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POST – HARVEST PHYSIOLOGICAL INDICATORS ON THE PHENOTYPIC VARIATION OF MARULA FRUITS (*Sclerocarya birreasubspp. caffra*) IN SWAZILAND

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ABSTRACT

The marula tree is now a very important indigenous fruit species in Swaziland, with great potential for further improvement, yet very little research has been done on its fruits. The overall objective of this study was to determine the physiological indicators on the phenotypic variation of marula fruits from different ecological zones in Swaziland, putting emphasis on fruit maturity indices. Three marula selections were identified during the peak production season at Buhleni, Malindza, and Siphofaneni areas. Five trees were selected at random and marked from farmer's fields and communal grazing areas.Twenty fruits from each marula tree per selection were randomly collected and after each harvest, the fruits remaining under the tree canopy were removed so as to get fresh fruits on the next harvest. Results showed a significant ($P<0.05$) increase in the fruit pH, TSS, diameter, fresh mass, and dry mass with each successive harvest from the three different areas. However, there was a decrease in flesh firmness with each successive harvest from the three different areas. The use of marula fruits should be based on such characteristics for the different products that are to be produced. It is recommended that if one wants marula fruits of high pH, the fruits must be collected from Buhleni, high TSS to be collected from Sphofaneni, high fresh mass to be collected from Malindza, high flesh firmness to be collected from Buhleni, and larger diameter fruit to be collected from Malindza under the conditions similar to those of this study.

Keywords: Fruit Quality, Maturity Indices, Phenotypic Variation, Ecological Zones, Marula (*Sclerocaryabirrea*)

INTRODUCTION

Marula tree (*Sclerocarya birrea* L.sub *spp caffra*) belongs to the Anacardiaceae family and the genus name Sclerocarya derived from the Greek word skleros, meaning hard, and karyon, meaning a nut which refers to the hard stone of the fruit. The World Agroforestry Centre stated that 'birrea' comes from 'birr', the common name for the tree in Senegal, and 'caffra' from the Hebrew word, 'kafri' meaning a 'countryman'**[1]**. Archaeological evidence shows that the marula tree was a source of food as long as 10,000 years B.C. It is believed that *Sclerocarya birrea* originated in Madagascar, but it now grows wildly in several countries in the Southern African Development Community (SADC) region, and in other regions with similar climatic conditions. Not only the fruit, but also the nut, are rich in minerals and vitamins. Legend abounds on the multiple uses of the tree, bark, leaves, fruit, nut and kernels **[2]**.

The plum sized fruits are covered in a soft, leathery, pale green-yellow exocarp which encloses the juicy white flesh **[3]**. The fruit has an exotic flavor and a distinctive scent. The fruit contains a large hard seed, surrounding two or more edible kernels, rich in oil. The fruits are edible, either raw or made into a delicious jelly. They are also fermented into a popular wine; a marula liquor which is available commercially. The kernels are either eaten raw or roasted. Oil can be extracted from the kernels which are traditionally used for cooking, as a meat preservative and for skin care. The bark is widely used medicinally to treat diarrhoea, diabetes, fever and malaria, and the roots are used to treat sore eyes. The leaves are used to make relish, and the hard wood makes excellent kitchen utensils and furniture **[4]**.

In late summer (February and March) each year in Swaziland, the female trees produce pale green fruits. These fruits fall and ripen on the ground, turning a waxy yellow colour and taking a distinctive sharp, sweet scent. People collect large quantities of ripe fruits, with different cultural groups having variety of uses for them, for example making jam and wine. The dried nuts are usually often strung together in a necklace, and that traditionally symbolizes love **[5]**.

In Swaziland, about two million marula trees grow, mostly in the Lowveld and dry Middleveld. It grows naturally in indigenous forests and bushveld, in communal grazing lands, fields and homesteads **[6]**. A mature marula tree produces about 500 kg of fruit each year, which drops to the ground while still green around in February and March.

Animals eat some of the fruit and thus help in dispersal of seeds. Much of the fruit is gathered by rural women who strip the pulp to brew a traditional alcoholic drink, called *buganu* .The Kingdom of Swaziland celebrates the start of the marula season with the annual marula festival since 1985. The festival is increasing in popularity, and swiftly becoming one of the country's most exciting traditional ceremonies. Each year His Majesty King Mswati III and Her Majesty the Queen Mother make their way to various regions of the Kingdom to celebrate the beginning of the *Marula* Season. This initiated marula certification in the Kingdom in 2004, through the formation of the Swazi Indigenous Products Company at Mpaka in the Lowveld. In 2006, the Natural Futures Programme, jointly implemented by the World Conservation Union and PhytoTrade Africa, and Southern African Natural Products Trade Association, provided support to Swazi indigenous products for the development of systems to produce organically certified marula oil **[7]**.

According to **[8]**, marula wine (*buganu*) plays a very important role in the culture of the Swazi people as demonstrated by the annual *buganu* ceremony officiated by the Royal Family. It is, therefore, important to document the traditional *buganu* processing technologies thus preserving indigenous knowledge systems as modernization takes root with time.

Recently, an effort has been made to domesticate the tree in southern Africa and Israel in order to establish orchards that will supply both fresh fruit and fruit for canning and the beverage industry. This is due to the fact that marula provides a variety of natural products such as processed fruit pulp, juice, edible oil and essential oil to name a few which are highly priced in the market **[9]**.

According to **[1]**, marula fruits are rich in sugars, essential vitamins, oils, and proteins necessary for human consumption. Improved nutrition increases immunity to HIV/AIDS, reduces its effect and its progression. The rural areas are at risk of HIV/AIDS, which affects food production and economic activities of the people. Marula and other indigenous fruits therefore constitute an important source of essential vitamins and minerals for the poor people.The contribution of marula and other indigenous fruits to trade has grown rapidly. Therefore, efforts are underway to strengthen and improve processing of indigenous fruits including marula, as an important strategy to promote fruit export and create employment opportunities in the rural areas. Processing and marketing of marula and other indigenous

fruits would complement the efforts of government to diversify product range in the local markets, improve nutrition and expand local processing industries.

The fruits are easy to handle because they are firm when they fall from the tree and they are relativelylarge. At that point the skin is tough enough not only to resist bruising from the fall but also to give the fruit a good shelf life. A study in Israel indicated that although different trees drop the fruits at different times, each tree drops 80 percent of its fruits within two weeks. The fruits are harvested after falling to the ground when still green, turning yellow in 10 days or so. The fruits from the ground were then picked and processed. The yield ranged from 17,500 – 90,500 fruits per tree per annum. Post-harvest handling methods showed that the fruits be stored at 12-20°C for suitable juicing. Fruits stored at a higher temperature had a deeper yellow color, a higher juice content, and lower acidity. Fruits kept at 4°C remained green and firm and developed brown spots and an off-flavor **[10]**. Marula fruits abscise before ripening; at this stage the skin color is green and the fruit is firm. The time for fruit abscission varies among trees. This can be attributed to genetic variation, which can be exploited for expanding the harvest period by planting clones that ripen at different times **[11]**.

Four important terms described by **[12]** are: maturity, physiological maturity, horticultural maturity and ripening. Maturation as the stage of development leading to attainment of physiological or horticultural maturity. Physiological maturity, the stage of development when a plant or plant part will continue ontogeny even if detached. Horticultural maturity, the stage of development when a plant or plant part possesses the pre-requisites for utilization by consumers for a particular purpose. Ripening, the composite of the processes that occur from the later stage of growth and development through the early stages of senescence, that result in characteristic aesthetic and/or food quality, as evidence by changes in composition , colour, texture, or other sensory attributes.

Quality parameters are affected by the environment during growth, maturity at harvest, and holding conditions after harvest. Useful indices are needed for evaluation of fruit quality in the field, proper time of harvest, and maintenance or deterioration of quality after harvest **[13]**.

Maturity indices used for marula fruits include: size, ground color, flesh firmness, weight and amount of soluble solids. During

maturation of marula fruits, the flesh softens, the composition changes, a characteristic flavour develops, the green colour of the skin decreases and becomes more evident, and the size and weight increases as the fruit matures **[14]**.Quality in fruits is that combination of characteristics or properties that make them desirable to the buyer or user. Components of quality include: appearance, texture, flavour and nutritive value of the fruit. Maturity indices are important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure the attainment of acceptable eating quality to the consumer **[15].**

Differences in germination patterns and seedling growth rates may be due to climatic and geographic influences or, more even genetic differences **[12].** Forest trees seedlings used for genetic testing are traditionally produced in outdoor nurseries. Most forest tree seedlings are characterized by slow growth rates. Consequently, forest genetic studies need methods that accelerate identification of superior genotypes and evaluation of juvenile-maturity correlation. The accelerated growth concept may be based upon the control of growth by the manipulation of one or more growth factors, such as light, temperature, mineral nutrients, water, carbon dioxide, growth regulating chemicals and container dimensions **[16]**.

It is evident that Sclerocarya species is increasing in importance. Our study was inspired by the need to know more about maturity indices of marula fruits, and their potential for use as fresh fruit or for processed products, from different areas in some agro-ecological zones of Swaziland.

METHODS AND MATERIALS

Experimental Sites

The experimental sites were:

I. Siphofaneni

Siphofaneni was one of the three areas where the marula fruits were collected. The geographical location of the area is 26° 41' South and 31° 41' East. It has an altitude of 400-600 m, mean annual temperature of 23°C and mean annual rainfall of 650-800 mm. The area has rolling piedmont, undulating basins, and isolated hills. The area has gneiss, granite and granodiorite rocks and found in the southern dry Middleveld **[6]**.

II. Buhleni

The marula fruits were also collected at Buhleni. The geographical location of Buhleni is 25° 57' South and 31° 17' East. The areas has an altitude of 600-800m, mean annual temperature of 20°C and mean annual rainfall of 800-1000 mm and has medium height hills associated with low hills. The area

has granodiorite and granite rocks and found in the northern Middleveld **[6]**.

III. Malindza

Malindza was where the marula fruits were also collected. The geographical location of Malindza is 26° 39' South and 31° 67' East. The area has an altitude of 250-400 m, mean annual temperature of 25°C and mean annual rainfall of 550-625 mm. This area is generally flat. The area has sandstone/clay stone, dolerite intrusions and granite/granodiorite rocks and found in the Lowveld **[6]**.

IV. Luyengo

Luyengo was the area where the samples from the different areas were tested for their physiological indicators /maturity indices, from January 15th to January 30th in the Biology Laboratory, Faculty of Agriculture, University of Swaziland, Luyengo Campus. The geographical location of Luyengo is 26° 5' S and 31° 17' E at an average altitude of 730 m above the sea level, in the wet Middleveld of agro-ecological zone of Swaziland **[6]**.

Experimental Design

The experiment was a 3*5 factorial laid in a randomized complete block design (RCBD). There were five harvests which consisted of harvest 1, harvest 2, harvest 3, harvest 4 and harvest 5, from three areas of Siphofaneni, Buhleni and Malindza. Twenty fruits were used in each harvest from the three different areas.

Collection of Marula Fruits

Marula fruits, which were free from defects such as sun scorch and pest or disease damage, were randomly collected from three different places in Swaziland namely; Buhleni (northern dry Middleveld), Malindza (Lowveld) and Siphofaneni (southern dry Middleveld). Up to five harvests were made from each tree after every two days, with five trees per area, and 20 fruits collected from each tree per harvest. After each harvest, the remaining fruits were removed beneath the trees so as to be able to collect fresh fruits on the following harvest.

Data Collection

Data was collected for flesh firmness, total soluble solids, fruits fresh weight and dry weight, and diameter measurements.

Removing Field Heat

The fruits were removed of field heat by placing them in a refrigerator at the Biology Laboratory at a temperature of 12.5° C for 24 hours.

Fresh Mass and Dry Mass of Fruits.

The fruits were washed to remove soil particles and other inert material. The fresh mass of the fruits was measured by using a beam balance. The dry mass was determined

by placing the fruits in the oven at 70°C until constant mass. After 72 hours the fruits were then weighed again to determine the moisture content **[17]**.

Flesh Firmness

The fruits were tested for flesh firmness using the Wagner FT ripeness tester (Rome, Italy) (mm force dial FDK 32), which is a compact penetrometer universally used to measure ripeness of fruits. The FT fruit tester measures the force required to push a plunger tip of specific size into the fruit pulp. The force reading assists in determining the appropriate picking time or to monitor fruit softening during storage. Because of the number fruit and vegetable varieties, geographical locations, and other factors, the appropriate firmness for harvesting can vary. Each marula fruit was cut on at least three different sides, then a plunger was inserted on each cut for at least 3-5 seconds, then readings were taken and then an average taken as the fruit flesh firmness.

Total Soluble Solids

To measure the total soluble solids (TSS) of the fruits, an Atagorefractometer (Itabashi-ku, Tokyo, Japan), which is a device used to measure the °Brix of a solution was used. The cuts which were made when testing for flesh firmness were used to squeeze the juice from the marula fruits onto the refractometer prism. The refractometer was calibrated first to read accurately at a fixed temperature of 20°C.A reading was then taken through the eyepiece of the refractometer to get the TSS level of each fruit. An average was taken from the three readings to get an approximate of each fruit's TSS level.

The pH of Marula Fruits

The fruits were squeezed for juice into a 10 ml beaker, with each harvest from the different areas squeezed into different labelled beakers. The solids were filtered out through a cheese cloth. The pH meter was first calibrated by using, a buffer solution of pH 7.01, which had potassium di-hydrogen phosphate and di-sodium hydrogen phosphate. Another buffer solution of pH 4.01 which had potassium hydrogen naphthalate was also used after the initial buffer solution. The electrode was put inside distilled water after every reading and during the testing. It was ensured that the electrode did not get in contact with the sides or base of the beaker.

Diameter of the Fruits

Diameter of the fruits was measured using a caliper. As the fruits are oval shaped, it was much easier to use the caliper (Rome, Italy).

Colour of the Fruits

The colour of the fruits was determined by using a colour chart obtained at Build. It Stores (Global Coatings, Matsapa, Swaziland).

Data Analyses

Data collected were subjected to analysis of variance (ANOVA) using MSTAT-C statistical package **[18]**. Means that were significant at the 5% level were separated using the Duncan New Multiple Range Test (DNMRT) **[19]**.

RESULTS

Fruit Fresh Mass

There was a significant (P< 0.05) difference in the marula fruits fresh mass from harvest 1 to harvest 5, and significant differences (P<0.05) from the different areas of Swaziland **(Table 1)**. The highest overall fresh weight (1908.51 g) was obtained from Malindza marula fruits, followed by fruits from Sphofaneni (1489.75 g) and the lowest overall fresh mass (1251.32 g) was obtained for fruits from Buhleni. From the different harvests, there was an increase in weight in each successive harvest from the three different areas.

Marula Fruits Diameter

There were significant (P<0.05) differences in the marula fruits diameter from harvest 1 to harvest 5, and significant differences (P<0.05)from the three different areas of Swaziland **(Table 2)**. The overall diameter was significantly higher for fruits from Malindza (27.7 cm), followed by fruits from Sphofaneni (21.4 cm) and the lowest overall diameter was recorded for fruits from Buhleni (18 cm). From the different harvests, there was an increase in each successive harvest from the marula fruits diameter, but there was variation at Malindza.

Fruit Flesh Firmness

There was a significant (P<0.05) difference in the marula fruits flesh firmness from harvest 1 to harvest 5, and significant differences (P<0.05) from the different areas of Swaziland **(Table 3)**. The highest overall flesh firmness (94 mm) was obtained from Buhleni fruits; followed Sphofaneni fruits (68.3 mm) and the lowest overall flesh firmness (50.7 mm) were obtained from Malindza fruits. From the different harvests, there was a decrease in flesh firmness with each successive harvest.

Total Soluble Solids (TSS) of Fruits

There was a significant (P<0.05) difference in the total soluble solids (TSS) of marula fruits from harvest 1 to harvest 5, and significant differences (P<0.05)from the different areas of Swaziland **(Table 4)**. The highest total soluble solids was obtained for fruits from Sphofaneni (65.8° Brix), followed by fruits from Buhleni (55.4° Brix) and the lowest total soluble solids (45.2°Brix) was obtained for fruits from Malindza. From the different harvests, the °Brix increased with each successive harvest.

pH of the Fruits

There was a significant (P< 0.05) difference in marula fruits pH from harvest 1 to harvest 5, and significant differences (P<0.05) from the different areas of Swaziland **(Table 5)**. The overall highest pH (16.34) was obtained from Malindza fruits, followed by Buhleni fruits (15.99) and the lowest pH (15.77) was obtained from Sphofaneni fruits. From the different harvest, the pH of marula fruits increased with each successive harvest from the three different areas.

Fruit Dry Mass

There was a significant (P<0.05) difference in the marula fruits on dry mass from harvest 1 to harvest 5, and significant differences (P<0.05) from the different areas of Swaziland **(Table 6)**. The overall dry mass (589.95 g) was significantly higher from Buhleni marula fruits, followed by Sphofaneni fruits (545.76 g) and the lowest overall dry mass (412.79 g) was obtainedfrom Malindza fruits. From the different harvests, there was an increase in with each successive harvest from the marula fruits dry weight after oven drying.

Table 1: The Effect of Time of Harvest on Marula Fruits Mass (g) From Different Areas In Swaziland

Harvest	Buhleni	Malindza	Siphofaneni
1	$176.8^{e\,3}$	$263.95^{e\,2}$	$268.78^{e\,1}$
2	$206.81^{d\,3}$	$356^{d\,1}$	$287.4^{d\,2}$
3	$232.83^{c\,3}$	$409.24^{c\,1}$	$298.1^{c\,2}$
4	$270.56^{b\,3}$	$410^{b\,1}$	$310^{b\,2}$
5	$364.32^{a\,2}$	$469.32^{a\,1}$	$325.47^{a\,3}$

Table 2: The Effect of Time of Harvest on Diameter (cm) of Marula Fruits Harvested From Different Areas of Swaziland

Harvest	Buhleni	Malindza	Siphofaneni
1	$2.25^{e\,3}$	$4.18^{e\,1}$	$3.02^{e\,2}$
2	$3.32^{d\,3}$	$6.25^{a\,1}$	$3.97^{c\,2}$
3	$3.63^{c\,2}$	$5.31^{d\,1}$	$3.59^{d\,3}$
4	$4.25^{b\,3}$	$6.1^{b\,1}$	$4.88^{b\,2}$
5	$4.47^{a\,3}$	$5.58^{c\,1}$	$4.98^{a\,2}$

Table 3: The Effect of Time of Harvest on Flesh Firmness (mm) of Marula Fruits Obtained From The Different Growing Areas of Swaziland.

Harvest interval	Buhleni	Malindza		Siphofaneni
1	22 $^{a\,1}$	11.8$^{a\,3}$		17.2$^{a\,2}$
2	20 $^{b\,1}$	10.8$^{b\,3}$		14.5$^{b\,2}$
3	18.4$^{c\,1}$	10.3$^{c\,3}$		13.3$^{c\,2}$
4	17.5$^{d\,1}$	9.4$^{d\,3}$		12.3$^{d\,2}$
5	364.32$^{a\,2}$		469.32$^{a\,1}$	325.47$^{a\,3}$

Table 4: The Effect of Time of Harvest on the TSS (%) of Marula Fruits From the Different Areas in Swaziland

Harvest interval	Buhleni	Malindza	Siphofaneni
1	8.7$^{e\,2}$	7.3 $^{e\,3}$	11.1$^{e\,1}$
2	10.7$^{d\,2}$	8.1$^{d\,3}$	12.7$^{d\,1}$
3	11.3$^{c\,2}$	8.8 $^{c\,3}$	13.5$^{c\,1}$
4	12$^{b\,2}$	10 $^{b\,3}$	14$^{b\,1}$
5	12.7$^{a\,2}$	11$^{a\,3}$	14.5$^{a\,1}$

Table 5: The effect of Time of Harvest on Marula Fruits pH From the Three Different Areas in Swaziland

Harvest	Buhleni	Malindza	Siphofaneni
1	3.09$^{e\,2}$	3.14$^{e\,1}$	3.02$^{e\,3}$
2	3.13$^{d\,1}$	3.2$^{d\,2}$	3.1$^{d\,3}$
3	3.18$^{c\,2}$	3.26$^{c\,1}$	3.17$^{c\,3}$
4	3.19$^{b\,3}$	3.31$^{b\,1}$	3.22b 3
5	3.23$^{a\,3}$	3.43$^{a\,1}$	3.26$^{a\,2}$

Table 6: The Effect of Time of Harvest on Marula Fruits Dry Mass (g) Obtained From Differentareas of Swaziland

Harvest	Buhleni	Malindza	Siphofaneni
1	$88.89^{e\,2}$	$57.61^{e\,3}$	$92.02^{e\,1}$
2	$101.23^{d\,1}$	$66.84^{d\,3}$	$99.56^{d\,2}$
3	$124.53^{c\,1}$	$73.69^{c\,3}$	$112.11^{c\,2}$
4	$133.23^{b\,1}$	$95.47^{b\,3}$	$115.19^{b\,2}$
5	$141.97^{a\,1}$	$119.18^{a\,3}$	$126.88^{a\,2}$

- **Means followed by different letter superscripts in a column are significantly different at 5% level of significance.**
- **Means followed by different number superscripts in a row are significantly different at 5% level of significance.**

DISCUSSION

The results indicated that marula fruits from the three different areas had significant ($P < 0.05$) differences, in terms of their quality attributes or maturity indices. This was because the places have different climatic conditions, as well as the soil characteristics of the different areas, which have an effect on the water holding characteristics of the soil, as well as the availability of nutrients to marula plants **[16]**.

From the results, the marula fruits showed an increase in pH with each successive harvest in all the three different areas, with Malindza fruits recording the highest pH, followed by Buhleni fruits, while Sphofaneni fruits recorded the lowest pH. This shows that the acidity in the marula fruits decreased with each successive harvest. This is similar as reported by **[20]**, that it is the sugar/acid ratio which contributes towards giving many fruits their characteristic flavor and so is an indicator of commercial and organoleptic ripeness associated with pH increase. At the beginning of the ripening process the sugar/acid ratio was low, because of low sugar content and high fruit acid content, which makes the fruit taste sour. During the ripening process the fruit acids were degraded, the sugar content increased. Over ripe fruits have very low levels of fruit acid and therefore lack characteristic flavour and are undesirable. The idea is to avoid overripe fruits whether for fresh market or for processing.

The TSS increased with each consecutive harvest in the three different areas; with fruits

from Siphofaneni recording the highest TSS, followed by those from Buhleni and Malindza had the lowest TSS fruits. This is the similarto findings of **[11]**, who reported that as the TSS increased, the pH of the fruits decreased, meaning that an increase in the sucrose level has an antagonistic effect on the acidity of the fruits. This was due to the fact that in the ripening of fruits; there was conversion of starch to sugars. Since most samples contain substances other than sugar such as salts, minerals and proteins, the °Brix percentage represented the total concentration of all soluble solids in the sample, thus the name total soluble solids.

The fruits showed an increase in weight with each successive harvest, with Malindza recording fruit of highest fresh weight, followed by those from Sphofaneni, while Buhleni recording the lowest fresh weight. This is similar to findings of **[15]**, who reported that the increase in fresh weight may be caused by an increase in the size of the fruits, which may be stimulated by an increase in water content of the fruits, soluble solids, and an increase in the kernel size of the fruit.

There was a decrease in the flesh firmness of fruits, with each successive harvest of the marula fruits. Buhleni had the highest flesh firmness fruits, followed by Sphofaneni fruits and Malindza fruits had the lowest flesh firmness fruits. This is similar to findings of **[11]**, who reported a decrease in flesh firmness with each successive harvest was caused by the fact that the fruits were maturing, so their skin and pulp became tender, which was a sign of a post-harvest physiological indicator of ripening and subsequent senescence.

The dry matter of the fruits was significantly different at successive harvests and from different areas. Buhleni had the highest dry mass of fruits, followed by Siphofaneni fruits, while Malindza fruits had the lowest dry matter, yet Malindza had the highest fresh weight and Buhleni had the lowest fresh mass. This is similar to study by **[21]**, who reported that fruits with the largest surface area/volume ratio will lose more water per given time.

The fruits increased in size with each successive harvest, with Malindza fruits recording the highest diameter, followed by Siphofaneni fruits, while Buhleni fruits had the lowest diameter. This is similar to work by **[15]**, who reported that the increase in diameter may be caused by an increase in the weight of the marula fruits, which may be stimulated by an increase in water content of

the fruits, soluble solids, and an increase in the kernel size of the fruit with time.

There was no much variation in the marula skin fruit colour in respect to the different harvests. Most of the fruits were green and green-yellow at the time of harvesting, irrespective of the harvest. They then changed to green- yellow or pale green after removal of field heat, for 24 hours. This is similar to work by **[15]**, who reported that fruits were green at the time they dropped from the tree and changed to pale green or yellow in colour with time as a sign of maturation.

It is evident from the study that fruit of varying maturity is obtained with each harvest and from different areas. There is a need to further ripen the marula fruits to required level depending on the harvest date or area of harvest. It would be much desirable to do further studies in order to standardize ripening of marula fruits of various harvests, and from various areas and get the industry organized.

CONCLUSION

The marula fruits showed a variation in terms of fresh weight, flesh firmness, TSS, dry weight, pH and diameter from the three selected areas and at successive harvests. The use of marula fruits should be based on such characteristics for the different products that are to be produced from the fruits, depending on the quality and quantity of the product to be produced. Further ripening to the appropriate stage desired, is necessary depending on harvest stage or area of production.

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