ADAN J. Agric. 2022, 3: 39-48 DOI:10.36108/adanja/2202.30.0150

ISSN 2736-0385

Effect of postharvest treatments on the shelf life of two mango cultivars

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Abstract
Mango is one of the numerous delicious seasonal fruits that are cultivated in Nigeria. It is also a good source of income for farmers that are involved in its cultivation. It is therefore important to have good information about the preservation of this fruit for maximum profit. To achieve this, four levels of treatment that could affect the shelf life were applied to matured but not yet ripe mango fruits. Four storage properties were also used to assess the shelf life of the mango fruit. Data on fruit weight were collected at three days intervals in a space of nine days for two mango varieties, Keitt and Palmer. Analysis of Covariance (ANCOVA), was carried out using fruit weight as the dependent variable modeled against three independent variables namely: treatment, cultivar and initial fruit weight. The initial weight of the mango fruit before applying the treatments was used as our covariate. Bar charts showing the frequencies and percentages of the storage variables comparing the two cultivars were also plotted. The results revealed that the treatments had a significant effect (p = 0.001) on the fruit weight of the mangoes and the storage variables were important in determining the shelf life of mango with respect to the two varieties. It was observed that the Keitt cultivar has a better shelf life than the Palmer. The study recommended that for a longer shelf life of mango, the treatment of dipping in hot water at 55^0C should be put into consideration by farmers in Nigeria and that ANCOVA statistical method could be a good model for predicting the storage life of other fruits.

Key words: *ANCOVA, mango, cultivar, plantation, shelf life*

Introduction

Mango (*Mangifera indica*), is an Indian or a tropical evergreen tree that produces green fruits when unripe but green to light green or yellowish to reddish (sweet, juicy and succulent) fruits when ripe (Bally, 2006; Morton, 2013; Shishir & Chen, 2017; Zeberga, 2010). It is the most economically important fruit in the *Anacardiaceae* family (Bally, 2006)). The genus *Mangifera* contains several species that bear edible fruits. Most of the fruit trees that are commonly known as mangoes belong to the species *Mangifera indica*. There are other edible Mangifera species that generally have lower-quality fruits that are commonly referred to as wild mangoes (Bally, 2006).

Among the major producers of mango in the World, Nigeria ranks 8th (Morton, 1987; FAO 2004; Yusuf and Salau, 2007) and, Benue ranks first in the league of states that produce mangoes in Nigeria (Yusuf and Salau, 2007). The other mango-producing states in Nigeria include; Jigawa, Plateau, Kebbi, Niger, Kaduna, Kano, Bauchi, Sokoto, Adamawa, Taraba, Oyo and the Federal Capital Territory (FCT) (Garuba et al., 2018; Yusuf and Salau, 2007). In Nigeria, the Hausas in the North call it 'mangoro' (FAO, 2004) while the Tivs in North-Central (Benue state), where it is mostly cultivated, call it 'mongo'. Among internationally traded tropical fruits, mangoes rank second only to banana both in quantity and quality and fifth in total production among major fruit crops worldwide.

(Zeberga, 2010; FAO, 2004). World production of mangoes is estimated to be over 26 million tons per annum and India ranks first among the world's producing countries, accounting for 54.2% of the total mangoes produced worldwide. It is commercially the most important fruit crop in India with more than a thousand varieties known to date. The other prominent mango producing countries are China, Thailand, Mexico, Pakistan, Indonesia, Philippines and Nigeria (Morton, 1987; FAO, 2004). The mango fruit is classified as a drupe (fleshy with a single seed enclosed in the endocarp) (Zeberga, 2010; Bally, 2006) The mesocarp is the fleshy, edible part of the fruit that usually has a sweet and slightly turpentine flavor when ripe. Its colour varies from yellow to orange and its texture from smooth to fibrous (Bally, 2006; Morton, 1987).

More than most fruits, greater percentage of mango fruits produced in the country ended up as waste. This is due to the lack of appropriate handling systems. The spread of commercially (International) acceptable cultivars is still low in the country. Most areas are being planted with cultivars like Gola alphonso (North) and Ogbomoso (South) that have been known to be adaptable / indigenous to the country (Akinyemi, 2012). Marketing of mango in Nigeria is mainly organized by entrepreneurs or collectors who purchase the fruit from farmers and arrange for its harvesting and transportation to suitable collection points where fruit is consigned either to nearby markets or to city markets. Most of the mangoes produced are consumed locally with no proper record of export (Akinyemi, 2012). The improper post-harvest handling resulting in reduced fruit quality and non-conversion of the fruits are considered to be important factors in the consideration of export trade for mango. These factors have deprived Nigeria of trading this important commodity in the international market.

Analysis of covariance (ANCOVA) is a statistical technique that combines the methods of the analysis of variance (ANOVA) and regression analysis (Yang & Juskiw, 2011). It can be seen also as an extension of ANOVA that provides a way of statistically controlling the effect of variables one does not want to examine in a study (Seltman, 2015). These extraneous variables are called covariates, or control variables. ANCOVA allows the removal of covariates from the list of possible explanations of variance in the dependent variable. ANCOVA does this by using statistical techniques rather than direct experimental methods to control extraneous variables (Vogt and Johnson, 2011). It also has the capability to increase the power or the sensitivity of the F-test and thereby increasing the chances of detecting the differences between the groups in an experiment (Muller and Vernon, 1992). ANCOVA is used in experimental studies when researchers want to remove the effects of some antecedent variable (Vogt and Johnson, 2011).

Mango postharvest diseases and disorders reduce fruit quality and cause severe losses. In many cases, because the blemished fruit does not meet the cosmetic standards for the A-class fruit, mangoes fetch low price in the international markets. Postharvest hot water dips have been proven to be effective in protecting mango against postharvest pathogen infection and in extending storage life of mango fruit during overseas shipments (Obsa *et al.,* 2014). The adverse effects of synthetic chemicals residues on human health and the environment (Oladele et al., 2022; Oladele and Fatukasi, 2018) have led to the intensified worldwide research efforts to develop alternative control strategies. Non-chemical quarantine treatments in mango industry are increasingly becoming important.

In an attempt to assist in finding solution to part of this post-harvest issues, this study therefore compared the effect some postharvest treatments have on the keeping quality of two mango cultivars namely Keitt and Palmer using the initial weight of the matured but unripe fruit as a covariate in the analysis. This is to assist in identifying the impact of the storage variables on the fruit and to determine which variety has the greater shelf life.

Table 1: Storage properties used in determining shelf life of mango fruits

Storage Property	Category1	Category2	Category3	Category4	Category5
Colour change	No change	Slight change	Moderate change	Distinctive change	-
Softness	No change	Slightly soft	Moderately soft	Very soft	Extra soft
Spoilage	< 25%	25% - 50%	51% - 75%	> 75%	-
Dark patches	< 20%	21%– 40%	41% - 60%	> 60%	-

Table 2: ANCOVA table with fruit weight as the dependent variable

Source	Sum of Squares	Degree of Freedom	Mean Square	F- value	Prob > F	Partial Eta Squared
Intercept	18.477	1	18.477	0.0001	0.000*	0.988
Startwt	0.592	1	0.592	368.148	0.000*	0.732
Trt	0.29	3	0.010	5.951	0.001*	0.117
Variety	0.047	1	0.047	29.231	0.000*	0.178
Trt*Variety	0.005	3	0.002	1.138	0.336	0.025
Error	0.217	135	0.002			

*significant at 5%

Materials and Method

Collection and treatment of Mango cultivars

Fruits of two Mango cultivars (Keitt and Palmer) were selected at matured fruit stage within the mango orchard of the National Horticultural Research Institute (NIHORT), Idi- Ishin, Ibadan, Oyo State, Nigeria. Seventy-two fruits were picked for each cultivar making a total of 144 fruits. The selected fruits of the two cultivars were treated with or without fungicide and warm water thus: (TRT1) dipped into ordinary water at room temperature, (TRT2) fungicide in ordinary water, (TRT3) fungicide in hot water at 55^0C and (TRT4) hot water at 55^0C. These were replicated six times. The treated fruits were placed on working bench at room temperature (28 ± 2°C) in the fruit research laboratory throughout the period of observation. The initial weights of the fruits were recorded before immersion in the solutions. Four storage properties namely: colour change, softness, spoilage and dark patches (Table 1) were measured and recorded in other to evaluate the keeping quality of the mango fruit. The grouping of the different categories is shown in Table 1. Pictures of the two mango cultivars are shown in figure 1.

Analysis of covariance

The ANCOVA model included the treatment, cultivar and a covariate. In the analysis, the dependent variable was the fruit weight after treatment (fruitwt), the covariate was the initial fruit weight (startwt) and the independent variables were: treatment and cultivar. ANCOVA was conducted to investigate the effect of different types of treatment on the fruit weight of mango with respect to its storage.

Table 3: Adjusted Marginal Means for Treatment (Trt)

Trt			95% Confidence Interval	
	Mean	Std. Error	Lower Bound	Upper Bound
1	2.751[a]	.007	2.738	2.764
2	2.752[a]	.007	2.739	2.765
3	2.725[a]	.007	2.711	2.739
4	2.768[a]	.007	2.754	2.781

[a] covariates appearing in the model are evaluated at startwt=630.63

A typical ANCOVA model is described as follows:
Suppose that each observation consists of a response variable, *Y*, and one or more covariate measurements: $X_1, X_2, ..., X_p$. Also suppose that samples of $n_1, n_2, ..., n_k$ observations will be obtained from each of *k* groups. The multiple regression equation relating *Y* to the *X's* within the i^{th} group is

$$Y_i = \beta_{0i} + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_p X_p + \varepsilon$$

where the β's are the regression coefficients or slopes. In ANCOVA, it is assumed that the slopes are equal across all groups except for β_0, which is the intercept. Therefore, the difference between the means of any two groups can be calculated by finding the difference between their intercepts. An expression for the covariance model is given as

$$Y_{ij} = \mu + \tau_i + \beta X^* + \varepsilon_{ij}$$

where $X^* = X_{ij} - X..$

Figure 1: A - Keitt Mango cultivar, B - Palmer Mango cultivar
Source A: https://plantogram.com/product/mango_keitt/
Source B: http://www.mango.org/Mangos/media/Media/Images/Consumer%20Page%20Teaser/palmer.png

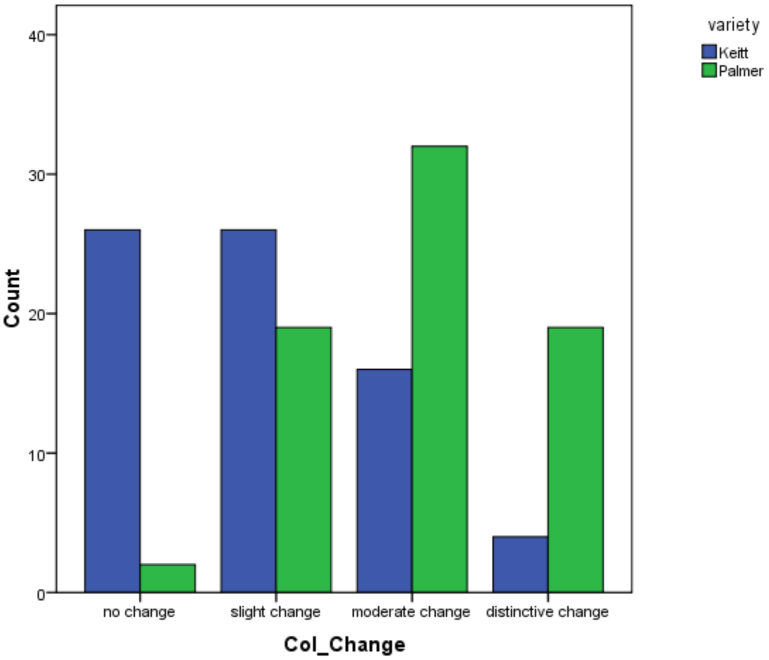

Figure 2: Bar chart for colour change for Keitt and Palmer mango cultivars

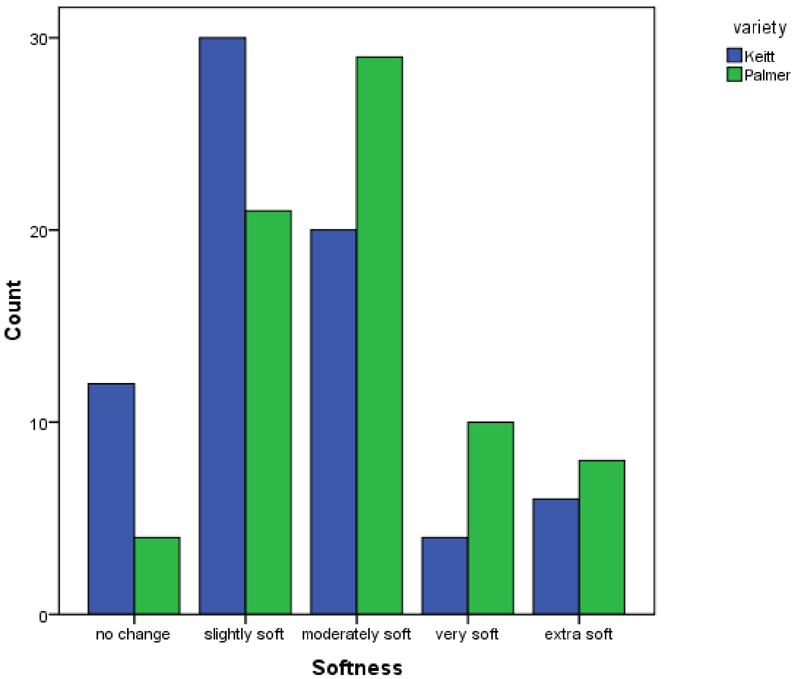

Figure 3: Bar chart for counts on softness of Keitt and Palmer mango cultivars

Data Analysis

A two-way ANCOVA (Pallant, 2011) was performed to investigate the effect of the post-harvest treatments and cultivar on the fruit weight controlling for the initial weight of the mango fruits before treatment to gain power of the test (Saha *et al*., 2017; Seltman, 2015) using IBM® SPSS® software (version 26) (IBM, SPSS) and SAS version 9.3 software (SAS, 2011). Effect size (By Kampenes *et al*., 2007.) that shows the magnitude of the relationship between the dependent variable and the independent variables was also computed. ANCOVA assumptions (Tabachnik & Fidell, 2019) that might distort the significance of the statistical tests were investigated before carrying out the analysis. Bar charts depicting the variation in the storage variables for the two mango varieties were also constructed for change in the colour of the fruit, softness of the fruit, dark patches seen on the fruit and percentage spoilage.

Results and Discussion

The effect of initial weight of matured but unripe mango fruits on the final fruit weight as well as immersion of the fruits in fungicide mixed with water either hot or cold were investigated using analysis of covariance. The simple linear regression of the fruit weight and the initial weight before treatment shows there is a significant linear relationship between these two variables ($p < 0.0001$, $R^2 = 0.83$). This strong dependence of the initial fruit weight on the final fruit weight suggests that the initial fruit weight could be a useful covariate for the analysis (Saha et al., 2017). The dependent variable (fruit weight) was transformed when it was observed that the data were not normally distributed. The log of fruit weight is now the new dependent variable. Partial Eta Squared (η^2) was used to determine the effect size, that is the proportion of the variance in the dependent variable that is explained by the independent variable. The effect size is interpreted as follows:

0.01.1 – 0.06 = small effect
0.06– 0.14 = moderate effect
> 0.14 = large effect (Cohen, 1988)

Furthermore, Analysis of variance carried out separately within each treatment group revealed that the regression analysis is fairly uniform across all the treatment levels. This is essential since adjustments are made to all treatment groups using the same slope in ANCOVA. The estimates of the slopes within each treatment group are: TRT1 (2.212), TRT2 (2.135), TRT3 (2.287) and TRT4 (2.228).

Table 2 shows a very significant effect of TRT, and CULTIVAR on fruit weight ($p < 0.0001$). There was a significant effect of the treatment (p=0.001) and cultivar (p<0.001) on the fruit weight. However, the interaction between the two variables was not significant (p=0.336). This suggests that the initial weight of the fruit does have a significant impact on the fruit weight with respect to the application of the fungicides on the two mango cultivars (Campoy *et al,* 2015). Post hoc test showed that there was significant difference between trt1 and trt3 (p<0.03), trt2 and trt3 (p<0.02) and trt3 and trt4 (p<0.0001). These results suggest that there were significant differences in the fruit weight of mangoes that were dipped in ordinary water and fungicide that was dissolved in ordinary water and those dissolved in hot water as well as those dipped in fungicide in hot water and those dipped just in hot water. Several studies have investigated the impact of different treatments on the shelf life of mangoes. Njie *et al* (2022) examined the effect of melatonin treatment on the shelf life of mango fruits during cold storage. They found that melatonin treatment minimized decay, maintained fruit quality, and extended the postharvest shelf life of mangoes by enhancing physiological and metabolic processes.

The effect sizes for startwt, Trt and cultivar were 0.732, 0.117 and 0.178 respectively as shown in Table 2. This revealed that the covariate and the cultivar had large effects on the fruit weight while the treatment had a moderate effect on the fruit weight.

Back transforming (taking the log) of the data as seen in Table 3 gives T1 = 2.751 (563.64), T2 =2.752 (564.94), T3 = 2.725 (530.88) and T4 = 2.768 (586.14). Comparing the estimated marginal means showed that the fruits that received treatment 4 have the least weight loss. It was also observed that the Keitt cultivar (2.774 = 594.29) has a lower fruit weight loss than the Palmer cultivar (2.724 = 529.66).

Figure 2 shows a plot of the bar chart for color change for the two mango cultivars. This chart revealed that the Keitt cultivar has the highest number of mangoes that did not change color (26 out of 72 mangoes for each cultivar), while the Palmer cultivar has the highest number of mangoes that had distinctive change in their colour. Given that low-temperature storage is frequently utilized to increase shelf life, strategies to reduce chilling harm in mangoes are urgently needed. Mangoes that have been chilled may soften abnormally, have an unfavorable color, and lose flavor (Bhardway *et al*, 2022). The use of nitric oxide as a postharvest treatment to increase the shelf life of mango fruits was investigated by Bambalele *et al*, 2021. It was discovered that nitric oxide lowers the frequency of postharvest infections and chilling injury, thereby, preserving the fruit quality.

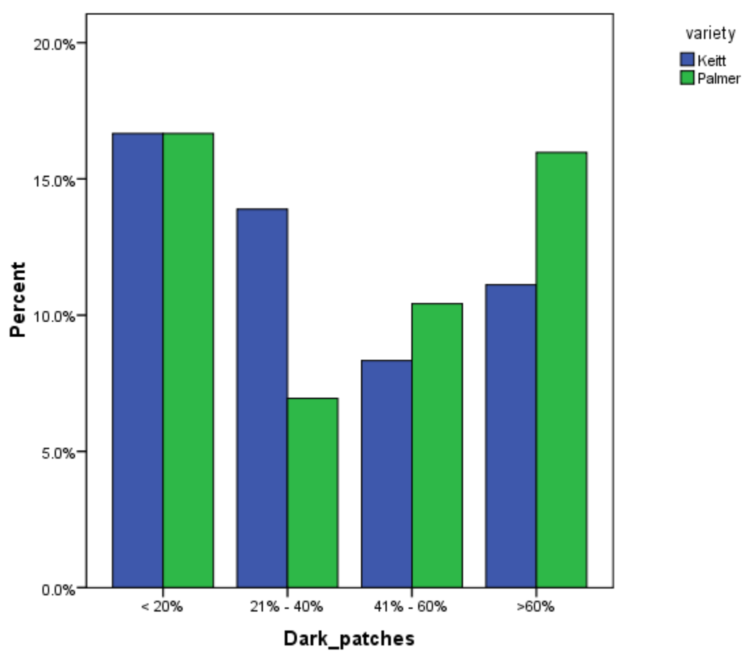

Figure 4: Bar chart for percentages of dark patches for Keitt and Palmer mango cultivars

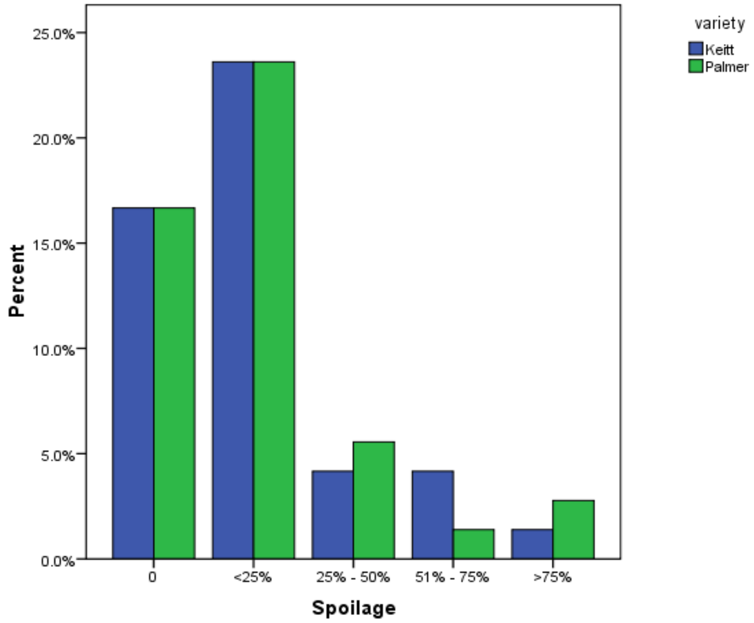

Figure 5: Bar chart for percentages of spoilage for Keitt and Palmer mango cultivars

Figure 3 shows the bar chart plot for softness of the fruit for the two cultivars. Here, it was also revealed that the Keitt cultivar has the highest number of mangoes that had no change with respect to the softness of the fruit. The bar chart for percentage of dark patches seen on the fruits is displayed in figure 4. This showed that the Palmer cultivar has a higher number of fruits that had above 60 percent dark patches on the fruits. Figure 5 shows the percentage spoilage recorded among the fruits. The two cultivars recorded equal number of fruits that had between zero and 25 percent. However, the Palmer cultivar had the number that had above 75 percent spoilage.

These storage variables determine the shelf life of these fruits which could help in preserving them to make maximum gain in their cultivation. The Keitt cultivar was observed to have a better shelf life with respect to these measures. Hassan, 2022 highlighted how crucial post-harvest procedures are for extending mangoes' shelf life. For consumer acceptance and marketing, it is essential to develop postharvest technologies that preserve fruit quality and prolong shelf life. Overall, the impact of these postharvest treatments on the shelf life of different mango cultivars may be evaluated using the analysis of covariance.

Conclusion and Recommendations

The current study revealed that the fungicide treatment of the mango fruits had significant effect on the fruit weight. Furthermore, the analysis provides an explanation on the cultivar of mango that has the better and greater shelf life, it revealed that the Keitt mango has a better keeping quality than Palmer. A better shelf life helps to solve the problem of preservation where there is no easy means of transportation. This statistical method can be used to predict the storage life for other fruits as well. Since Keith is one of the internationally acceptable cultivars, the cultivation of Keitt is hereby recommended to Nigerian farmers for consideration because of this additional keeping quality for maximum profit.

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