Assessment of the Colour of *Parinari Curatellifolia* Fruit Using an Image Processing Computer Software Package

Chakare Benhura¹*, Mudadi Albert N. Benhura², Maud Muchuweti², and Power E. Gombiro¹

¹Institute of Food, Nutrition and Family Sciences, University of Zimbabwe, Mount Pleasant, Harare
²Department of Biochemistry, University of Zimbabwe, Mount Pleasant, Harare

Abstract

*Parinari curatellifolia* fruits whose colours were to be measured were collected from locations close to Harare. The fruits representing a broad range of colours were spread on a flat surface next to the white side of a Kodak grey card. Pictures of the fruit were taken using a Nikon D70 digital camera. The pictures were loaded onto a computer and analysed using Photoshop CS6 Extended from Adobe. The colour of fruits from different sites ranged from green to yellowish to brown with shades of grey. The RGB values of the yellow fruit were higher than corresponding values for brown and green fruit. In all the groups of fruits that were green, brown and yellow, the red component of the RGB colour space had the highest intensity followed by green and then blue. The means of RGB values were significantly different (*p*<0.05) for more than 80% of fruit from the sites. Quantitative measurement of colour of the fruit was successfully achieved by using the camera and computer with Adobe Photoshop software package.

Key words: *Parinari curatellifolia*, colour, green, brown, yellow, RGB

1. Introduction

Consumers of various foods consider colour as one of the criteria of choice. Colour is an intrinsic property of food characterizing its identity and quality (Socaciu and Diehl, 2008). Consumers evaluate and use colour as one of the indicators for acceptance or rejection of foods (Fernandez et al., 2005; Valadez Blanco et al., 2007). The colour of fruit is used to determine the extent of ripeness (Jouybari and Farahnaky, 2011).

The colour of biological materials is often reported in subjective terms making it difficult for readers who are unfamiliar with the terms used to visualize the colours reported (Villafuerte and Negro, 1998). Differences in the description of colour by humans can arise from variation in visual ability that depends on age, occurrence of red-green colour blindness and defects of vision in specific individuals. Descriptions of colour are further complicated by cultural and language differences. The development of new technology in colour measurement introduced objective or quantitative methods of colour assessment.

The colour systems that are most widely used by the food industry are the Hunter L, a, b and the CIE L*, a*, b* scales (Garrido-Novell et al., 2012; Yun, 2006). In the two systems, red, green and blue colours that are perceived by cones of the human eye are represented on a scale where
variations from black to white are indicated on an L scale, with the axes a and b representing red-green and yellow-blue respectively (Mendoza and Aguilera, 2006).

Digital cameras and the associated software for the processing of images are becoming increasingly common. Digital images, which can be saved in a variety of formats, the most common of which is JPEG, are made up of picture elements, each of which can represent Red, Green or Blue (Yam and Papadakis, 2004). The intensity in each picture element can vary from 0 to 255; assigning the Red, Green and Blue defines the colour making it possible to reproduce colour reliably (Gokmen and Sugut, 2007; Yam and Papadakis, 2004). The principles described by Gokmen and Sugut, (2007) and Yam and Papadakis, (2004) form the basis of the RGB colour model. The RGB model is an additive colour model using transmitted light to display colours. Varying proportions and intensities of three primary colours namely red, green and blue are employed to form cyan, magenta, yellow and white (Yam and Papadakis, 2004). The model resembles the way humans perceive colour in the eye retina.

It would be useful to determine the colour of biological materials like fruits objectively using inexpensive equipment. The application of computer vision to food classification problems has been widely successful but there is scope for improving the implementation of computer vision without having to incur additional hardware costs (Jackman and Sun, 2013). While the computer and software may still be considered expensive by some investigators, the equipment can be used for other purposes and is not dedicated to the measurement of colour.

The measurement of colour of apples from parts of New Zealand was reported by Hirst et al. (1990). For the purpose of quality control, the colour of fruits and vegetables from one of the largest hypermarkets in Budapest, Hungary, were measured by colorimetric method (Samu et al., 2010). Colour of Kalakand, a dairy product of India was quantified using Adobe Photoshop Version 8 Software (Vyavahare et al., 2013). Quantitative determination of colour may be applied to measurement of colour of edible wild fruits found in Southern Africa. The fruits play an important role especially during times of famine, providing an alternative source of nutrition and cash income (Mithofer and Waibel, 2003; Kalaba et al., 2009). Examples of the fruits are *Parinari curatellifolia*, *Sclerocrya bierra*, *Uapaka kirkiana* and *Strychnos cocculoides*. The physical and nutritional properties of fruit of *Parinari curatellifolia* in Zimbabwe have been reported (Benhura et al., 2013).

*Parinari curatellifolia* is a miombo woodlands tree that belongs to the family *Chrysobalanaceae* (Sonogo et al., 2006). It grows in tropical Africa with highest concentration in Southern Africa (Benhura et al., 2013). *Parinari curatellifolia* tree bears an edible fruit that may be consumed when fresh or processed into products like jam, porridge and beverages (Kalaba et al., 2009). The fruit saved some rural families in Zimbabwe from starvation in 2008 when the country faced severe food shortages caused by drought and economic problems (Mutasa, 2010).

The colour of the fruit of *Parinari curatellifolia* changes from greyish-green to yellowish-brown on ripening. Consumers detect ripening of fruit of *Parinari curatellifolia* by visual inspection of colour of the fruit when it ripens. For consistency of measurement of colour, a quantitative method would be useful in assessing the extent of ripeness of the fruit. Quantitative determination of the colour of *Parinari curatellifolia* fruit is important as it is planned to develop food products using pulp of the fruit. To date, there is no published data on determination of colour of *Parinari curatellifolia* fruit. The objective of this study was to quantitatively determine the colour of *Parinari curatellifolia* fruit using a camera and a computer with Photoshop software from Adobe.

2. Materials and Methods

Collection of Fruit

Fruits were collected from Greendale, Hatfield and Harare Airport areas in Harare, Zimbabwe. Ripe fruits were picked from the ground while semi-ripe and unripe fruits were picked from the trees. Ripe and unripe fruits were mixed and collected in polythene bags with holes to allow free movement of air (Benhura et al., 2012).
Photographs of Fruit

The fruit were evenly spread on a flat surface next to the white side of a Kodak grey card as shown in Figure 1. Pictures of fruit were taken using a Nikon D70 digital camera (Nikon Corporation, Japan) equipped with a 17-300 mm zoom lens at a focal length of 70 mm, pattern metering mode, F stop 4.5, exposure time 1/50 second and set for macro with the camera 60 cm above the fruit. The images were obtained at the maximum resolution of 3008 by 2000 pixels in the RGB colour mode and saved in the JPEG format. The fruit were selected to represent as much of the variation in colour as possible.

Analysis of Colour Using Adobe Photoshop

The photo images taken using a camera were transferred to a computer hard disc and opened with Adobe Photoshop software (Vyawahare and Rao, 2011). In this study, the colour of Parinari curatellifolia fruit was measured using Adobe Photoshop CS6 Extended, licensed to the University of Zimbabwe. Photoshop is a standard software designed for graphics producers and photographers for photo retouching and image editing (Yam and Papadakis, 2004). The software has other features that may be adopted for analyzing colour of food materials (Yam and Papadakis, 2004). The software is rich in image editing features and its colour analysis capability compares well with more expensive colour analysis software. Colour was quantified in the RGB colour model utilizing accessories in Adobe Photoshop software (Vyawahare and Rao, 2011). The algorithm employed for the measurement of RGB values was based on a procedure described by Dadwal and Banga, (2012) and is outlined in Figure 2.

Figure 2: Steps illustrating measurement of RGB values of Parinari curatellifolia fruit

Histogram Window

A histogram window was used to determine distribution of colour along the x and y axes (Yam and Papadakis, 2004). With a specific fruit selected, the histogram of the selection was accessed from Image > Histogram. The mean of the readings in the red, blue and green channels and the total number of pixels contributing to the picture were recorded.

The window output included mean, standard deviation and median of the RGB colour value. The average colour of the fruit was obtained from the Histogram window. Typical information that can be obtained from the image histogram is shown in Figure 3 for the Red channel.

Statistical Analysis of Data

Statistical analysis of data was done using Graph Pad Prism 4 software package. The means of RGB values for the data sets were compared by one way analysis of variance (ANOVA).
3. Results

Brown Colour

As shown in tables 1 to 4, fruit from different sites had different RGB values. R values ranged from 208±10 to 229±10 while G values fell between 76±10 and 108±20. B values ranged from 8±1 to 53±20. The variation of the RGB values shows that there were different shades of brown in the fruit. Differences in colour of fruit may arise from differences in varieties of the fruit of Parinari curatellifolia. Different varieties differ in shape and size which may influence distribution of brown colour on the fruit surface. The RGB colour model provided a quantitative measurement method for determination of different intensities of brown colour of the fruit.

Table 1

Mean RGB values obtained from Photoshop histograms of selected fruit, for Parinari curatellifolia fruit from Greendale classified into greenish, brown and yellowish.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Colour Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Greenish</td>
</tr>
<tr>
<td>R</td>
<td>132±10</td>
</tr>
<tr>
<td>G</td>
<td>110±10</td>
</tr>
<tr>
<td>B</td>
<td>58±20</td>
</tr>
</tbody>
</table>

Data are expressed as Mean± σ, n=3, σ is the standard deviation.

Green Colour

There were differences in RGB values of fruit obtained from different sites. R values ranged from 111±10 to 214±10, G values from 90±10 to 137±10 and B values from 53±20 to 90±10 (Tables 1 to 4). The differences in the intensities of red, green and blue colours adding to green account for the different shades of green observed. Green colour has been used as an indicator of unripeness in fruit of date palm (Mohd Hudzari et al., 2012). Unripe fruit of Sclerocarya bierra were green in colour and had higher RGB values (Buchwald and Beckett, 2012) than those obtained for unripe fruit of Parinari curatellifolia. Similarly, unripeness of Parinari curatellifolia fruit may be described on the basis of the green colour.

Table 2

Mean RGB values obtained from Photoshop histograms of selected fruit, for Parinari curatellifolia fruit from Harare Airport area classified into greenish, brown and yellowish.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Colour Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Greenish</td>
</tr>
<tr>
<td>R</td>
<td>111±10</td>
</tr>
<tr>
<td>G</td>
<td>90±10</td>
</tr>
<tr>
<td>B</td>
<td>53±20</td>
</tr>
</tbody>
</table>

Data are expressed as Mean± σ, n=3, σ is the standard deviation.

Table 3

Mean RGB values obtained from Photoshop histograms of selected fruit, for Parinari curatellifolia fruit from Hatfield classified into greenish, brown and yellowish.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Colour Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Greenish</td>
</tr>
<tr>
<td>R</td>
<td>214±10</td>
</tr>
<tr>
<td>G</td>
<td>137±10</td>
</tr>
<tr>
<td>B</td>
<td>90±10</td>
</tr>
</tbody>
</table>

Data are expressed as Mean± σ, n=3, σ is the standard deviation.
Yellow Colour

R values for fruit from the different sites ranged from 253±0 to 255±0, G values from 152±10 to 194±10 and B values from 65±10 to 112±10. (Tables 1 to 4). The RGB values of the yellow fruit were higher than corresponding values for brown and green fruit. In all the groups of fruits that were green, brown and yellow, the red component of the RGB colour space had the highest intensity followed by green and then blue.

Table 4

Mean RGB values obtained from Photoshop histograms of selected fruit, for Parinari curatellifolia fruit from the sites referred to in Tables 1 to 3 and classified into three broad groups

<table>
<thead>
<tr>
<th>Channel</th>
<th>Colour Measurements</th>
<th>Brown</th>
<th>Green</th>
<th>Yellowish</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td></td>
<td>179±10</td>
<td>151±10</td>
<td>240±10</td>
</tr>
<tr>
<td>G</td>
<td></td>
<td>97±20</td>
<td>108±10</td>
<td>157±20</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>49±10</td>
<td>75±20</td>
<td>86±10</td>
</tr>
</tbody>
</table>

Data are expressed as Mean±σ, n=3, σ is the standard deviation.

4. Discussion

The colour of individual fruit units ranged from a greenish grey for unripe fruit to almost red for the ripe fruit. Typical distribution of colour in an individual fruit is shown in Figure 4. All fruit had greyish patches whose colour was more or less the same for greenish, brown and yellowish fruit. The observed colour may be a result of mixing of grey shades with green, brown and yellow colours of the fruit.

For unripe green fruit considered in tables 1 to 4, the mean values for each of R and G were significantly different (p<0.05), while there were no significant differences among B values for the same fruit (p>0.05) (Table 5). The differences in RGB values account for the different shades of green observed in fruit from the different sites.

Mean values of each of R and B for ripe brown fruit were significantly different (p<0.05), while no significant differences were obtained for mean values of G for the fruit (p>0.05). The variation of RGB values measured on the fruit may explain the different intensities of brown colour of fruit from the sites. The RGB values may differ as fruit may be at different stages of ripening. The brown colour intensifies or darkens as the fruit ripens.

Table 5

Compilation of P values from ANOVA assessment for means of RGB values for data in Tables 1 to 4

<table>
<thead>
<tr>
<th>Colour band</th>
<th>Green</th>
<th>Brown</th>
<th>Yellowish</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>p&lt;0.05*</td>
<td>p&lt;0.05*</td>
<td>p&lt;0.05*</td>
</tr>
<tr>
<td>G</td>
<td>p&lt;0.05*</td>
<td>p&gt;0.05</td>
<td>p&lt;0.05*</td>
</tr>
<tr>
<td>B</td>
<td>p&gt;0.05</td>
<td>p&lt;0.05*</td>
<td>p&lt;0.05*</td>
</tr>
</tbody>
</table>

For p<0.05*, means are significantly different and where p>0.05, there is no significant difference among the means.
Significant differences were obtained for R, G and B values of ripening yellowish fruit from the different sites ($p<0.05$). The variation in the mean values of RGB explains the differences in intensities of yellow colour observed in the fruit.

The characteristics observed define the unique colour of *Parinari curatellifolia* fruit at the unripe, semi ripe, ripe and overripe stages. The observed differences in colour of the fruit may be related to classes of ripeness as demonstrated in date palm fruit (Ishak and Hudzari, 2010). The colour of date palm fruit ranges from purple for unripe fruit through red for ripe and pink-yellowish for overripe fruit (Ishak and Hudzari, 2010). Similarly as for date palm fruit, the variation in colour of *Parinari curatellifolia* fruit may be explained. The distribution of different shades of red was observed in “Gala” apples grown in New Zealand (White and Johnston, 1991). The measurement algorithm used classified images obtained for the fruits into four intensity bands representing dark red, medium red, light red and non-red (White and Johnston, 1991). The variation in the colour of *Parinari curatellifolia* fruit may be described in a way similar to distribution of colour in apples.

Studies of fruit skin pigments in apples have shown that colour changes mainly resulted from variations in the concentrations of chlorophylls, which impart a green colour, carotenoids and flavonoids that cause yellow colour (Hirst et al., 1990). The expression of pigment colour is also influenced by factors like cuticular waxes, epidermal hairs, shape and orientation of cells in the epidermis and sub epidermis (Lancaster et al., 1997). Although the carotenoids, flavonoids and chlorophyll pigments were not measured in *Parinari curatellifolia* fruit in the current study, changes of their levels in the fruit skin were likely to influence colour measured in the fruit.

5. Conclusion

There is wide variation in the quantitative colour of *Parinari curatellifolia* fruit. The colour of the fruit from the different sites ranged from green, yellowish to brown with shades of grey. The observations relate to the measured RGB values where comparison of the means showed that $p<0.05$ for more than 80% of gathered fruit. The colour of the fruit was successfully measured using a camera and a computer with Adobe Photoshop software package.

Acknowledgement

The authors acknowledge the support of the University of Zimbabwe for funding the research.

References


