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Image analysis to quantify the browning in fresh cut tender jackfruit slices

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Abstract

Changes in physicochemical properties of fresh cut tender jackfruit during storage is depend on its colour. Colorimeter measurements are best for the samples with homogeneous colour. However, for samples with non-homogenous colors or large sizes (like fruits and vegetables), the colorimeters are inappropriate and inaccurate. The aim for this study is to quantify the amount of browning in fresh cut tender jackfruit slices by using image analysis technique and justify the results by comparing them with existing techniques like sensory examination, enzyme activity, and colorimeter. It can be concluded from the results that browning in fresh cut tender jackfruit slices increase rapidly in control and normally packed samples. Correlation coefficient as high as 0.963, represent that image analysis system is an accurate and highly consistent method to quantify the colour of fruits and vegetables.

Key-words: Image analysis; colorimeter; browning; tender jackfruit.

1. Introduction

Jackfruit is a sub-tropical fruit and widely spread all over the India. It is also available in other countries such as Bangladesh, China, Pakistan, Indonesia, South Africa, Brazil etc. Jackfruit is also known as the largest tree-borne fruit. It is a multi-purpose fruit, which provides food, timber, fuel, fodder, medicines and industrial products. Tender jackfruit is having enormous nutritional benefits and ethical values in culture as well. The young and pre-mature fruit is used as a vegetable, which contain high amount of vitamins and mineral. Jackfruit is found to be a novel, high in nutritive quality, functional and inexpensive edible fruit (Haq, 2006). For the processing of tender jackfruit, various unit operations such as harvesting, cleaning and washing, sorting and grading, storing, peeling, cutting and value addition is done.

During processing, the tender jackfruit undergoes enzymatic browning. Browning negatively affects the quality parameters (like colour, texture, and flavor) in such a way that it results in less shelf life of processed fruits and vegetables. Haung et al., (2013) reported similar type of problem for bananas. Different methods like ultraviolet treatment (UV-C) (Jand and Moon, 2011), blanching, chemical treatment, and modified atmospheric packaging (Jung and Watkins, 2011) were tried by many researchers to solve the problem of browning for various fruits and vegetables.

According to Jeong et al., (2016) computer vision systems is a novel technique to precisely measure the colour of an agricultural commodities. Image analysis system is most accurate and highly consistent method to quantify the colour of fruits and vegetables (Du and Sun, 2004). It also eliminates the subjectivity of manual inspection. On this account image analysis is the most popular method in numerous studies to find the colour changes (Cho and

Moon, 2014; Iqbal et al., 2011; Jeong et al., 2016) This is a non-destructive, cheap and the most precise method to determine the colour.

Image analysis can be performed with a help of proper software and hardware. A high-resolution camera (preferably DSLR) can be used to take the clear picture. The picture is analyzed with the help of image analysis software (such as MATLAB). The software calculates colour information from each pixel of the entire sample surface by using heavy algorithms like colour segmentation and colour space conversion.

However, another non-destructive and easy method to quantify colour of a sample is by using colorimeters. It is also an extensively used technique. Overall colour of sample determined by average of the values taken from various sides (angles/ positions) of sample (Trinderup et al., 2015). Colorimeter measurements are the best method for the samples with homogeneous colour. However, for samples with non-homogenous colour or large sizes (like fruits and vegetables), the colorimeters are not appropriate and inaccurate. The measurements from colorimeters of such samples are then unrepresentative for the entire surface. The drawback of colorimeters is that they are point specific not area specific.

The aim of this experiment is to precisely and accuratly quantify the amount of browning in fresh cut tender jackfruit slices by using image analysis technique and justify the results by comparing them with existing techniques like sensory test, enzyme activity, and colorimeter.

2. Materials and Methods

2.1 Sample preparation

Tender jackfruits (*A. heterophyllous L.*) were plucked from the trees in National Institute of Technology, Rourkela campus, Orissa, India. While collecting samples, it was ensured that all jackfruits were of at same maturity level (the fruits were of 80±5 days old on the day of harvesting). The Jackfruit samples collected were green, fresh and without mechanical injuries or microbial infections. Later sanitization was carried out with the help of chlorinated water (100ppm). Jackfruits were peeled and cut manually with sharp and serrated stainless steel knives. The peel and non-edible latex part were separated. The edible part was sliced ($4 \times 3 \times 2$cm). Then slices were dipped in chilled chlorinated water (30ppm) for 5 minutes for sanitization (Saxena *et al.*, 2009). To compare the browning among tender jackfruit slices, the slices were divided into the following treatment groups: Without any package (Control); Normal packaging sealed with sealing machine (SAIFPRO Hand Held Heat Sealer (450mm, 18inch)); Modified atmosphere packaging packaging (MA-Pack); Vacuum packaging (V-Pack) with the help of packaging machine (DZ300A, Vacuum Packaging Machine, Zhejiang Hongzhan Packing Machinery Co., Ltd. China). The samples were packed in 0.05 mm polyethylene film and stored in normal conditions (27±3 ^{o}C) for 10 days.

2.2 Browning index (BI)

Browning index (BI) was measured to estimate the browning in jackfruit slices. 5 g sample was extracted in 100 ml ethanol (67 %) for 60 minutes. Then the extract was filtered by using filter paper (Whatman filter no.1). Then filtrate was used to determine browning index by using double beam UV-visible spectrophotometer (Model: AU2701, Systronics (India) Ltd., Ahemdabad, Gujrat, India) (wavelength at 420 nm) with blank as 67% ethanol (Sexena *et al.*, 2009).

2.3 Determination of colour value of tender jackfruit slices

2.3.1 Sensory evaluation

The sensory evaluation of jackfruit slices were done based on its colour. The most popular nine-point hedonic scale method was used (Larmond, 1977) and the team of 20 trained panelists were selected. The product was overviewed to the panelists before the evaluation. The sensory evaluation was completed in ideal conditions. The scores assigned to each parameter were 1 to 9, where 1 stands for least brown and 9 stands for extreme brown. The samples were coded and randomly drawn by the panelists.

2.3.2 Colorimeter (CIE)

Visual colour of samples was determined after packing of tender jackfruit slices in their respective pack. The values for L*, a* and b* were measured from 6 different places of each jackfruit slice and each measurement was taken in triplicate. The colour was measured with the help of colourflex EZ (Hunter Associate Laboratories Inc., Reston, Virginia, USA). The values were expressed in the term of L^* (black to white), a^* (red to green) and b^* (yellow to blue). Then the change in colour was determined by using the formula:

$$\Delta E^*_{ab}=\sqrt{\left(L^*-L^*_0\right)^2+\left(a^*-a^*_0\right)^2+\left(b^*-b^*_0\right)^2} \quad (1)$$

Where,

ΔE^*_{ab} - A measure of change in visual perception of two given colour.

L^*, a^*, b^* - Measure of colour values for provided samples.

L^*_0, a^*_0, b^*_0 - Measure of colour values for standard sample (fruit on the day of harvesting).

2.3.3 Image analysis

Sample images was captured by DSLR camera (24.3 MP Nikon D-5300, D-SLR, Minato, Tokyo, Japan). With the help of tripod stand the camera was carefully fixed at 30 cm (approx) away from the sample. A black chart/ mat was used to provide as background for the sample and photographed subsequently. A dark/low light room at normal temperature and pressure was used for the experiment. JPEG format of photographs were analysed with the help of MATLAB image processing toolbox (version 8.3 Mathworks, Natick, MA, USA) to quantify the browning precisely.

Two methods were used to estimate the degree of browning in tender jackfruit slices (Schwarz et al., 1987).

Methods are as follow.

1. The changes in CIE (L*, a* and b* values) were determined and examined by using algorithms in connection with colour space conversion based on the RGB colour space. Where L*- signifies brightness/ lightness, a*- signifies redness and b*- signifies yellowness.
2. The changes in RGB colour values were determined for each channel (R, G, and B) individually. Where R stands for red colour, B means blue and G stands for green. The colour range varies from 0 to 255.

2.4 Statistical analysis

Experimental design is based on completely randomized design and all the experiments were performed in triplicate. The SPSS for window version 10 (SPSS Inc., Illinois, USA) was used to perform ANOVA. The statement of significance was based on P< 0.05 unless otherwise indicated. Pearson's test and Duncan's multiple range test were done to find out correlation coefficients for image analysis and sensory test.

3. Results and discussion

3.1 Relationship between browning Index and storage of tender jackfruit

Browning index (BI) was measured to estimate the browning in fresh cut tender jackfruit slices. The browning index of the control and normally packed sample was high after three days of storage (at level of significance, P < 0.01). Phenylalanine ammonia-lyase (PAL), polyphenol oxidase (PPO) and peroxidase (POD) are enzymes that are accountable for browning of fresh cut fruits and vegetables. Enzymatic activity of these enzymes has been extended rapidly during storage of fresh cut tender jackfruit. As indicated, the change in colour during day 1 and 2 of storage was midst and this represents that enzyme activity during this time was less. Yet, it increased on third day in normally packed and conrtol samples and the signs of early browning were also visible. This resembled the results procured from the sensory evaluation and these results exhibited the tender jackfruit slices browning developed more quickly in the control group.

Where as in case of V-packed and MA-packed groups the BI index was low until day 6. The value of BI for V-packed on day 6 was 0.214 which suddenly raised to 0.399 on day 8. Whereas, in case of MA-packed group the BI increased suddenly on from 0.188 to 0.316 between day 4 and day 6, respectively. These results shows that packaging helps in delaying the browning process hence enzymatic activity can be reduced to certain limits with the help of packaging. V-packed samples were having the longest shelf life i.e. 10 days among different packaging tried in this experiment. Fig. 1 shows the browning index values of tender jackfruit slices during storage when packed in different packaging conditions.

3.2 Changes in colour values of tender jackfruit slices using sensory evaluation

The change in colour of packed tender jackfruit slices in initial 2 days was not significant ($p<0.01$). ΔE value was significantly less in that duration (less than 3 points). Whereas after the third day the browning developed quickly during storage. The results of the sensory evaluation from Fig. 2, clearly depicts the influence of browning on tender jackfruit slices and its colour change. Control and normally packed tender jackfruit slices showed higher scores (i.e. nearly 8) than the MA packed and vacuum packed group (i.e. <6) during storage. Specifically, after 8 days of storage, the control group demonstrated a significantly higher score than the normally packed group. Since, initial concentration of gases in normally packed samples were CO_2 = 0.04%; O_2 = 20% (same as air). In case of MA packed samples the concentration were CO_2 = 10%; O_2 = 10%, where as in case of V-packed there were no gas. These outcomes demonstrate that CO_2 and ethylene gas advanced the aging and browning of samples. Many researchers has found similar changes in other fruits due to presence of CO_2 and ethylene (Brecht, 1995; Buron-Moles et al., 2015; Villalobos-Acuna et al., 2011). In this study, the ethylene generator influenced aging and browning of fresh cut tender jackfruit slices.

On the other hand, a few researchers have detailed that a high concentration of CO_2 gas influences the browning during post-harvest processing of products from fruits and vegetables (Guevara et al., 2003; Zhang et al., 2013). In this investigation, fresh cut tender jackfruit slices were influenced by oxidative reaction generated because of high-CO_2 injury. But, further, in depth study is needed to understand the fundamental mechanism between browning and high-CO_2 injury.

3.3 Changes in colour value of tender jackfruit slices using colorimeter

Changes in the CIE L* a* b* values (i.e. ΔE) assessed by utilizing a colorimeter are shown in graph (Fig. 3). In general, L* and b* values diminished and a* values increased for all the samples during storage. Specifically, the control group demonstrated a fast reduction in the L* and b* values and an increase in the a* values. This demonstrated control group develops browning more rapidly, steady and same with the results of the image analysis and sensory test.

The initial L* value and b* for fresh cut tender jackfruit slice was 74.31 and 30.16 respectively. Which represents that tender jackfruit slice was bright when it was fresh. There was significance decrease in L* values in all the groups (i.e. Control; Normal; MA-pack and V-Pack. L* value decreased to 46.22, 54.36, 61.61 and 68.74 in control, normal, MA pack and V-Pack samples respectively after 10 days of storage. Similarly b* values decreased to 12.54, 15.11, 20.2 and 22.05 in control, normal, MA pack and V-Pack samples respectively after 10 days of storage

In case of a* values there were increase in values for all groups. The initial value for fresh cut tender jackfruit slices on day 0 was recorded as 2.14. The increase in a* values explains the increase in dullness in colour of tender jackfruit slices during storage. The a* values increased to 20.48, 15.63, 14.74 and 9.39 in control, normal, MA pack and V-Pack samples respectively after 10 days of storage. On close inspection of these values one can find that the rate of loss in colour (ΔE) were different in different groups Hence the rate of loss in colour (ΔE) value was highest in control samples, least in V-packed samples and moderate in Normal and MA-packed samples.

3.4 Changes in colour value of tender jackfruit slices using image analysis

Changes in the RGB and CIE $L^*a^*b^*$ colour values are shown in Fig. 4 and Fig. 5. For the RGB colour value decreased consistently. The control and normally packed groups showed lower values. Browning of tender jackfruit slices develops as the storage period increases. Hence, there is significant increase in overall colour change value (ΔE) during storage, therefore as the storage time increase the browning develops on the tender jackfruit slices. Since, G value is indicator of green colour in surface, with browning the jackfruit losses its green colour, for this reason decrease in the G value is a more accurate indicator than the R and B values.

The decrease in R, G and B values of samples were significantly different (level of significance, $P < 0.05$). The initial values for R, G and B were 203, 182 and 129 respectively on day 0. These values were decreased with different rates in case of control, normal, MA-pack and V-pack samples. The rate of change of colour was highest in control samples, least in V-packed samples and moderate in Normal and MA-packed samples.

The CIE $L^*a^*b^*$ values consistently varies from sample to sample and with time, it may increase or decrease. The reason for that is the lightness and yellowness decreased and redness increased during browning of fruit. Many studies have also reported that the L^* value decreases and the a^* values increase with the browning of fruit (Arias et al., 2009; Cho et al., 2012; Chung et al., 2015).

The browning was homogenous. Particularly in tender jackfruit slices, colour change is simultaneous in all samples. Image analysis can be utilized to break down the complete surface of a sample in one RGB value and this values can be utilized to determine the colour change a sample. This study demonstrated that the RGB value of sample and CIE L^* a^* b^* values found by using image analyses are appropriate for the investigation browning of tender jackfruit slices because colorimeters is point based method (very small area on surface is considered to determine the colour value and rest of the surface is assumed as uniformly colour) whereas, image analysis method is area specific method and consider whole surface area to determine the colour.

3.5 Correlation coefficient

The correlation coefficients between the sensory evaluation and the outcomes from other analytical methods presented in Fig. 6. From the R and L^* values we can conclude that the image analysis demonstrated a high correlation coefficient, more than 0.9. For the colorimeter results, the CIE $L*$ value demonstrated the highest correlation coefficient (0.963) between colour readings found by colorimeter and image analysis method. Image analysis depends on the overall picture of the sample and therefore able to analyze the entire surface of samples.

From Fig 6, the difference in values can be found and this difference in values are because of colorimeters is point specific not area specific whereas, image analysis method is area specific.

4. Conclusion

The high correlation coefficient from the study showed that image analysis is reasonably accurate to analysis of the colour and browning in fresh cut tender jackfruit slices during storage. The study affirmed that the browning of fresh cut tender jackfruit slices grew more rapidly in control and normally packed groups than MA-pack and V-pack groups. The change in colour values (ΔE) for the control and normally packed groups were higher for every single investigative technique, and for the vacuum packed group the change in colour values (ΔE) were moderate. From the image analysis and sensory evaluation results, the RGB and CIE L∗ a∗ b∗ values demonstrated a high correlation coefficient to each other (more than 0.9). CIE L∗ a* b∗ values by using a colorimeter, demonstrated high correlation coefficients. Image analysis can be utilized to acquire the colour data from the whole surface of samples. Besides, it is conceivable to express different colour values and limit errors which is not possible in the manual inspection. Additionally, the study is expected to distinguish the changes in colour values by the degree of brightness. The other outcome of the study was that by using vacuum packaging one can reduce the rate of enzymatic browning in fresh cut tender jackfruit slices. The shelf life of fresh cut tender jackfruit slices was increase to 10 days from 2 days when vacuum packed in 0.05mm polyethylene film.

Conflict of interests

The authors declare that they have no conflict of interests.

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List of Figures:

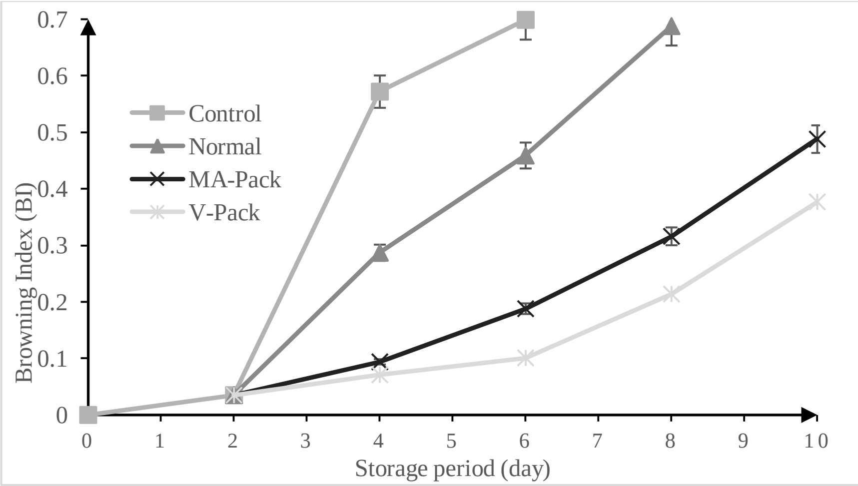

Fig. 2: Browning Index values of tender jackfruit slices during storage when packed in different packaging conditions.

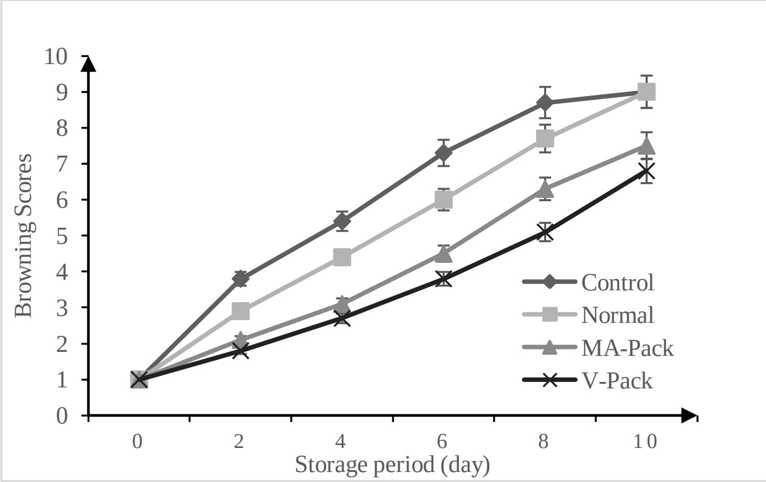

Fig. 2: Browning scores for sensory analysis of tender jackfruit slices during storage when packed in different packaging conditions.

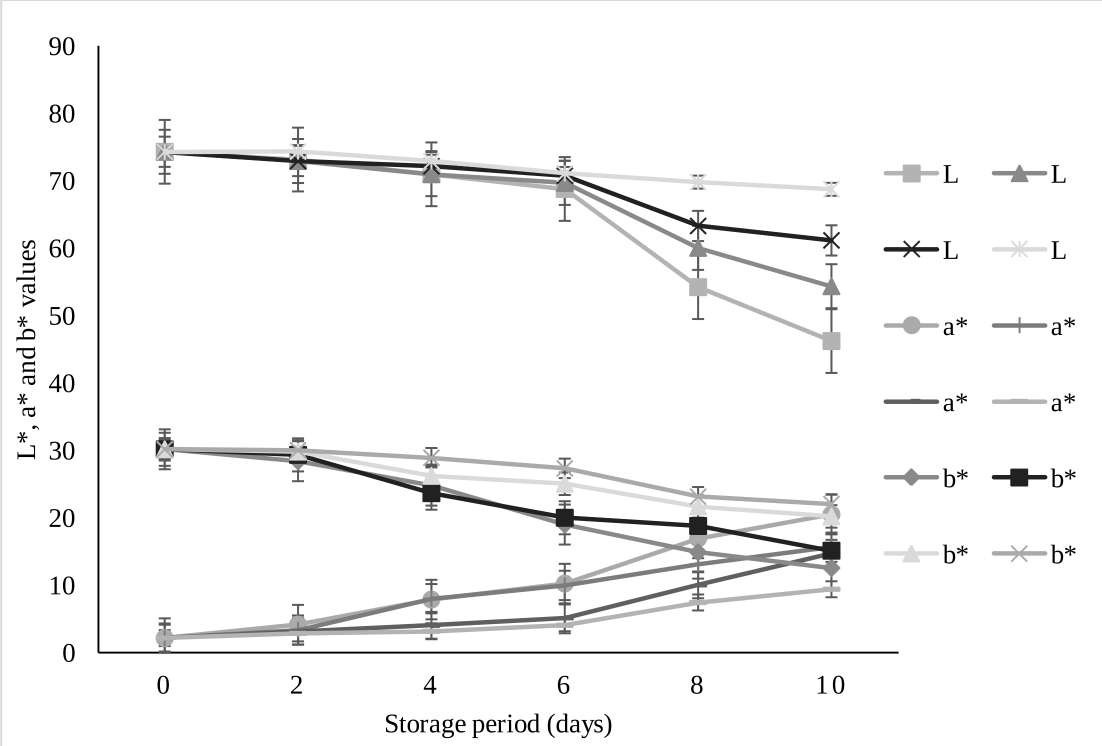

Fig. 3: Changes in L*, a* and b* Values of tender jackfruit slices during storage when packed in different packaging conditions determined by using colorimeter.

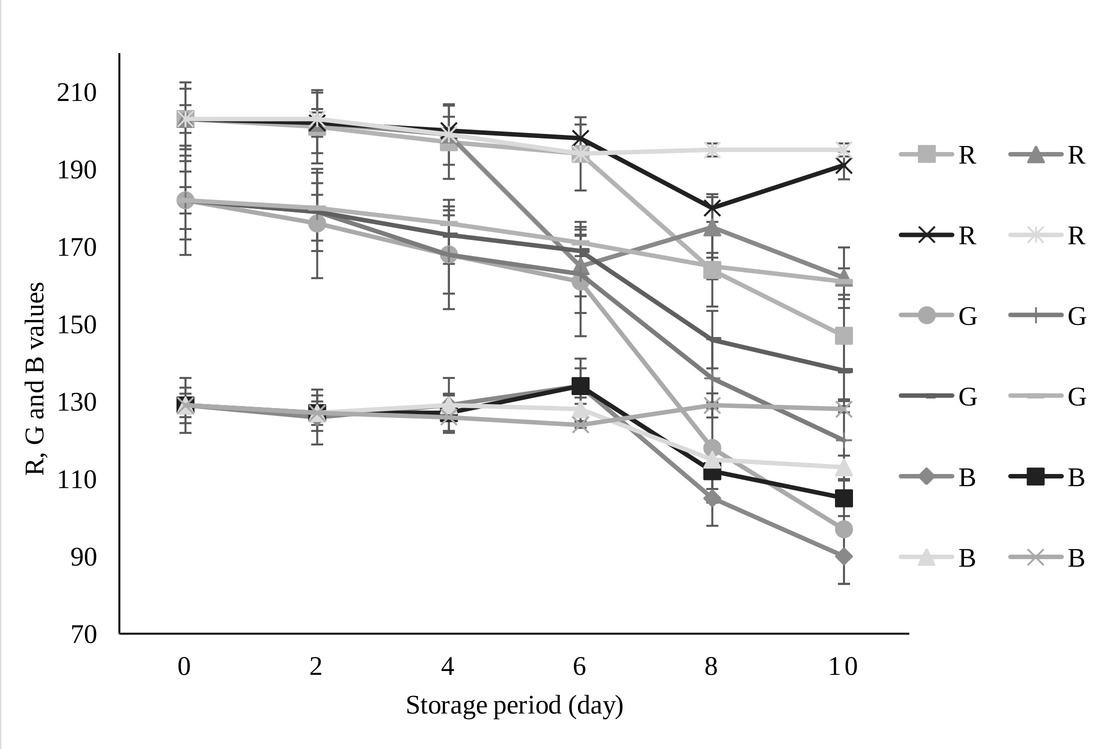

Fig. 4: Changes in R, G and B Values of tender jackfruit slices during storage when packed in different packaging conditions determined by using image analysis.

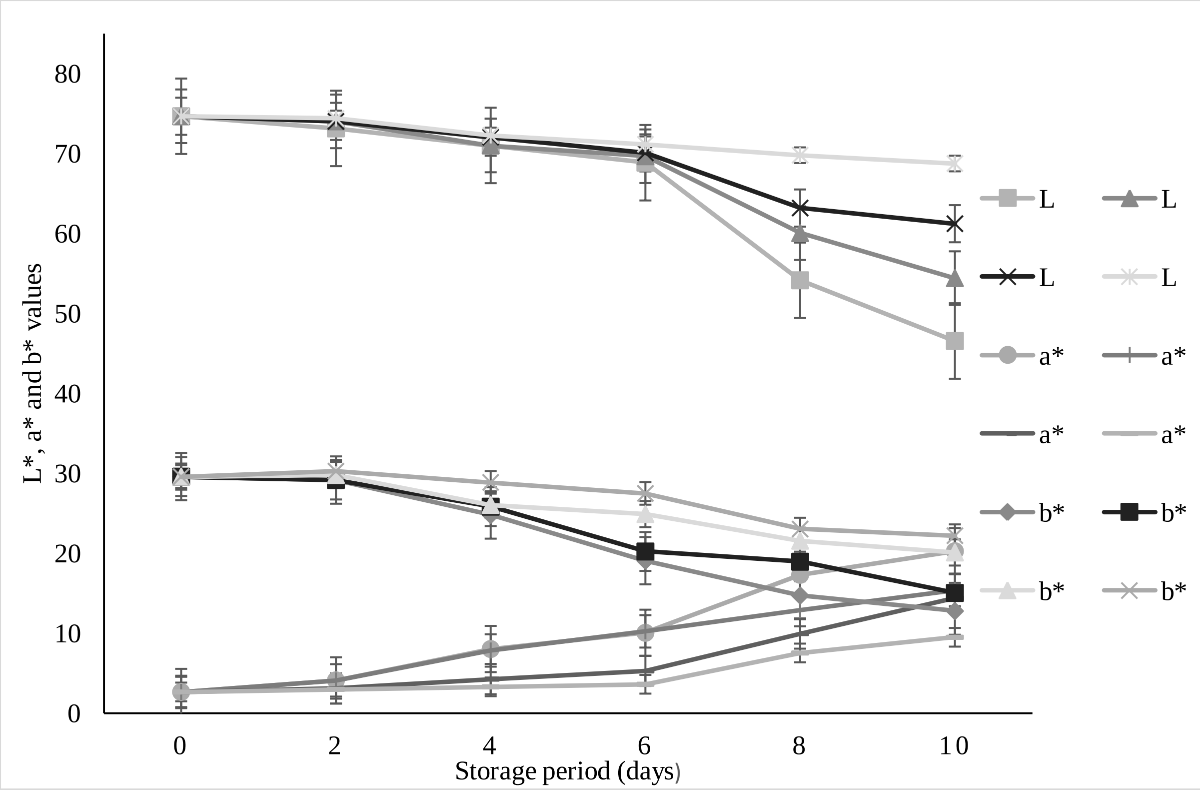

Fig. 5: Changes in L*, a* and b* Values of tender jackfruit slices during storage when packed in different packaging conditions determined from image analysis.

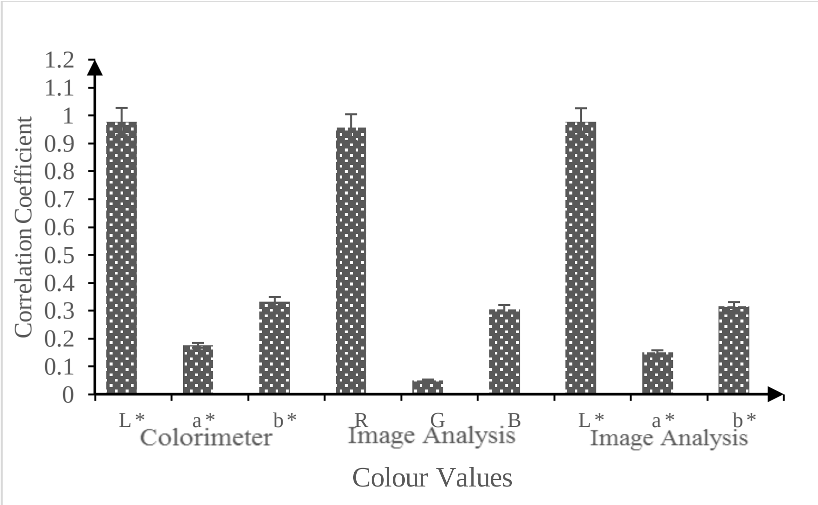

Fig. 6: Correlation coefficients.

Highlights:

1. Quantify the browning of tender jackfruit slices using image analysis technique.
2. Comparing results from sensory test, enzyme activity and colorimeter.
3. Variation in rate of browning of fresh cut tender jackfruit slices with time.
4. Prevention of browning by using different packaging techniques.