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Full Paper

CHANGES IN SOME PHYSICAL QUALITY PARAMETERS AND TOTAL ANTIOXIDANT STATUS OF TOMATO BASED PULP BLENDS DURING STORAGE

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ABSTRACT

Tomato pulp blends prepared from tomato – watermelon – pineapple pulp in the ratios 1:1:1, 1:1:2 and 2:1:1 (v/v/v) were pasteurized and stored in brown crown corked bottles under refrigeration (5 ºC), ambient (29 ºC) and at 40 ºC in thermostatically controlled environment. Change in colour, viscosity and total antioxidant capacity were evaluated using Hunter *L a b* colourimetric, rotational viscometric and conductometric techniques. The *a*-values and redness factor $(a/b)^2$ changed from 28.89 and 1.77 to 30.22 and 2.83 after 40 days at 40 ºC in TWP 211_P, and the increase in a-value and redness factor correlated positively ($r^2 \geq 0.830$) with the increase in total antioxidant capacity of blends.

Key words: *Tomato blends, colourimetry, redness factor, total antioxidant capacity.*

1. INTRODUCTION

The visual quality of tomato products is a factor in consumer acceptance and preference, and thus a major factor in tomato products' quality evaluation. Lycopene, a major carotenoid in red tomato is responsible for the intense red colour of ripe tomato and tomato products. The Π-electrons of the extended conjugated double bonds systems of lycopene has been identified as the light absorbing chromophore responsible for the attractive colour in tomato (Rodriguez – Amaya, and Furr, 1993).

However, autoxidation of lycopene during heat processing and storage have been known to deplete lycopene and color in tomato products (Shi and Lemaguer 2000). This may not be visually perceived because of darkening resulting from the interaction between the intermediates of polyphenol degradation and product of ascorbic acid depletion products in fruit pulp (Anese *et al.*, 1999, Krifi *et al.*, 2000). The product of Maillard reaction have also been implicated for colour darkening in fruit products and have been shown to contribute to the total antioxidant capacity (TAC) of such products (Anese *et al.*, 1999).

The role of natural antioxidants in human health have shifted the focus of nutritionist and food technologist away from allergens and intoxicants to food phytonutrients capable of scavenging free radicals and reactive oxygen species in human tissues. This paradigm shift has positioned tomato and tomato products as "functional diet" recommended for healthy living and longevity. Watermelon has also been listed as a good source of lycopene (Lovric *et al.*, 1970) and other phytochemicals having diuretic and antioxidant activities. Pineapple fruit is renowned for its delicate flavor and sweet taste, and it contains thiols (sulphyldryl compounds) and polyphenols known to have antioxidant activities. By blending tomato juice with other fruit juice, the nutritional values may be augmented and at the same time the flavor may be altered to make them more attractive to some consumers (Luh and Woodrof, 1975). A combination of the pulp of these choice fruits may improve the organoleptic and consumer acceptance of the hitherto unpopular tomato juice in Nigeria.

This study evaluates the correlation between change in colour and TAC of tomato based products during storage. Information from this research may allow for a quick and simple way to estimate the total antioxidant capacity of tomato products, using color as an indicator.

2. MATERIALS AND METHODS

2.1. Preparation of tomato blends

Tomato blends were prepared from a mixture of the pulps of tomato (*Lycopersicon esculentum* var RomaVF), water melon (*Citrullus vulgaris* var Babylack) and pineapple (*Ananas comosus* var Smooth cayennes). The tomato and pineapple fruits were purchased in Ile-Ife fruit market, while watermelon fruits were purchased from Bodija market at Ibadan.

Whole fruits were washed in chlorinated (5ppm chlorine solution) water, thoroughly rinsed in portable water and allowed to drain. Tomato was pulped whole, while watermelon was peeled and sliced into approximately $6cm^3$ chunks. Pineapple fruits were peeled, cored and the flesh was cut into approximately $8cm^3$ chunks with sharp stainless steel knife prior to pulping.

The fruit were pulped separately using Lansenkamp stainless steel pulper having a 2mm mesh sieve (Model 18 SER L 295, UK).

The screened pulps were stabilized by adding 0.8% NaCl (w/v), 3ppm potassium sorbate and 1.5 ppm sodium benzoate. The stabilized pulps were divided into two lots, one for immediate analysis, and the other was mixed in three proportions of 1:1:1, 1:1:2 and 2:1:1, tomato-watermelon-pineapple (TWP, v/v/v). Samples from the fresh blends were taken for analyses.

Blended pulps were ladled into previously sanitized brown bottles (330mL), crown corked and pasteurized in hot water bath at 90 ºC for 20 minutes. Bottled pulp blends were cooled to ambient temperature and stored under refrigeration; 5 ± 1 ºC, ambient; 29 ± 1 ºC and in thermostatically controlled cabinet; 40 ± 1 ºC temperature conditions. Stored bottled tomato pulp blends were analysed for the basic tristimulus colour qualities, apparent viscosity and total antioxidant capacity at regular time intervals till a gradual decline in antioxidant capacities were observed.

2.2. Apparent viscosity and colour measurement

Apparent viscosity evaluations were carried out on the fruit pulps and blends using a rotational viscometer (Ni Run NDJ-85 Digita viscometer, Shanghai Nirun Intelligent Technology Co. Ltd.) equipped with temperature meter. Appropriate measuring spindle and cup were used during viscosity measurements according to the viscosity of dispersion. The prepared samples were loaded into cup; the spindle was spurned in the sample and allowed to equilibrate to constant measure at ambient temperature.

Colorimetric measurement was performed through a tristimulus colorimeter (Sahin and Sumnu, 2006), Macbeth Munsell disc colorimeter. Color was expressed as *L*, *a* and *b* (brightness, red/green balance, first chromatic coordinate and yellow/blue balance, second chromatic coordinate) values, respectively. The values were estimated from the exposed fraction of the coloured disc and their color notations.

2.3. Total antioxidant capacity measurement

Evaluation of the ability of experimental fruit pulp to slow down lipid oxidation in accelerated stability test as adapted by (Alammani and Cossu, 2004) was applied in this study. Oxidation of soya oil (3.0g) in the presence and absence (Test) of the pulp sample (5.0g) was conducted. The induction time for cathecin (0.5mg – 10mg/L) in methanolic solution was compared with those of the pulp samples at the same concentrations. Air flow rate and temperature were set at 5.6 mL sec^{-1} and 110ºC, respectively.

By conductometry, the oxidation inhibition rate was measured. Air bubbled through heated soya oil was trapped in deionized water and was continuously monitored with a conductometer (Hanna Instrument, HI 8733, Italy), calibrated with conductivity calibration solution (KCl, 7447-40-7) HI 7030, 12880 µs/cm at 25 ºC. The temperature coefficient was set at 1.25. The variation in the electric conductivity of de ionized water due to the highly volatile organic acids produced by free radicals in water was monitored within a set time.

The total antioxidant capacity (expressed as catechin hydrate equivalent) was calculated as;

$$It_s = 49.18e^{45.80x} \qquad (1)$$

Where It_s is the induction time (s) of oil with the addition of fruit pulp, x is catechin hydrate equivalent (mg / mL).

2.4. Statistical analysis

Data was analysed using the two way analysis of variance (ANOVA) and T-test with $\alpha = 0.05$ (SPSS 16.0 for window, 2007, Micosoft INC. USA) to determine statistically the significant differences between the quality attributes and antioxidant capacity of pulp samples. Multiple range test using Fisher's Least Significant Difference (LSD) procedure at 95.0% confidence level discriminated among the means according to (Stoodley *et al.*, 1980). Two tailed Pearson's correlation with $\alpha = 0.05$ or 0.01 was used to test the relationship among TAC and redness.

3. RESULTS AND DISCUSSIONS

3.1 Viscometric and colorimetric characteristics of fruit pulp and blend

Table 1 shows the viscosity and colour parameters of the fruit pulps and their fresh and pasteurized blends. The watermelon pulp had the lowest apparent viscosity value of 6.33 cPa.s^n, while the highest apparent viscosity of 81.20 cPa.s^n was recorded for pineapple pulp. Fresh pineapple pulp has been reported to contain pectin which has low viscosity compared to other plant gums, but increases the viscosity of the aqueous solution. These pectin solutions are close to Newtonian in their flow properties but changes to pseudoplastic when the pectin concentration increases (Krokida *et al.*, 2001)

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Table 1. Viscometric and colourimetric characteristics of fruit pulp and blends

Sample	Apparent Viscosity	Colourimetric			
	(cPa.s^n)	[L	a	b	$(a/b)^2$]
Tomato	23.60^b	28.64^b	28.40^a	17.98^b	2.50
Watermelon	6.33^c	31.11^b	27.77^a	19.87^b	1.95
Pineapple	81.20^a	77.59^a	-4.20^b	49.28^a	0.01
TWP111$_f$	36.41^b	34.56^b	28.23^a	22.98^b	1.51
TWP112$_f$	38.87^b	34.58^b	25.99^a	22.49^b	1.34
TWP211$_f$	32.00^b	31.41^b	27.55^a	20.10^b	1.88
TWP111$_p$	33.20^b	28.89^b	28.04^a	21.74^b	21.74^b
TWP112$_p$	36.06^b		27.18^a	22.30^b	1.49
TWP211$_p$	31.16^b	27.19^b	28.89^a	22.39^b	1.66

Each value is the average of five measurements per sample

Standard variation of the determination is 0.153

Means ± SD in the same column followed by a common letter are not significantly different (p < 0.05 LSD)

f = fresh, p = pasteurized, TWP 111 = 33% tomato+33% watermelon + 33% pineapple, TWP 112 = 25% tomato + 25% watermelon + 50% pineapple, TWP 211 = 50% tomato + 25% watermelon + 25% pineapple (v/v/v).

Tomato pulp had apparent viscosity value of 23.60 $cPa.s^n$ and these values were similar to the apparent viscosity (23.67 $cPa.s^n$) reported by D'Ambrosio *et al.* (2008) for the fruits of 9 different transgenic tomatoes plants. Fruit juices have been reported by (Bonilla-zavaleta, 2006) to exhibit shear thinning properties and the soluble solid in fruit pulp increases the apparent viscosity. Watermelon pulp serves to dilute the pulps in the blends giving rise to pulp blends with viscosity values ranging from 32.00 to 38.87 $cPa.s^n$. The difference in apparent viscosity was not significant ($p < 0.05$) among the blends. Pasteurization seems to insignificantly ($p > 0.05$) reduce the apparent viscosity of the tomato pulp blends.

The fresh pineapple pulp had a different colour (light yellow/cream beige) threshold and it gave 77.59 lightness/brightness (*L* - value), -4.20 red/green balance (*a* - value) and 49.28 yellow/blue balance (*b*). The tomato *L*, *a* and *b* values recorded in this work were slightly higher than 23.9 to 26.1 (*L* - values), 8.8 to 12.2 (*a* - values) and lower than 19.4 to 21.5 (*b* -values) reported by (Muratore *et al.*, 2005) for cultivars of plum and cherry tomato.

While, L values (31.11), *a* - values (27.77), and *b* values (19.87) were observed in fresh watermelon pulp. Initial *a*- value for untreated watermelon slice was reported (Dermesonlouoglou *et al.*, 2007) to be 17.41, which increased to 20.73, 21.98 and 19.51 when treated with glucose, oligofructose and maltodextrin. However, these values were lower than the values estimated in this experiment. Variation in the measured colour parameters may be instrumental and/or the result of variation in the cultivar of the sampled fruit.

The colourimetric results shows that tomato pulps were characterized by a more intense red hue than the watermelon and the pulp blends, as indicated by the higher $(a/b)^2$ ratio (2.50) which is an index of red colour development (Muratore *et al.*, 2005). The $(a/b)^2$ ratio recorded for fresh tomato pulps in this study were higher than 0.21 to 0.32 reported by Muratore *et al.*, (2005) in cherry and plum cultivars of tomato using a portable colorimeter.

3.1.1. Changes in Apparent Viscosity of Tomato Blends During Storage

Tomato pulp blends are concentrated dispersions of insoluble matters in aqueous media. The apparent viscosity of tomato pulp blends is a major quality component for consumer acceptance (Koocheki *et al.*, 2009). Fruit products obtain their apparent viscosity from naturally occurring pectic substances in fruits. The gross viscosity of tomato pulp depends on the viscosity of the serum and the viscous character of the suspended solids (Luh and Woodrof, 1975). Other factors such as enzymatic degradations, pectin/protein interaction, pulp content, homogenization process and concentration may also affect the consistency of tomato products (Koocheki *et al.*, 2009).

The changes in apparent viscosity of tomato blend TWP 111 (Figure 1) during storage showed that the initial apparent viscosity of 53.20 $cPa.s^n$ decreased to 28.41 and 28.69 $cPa.s^n$ at 5 and 29 °C on day 60, and 27.45 $cPa.s^n$ on day 40 at 40°C. These values later increased to 37.28, 33.88 and 37.95 $cPa.s^n$ on day 100 at 5, 29 and 40°C temperature conditions, respectively.

The initial apparent viscosity of tomato blend TWP112 of 36.09 $cPa.s^n$ rose to 46.48 $cPa.s^n$ at 5 °C on day 80, and 46.39 and 43.88 $cPa.s^n$ on day 40 at 29 and 40 °C, respectively. This later dropped to 43.57, 43.29 and 39.21 $cPa.s^n$ at 5, 29 and 40 °C temperature conditions, respectively.

The rise and fall in the apparent viscosity observed in tomato pulp blends may be explained by the activities of fungi on sugars and de-esterification of pectin, the condensation of polyphenols, and the reaction of condensates with sugar and ascorbic acid degradation markers (2-F and HMF). The production and use up of reactants in the tomato blend media may result in the very unstable apparent viscosity observed, as the concentration of the suspended insoluble matters changes with changing aqueous media. The most unstable apparent viscosity was noticed in blend TWP 211.

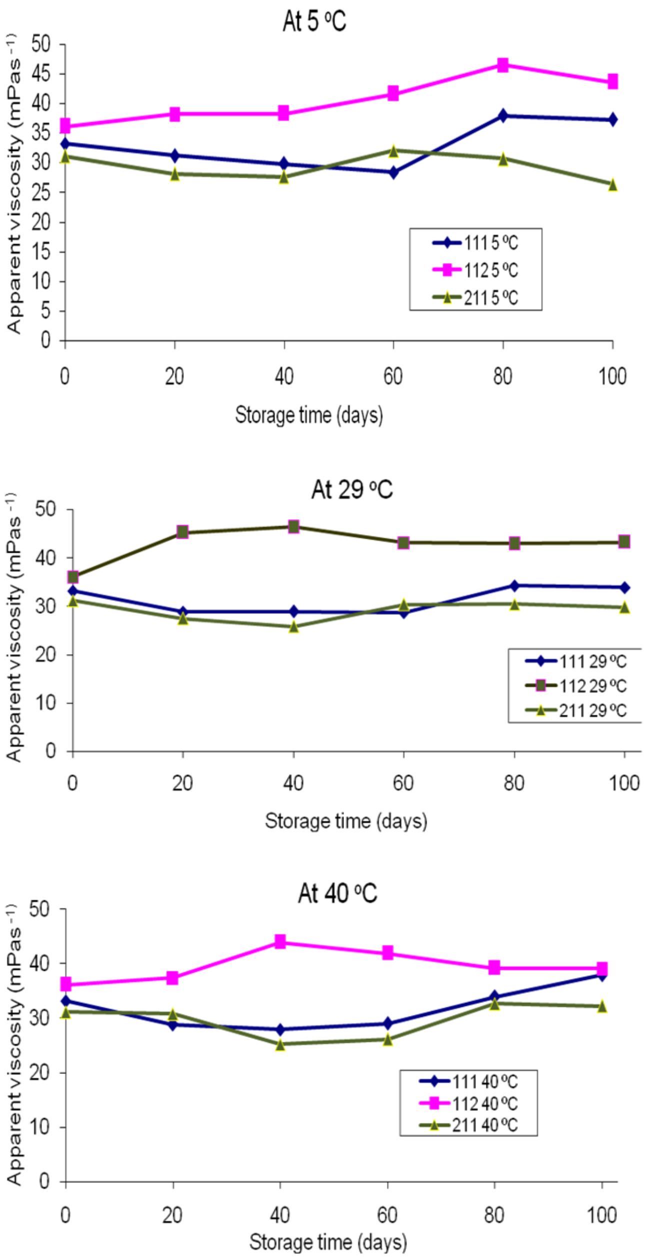

Figure 1. Change in Apparent viscosity of Blends as a function of time and Temperature

3.1.2. Changes in the Color Parameters of Stored Tomato Based Pulp Blends

The stability of the observed colour parameters, Hunter *L a b* in tomato pulp blends is shown in Figures 1 - 3. Colour changes in foods are always three-dimensional but not all three dimensions may be of practical importance. It was further stated that colour parameter(s) having high correlation coefficient with visual scores is selected (Sahin and Sumnu, 2006). Hunter *a* and *b* provides information on changes in chromatic attributes while *L* provides information on the lightness of the color.

3.1.3. Changes in L –values of tomato based pulp blends during storage

Figure 2 shows the changes in estimated *L* – value for tomato pulp blend during storage at 5, 29 and 40°C as a function of time. The initial *L* –value, 28.89 of the Blend TWP 111 increased to 35.65, 36.99 and 33.76, after 20 days and decrease to 32.95, 32.73 and 31.83 on day 100 of storage under refrigeration, ambient and 40°C temperature conditions, respectively. Lightness value of blend TWP 112 also followed a similar trend. Since lycopene, the primary red colour component in tomato and watermelon gradually degrades in the blends, the early observation of *L*-value increase was justified.

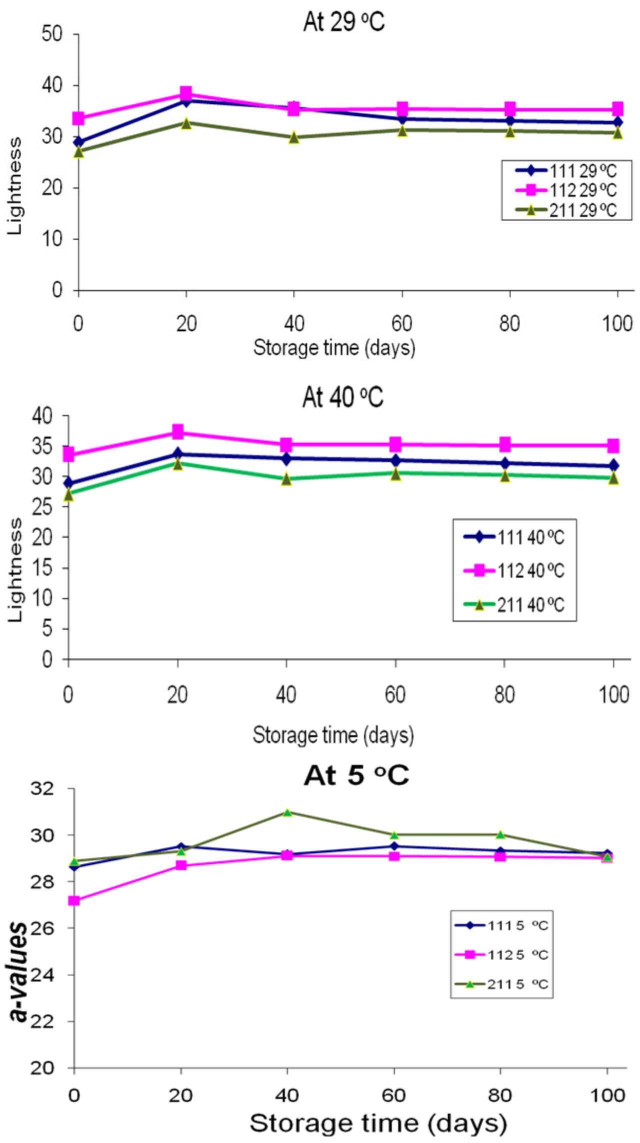

Figure 2. Change in L-values of Blends as a function of time and Temperature.

3.1.4. Changes in the a- values of tomato based pulp blends during storage

Figure 3 shows the changes in the red/green balance – first chroma coordinate (*a*) in tomato pulp blends. The very attractive intense red color of the blends resulted from the carotenoid – lycopene in tomato and watermelon. Pineapple pulp (light yellow beige) on the other hand serves to dilute (reduce) the redness of tomato blends' colour. In blend TWP 111, the initial *a*- value (28.64) gradually increased to 29.53, 30.32 and 30.12 on day 60, and further declined to 29.24, 29.83 and 29.63 by day 100 at 5, 29 and 40 °C, respectively. An initial increase in *a*- value was observed in all the blends up to days 60 and 40 in tomato blend TWP 111, 112 and 211, respectively. The intensity of redness in blend TWP 211 was more at higher storage temperature.

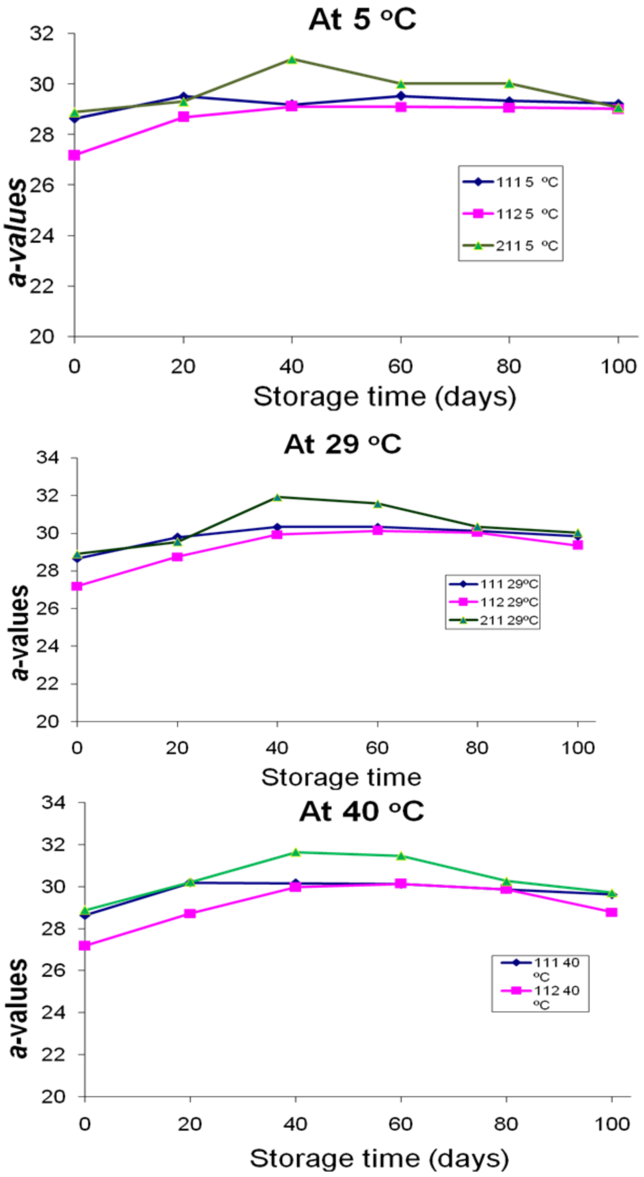

Figure 3. Change in a-values of Blends as a function of time and Temperature

Though the lycopene content responsible for the red color in the blends would decrease during storage, the observed redness intensity using Macbeth Munsell Disc Colorimeter increased up to day 40 and 60. Colour darkening in fruit pulp due to heating and in storage has been reported by many researchers (Anese *et al*., 1999, Krifi *et al*., 2000, Lovric *et al*., 1970). Dermesonlouoglou *et al*. (2007) also observed an improved intense red colour for osmodehydrated samples of watermelon flesh. The development of red colour depends on a complex interaction between the polyphenolic compounds content (hydroxycinnamic derivatives) and concentration of ascorbic acid, reducing sugars and amino acids. It was reported that, in media riched in polyphenolic compounds, the colour polymers result for the most part from complex condensation reactions between catechins and proanthocyanidins. And in acid media rich in sugars and ascorbic acid, it is probable that condensation reactions between polyphenols and degradation of ascorbic acid and sugar intermediates are responsible, for the most part, for the transformation of the red colour juices and in the formation of degradation polycondensation compounds (Arena *et al*., 2001).

In this study the tomato blend TWP 211 having the high ascorbic acid (AA) content showed marked increase red colour intensity. This finding supports the report that the interaction between AA degradation product and polyphenols (Krifi *et al*., 2000) may be responsible in most part for the intense red colour development in stored tomato pulp blends.

3.1.5. Changes in b-values of tomato blends during storage

Changes in the yellow/blue balance – 2nd chroma coordinate (*b*) in tomato blends are shown in Figure 4. The *b* – values in tomato product colour quality measurement may not be of significance but it is considered for the estimation of redness factor in such products. Increase in *b* – values was observed in tomato pulp blends TWP 111 and 112 after day 20. While a gradual and steady decrease in *b* – value was observed in blend TWP 211.

The highest *b*-values were recorded for blend TWP 112 which showed a comparatively marked increase on day 20 in store at ambient temperature. Estimates of *b*-values in the blends indicated the effect of pineapple colour (light yellow beige) on blend TWP 112.

3.1.6. Changes in redness factor (a/b) 2 of tomato blends during storage

The changes in the redness factor as a function of time and temperature is shown in Figure 5. The initial $(a/b)^2$ value, 1.65 of the blend TWP 111 steadily increased to 1.90, 2.02, and 2.11 on day 100 of storage under refrigeration, ambient and 40 °C temperature conditions. The increase in redness intensity account for 15%, 37% and 46% in blend TWP 111 at 5, 29 and 40°C, respectively.

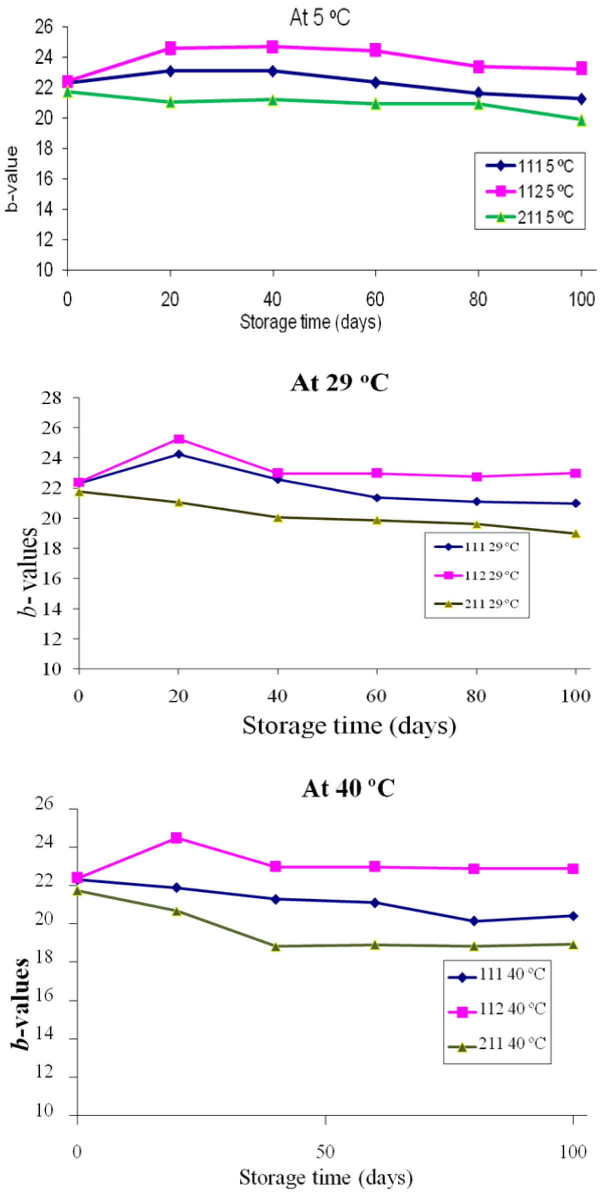

Figure 4. Change in b-values of Blends as a function of time and Temperature

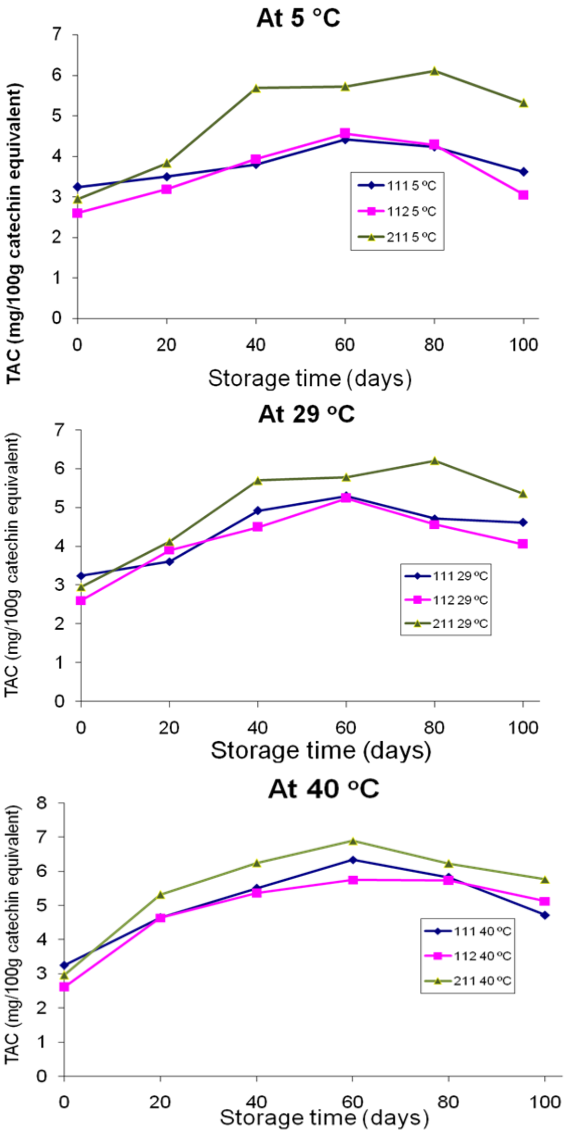

Figure 5. Change in Total Antioxidant Capacity of Blends as a function of time and Temperature

In blend TWP 112, initial redness factor 1.47 increased gradually to1.56 on day 20, and to 1.74 on day 80 after which it reduced to 1.63 on day 100 at 40^{o}C, temperature condition. This account for 6%, on day 100 and, 18%, and 16% on day 80, at 5, 29 and 40^{o}C, temperature condition, respectively. The initial redness factor, 1.77 increased to 2.14, 2.54 and 2.83, accounting for about 37%, 77% and 106% increase in blend TWP 211 at 5, 29 and 40^{o}C, respectively. These values later fell to 1.99, 1.98 and 1.89 on the 100th day in storage.

3.1.7. Changes in TAC and pulp color

Change in TAC as function of time and temperature is shown in figure 5. The *a*- value and $(a/b)^{2}$ followed a similar stability trend with the TAC. The highest TAC increase was recorded in blend TWP 211 at 40^{o}C. The compounds responsible for increased red colour intensity may be responsible for the increased TAC (Anese *et al*., 2003). That is the product of the interaction between polyphenols, reducing sugars and product of AA degradation may have considerable antioxidant properties

The TAC increase in all the stored blends was temperature dependent. Temperature dependency of the increase in TAC was most pronounced in tomato blend TWP211p having the highest proportion of tomato pulp. The observed red colour darkening showed significant correlation ($p < 0.05$) with increase in TAC especially at 40ºC temperature condition in all the stored pulps (Table 2).

Table 2: Correlation coefficients of the relationship between Redness factor (RF), a-value and TAC.

Samples	Parameters	Temperature		
		[5ºC	29ºC	40ºC]
TWP111	RF X *a*-value	0.216	0.525	0.659
	TAC X *a*-value	0.647	0.875*	0.808
	TAC X RF	0.390	0.817	0.803
TWP112	RF X *a*-value	0.018	0.717	0.796
	TAC X *a*-value	0.726	0.963**	0.953**
	TAC X RF	0.091	0.641	0.675
TWP211	RF X *a*-value	0.612	0.656	0.881*
	TAC X *a*-value	0.694	0.689	0.830*
	TAC X RF	0.897*	0.931**	0.937**

Correlation is significant at the 0.05 level (two tailed)
Correlation is significant at the 0.05 level (two tailed)

TWP 111 = 33% tomato+33% watermelon + 33% pineapple,
TWP 112 = 25% tomato + 25% watermelon + 50% pineapple,
TWP 211 = 50% tomato + 25% watermelon + 25% pineapple (v/v/v).
TAC = total antioxidant capacity

4. CONCLUSION

Color darkening fairly correlated with increase in TAC, and the correlation was more significant ($p < 0.05$) at higher storage temperature condition. However, careful study of the rate of redness darkening and TAC increase is essential to note the peak of TAC increase. The eventual drop in the TAC may not be quickly indicated by color change. This study would be most applicable to tropical condition, and color darkening in tomato products may reflect the TAC of such products.

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