic acid retention, maintenance of the juice consistency, nonseparation of clear serum, and other changes (i.e. changes in soluble solids, pH, acidity and colour grading) were concerned as compared to the other cultivars studied during these investigations. Similar results were obtained when the experiment was repeated during the second season.

The pilot-plant scale production of tomato juice showed that it may prove industrially economical and viable project. The cost of this juice can certainly be decreased by overcoming the cost of packaging material, as about 80% of the funds are consumed for the purchase of packing materials. This cost would decrease if an arrangement could be made for the recycling of the bottles or if a cheap disposable packaging material is used. However, if that is not possible at present, even then this cost can still be decreased by going into commercial production of the juice, where the price of raw materials, processing cost and depreciation would decrease, resulting in a cheaper product, consequently making the production of tomato juice more economical.

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