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Effect of anti-browning agents on shelf life extension and color parameters of tamarind (*Tamarindus indica* L.) pulp

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ABSTRACT

Major challenge in tamarind storage is prevention of blackening or browning of tamarind at tropical conditions. The pulp of tamarind fruit has tartaric acid, which renders it acidic in taste, and hence, is widely used for domestic and industrial purposes. It also rich in reducing sugars, pectin, proteins, fiber, and cellulosic materials. Reaction of sugars with amino acids (especially lysine) through Maillard reaction is responsible for the non-enzymatic browning of tamarind pulp. In this study fresh tamarind pulp was treated with anti-browning agents such as ascorbic acid added @ 0.34 g/100 g, sodium chloride (NaCl) added @ 0.58 g/100 g, ethylenediamine tetra acetic acid (EDTA) added @ 0.5 g/100 g and potassium metabisulphite (KMS) added @ 0.125 g/100 g of tamarind and were analysed for and total reducing sugar and colour values to assess extent of the browning reaction. The tamarind pulp was treated with anti-browning agents such as ASC added @ 0.34 g/100 g, NaCl added @ 0.58 g/100 g, EDTA added @ 0.5 g/100 g and KMS added @ 0.125 g/100 g allowed for six months storage and were analysed for reducing sugars and colour values to assess extent of the browning reaction. The results showed that the treatment T_{11} (combination of anti-browning agents such as ASC, KMS and NaCl) showed lowest color change (23.84) and preserving the natural color of tamarind pulp during six months of storage.

Key words: Tamarind pulp, anti-browning agents, shelf-life, color values.

INTRODUCTION

The tamarind fruit's pulp contains tartaric acid, giving it an acidic flavour and making it popular for both home and commercial uses. India produces about 2.5 lakh tonnes of tamarind pulp annually. Reducing sugars, pectin, proteins, fibre, and cellulosic components are also present. Each sample has a different amount of sugar and acid; for instance, tartaric acid ranges from 8 to 18%, reducing sugars are 25 to 45%, pectin is 2.5 to 3.5%, and proteins are 2 to 3% (Gunasena *et al*., 6). Tamarind is a good source of vitamins, minerals, and fiber. It is particularly rich in magnesium, potassium, iron, and calcium (Kumar *et al.,* 23). Proline and pipecolinic acid are the two main amino acids found in tamarind pulp, which has an approximate 3% crude protein content total protein in tamarind pulp (Shankaracharya, 17). The combined form of tartaric acid makes up half of it, mostly in the form of potassium bitartrate and, to a lesser extent, calcium tartrate. Glucose and fructose constitute approximately 70% and 30%, respectively, of the total sugar content, while sucrose is present in only trace amounts. Non-enzymatic browning of food and agricultural products results from the Maillard reaction, which involves the combination of sugars with amino acids. Because it possesses a free -amino group that may easily react with reducing sugars, lysine is the main amino acid that contributes to this kind of reaction. The color development of the pulp is minimal since the Maillard reaction is reversible in its early stages, although some findings suggest that the amino acid's nutritional availability is decreased (Ajandouz and Puigserver, 2). The alkaline breakdown of sugar and, to a lesser extent, the interaction between lysine and glucose have been reported to be the principal causes of the generation of dark coloured products in glucose-lysine solutions at pH values ranging from 3 to 9. The two other basic amino acids, histidine and arginine, did not significantly impact the colour development in heated glucose solutions, therefore the effect of lysine cannot be attributed to its properties alone (Nooshkam *et al*., 14). Proline and other hydrophobic amino acids were found to be less reactive than the other amino acids, with the exception of tryptophan and hydroxyl amino acids, which reacted quickly, in a study on the extent of Maillard product formation in parenteral alimentary solutions containing 25% glucose and 4.25% 14C-labeled amino acids (Kotecha and Kadam, 10). It is well known that the mechanisms involved in the sugar caramelization account for at least some of the complexity of nonenzymatic browning reactions.

The shelf life of food is determined by both intrinsic factors (related to the food itself) and extrinsic

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factors (related to storage and handling) (Khushbu *et al*., 20). Post-harvest management of horticultural crops involves practices and techniques that preserve quality, extend shelf life, and reduce losses during storage (Barua *et al*., 25). Major food quality losses result from the Maillard process. Melanoidins, which are chemically stable and nutrient-unavailable compounds, might result in unfavourable alterations. The Maillard reaction results in the degradation of amino acids as well as a reduction in amino acid availability. This reduced availability is caused by at least three different processes: the Maillard reaction involving an amino acid side chain, internal condensations or aldol reaction that cause cross-links to form between peptide chains, and the general lower digestibility of the protein processes. The ratio of amino acids to sugars, water quantity, pH, and organic acids all have an impact on the Maillard process. While the Maillard process was favoured by higher temperatures, the non-enzymatic browning reaction was increased at neutral or alkaline pH (Adrian *et al*., 1). Therefore, it is crucial to keep an eye on how the colour of tamarind pulp changes while it is being stored in order to identify the root of the problem. Enzymatic and non-enzymatic (Maillard) reactions, which are frequent in many agricultural and food products, appear to be the two most likely sources. However, even though it is known that tamarind pulp darkens during storage procedures, it is difficult to determine colour changes during storage and comprehend how such changes in tamarind pulp occur. Within a year, the tamarind pulp's initially brownish-red hue darkens and nearly becomes black. Numerous agricultural produce goods, including potatoes. and apples have been shown to contain polyphenol oxidase (Gudeta *et al*., 5). Although it is recognised that the phenomena of tamarind pulp darkening are important both academically and economically, the cause of the phenomenon is still not fully understood. Browning reactions from enzymatic and non-enzymatic (Maillard) reactions can be controlled by using of various anti browning agents such as ASC (Kumar *et al*., 24).

MATERIALS AND METHODS

Ripened tamarind pods were collected from tamarind farms of Madanapalle village, Chittoor district, Andhra Pradesh. After harvesting the tamarind pods, the outer hard shell was removed and deseeded. This deseeded pulp was used for this study. Incorporation of chemicals into the food and stored under different conditions had a significant influence on food browning (Rather *et al*., 21). Anti-browning agents such as ASC added @ 0.34 g/100 g, NaCl added @ 0.58 g/100 g, EDTA added @ 0.5 g/100 g and KMS added @ 0.125 g/100 g of tamarind were added individually and in combination of them according to safe levels given by World Health Organization. An experimental design for treatments for prevention of browning in tamarind pulp given in Table 1.

Moisture analysis for tamarind pulp was performed by method no. 44-19 (AACC, 3) and crude fat with adopting AACC (2000) method no. 30-20 with the help of soxhlet instrument (FossST243 Soxtec B-811, Denmark) using n-hexane as solvent. Sample's crude protein contents in tamarind pulp determined following AOAC method no. 950.48 using Foss Auto Kjeldahl (Kjeltec 8100). Crude fibre of samples analyzed (AOAC, 4) using Foss FT 122 Fibertec instrument.

By using the Karel and Labuza (9), reducing sugars were calculated. There were three replications carried out. 10 cc of distilled water were used to dissolve 1 g of tamarind pulp, which was then extracted for 2 hours. It was then centrifuged for 20 minutes at 5000 rpm. In a test tube, 1 ml of supernatant and 1 ml of DNS were added. For 10 minutes, tubes were boiled, then cooled. At a wavelength of 550 nm, absorbance was measured after the addition of two ml of distilled water.

Color characteristics studied with color lab (Lovibond RT850i) which records L* (lightness), a* (-a greenness; +a redness) and b* (-b blueness;

Table 1. Experimental design for treatments for prevention of browning in tamarind pulp.

Treatment code	Treatment
T_1	
T_2	NaCl
T_3	KMS
T_4	EDTA
T_5	ASC + NaCl
T_6	ASC + KMS
T_7	NaCl + KMS
T_8	ASC + EDTA
T_9	NaCl + EDTA
T_{10}	EDTA + KMS
T_{11}	ASC + NaCl + KMS
T_{12}	ASC + NaCl + EDTA
T_{13}	ASC + EDTA + KMS
T_{14}	NaCl + EDTA + KMS
T_{15}	ASC + NaCl + EDTA + KMS
T_{16}	Control

+b yellowness) with a measuring head hole of 22 mm, illuminance of D65 and 108 standard observer, calibrated to a white plate (X: 79.61, Y: 84.45, Z: 90.64) (Schnell *et al*, 16). Following equations (1 and 2) were used to describe the colour characteristics such as browning index and color change of tamarind pulp treated with anti-browning agents over the period of six months with 30 days interval.

$$\text{Browning Index (B.I)} = \frac{[100\,(x - 0.31)]}{0.17};$$

$$\text{(Where, } x = \frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 0.3012b^*)} \quad (1)$$

$$\text{Color change } (\Delta E) = \sqrt{(L_0^* - L^*) + (a_0^* - a^*) + (b_0^* - b^*)} \quad (2)$$

Where L_o^*, a_o^*, and b_o^* denote the initial color parameters for the pulp; and L^*, a^*, and b^* correspond to the ones afterwards.

RESULTS AND DISCUSSION

The results pertaining to proximate analysis and characteristics of fresh tamarind pulp are presented in Table 2. Moisture plays major role in properties of food products and their shelf life. This moisture (21 ± 0.3 %) in tamarind pulp favors the enzymatic browning and solubility of solids and effect on shelf life of tamarind pulp during storage (Kaleemullah and Gunasekar, 7). Some findings revealed that the tamarind pulp stored in aluminium foil and polyethylene bags showed significantly lower moisture absorption rates, attributed to the impermeable nature of aluminium foil and polyethylene bag. It was also noted that aluminium foil demonstrated higher water vapour resistance, followed by the polyethylene bag (Pal and Mukherjee, 15; Kan and Miller, 8). Tamarind pulp is rich source of natural acids (12.5 ± 0.2 %) such as tartaric acid and ASC. Fresh tamarind pulp had protein content of 2.8 ± 0.1 %, fat as 0.12 ± 0.0 %, crude fiber 5.6 ± 0.2, carbohydrates (%) 66.48 ± 1.2 and pH as 2.3 ± 0.1. Color of pulp was light brownish red whereas the color values of fresh tamarind pulp were recorded as follows *L** as 49.25 ± 0.2, *a** as 38.01 ± 0.2, and *b** as 20.03 ± 0.2 the results pertaining to properties and proximate composition of tamarind pulp (Table 3).

Table 2. Properties and proximate composition of tamarind pulp.

Properties	Value (±S.D.)	Properties	Value (±S.D.)
Protein (%)	2.8 ± 0.1	Color values (*L*, a*, b**)	49.25 ± 0.2, 38.01 ± 0.2, 20.03 ± 0.2
Fat (%)	0.12 ± 0.0	Color	Light brownish red
Ash (%)	2.8 ± 0.1	Acidity (%)	12.5 ± 0.2
Crude fiber (%)	5.6 ± 0.2	pH	2.3 ± 0.1
Carbohydrates (%)	66.48 ± 1.2	Moisture (%)	21 ± 0.3

Table 3. Reducing sugars (%) content changes during storage of tamarind pulp.

Treatment	0 day	30 days	60 days	90 days	120 days	150 days	180 days	S.E.
T_1	12.44	12.55	14.63	15.62	19.44	20.44	20.14	1.33
T_2	11.05	11.44	13.24	15.26	17.05	20.05	24.05	1.80
T_3	13.93	14.05	15.12	16.15	17.93	19.93	23.93	1.37
T_4	12.27	13.93	14.46	15.38	17.27	19.44	22.27	1.31
T_5	12.14	12.27	13.44	16.01	16.54	20.05	24.54	1.72
T_6	12.29	14.44	15.05	17.51	19.44	24.15	26.12	1.94
T_7	12.94	13.05	14.93	16.01	17.05	17.27	21.05	1.06
T_8	12.98	16.93	17.27	18.16	20.91	22.34	24.35	1.45
T_9	12.6	15.27	15.69	16.73	17.05	18.05	20.96	0.98
T_{10}	12.99	15.93	16.08	17.13	20.45	23.54	24.51	1.62
T_{11}	12.04	14.27	16.13	17.01	17.27	20.27	20.94	1.19
T_{12}	12.31	14.54	15.48	16.84	19.24	22.04	23.62	1.55
T_{13}	12.418	15.21	16.13	16.67	18.24	21.34	23.14	1.39
T_{14}	12.14	14.35	16.37	17.41	19.44	20.44	22.14	1.33
T_{15}	12.64	14.17	15.79	16.42	17.05	19.05	22.93	1.27
T_{16}	12.2	15.77	16.29	17.25	19.45	20.15	23.54	1.37

The amount of reducing sugars in tamarind pulp ranged from 11.05 % - 26.12 % and were increased gradually as the stotage period increased. The minimum amount of reducing sugars observed in treatment T1 (20.14 %) followed by treatment T11 (20.94 %) and treatment T9 (20.96 %) after 180 days of storage. The maximum amount of reducing sugars observed in treatment T6 (26.12 %) followed by treatment T5 (24.54 %) and treatment T10 (24.51 %) after 180 days of storage of tamarind pulp (Fig. 1). These reducing sugars increased slowly upto 90 days then sudden increase was observed upto 180 days. The fact that anti-browning agents may interact with so many distinct chemical processes accounts for the efficiency of their addition in regulating a range of chemical reactions in tamarind pulp (Ubbaonu, 18). During fruit ripening, the conversion of starch hemi celluloses and organic acids into sugars leads to an increase in sugar content from harvest to ripening, followed by a decline during the peak of the senescence (Marichamy *et al*., 12). Reducing sugars and amino acids combine to form the nonenzymatic browning process known as the Maillard reaction (Kotecha and Kadam, 10). The enzymes in the browning reaction are irreversibly inactivated at lower pH values, may be around 3.0 or lower, due to the addition acidulents like ascorbic acid. ASC addition increased the pulp's acidity, attributed to the combined effects of tamarind pulp's tartaric acid and the added ASC (Younis *et al*.,19). Further, ascorbic acid's oxygen scavenging activity supports its role in preventing browning (Li-Beisson *et al*., 11; Hazarika and Lalrinpuii, 22).

These reactants are present in the tamarind pulp, and how much browning occurs depends on the concentration of the reactive species as well as the moisture content, pH, and temperature to which the tamarind pulp is subjected during processing, storage, and cooking. Because they result in the development of undesirable colours and off-flavors as well as losses in solubility and nutritional content due to reactions involving the lysine moieties and other groupings in tamarind protein, browning reactions in tamarind pulp are frequently seen as harmful (McWeeny *et al*., 13). The colour change in tamarind pulp during storage was observed. The results related to effect of anti-browning agents on tamarind pulp's colour parameters such as Δ*E* (Colour change) (Table 4 & Fig. 3) and browning index presented in (Table 4 & Fig. 2). There was a decrease in luminosity (*L**-values) of the fresh and samples with six months storage which ranged from 62.56 to 1.00 which occurred for 0 month of storage to six months storage. This represents the transition from fresh to stored samples. For the 0 and 6 months, there was a gradual change in the color parameters. The *L** values decreased gradually. During zeroth day storage the treatment T_6 sample showed maximum lightness (*L** 62.56) and T_1 sample showed lowest lightness (*L** 25.25). The color value, *a** with positive value indicates redness. T_{15} sample had maximum *a** value (15.00), this redness may be due to natural color of tamarind compared to other samples whereas lowest *a** value (3.40) observed

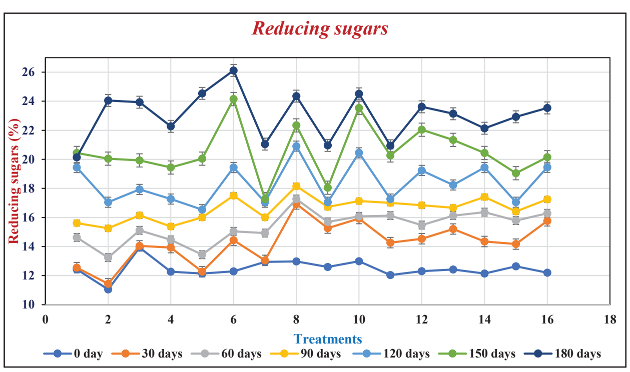

Fig. 1. Reducing sugars (%) content changes during storage of tamarind pulp.

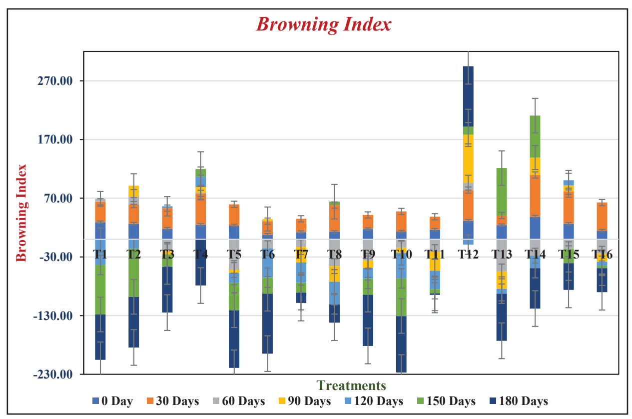

Fig. 2. Browning index of tamarind pulp treated with anti-browning agents.

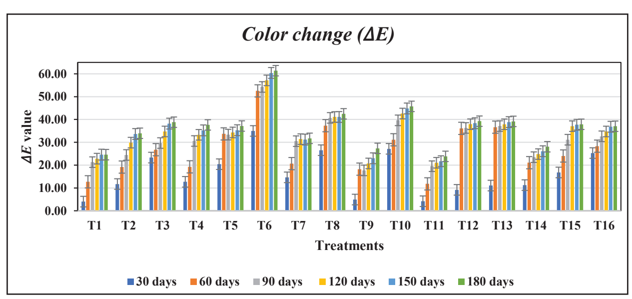

Fig. 3. Color change (ΔE) in tamarind pulp treated with anti-browning agents.

Table 4. Browning index of tamarind pulp treated with anti-browning agents.

Treatment	0 day	30 days	60 days	90 days	120 days	150 days	180 days	S.E.
T_1	29.13	34.84	4.97	-1.07	-42.67	-84.31	-77.26	18.47
T_2	26.66	32.57	12.88	19.20	-15.73	-82.33	-86.21	19.23
T_3	18.01	35.04	-20.31	-5.58	3.23	-21.21	-77.78	13.66
T_4	24.67	53.55	1.59	9.15	17.76	13.06	-78.75	15.44
T_5	23.54	36.00	-52.39	-4.51	-17.41	-46.54	-98.18	17.65
T_6	7.74	23.13	-15.14	3.65	-50.31	-27.32	-102.00	16.07
T_7	12.34	22.69	-13.24	-26.14	-34.43	-16.99	-17.69	7.78
T_8	12.43	45.96	-45.72	-26.42	-38.77	5.69	-31.06	12.62
T_9	17.39	24.10	-36.65	-12.32	-18.20	-27.09	-87.34	14.03
T_{10}	13.25	34.18	-14.34	-9.13	-43.10	-64.19	-96.28	17.09
T_{11}	16.44	22.03	-21.68	-31.86	-31.40	-7.19	-2.56	8.21
T_{12}	31.63	52.23	12.65	82.03	-9.07	13.54	102.78	15.26
T_{13}	24.11	16.46	-54.79	-29.63	-8.24	80.74	-80.18	20.34
T_{14}	38.61	71.02	-27.88	29.67	-21.28	71.38	-68.82	20.27
T_{15}	26.45	55.31	-16.82	10.17	8.83	-23.69	-45.59	12.75
T_{16}	14.72	47.87	-24.47	-14.13	-6.70	-3.93	-40.92	10.84

in T_{11} in which redness was masked by added anti-browning agents. The color value, b^* with positive value indicates yellowness and was gradually decreased in this study. During zeroth day storage the maximum b^* value (2.40) was found in T_{12} sample followed by T_1 sample, remaining samples showed similar yellowness values. The interaction of storage temperatures, relative humidity and sugars, amino acids present in tamarind pulp might be the cause to decrease in lightness (L^* value) and caused browning of tamarind pulp (Kotecha and Kadam, 10). Some of the findings revealed that the tamarind pulp treated with 0.2% sulphur fumes and kept in aluminium foil followed by refrigerated storage significantly reduced browning (Marichemy *et al.*,12).

There was a decrease in browning index of the fresh and samples with six months storage which ranged from 38.61 to -102.0 which occurred for 0 month of storage to six months storage except in T_{12} treatment sample (102.7). This represents the browning transition from fresh to stored samples. For the 0 and 6 months, there was a gradual change in the color parameters. The browning index values decreased gradually. During zeroth day storage the treatment T_{14} sample showed maximum browning index (38.61) and T_6 sample showed lowest browning index (7.74). During 6 months storage the treatment T_{12} sample showed maximum browning index (102.7) and T_6 sample showed lowest browning index (-102.00). During zeroth day storage the treatment T_6 sample showed maximum color change (*ΔE*) (34.98) and T_1 sample showed lowest color change (Table 5). During 6 months storage the treatment T_6 sample showed maximum color change (61.38) and T_{11} sample showed lowest color change (23.84). For tamarind pulp, Table 4 displays the browning index, which is a measurement of the Maillard process. The Maillard process is present in ripe tamarind pulp as evidenced by a significant decrease in browning index during storage due to addition of anti-browning agents to the tamarind pulp. The results showed that the treatment T_{11} had lowest color change (23.84) and preserving the natural color of tamarind pulp during six months of storage.

The tamarind pulp was treated with anti-browning agents such as ASC added @ 0.34 g/100 g, NaCl added @ 0.58 g/100 g, EDTA added @ 0.5 g/100 g and KMS added @ 0.125 g/100 g allowed for six months storage and were analysed for reducing sugars and colour values to assess extent of the browning reaction. The combination of anti-browning agents such as ASC, KMS and NaCl showed maximum prevention of color change in tamarind pulp.

AUTHORS' CONTRIBUTION

Writing - original draft, Formal analysis, Software, Data curation (RRM); Investigation, Writing – review

Table 5. Color change (ΔE) in tamarind pulp treated with anti-browning agents.

Treatment	0 day	30 days	60 days	90 days	120 days	150 days	180 days	S.E.
T_1	0.00	4.01	12.70	21.31	22.84	24.59	24.58	3.88
T_2	0.00	11.71	19.15	24.45	29.86	33.65	33.96	4.74
T_3	0.00	23.30	26.77	29.68	34.75	38.19	38.81	5.06
T_4	0.00	12.69	19.25	30.57	33.29	35.24	37.62	5.27
T_5	0.00	20.41	33.69	33.37	34.32	35.30	37.13	5.07
T_6	0.00	34.98	52.53	54.25	57.13	60.39	61.38	8.33
T_7	0.00	14.65	20.66	30.49	31.39	31.20	31.74	4.56
T_8	0.00	26.55	37.29	40.70	41.11	41.10	42.48	5.83
T_9	0.00	4.92	18.24	17.71	20.73	23.01	27.34	3.74
T_{10}	0.00	27.15	31.11	39.62	42.61	44.83	45.74	6.11
T_{11}	0.00	4.19	11.79	19.53	21.03	21.72	23.84	3.56
T_{12}	0.00	9.17	36.10	36.29	37.93	38.37	39.25	6.18
T_{13}	0.00	11.05	36.63	37.11	37.90	38.85	39.17	6.11
T_{14}	0.00	11.25	21.08	23.48	24.84	26.09	28.05	3.82
T_{15}	0.00	16.79	24.00	31.13	37.07	37.69	37.90	5.33
T_{16}	0.00	25.29	28.31	32.64	34.75	36.82	37.05	4.92

& editing, Supervision, Validation (BP); Writing – review & editing (KS).

DECLARATION

The authors do not have any conflicts of interest to declare.

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