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Physico Chemical Quality Analysis of Mango (Mangifera indica L.) Ecotypes of Fruits under Different Management Practices in Harari Region, Ethiopia

Mekonnen Tensaw[1*], Tigist Taddese[2], Kebede WoldeTsadik[2] ,Muluken Endale [1]and Chala Lemma[1]

[1]Oda Bultum University, College of Agriculture, Department of Horticulture,Chiro ,Ethiopia.P.O.BOX.226.

[2]Haramaya University, College of Agriculture and environmental science, School of plant science,Dire Dawa.P.O.BOX.138.

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***Correspondence :**
Mekonnen Tensaw
mekotensaw35@gmail.com

Abstract

Mango (Mangifera indica L.) is one of the most popular, widely cultivated and commonly consumed fruits in Ethiopia; particularly in Harari regional state, eastern Ethiopia where farmer's livelihood is highly supplemented by the income from their mango trees. However, identified mango fruits ecotypes with better quality both for growers and consumers are not available as consumers' preferences vary for the different mango ecotypes being grown in Harari region. Therefore, to investigate consumer preference to help the growers to produce according to preferred quality that meet consumers' value in the market, this study was initiated with the objective of evaluating the physicochemical and sensory quality of four mango ecotypes fruits under four farmers management practices in Harari regional state, eastern Ethiopia. The experiment consisted of a factorial combination of 4 mango ecotypes and 4 farmers' management practices with 3 replications in CRD design. Data on physicochemical and sensory attributes: titratable acidity, pH,total soluble solid, sugar to acid ratio, ascorbic acid, total phenol content, physiological loss in weight, taste, texture, aroma, flavor and overall fruits acceptability of local mango ecotypes harvested from four farmers were evaluated at four days interval during a storage period of 15 days at an ambient temperature of 25ºC and relative humidity of 65-70%. From the finding it was observed that Amba Kurfa ecotypes were found to have significantly higher total soluble solid, sugar to acid ratio, pH, total phenol content, aroma, taste, flavor, overall acceptability and lowest physiological weight loss than the rest. Amba Bare was found to have significantly higher titratable acidity and weight loss than the rest while Amba Negus was found to have significantly higher ascorbic acid and texture than the rest. As a result, Amba Kurfa grown by Farmer 3 was relatively better in physicochemical and sensory quality whereas, Amba Bare grown by Farmer 4 was relatively the least in physicochemical and sensory quality.

Keywords: *ecotypes, management practices, physicochemical, quality, and sensory*

1. Introduction

Mango (Mangifera indica L.) is one of the most widely cultivated crops in tropical and subtropical Regions of the world (Altendorf, 2019). Mango fruit is an important source of macro and micro nutrients, and also non-nutrient compounds such as phenolic compounds, flavonoids and other polyphenols, chlorophyll, carotenoids, and volatile compounds (Maria *et al*., 2019). Ethiopia has large tract of suitable land for mango production with the area of about 15,373.04 ha (CSA, 2018). Western and eastern Ethiopia are among the major growing regions that account, respectively, for 28 and 23% of the wholesale market share of Addis Ababa (Semwanga *et al*., 2008). In Harari region, mango is grown dominantly in the central and lower parts of the Bisidimo and Erer River basins including in the vicinities of the Harar city, Harawe and Kile. According to Yeshitela and Nessel (2003), farmer's livelihood is highly supplemented by the income from their mango trees, though there is a declining trend in yield and quality of mango due to old age, poor management and seedling originated nature of the trees.

However, identified mango fruits ecotypes with better quality both for growers and consumers are not available and this is one of the basic information lacking in Harari Regional State mango production. Consumers' preferences vary for the different mango ecotypes being grown in Harari regional states and the available mango fruits ecotypes may also differ in their response to the farmers' management practices, which has its own contribution to the postharvest physicochemical qualities of the product. Limited research was also done on postharvest physicochemical quality of mango local ecotypes in Harari region, eastern Ethiopia. Hence, studies are needed to investigate consumer preference to help the growers to produce according to preferred quality that meet consumers' value in the market. This study, therefore, was initiated with the objective of evaluating the physicochemical quality and sensory attributes of mango fruits under different farmers' management practices in Harari region, eastern Ethiopia.

1. MATERIALS AND METHODS

2.1. Description of Experimental Site Harari Regional State

Harari region is located in the eastern part of Ethiopia between 42°03'–42°16' N and 9°11'-9°24' E. The region is mainly categorized in two agro-ecological zones, i.e. 90% of the land area of the region is mid-high land, between 1400 – 2200 meter above sea level, while the remaining 10% is lowland or kola (< 1500) (Sultan *et al*., 2011). Temperature ranges 17.1°C - 20.2°C throughout the year. The average annual amount of precipitation is about 750-1,000 mm (http: //hararconnection.com/hnrs.html).**Sofi** is located at 09°15'40'' to 09°16'22.7'' N latitude and 042 °10'22.7'' to 042°11'29.6'' E longitude and elevation 1749 m above sea level. It is characterized by sandy loam soil and relatively warm temperature. It is 11 km from Harar town at the south-east side (Harari National Regional State, Harar City Administration Urban Local Government Development Project Office); (Camilla,1997);(Christine, 1999).

2.2. Sample collection and preparation

Mango samples were collected from four Farmers of Harawe kebele (from the specific village of Barasar) of Sofi district of Harari Regional State. Four most commonly grown ecotypes of mango namely Amba Adi, Amba Bare, Amba Kurfa and Amba Negus were identified and selected at similar maturity level from the existing local ecotypes. The four ecotypes of mangoes each from the four farmers were harvested at dark green stage from the middle portion of the tree and the four directions; north, south, east and west ignoring the top and bottom of the mango tree. Those samples were packed in plastic bags and sent to the Food Science Laboratory of Haramaya University for physicochemical and sensory quality analysis. The analysis were made at four days interval during the 15 days storage period at ambient conditions (i.e. day-3, day-7, day-11 and day-15 after harvest for physicochemical quality analysis whereas, day-3, day-7 and day-11 after harvest for sensory quality analysis). The differences in physicochemical and sensory quality and storage stability of the mango fruits among the ecotypes from different growers were investigated. Total numbers of fruits used for analysis were 2640 (660 fruits from each ecotype); which were 1920 fruits for physicochemical and 720 fruits for sensory evaluation.

2.3. Experimental design

The experiment consisted of a factorial combination of 4 mango ecotypes and 4 farmers' management practices with 3 replications in CRD design. The four mango ecotypes (Amba Negus, Amba Bare, Amba Kurfa and Amba Adi) and the four growers were used as treatments and there were 4 x 4 = 16 different combination treatments, replicated 3 times.

Table1

Key for the differences of the four farmers' management practices

Farmers' management	NPK	Urea	Age	Organic matter	Weeding and cultivation
F1M	Not applied	Not applied	40-43	Rarely applied	Rarely applied
F2M	Not applied	Not applied	40-43	Applied some times	Yes
F3M	Applied	Applied	40-43	Applied	Yes
F4M	Not applied	Not applied	40-43	Not at all	No

Source: own preliminary survey result, 2019

2.4. Analytical method

All mango samples were thoroughly washed with double distilled water to eliminate any pollutant, pesticide residue, dirt and dust from their surfaces and stored at room temperature (25°C) and relative humidity (65-70%). The fruit from each mango cultivars were weighed, peeled, sliced and blended to extract the juice from each mango sample. Percentage weight loss and chemical compositional analysis including titratable acidity, pH, total soluble solids, total phenol content and ascorbic acid were carried out at four days interval during the 15 days of storage period as follows:

Titratable acidity

AOAC titration method with 0.1N NaOH titration was applied to measure titratable acidity content. Three replicates of total acids were taken. Titratable acidity as percentage of malic acid of fresh tissue was determined following the standard methods (AOAC, 2005). Ten ml fruit juice was taken from each sample in a beaker, diluted (1:4) with distilled water and titrated against N/10 NaOH solution after adding 2-3 drops of phenolphthalein (C20H14O4) as indicator. The results were expressed as % malic acid. Calculations were made by the formula (AOAC, 2005).

Titratable acidity (mg/100g) =

$$\frac{0.1\text{N NaOH} \times \text{mls NaOH used} \times 0.067 \times 50\text{ml} \times 100}{\text{Grams of sample used} \times 10\text{ml}}$$

Where: 0.1N NaOH - is a constant used for preparation of solution used for titration and mls NaOH - is average burette reading for a sample and 0.067 - is a constant for malic acid; the dominant acid in mango fruits and 50ml represents the dilution made with distilled water. 'Gram of sample used' represents weight of juice taken from each sample for extraction which was 6g and 10ml represents aliquot taken for examination (AOAC, 2005).

pH

The pH of mango fruit juice was recorded according to (Anonymous, 1984) method using a digital pH meter (Model: Jenway 3310). The pH meter was standardized with the help of a standard buffer solution prior to measurement.

Total soluble solids (TSS)

A handheld Refractometer (Tokyo, Japan) was used for the determination of TSS. A drop of juice was placed on the prism of the Refractometer, the lid closed and TSS (°Brix) was noted directly from the scale at room temperature. The TSS content was then determined and the results was expressed in °Brix (AOAC, 1997).

Sugar to acid ratio

Sugar to acid ratio was calculated from TSS and titratable acidity according to (Rajak *et al*. 2014) by using the formula:

S/A= TSS/TA Where S/A = Sugar to acid ratio

Total phenol content

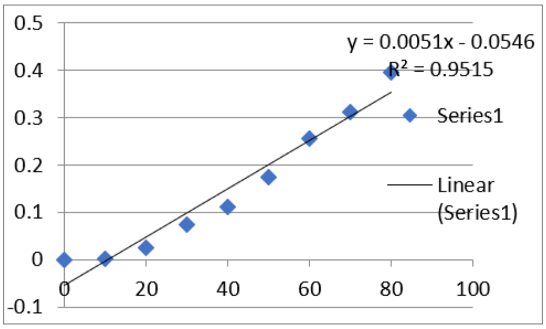
Total phenol content was determined according to Folin-Ciocalteu method (Sharma and Gupta, 2010). With a little modification of the Sample, 500 mg was extracted with 5 ml of methanol (Methanol/water,) at room temperature (25 °C) for 2 hrs. Aliquot of extract (200 µl) was added to 1.5 ml freshly diluted (10-fold) Folin-Ciocalteu reagent. The mixture was allowed to equilibrate for 5 min and then mixed with 1.5 ml of sodium carbonate solution (75 g/l). After incubation at room temperature (25 ^{O}C) for 90 min, the absorbance of mixture was read at 760 nm (6505 uv/vis spectrophotometer, Model 6505, U.K, GENWAY) and Methanol was used as a blank. From the stock solution of standard gallic acid, a series of nine standard solutions (0, 10, 20, 30, 40, 50, 60, 70, and 80ppm) were prepared (Figure 1). Total phenol content was estimated from the calibrated curve as gallic acid equivalent (GAE) in milligram per 100g and it was calculated using the formula:

$$\text{Total phenol content (mg GAE /100 g)} = \frac{(\mu g/ml) \text{ x Df x 10}}{\text{Sample mass x 100}}$$

Where: µg/ml is the absorbance reading concentration, Df is dilution factor, Sample mass – the weight of a sample taken for extraction which was 0.5g.

Where: µg/ml is the absorbance reading concentration, Df is dilution factor

Figure 1 *The calibrated curve for estimation of the total phenol content*



Ascorbic acid

Ascorbic acid content was determined by the 2, 6-dichlorophenolindophenol method (Fernandez *et al.*, 2006). An aliquot of 10 ml mango juice extract was diluted to 50 ml of water with 3% metaphosphoric acid in a 50 ml volumetric flask. An aliquot was filtered and titrated with the standard dye to a pink endpoint (persisting for 15 sec.). The ascorbic acid content (%) was calculated from the titration value, dye factor, dilution and volume of the sample using the following formula.

Ascorbic acid (mg/100 g) =

$$\frac{\text{Titre x dyefactor x volume made up}}{\text{volume of sample used}} \text{ x } 100\%$$

Where: volume of sample used = Weight of sample taken for extraction (5g) x aliquot taken for examination (10ml). Titre - average burette reading and Dye factor – 0.05

Volume made up – 50ml - volume made with 3% metaphosphoric acid.

Physiological loss in weight (PLW)

The weight of 5 fruits from each sample were taken in each examination day using a precision digital balance (Model: YP10002) to calculate loss in weight during the storage period and then the PLW was calculated as follows (Moneruzzama *et al.*, 2009).

PLW (%) =

$$\frac{\text{Weight of first interval (g)} - \text{Weight after interval (g)}}{\text{weight of first interval (g)}} \text{ x } 100$$

2.5. Sensory evaluation

Aroma, taste, flavor, texture and overall acceptability of mango ecotypes fruits were evaluated. The 48 mango samples with 15 mango fruits per sample were kept separate at the start of the experiment for three round (day-3, day-7 and day-11) and 5 fruits from each sample were taken in each examination day to determine the sensory parameters. The evaluations were made using 30 trained panelists sourced from staff and students of Haramaya University with their age in the range of 20-30 years. It was based on the 9 hedonic scales (1-Dislike extremely; 2- Dislike it very much. 3- Dislike moderately; 4- Dislike it; 5- Neither like it nor dislike it. 6- Like it; 7-Like it moderately; 8- Like it very much; 9- Like it extremely) (Srivastava and Kumar, 2007).

2.6. Statistical Analysis

All trials were carried out in triplicate and the means are reported. Analysis of variance (ANOVA) in Gen stat 18th edition statistical software under completely randomized design with three replications were applied to analyze the quality (total soluble solid, sugar to acid ratio, pH, titratable acidity, Ascorbic acid, Total phenol content, Physiological Weight Loss, and Sensory attributes; color, flavor, taste, aroma, texture and overall acceptability) of mango fruit. Tukeys Test (CD) was applied to separate statistically significant means (at 5 %) (Chase and Bown, 1997).

2. RESULTS AND DISCUSSION

Postharvest physicochemical and sensory quality parameters; titratable acidity, pH, total soluble solid, sugar to acid ratio, ascorbic acid, and total phenol content, physiological loss in weight, taste, texture, aroma, flavor and overall fruit acceptability of four mango ecotypes; Amba Adi, Amba Bare, Amba Kurfa and Amba Negus were examined during the 15 days of the storage period. The results obtained are presented and discussed below.

3.1. Mango Fruit Chemical Composition

3.1.1. Effects of farmers' management practices on titratable acidity and pH of mango ecotypes

Titratable acidity

The result of analysis of variance exhibited highly significant interaction effect of ecotypes and farmers' management on titratable acidity ($p < 0.001$) throughout the 15 days storage period (Table 2). Most of the treatments exhibited a decreasing trend during the storage period; hence, it implied that fresh harvested mangoes are more acidic than fully ripened ones. Almost the four mango ecotypes from Farmer 3 recorded relatively the lowest TA values while Amba Bare under management of Farmer 4 scored the highest TA throughout the storage period. This may be due to genetic variability and field management practices by the different growers contributing to the difference in chemical composition among the ecotypes. The present finding is in agreement with reports of Cordenunsi *et al*. 2005 and Hossain *et al.* (2014).

pH

The interaction between ecotypes and farmers' management practices exhibited highly significant effect on pH (at $p < 0.001$) on 7th, 11th and 15th days of storage period. At dark green state, mango fruit is relatively high in acid content whilst maintaining low pH than at fully ripened state. This is due to the high acid content while low sugar content of fruit at dark green state and the reverse at fully ripened state, and this idea is in agreement to Hossain *et al*. (2014). Half of the treatments increased scoring the highest pH value on 11th day of storage period and half of them increased continuously throughout the 15 days storage period (Table 2). High pH value was recorded in Amba Kurfa under management of Farmer 3 throughout the storage period, and Amba Negus under management of Farmer 3 (5.93) on day 15 and Amba Adi under management of Farmer 3 (6.03) on day 11. This is because, Farmer 3 managed his mango trees better than other farmers and the organic management which was practiced could be the source of nutrients enhancement of fruit quality (Dutta *et al.,* 2016).

The result of interaction (Table 2) depict that Amba Bare pH was lowest almost with the four farmers' management practices particularly those under management of Farmer 4 throughout the storage period which was due to the poor quality potential of Amba Bare and the completely poor management of Farmer 4 could be the reason behind the lowest pH recorded.

Table 2

Effects of farmers' management practices on titratable acidity and pH value of mango ecotypes at different days of the storage period

Mango ecotypes	Farmers' management practices	Titratable acidity				PH			
		Storage period (days)							
		3	7	11	15	3	7	11	15
Amba Adi	FMP1	1.104^{f}	0.96^{efg}	0.34^{fg}	0.36^{j}	4.13^{a}	4.51^{bc}	5.53^{abcd}	5.17^{bcde}
	FMP2	1.99^{bcd}	1.81^{bcd}	1.05^{e}	0.59^{def}	4.16^{a}	4.32^{bc}	$4.97cd^{efg}$	5.63^{ab}
	FMP3	1.26^{def}	1.02^{defg}	0.33^{fg}	1.21^{b}	4.15^{a}	4.70^{abc}	6.03^{a}	5.10^{cde}
	FMP4	1.16^{ef}	0.71^{fg}	0.38^{fg}	0.5^{gh}	4.16^{a}	4.71^{abc}	5.34^{abcde}	4.83^{def}
Amba Bare	FMP1	2.04^{bc}	1.70^{bcde}	1.62^{bc}	0.50^{gh}	4.10^{a}	4.27^{bc}	4.47^{fgh}	5.23^{bcd}
	FMP2	2.32^{bc}	2.26^{abc}	1.41^{cd}	0.41^{ij}	4.12^{a}	4.51^{bc}	4.61^{efgh}	5.59^{abc}
	FMP3	0.96^{f}	0.86^{fg}	0.48^{fg}	0.61^{de}	4.17^{a}	4.61^{abc}	5.69^{abc}	5.04^{def}
	FMP4	3.41^{a}	2.78^{a}	2.12^{a}	2.21^{a}	4.06^{a}	4.05^{c}	4.21^{h}	4.14^{h}
Amba Kurfa	FMP1	1.86^{cde}	0.38^{g}	0.35^{fg}	0.43^{hi}	4.12^{a}	4.71^{abc}	5.83^{ab}	5.07^{def}
	FMP2	2.20^{bc}	1.90^{bc}	1.34^{d}	1.21^{b}	4.12^{a}	4.28^{bc}	4.81^{defgh}	4.59^{fgh}
	FMP3	0.86^{f}	0.67^{g}	0.28^{g}	0.27^{k}	4.17^{a}	5.3^{a}	5.31^{abcde}	5.87^{a}
	FMP4	2.6^{b}	2.32^{ab}	1.06^{e}	0.52^{fg}	4.12^{a}	4.19^{c}	4.66^{efgh}	5.64^{ab}
Amba Negus	FMP1	2.41^{bc}	1.96^{bc}	1.65^{b}	0.66^{d}	4.10^{a}	4.28^{bc}	4.89^{defgh}	4.97^{def}
	FMP2	1.97^{bcd}	0.58^{g}	0.38^{fg}	0.56^{efg}	4.18^{a}	5.07^{ab}	5.66^{abc}	4.70^{efg}
	FMP3	1.15^{ef}	0.91^{efg}	0.53^{f}	0.26^{k}	4.18^{a}	4.68^{abc}	5.20^{bcdef}	5.93^{a}
	FMP4	2.12^{bc}	1.5^{cdef}	1.21^{de}	1.09^{c}	4.12^{a}	4.28^{bc}	4.37^{gh}	4.25^{gh}
CV%		13.19	18.76	8.35	3.38	1.36	6.08	4.83	3.14
SE $\pm$		0.1979	0.2144	0.0615	0.0195	0.0460	0.225	0.201	0.130
CD (0.05)		0.7372	0.7988	0.2292	0.0727	0.1712	0.839	0.749	0.488
Significance		***	***	***	***	NS	***	***	***

***Note**: CV (%): Coefficient of variation in percent. SE: Standard error, CD: Critical difference, NS: Non-significance at $P \geq 0.05$ and ***: Significance at $P < 0.001$. Means followed by common letters with in a column are not significantly different at $P \geq 0.05$.*

3.1.2. Effects of farmers' management practices on total soluble solids and sugar to acid ratio of mango ecotypes

The interaction of ecotypes and farmers' management practices exhibited highly significant ($p < 0.001$) effect on total soluble solids (TSS) and sugar to acid ratio (TSS: TA) throughout the 15 days of storage period. The value of half of the treatments increased, scoring the highest TSS and TSS: TA on 11th day of storage period and decreased again while the remaining increased continuously throughout the 15 days of storage period (Table 3). The increase in TSS could be due to the breakdown of carbohydrate into simple sugar by enzymatic activities which is in association with increase in respiration in fruit at standard temperature. Zheng *et al*. (2012) and Li *et al*. (2014) also reported similar results. The change of trend of some of treatments after day 11 may be attributed to the dynamic change from one developmental state to another. In this case, there is change from ripening state and onset of senescence, and the day further than 11 day may be beyond their shelf life which could be influenced by genetic variation among cultivars and farmers' management practices particularly the role calcium (Ca) has in extending the shelf life of the fruits (Passam *et al.*, 2007).

Amba Kurfa grown by Farmer 3 scored the maximum TSS and TSS: TA throughout the storage period ((11.5 °Brix, 17.37 °Brix, and 22.67 °Brix, 22.20 °Brix on the respective days of 3, 7, 11 and 15) and TSS: TA (13.4, 31.35, 82.01 and 81.04 on the 3rd, 7th, 11th and 15th days of the storage period)) than the other three ecotypes while the lowest results of TSS and TSS: TA was recorded by of Amba Bare grown by Farmer 4. Because of the genetic difference that exists naturally among fruit crops, and better management practices by Farmer 3, the interaction between Farmer 3 and Amba Kurfa and Amba Adi (on day 11) scored better quality than the other treatment combinations (Table 3). In addition, the genetically controlled poor quality potential of Amba Bare and the completely poor farm management of Farmer 4 could be the reason behind the lowest TSS recorded by the Amba Bare grown by Farmer 4. This is in line with the reports of Cordenunsi *et al*. (2005) and Scalzo and Mezzetti (2010).

Table 3

Effects of farmers' management practices on total soluble solids and sugar to acid ratio of mango ecotypes at different days of the storage period

Mango ecotypes	Farmers managemen t practices	Total soluble solid				Sugar to acid ratio			
		Storage period (days)							
		3	7	11	15	3	7	11	15
Amba Adi	FMP1	6.53^{cd}	13.87^{bcd}	15.37^{efg}	14.37^{gh}	5.99^{bcd}	15.4^{c}	45.63^{c}	40.28^{bc}
	FMP2	6.0^{cd}	13.37^{cde}	14.77^{efg}	20.4^{abc}	3.0^{defg}	7.52^{de}	18.88^{f}	34.36^{cd}
	FMP3	9.4^{ab}	14.37^{bc}	23.4^{a}	12.37^{hi}	7.65^{bc}	14.29^{c}	71.26^{b}	10.22^{g}
	FMP4	10.1^{ab}	13.37^{cde}	19.87^{b}	11.83^{i}	8.8^{b}	20.22^{b}	38.85^{cd}	23.61^{e}
Amba Bare	FMP1	5.03^{d}	8.37^{f}	18.47^{bc}	17.37^{def}	2.47^{efg}	5.06^{ef}	11.37^{gh}	35.57^{c}
	FMP2	5.0^{d}	14.37^{bc}	16.37^{de}	18.4^{cde}	2.2^{fg}	6.36^{de}	11.64^{gh}	45.23^{b}
	FMP3	8.03^{bc}	15.37^{b}	9.87^{h}	15.43^{fg}	8.6^{b}	22.23^{b}	20.57^{ef}	25.47^{e}
	FMP4	5.0^{d}	6.37^{g}	10.37^{h}	8.87^{j}	1.49^{g}	2.28^{f}	4.89^{h}	4.02^{g}
Amba Kurfa	FMP1	10.03^{ab}	12.3^{de}	17.7^{cd}	11.4^{i}	5.4^{cde}	32.68^{a}	45.42^{c}	26.34^{de}
	FMP2	6.37^{cd}	11.6^{e}	14.87^{efg}	14.37^{gh}	2.96^{defg}	6.1d^{e}	11.4^{gh}	11.85^{fg}
	FMP3	11.5^{a}	17.37^{a}	22.67^{a}	22.20^{a}	13.4^{a}	31.35^{a}	82.01^{a}	81.04^{a}
	FMP4	5.03^{d}	13.37^{cde}	19.0^{bc}	19.4^{bcd}	1.98^{g}	5.78^{e}	17.89^{fg}	37.14^{bc}
AmbaNegus	FMP1	5.7^{cd}	9.37^{f}	17.5^{cd}	16.37^{efg}	2.37^{efg}	4.88^{ef}	10.63^{h}	24.93^{e}
	FMP2	5.5^{cd}	12.37^{de}	14.1^{fg}	10.83^{ij}	2.79^{efg}	22.1^{b}	37.16^{d}	19.5^{ef}
	FMP3	6.03^{cd}	13.03^{cde}	13.9^{g}	21.37^{ab}	5.3^{cdef}	14.82^{c}	26.54^{e}	81.03^{a}
	FMP4	6.03^{cd}	13.37^{cde}	13.87^{g}	11.4^{i}	2.84^{efg}	9.24^{d}	11.43^{gh}	10.52^{g}
CV%		12.52	5.16	3.51	5.03	21.35	8.12	7.70	8.43
SE $\pm$		0.7111	0.5327	0.4666	0.6323	0.8436	0.9132	1.8306	2.1981
CD (0.05)		2.649	1.9844	1.7382	2.3556	3.1426	3.4020	6.8194	8.1886
Significance		***	***	***	***	***	***	***	***

Note: CV (%): Coefficient of variation in percent. SE: Standard error, CD: Critical difference and ***: Significance at $P < 0.001$. Means followed by common letters with in a column are not significantly different at $P \geq 0.05$.

3.1.3. Effects of farmers' management practices on ascorbic acid and total phenol content of mango ecotypes

The interaction between ecotypes and Farmers' management practices exhibited highly significant effect on ascorbic acid (at $p < 0.001$) content of mango fruits (Table 4). All of treatments exhibited a decreasing trend throughout the 15 days storage period which could be attributed to the highly susceptible nature of ascorbic acid to oxidative degradation during ripening. This is in agreement with the results of (Faasema *et al.*, 2014). The maximum results of ascorbic acid were recorded by Amba Negus under management of Farmer 3 (57.19, 48.3 and 29.64 mg/100g on days 7, 11, and 15, respectively), and Amba Kurfa under management of Farmer 3 (73.19 mg/100g) on day 3 and Amba Kurfa under management of Farmer 2 (56.58 mg/100g) on day 7 (Table 4). This might be due to the relatively good management practices of Farmer 3 and organic fertilizer, used by Farmer 3 and Farmer 2, could be the source for macronutrient like Ca, S and micro nutrients like Zn, B, and others, which could enhance fruit quality. There is even large variation of the same ecotypes with different management practices and this implies that balanced plant nutrition and other cultivation factors are very important in defining mango ecotypes fruit quality, and there could also be large genetic and chemical compositional variation among ecotypes of fruit species which is controlled hereditarily (Cordenunsi *et al.*, 2005; Scalzo and Mezzetti, 2010; Ali *et al.*, 2012).

The interaction effect of ecotypes and farmers' management on total phenol content was highly significant at $p < 0.001$ on 7^{th}, 11^{th} and 15^{th} days of storage period (Table 4). Most of treatments demonstrated that there was a sharp increase in total phenol content throughout the storage period and some of the treatments steadily increased up to 11^{th} day and then decreased during the ripening process which is in agreement with Hdider *et al.* (2013) and (Zuhair *et al.*, 2013). From 7^{th} to 15^{th} days of storage period, maximum record of total phenol content was exhibited in Amba Kurfa grown by Farmer 3 (23.67, 37.43 and 30.06 mg GAE/100g on the respective days of 7, 11 and 15). Amba Kurfa grown by Farmer 2 also exhibited highest phenolic content on 15^{th} day whereas Amba Bare under all management practices recorded lower values of phenolic contents (Table 4). These variations might be attributed to the differences in chemical composition that exist among mango ecotypes which could be controlled hereditarily and the clear differences in management practices that were made by the four farmers. This is in line with Dario *et al.* (2010) and Vason *et al.* (2010)

Table 4

Effects of farmers' management practices on ascorbic acid and total phenol content of mango ecotypes at different days of the storage period

Mango ecotypes	Farmers management practices	Ascorbic acid				Total phenol content			
		Storage period (days)							
		3	7	11	15	3	7	11	15
Amba Adi	FMP1	24.83^{g}	22.59^{de}	20.99^{e}	15.2^{fg}	5.01^{a}	5.84^{e}	17.93^{e}	7.4^{e}
	FMP2	24.74^{g}	22.74^{de}	20.29^{ef}	16.9^{efg}	5.63^{a}	6.25^{de}	7.09^{i}	22.63^{b}
	FMP3	51.16^{c}	28.77^{c}	21.68^{de}	19.7^{def}	6.69^{a}	17.23^{b}	22.46^{c}	15.1^{cd}
	FMP4	20.47^{ij}	15.89^{fg}	14.88^{g}	12.7^{g}	6.64^{a}	8.44^{d}	31.9^{b}	11.32^{de}
Amba Bare	FMP1	23.71^{ghi}	23.12^{d}	20.44^{e}	13.07^{g}	6.27^{a}	7.26^{de}	10.15^{gh}	8.58^{e}
	FMP2	38.25^{e}	27.97^{c}	22.7d^{e}	16.9^{efg}	6.01^{a}	6.7^{de}	7.16^{i}	8.1^{e}
	FMP3	44.91^{d}	38.9^{b}	32.5^{c}	24.2^{bcd}	5.38^{a}	6.29^{de}	6.31^{i}	11.17^{de}
	FMP4	23.88^{gh}	21.57^{de}	15.99^{fg}	14.66^{g}	6.62^{a}	7.13^{de}	8.44^{hi}	8.53^{e}
Amba Kurfa	FMP1	19.96^{jk}	19.47^{ef}	14.69^{g}	13.6^{g}	6.66^{a}	16.55^{bc}	20.38^{cd}	17.5^{c}
	FMP2	61.83^{b}	56.58^{a}	41.33^{b}	28.1^{ab}	6.29^{a}	7.79^{de}	11.1^{g}	31.09^{a}
	FMP3	73.19^{a}	38.13^{b}	35.11^{c}	21.1^{cde}	6.68^{a}	23.67^{a}	37.43^{a}	30.06^{a}
	FMP4	29.44^{f}	27.63^{c}	25.8^{d}	16.9^{efg}	6.67^{a}	8.24^{de}	14.32^{f}	25.69^{b}
AmbaNegus	FMP1	21.02^{hij}	17.29^{fg}	15.3^{g}	14.2^{g}	6.29^{a}	8.64^{d}	18.97^{de}	11.33^{de}
	FMP2	40.33^{e}	38.47^{b}	33.3^{c}	25.4^{abc}	6.31^{a}	14.68^{c}	21.63^{c}	22.96^{b}
	FMP3	60.46^{b}	57.19^{a}	48.3^{a}	29.64^{a}	6.37^{a}	7.15^{de}	7.54^{i}	9.07^{e}
	FMP4	17.05^{k}	15.74^{g}	14.3^{g}	13.69^{g}	6.69^{a}	7.09^{de}	7.35^{i}	10.53^{e}
CV%		3.10	4.06	5.73	8.29	10.08	8.08	5.07	8.58
SE $\pm$		0.9105	0.9789	1.1624	1.2520	0.52	0.6551	0.6469	1.0987
CD (0.05)		3.39	3.65	4.33	4.66	1.92	2.44	2.41	4.09
Significance		***	***	***	***	NS	***	***	***

Note: CV (%): Coefficient of variation in percent. SE: Standard error, CD: Critical difference, NS: Non-significance at $P \geq 0.05$ and ***: Significance at $P < 0.001$. Means followed by common letters with in a column are not significantly different at $P \geq 0.05$.

3.2. Mango Fruit Physical and Sensory Quality

3.2.1. Effects of farmers' management practices on percentage weight loss, on fruit taste and texture of mango ecotypes

Percentage weight loss

The result of analysis of variance showed highly significant (at $p < 0.001$) interaction effect of ecotypes and farmers' management on percentage physiological loss of weight of mango fruits. All treatments demonstrated a sharp increase in percentage physiological weight loss throughout the storage period which might be attributed to the gradual increment of transpiration in fruit during ripening at ambient condition. The result is in agreement with report by Khaliq *et al*. (2015). The highest loss was exhibited by Amba Bare under management of Farmer 4 (9.66%, 12.12% and 16.37% on 7th, 11th and 15th days of storage period, respectively) whereas the lowest values were recorded from Amba Kurfa under management of Farmer 3 throughout the storage period (Table 5). Accordingly, the lowest record of weight loss by Amba Kurfa and Amba Negus ecotypes of Farmer 3 might be attributed to best shelf life trait in them which is hereditarily controlled and the access of the ecotypes to both chemical and organic matter, which are the source of calcium (Ca) and boron (B) which has great role in maintaining fruit firmness and delay respiration and transpiration in fruits thereby extends fruit shelf life. Similar ideas were suggested by Jones *et al.* (1970), Singh *et al.* (1982), Mika (1983) and Smit and Combrink (2004).

Fruit taste

The interaction effect of mango ecotypes and farmers' management on mango fruit taste was highly significant (at $p < 0.001$). As it was determined by the trained panelist, mango taste overall liking gradually increased during the storage period (Table 5). Amba Kurfa ecotypes under management of Farmer 3 on days 7 and 11 and Amba Adi under management of Farmer 3 on day 3 were best in taste whereas, Amba Bare ecotype under management of Farmer 4 throughout the storage period were inferior in taste (Table 5). Taste is affected by nutritive quality parameters like TSS, PH, and Acidity which have considerable effect on sweetness, sourness, bitterness and astringency (Barrett *et al*., 2010). Amba Kurfa and Amba Adi under management of Farmer 3 had relatively the highest TSS and pH whereas; Amba Bare under management of Farmer 4 had the lowest TSS and pH (Tables 2 and 3). The variation in these nutritive compositions could be the basis for high taste preference of Amba Kurfa, Amba Adi ecotypes and the low preference of Amba Bare, which might be hereditarily controlled (Scalzo and Mezzetti, 2010; Isaac *et al.* (2015) and the differences in management practices.

Fruit texture

The result of analysis of variance demonstrated the interaction effect of mango ecotypes and farmers' management on mango fruit texture was highly significant (at $p < 0.001$) on days 3 and 11 whereas, it was highly significant (at $p < 0.01$) on day 7. As it was determined by the trained panelist, mango overall textural satisfactoriness gradually increased giving the lowest value at the start of the storage period, and relatively high value as mango gets ripened towards the end of the storage period (Table 5). The mean textural value determined by the panelist revealed that Amba Negus ecotype under management of Farmer 3 throughout the storage period and Farmer 2 on day 3 was more liked in texture than other ecotypes. Whereas, Amba Bare ecotypes under management of Farmer 4 throughout the storage period, and Farmer 2 on day 7 were disliked by panelist evaluators (Table 5). Generally, the result exhibited that there is great variation in texture of the four ecotypes. Amba Negus ecotype was best in texture while Amba Bare ecotype was poor as determined by the panelists. The principal difference in texture might be attributed to the variation of fruit ecotypes in their composition; water, total soluble solids, insoluble solids and cell wall composition like cellulose, hemicelluloses, pectin and proteins (Barrett *et al*., 2010). The significant variation among mango ecotypes may also be found in turgor pressure of the cell wall. The result is in agreement with Isaac *et al.* (2015) who suggested fruits of different cultivars differ in size, color, texture, and flavor as well as in storage potential. Besides, the difference in Farmers' management practices could also make variation in sensory quality among ecotypes. Farmer 3 mango trees were under relatively better management practices. Accordingly, ecotypes grown by Farmer 3 are likely to be better in sensory quality. Eman *et al*. (2007) suggested that organic management in apple improves fruit eating quality. Thus, the low in textural quality of Amba Bare mango ecotypes grown by Farmer 4 might be in one way attributable to generally poor management practices of Farmer 4.

Table 5

Effects of farmers' management practices on Percentage weight loss, fruit taste and texture of mango ecotypes

Mango ecotypes	Farmers management practice	Percentage weight loss			Fruit taste			Fruittexture		
		Storage period (days)								
		7	11	15	3	7	11	3	7	11
Amba Adi	FMP1	3.265^{g}	7.49^{d}	11.16^{cde}	2.05^{hi}	4.497^{gh}	6.27^{cdef}	3.54^{cd}	4.96^{def}	5.72^{def}
	FMP2	7.15^{c}	10.58^{b}	14.67^{ab}	4.45^{c}	5.597^{cdef}	7.42^{abcd}	3.40^{cd}	6.49^{abcd}	6.3^{bcdef}
	FMP3	4.63^{de}	4.93^{gh}	9.39^{efg}	5.81^{a}	7.03^{ab}	8.47^{ab}	5.30^{ab}	5.21^{de}	7.497^{abcd}
	FMP4	2.90^{gh}	3.57^{ij}	7.09^{hi}	2.31^{gh}	5.20^{defg}	7.6^{abc}	2.7^{def}	5.93^{cd}	5.97^{cdef}
Amba Bare	FMP1	8.77^{b}	9.93^{b}	10.87^{cdef}	2.98^{e}	4.83^{fgh}	5.9^{ef}	1.93^{f}	3.51^{fg}	7.0^{abcde}
	FMP2	4.68^{de}	5.07^{gh}	11.57^{cd}	1.85^{i}	5.14^{defgh}	6.4^{cdef}	1.66^{f}	2.73^{g}	6.1^{bcdef}
	FMP3	5.4^{d}	8.73^{c}	9.08^{efgh}	2.41^{fg}	6.497^{abc}	6.17^{def}	1.97^{ef}	4.0^{efg}	6.5^{bcdef}
	FMP4	9.656^{a}	12.12^{a}	16.37^{a}	1.54^{j}	4.16^{h}	5.77^{f}	1.79^{f}	2.58^{g}	5.0^{f}
Amba Kurfa	FMP1	3.39^{g}	6.44^{e}	9.1^{efgh}	5.45^{b}	6.27^{bc}	6.47^{cdef}	4.23^{bc}	3.66^{efg}	6.59^{bcdef}
	FMP2	3.75^{fg}	5.44f^{g}	8.75^{fgh}	3.18^{e}	5.77^{cdef}	6.17^{def}	3.23^{cde}	6.43^{bcd}	5.897^{cdef}
	FMP3	1.21^{h}	2.84^{j}	6.06^{i}	2.65^{f}	7.37^{a}	8.6^{a}	3.63^{cd}	5.96^{cd}	77^{abc}
	FMP4	4.07^{efg}	10.38^{b}	12.97^{bc}	2.01^{hi}	4.83^{fgh}	6.73^{cdef}	3.8^{cd}	3.99^{efg}	5.587^{ef}
AmbaNegus	FMP1	5.32^{d}	6.36^{ef}	12.02^{bc}	3.05^{e}	6.03^{bcd}	7.4^{abcd}	3.80^{cd}	7.99^{ab}	6.97^{abcde}
	FMP2	4.41^{ef}	7.78^{cd}	8.27^{gh}	3.01^{e}	5.96^{cde}	7.2^{bcde}	5.82^{a}	5.13^{de}	7.84^{ab}
	FMP3	2.04^{h}	4.23^{hi}	11.85^{cd}	3.05^{e}	4.997^{efgh}	6.13^{def}	5.83^{a}	8.057^{a}	8.51^{a}
	FMP4	7.065^{c}	7.1^{de}	9.71^{defg}	4.11^{d}	5.68^{cdef}	6.23^{def}	3.38^{cd}	6.86^{abc}	7.45^{abc}
CV%		5.71	4.54	6.68	3.17	5.88	6.42	12.20	10.01	8.93
SE $\pm$		0.2245	0.2621	0.5787	0.08	0.269	0.357	0.349	0.4265	0.4907
CD (0.05)		0.8364	0.9762	2.1558	0.301	1.004	1.330	1.3000	1.5889	1.8279
Significance		***	***	***	***	***	***	***	**	***

***Note**: CV (%): Coefficient of variation in percent. SE: Standard error, CD: Critical difference, **: Significance at P < 0.01 and ***: Significance at P < 0.001. Means followed by common letters in a column are not significantly different at P $\geq$ 0.05.*

3.2.3. Effects of farmers' management practices on fruit aroma, flavor and overall fruit acceptability of mango ecotypes

Fruit aroma and flavor

The minimum values of aroma and flavor were recorded at the beginning of the storage period while the maximum values were recorded towards the end, on day 11 (Table 6). The more liked mango aroma was exhibited by Amba Kurfa under management of Farmer 3 on days 3, 7 and 11 and Amba Kurfa under management of Farmer 1 and Amba Adi under management of Farmer 2 on day 7. The less liked aroma was exhibited by Amba Bare under management of Farmer 4 on days 3, 7 and 11, Amba Bare under management of Farmer 1 and Farmer 2 on day 3 (Table 6). Amba Kurfa ecotypes were most liked in aroma while Amba Bare ecotypes was disliked. Similarly, Amba Kurfa ecotypes under management of Farmer 3 on day 7 and Amba Adi under management of Farmer 3 on days 3 and 11 had best flavor whereas, Amba Bare ecotypes under management of Farmer 4 on days 3 and 7, Amba Bare under management of Farmer 1 on day 11 and Amba Bare under management of Farmer 2 on day 3 were found to be inferior in flavor (Table 6). In general, great variation in preference of aroma and flavor was manifested among the ecotypes and this could be attributed to the genetic differences that led the fruit ecotypes to evolve into distinct sensory qualities. Isaac *et al.* (2015) also reported that fruits of different cultivars differ in size, color, texture and flavor. The highest record of Amba Kurfa and Amba Adi under management of Farmer 3 could be attributed to the accessibility of Farmer 3 mango trees to NPK, Urea and organic matter, weeding and cultivation or soil working. Accordingly, ecotypes grown by Farmer 3 are likely to be better in aroma and flavor. The result is in agreement with Dutta and Kundu (2012) and Dutta *et al.* (2016)

Overall fruit acceptability

Overall acceptability increased sharply with high values recoded towards the end of the storage period. Consumer overall acceptance is brought about by the combination of the critical factors of sensory excellence like aroma, taste, appearance, texture and flavor. Accordingly, Amba Kurfa was superior in most of sensory quality parameters particularly under management of Farmer 3 which could be attributed to the better management practices where Farmer 3 applied NPK, Urea and organic matter, weeded and cultivated his mango trees compared to lowest record of ecotypes grown by other farmers due to their relatively poor farm management practices. The result is in agreement with Eman *et al*. (2007) and Dutta *et al.* (2016). Amba Bare under management of Farmer 4 was inferior in all the sensory quality parameters.

Table 6

Effects of farmers' management practices on fruit taste, aroma and overall fruit acceptablity of mango ecotypes

Mango ecotypes	Farmers management practices	Fruit aroma			Fruit flavor			Overall fruit acceptability		
		Storage period (days)								
		3	7	11	3	7	11	3	7	11
Amba Adi	FMP1	3.54^{bcde}	5.96^{abc}	7.91^{abcd}	3.7^{abcde}	6.29^{abcd}	8.30^{ab}	1.967^{hi}	4.4^{fg}	6.41^{defg}
	FMP2	4.1^{ab}	6.5^{a}	7.2^{cdef}	4.32^{ab}	6.62^{ab}	7.21^{abcd}	4.37^{c}	5.5^{cde}	7.59^{abcd}
	FMP3	3.72^{bcd}	5.96^{abc}	8.17^{ab}	4.78^{a}	6.13^{abcde}	8.45^{a}	5.337^{b}	6.93^{ab}	8.53^{ab}
	FMP4	2.72^{ef}	5.20^{cde}	7.97^{abc}	3.32^{bcdef}	5.41^{defg}	8.16^{ab}	2.237^{gh}	4.73^{efg}	7.83^{abc}
Amba Bare	FMP1	2.54^{f}	4.86^{ef}	6.5^{fg}	3.05^{cdef}	5.02^{fg}	6.43^{d}	2.867^{ef}	5.06^{defg}	6.03^{g}
	FMP2	1.93^{f}	5.58^{bcde}	7.00^{defg}	2.12^{f}	5.79^{bcdef}	7.20^{abcd}	1.78^{ij}	5.03^{defg}	6.53^{defg}
	FMP3	4.0^{b}	5.03^{def}	8.03^{abc}	4.147^{abc}	5.22^{efg}	8.23^{ab}	2.317^{g}	6.4^{abc}	6.31^{efg}
	FMP4	2.56^{f}	4.23^{f}	6.2^{g}	2.42^{f}	4.42^{g}	6.73^{cd}	1.467^{j}	4.03^{g}	5.90^{g}
Amba Kurfa	FMP1	2.8^{def}	6.50^{a}	7.10^{cdefg}	3.65^{abcde}	6.75^{ab}	7.26^{abcd}	2.537^{fg}	6.18^{bc}	6.59^{cdefg}
	FMP2	3.76^{bc}	5.83^{abcd}	7.3^{bcdef}	3.98^{abcd}	6.05^{abcde}	7.53^{abcd}	3.097^{e}	5.67^{cde}	6.36^{defg}
	FMP3	4.94^{a}	6.5^{a}	8.3^{a}	2.72^{ef}	6.85^{a}	8.077^{abc}	5.717^{a}	7.3^{a}	8.63^{a}
	FMP4	2.85^{cde}	5.44^{cde}	6.5^{fg}	2.98^{cdef}	5.52^{cdef}	6.70^{cd}	1.92^{hi}	5.1^{def}	6.85^{cdefg}
Amba Negus	FMP1	2.83^{cdef}	6.4^{ab}	7.46^{abcde}	2.82^{def}	6.48^{abc}	7.63^{abcd}	2.937^{e}	5.93^{bcd}	7.5^{abcde}
	FMP2	2.8^{def}	5.93^{abcd}	7.797^{abcd}	2.85^{def}	6.04^{abcde}	7.96^{abc}	2.897^{e}	5.82^{cd}	7.3^{bcdef}
	FMP3	3.9^{b}	6.43^{ab}	6.83^{efg}	4.02^{abcd}	6.62^{ab}	7.03^{bcd}	2.987^{e}	4.9^{defg}	6.25^{fg}
	FMP4	3.6^{bcde}	5.26^{cde}	7.03^{defg}	3.82^{abcde}	5.45^{def}	7.23^{abcd}	3.997^{d}	5.57^{cde}	6.35^{defg}
CV%		9.27	5.20	4.19	11.77	5.55	6.12	3.72	6.18	5.93
SE $\pm$		0.2491	0.2430	0.2508	0.329	0.268	0.375	0.0919	0.2793	0.3360
CD (0.05)		0.9280	0.9054	0.9343	1.225	0.999	1.398	0.3424	1.0403	1.2519
Significance		***	**	***	***	**	***	***	***	***

Note: CV (%): Coefficient of variation in percent. SE: Standard error, CD: Critical difference, **: Significance at $P < 0.01$ and ***: Significance at $P < 0.001$. Means followed by common letters in a column are not significantly different at $P \geq 0.05$.

3. Conclusions

The results of the study revealed that the combination of both mango ecotypes and the different farmers' management practices significantly affected physicochemical and sensory parameters of mango fruits. The most preferred mango aroma was Amba Kurfa grown by Farmer 3 followed by Amba Adi grown by Farmer 2. Amba Negus grown by Farmer 3 had the most preferred texture while Amba Kurfa followed by Amba Adi grown by Farmer 3 had the most preferred taste. Likewise, Amba Kurfa and Amba Adi grown by Farmer 3 were most preferred in their flavor. Overall acceptability was best for Amba Kurfa grown by Farmer 3 whereas Amba Bare grown by Farmer 4 had the least preferred overall acceptability. This showed that different ecotypes have different physicochemical and sensory characteristics where Amba Kurfa ecotype would be most suitable for fresh consumption due to its higher physicochemical and sensory quality than the rest. Generally, Amba Kurfa under Farmer3 Managemen-t practices, was found to be likely good in the overall physicochemical and sensory quality attributes , and meet the demands of the consumer which was verified by panelists' acceptance level.

Data Availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Conflicts of Interest

The authors declare that they have no competing interests.

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