ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2022; 22(6): 20737-20751 https://doi.org/10.18697/ajfand.111.22085

EFFECT OF HARVEST STAGE AND NITROGEN FERTILIZATION ON THE POSTHARVEST SHELF LIFE OF BLACK NIGHTSHADE (*Solanum nigrum* L.) AND COLLARD (*Brassica oleracea var. acephala* L.)

Gitau K[1]*, Ambuko J[1], Chemining'wa G[1] and W Owino[2]

Karen Gitau

*Corresponding author email: karenwambui1@gmail.com

[1]Department of Plant Science and Crop Protection, University of Nairobi, Kenya

[2]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Leafy vegetables play a crucial role in the human diet providing numerous nutrients and health benefiting compounds. Leafy vegetables like collard (*Brassica oleracea var. acephala*) and black nightshade (*Solanum nigrum l.*) are commonly consumed leafy vegetables in Kenya. However, their high perishability and short shelf life (usually 1-2 days at ambient temperature) limits their utilization resulting in significant high postharvest losses. This study assessed the effect of harvest stage and nitrogen fertilization on the postharvest shelf life of collard and black nightshade. Experiments were conducted at Kabete field station, University of Nairobi, using collard and black nightshade. Field experimental layout was a 4 x 3 factorial arrangement in randomized complete block design with three replicates. Factors were nitrogen levels and harvest stage. Four levels of nitrogen (0, 30, 60 and 90 kg N/ha) were applied on black nightshade and (0, 55.5, 111.1 and 166.6 kg N/ha) in collard where 0 kg N/ha was the control. Collard and black night shade were harvested at three harvest stages: 4 weeks, 6 weeks and 8 weeks after transplanting. The harvested vegetables were kept at ambient room condition (20 ºC, 55% relative humidity). Data collection was performed daily for quality related parameters which included color change, wilting index and cumulative weight loss. Results show that there was a progressive deterioration in quality of the collard and black nightshade with storage time regardless of harvest stage and nitrogen level. Harvesting at 8 weeks after transplanting resulted in longer shelf life in collard (three days) and black nightshade (two days) when compared to harvesting at 4 weeks or 6 weeks after transplanting. Collard and black nightshade showed reduced hue angles over storage time at different harvest stages. Black nightshade subjected to 90 kg N/ha and harvested at 4 weeks after transplanting had the highest wilting index of 33%. The highest cumulative weight loss of 29% was recorded in collard that were harvested at 8 weeks after transplanting. Black nightshade subjected to 90 kg N/ha and harvested at 6 weeks after transplanting showed the best color at a hue angle of 145°. Overall, harvesting at 8 weeks after transplanting resulted in the longest shelf life of both black nightshade and collard. These results show that low application of nitrogen fertilizer in black nightshade (30 kg N/ha) and in collard (55.5 kg N/ha) had minimal effects on weight loss and wilting and resulted in good keeping quality.

Key words: Black nightshade, Collard, Harvest Stage, Nitrogen nutrition, Shelf life

INTRODUCTION

Horticulture is the fastest growing subsector of agriculture in Kenya. It contributes to poverty alleviation, food security and generates job opportunities along the food value chain [1].

Leafy vegetables have received increased attention recently due to their high nutritional value and health benefits [1]. However, leafy vegetables have high moisture content of about 90%, which contributes to their high perishability nature and limits their shelf life [2]. The short shelf life nature of leafy vegetables limits their market shelf life and thereby reducing food and nutrition security.

Collard (*Brassica oleracea var acephala*) also known as 'sukuma wiki' in Swahili, is one of the major leafy vegetables that is extensively grown by small-scale farmers in East Africa. The annual production of collard in Kenya is 413,599 MT valued at KES 5.9 billion [1]. Collard is rich in dietary fiber, vitamins C, E, K and minerals such as magnesium, iron, and calcium [3]. Collard is harvested from 45-60 days after transplanting and can last 4–5 months in the field depending on the variety and environmental conditions [4].

African Leafy Vegetables (ALVs) are locally consumed, with their edible parts being leaves and young shoots [5]. Black nightshade (*Solanum nigrum L.*) is the second most important ALV in Kenya after cowpeas *(Vigna unguiculata)* with a production of 43,794 MT, valued at KES 1.9 billion [1]. Black nightshade is rich in vitamins, minerals, phytochemicals and antioxidant properties [2]. Black nightshade is harvested about 4-6 weeks after seedling emergence and harvesting of leaves and tender shoots can last up to 6 to 8 weeks growing period in the field [6]. Regular harvesting of young shoots of black nightshade encourages lateral growth therefore leading to extended harvesting period [6].

Postharvest quality of leafy vegetables is influenced by preharvest factors and postharvest factors. Some of the preharvest factors that affect quality of leafy vegetables are nitrogen nutrition and harvest stage of crops [7].

Maturity at harvest is a crucial determinant of storage life and quality in leafy vegetables. Small-scale farmers rely on non-specific determinators such as leaf size and plant height to start harvesting leafy vegetables according to their production schedule or when the produce is ordered by a consumer [8]. Leafy vegetables harvested at an immature stage have high water content, susceptible to shriveling and mechanical damage, therefore, reducing their storage life [9].

Nitrogen is an essential nutrient required in large quantities. It is a major constituent of many plant components including amino acids [10]. Nitrogen is essential for quality of vegetables but when applied in excess can lead to decay during postharvest. Nitrogen enhances growth and yield levels hence allowing farmers to adjust the harvest dates to meet marketing schedules [11]. Poor nitrogen nutrition reduces keeping quality of

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

harvested crops by reducing firmness and enhancing susceptibility to postharvest decay [12].

Postharvest losses have received global attention recently as new strategies and methods are sought to combat food losses and improve food and nutrition security [13]. Postharvest losses lead to quality and quantity vegetable losses which lowers the income of rural farmers as resources invested in production are wasted. Developing countries have postharvest losses of approximately 50%, and postharvest losses in Kenya are estimated to be between 9-25% [14]. Therefore, reduction of postharvest losses is crucial to achieve food and nutrition security in the developing countries [15]. The objective of this study was to determine the effect of harvest stage and nitrogen fertilization on the postharvest shelf life of collard and black nightshade.

MATERIALS AND METHODS

Study Site

The study was conducted at Kabete field station, College of Agriculture and Veterinary Sciences, University of Nairobi. Kabete field station lies at a latitude of 1° 15' S, longitude 36° 44' E, altitude of 1940 m above sea level, and is located 15 km west of Nairobi city. The climate of the area is subhumid with a minimum and maximum mean temperature of 13.7 °C and 24 °C, respectively. Soils in Kabete are red humic nitisols and are characterized as deep and well drained [16]. The climate of the area is semi-humid and receives a bimodal rainfall distribution with short rains from October to December and long rains from March to June.

Collection and preparation of plant materials

Seeds of collard and black nightshade were obtained from East African Seed Company Ltd, Nairobi, Kenya. The source of nitrogen was Urea fertilizer obtained from Kenya Farmers Association Ltd, Nairobi, Kenya. Nitrogen fertilizer was applied at a rate of 0, 30, 60 and 90kg N/ha in black nightshade and 0, 55.5, 111.1 and 166.6 kg N/ha in collard including the control (0 kg N/ha). These rates were influenced by small-scale farmers in the experimental site (Upper Kabete). The optimum nitrogen rate applied at Upper Kabete Field Station was 111.1kg N/ha in collard and 60 kg N/ha in black night shade. Therefore, there was need to include the lowest and the highest nitrogen rates in reference to optimum nitrogen rate applied by small-scale farmers in the experimental site. Collard and black nightshade were harvested at different harvest stages: 4 weeks, 6 weeks and 8 weeks after transplanting.

Experimental design

Collard and black nightshade leaves were harvested at different harvest stages: 4 weeks, 6 weeks and 8 weeks after transplanting from the nitrogen treatments with 0, 30 and 90 kg N/ha in black nightshade and 0, 55.5 and 166.6 kg N/ha in collard. Vegetable samples with (N3) treatment level were excluded from shelf-life experiment since they registered negligible significance in the field experiment in growth and yield parameters. This study focused on investigating the effect of highest and lowest nitrogen rates on the shelf-life of the sample vegetables. The harvested vegetables were batched and kept at ambient room condition with a temperature of about 20°C and 55%

relative humidity. The study adopted storage of the vegetables in ambient temperature as it is the most popular storage technique among small scale farmers and local retail vendors in the region. The storage experiment was laid out in a completely randomized design with three replicates per treatment.

Data collection

Data collection was performed daily for quality related parameters which included color change, wilting index and cumulative weight loss as shown below.

Percentage cumulative weight loss

In each treatment, the three batches of three leaves of collard and black nightshade (to represent the 3 nitrogen levels treatments) were used to determine cumulative weight loss using a computerized gauge scale (Model Libror AEG-220, Shimadzu Corp. Kyoto, Japan). The initial weight of each batch of leaves at day 0 after harvest was recorded and the new weight of the same batch of collard and black nightshade leaves on the following days was recorded. Data was collected every day in all treatments until they reached a pre-determined end stage. The end stage was based on level of wilting and yellowing at which the vegetable was saleable. Percentage cumulative weight loss was calculated using Equation 1:

$$cumulative\ weight\ loss\ \% = \frac{(initial\ \ weight - final\ weight)}{(initial\ weight)} \times 100 \qquad (1)$$

Color change

In each treatment, the color of the leaf surface of the three leaves in each of the three batches was measured using a portable colorimeter (Model TES-135A, Taiwan China). Data was collected every day on all treatments. The colorimeter was standardized with a white tile and the color coordinates (L*, a*and b*) were obtained and converted to hue angle (H°) according to *McLellan et al.* [17] using Equation 2:

Hue angle (H°) = arctan (b/a) (for +a and +b values)
= arctan (b/a) +180 (for -a and +b values) (2)
=arctan (b/a) + 180 (for -a and -b values)

Wilting

In the experiments, three leaves were taken from each batch of each treatment and used to determine the level of wilting of the stored black nightshade and collard. Wilting was evaluated subjectively and scored using a hedonic scale ranging from 1–5, where: 1 = (0-19%), 2 = (20-39%), 3 = (40-59%), 4 = (60-79%) and 5 = (above 80%). The wilting index was used to determine the level of wilting of the stored collard and black nightshade. Data on wilting was collected on the stored collard and black nightshade until the end of the shelf life. Wilting with a score of 2 and above was considered unmarketable and shelf life was considered to have ended.

Data analysis

The data collected on the quality related parameters was analyzed using GenStat 15th Edition statistical program. Analysis of Variance (ANOVA) was used to test for

https://doi.org/10.18697/ajfand.111.22085

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

significant differences among treatments for each parameter and means separated using Fischer's Protected least significant difference at 5%.

RESULTS AND DISCUSSION

Weight loss

The cumulative weight loss increased with storage time in both collard and black nightshade regardless of the nitrogen level and harvest stage. Harvest stage had a significant ($p<0.05$) effect on percentage cumulative weight loss on collard (Figure 1). Collard harvested at 4 weeks after transplanting (harvest stage 1) and 6 weeks after transplanting (harvest stage 2) had a shelf life of two days whereas those harvested at 8 weeks after transplanting (harvest stage 3) had the longest shelf life of three days. Collard harvested at 6 weeks after transplanting resulted in the lowest weight loss (13%) whereas harvesting at 4 weeks after transplanting resulted in the highest weight loss (23%) at day 2 of storage. Nitrogen treatments had no significant effect on percentage cumulative weight loss of collard.

Harvest stage had a significant ($p<0.05$) effect on the black nightshade (Figure 2). Black nightshade harvested at 8 weeks after transplanting had a longer shelf life of 1 day compared to those harvested at 4 weeks and 6 weeks after transplanting. Nitrogen treatments affected the weight loss of black nightshade, especially at 90 kg N/ha which resulted in the highest weight loss (40%) compared to 30 kg N/ha (32%) and 0 kg N/ha (30%). In agreement with *Bonasia et al.* [18], the increased vegetable weight loss was due to large leaf surface area therefore increasing transpiration. The interaction between nitrogen level and harvest stage had no effect on cumulative weight loss on both collard and black nightshade. The high percentage cumulative weight loss evident on collard and black nightshade harvested at 4 and 6 weeks after transplanting can be due to the high succulent nature of the leaf and poorly developed waxy layer on the leaf surface [19]. Weight loss occurs due to transpiration, and it is associated with the saleable weight of stored vegetables [20]. Loss of water reduces the saleable weight in stored leafy vegetables. Stored vegetables lose water over time and appear wilted [21]. *Martínez-Sánchez et al.* [22] found that lettuce (*Lactuca sativa*) harvested at a more advanced harvest stage showed higher firmness and had longer shelf life. Young immature collard leaves have high respiration rates which lead to shorter shelf life [23].

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

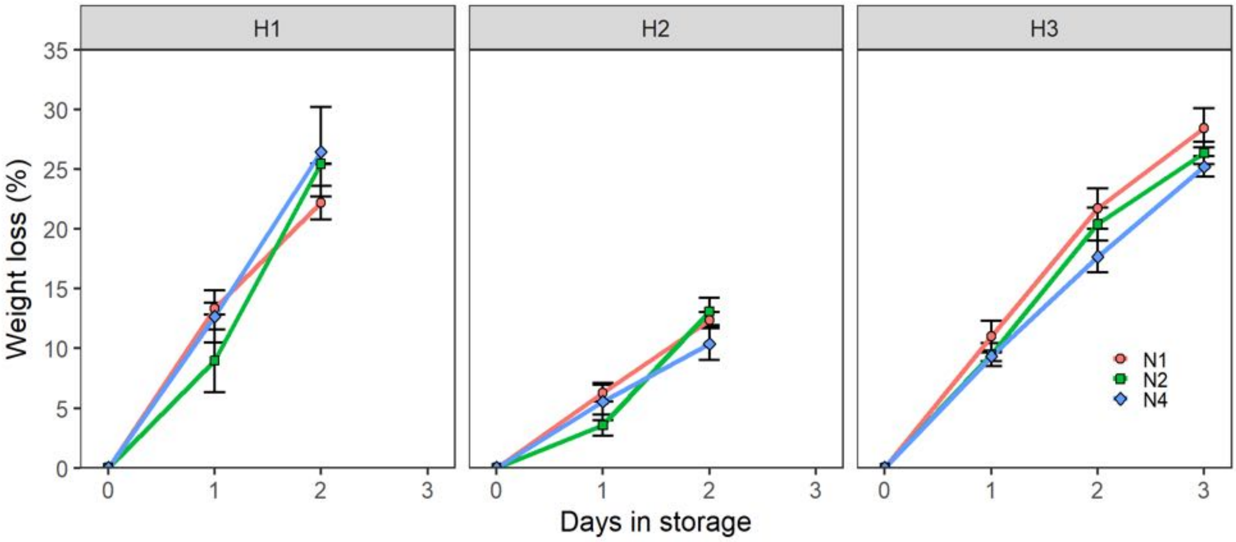

Figure 1: Cumulative weight loss of collard as affected by different harvest stages and nitrogen levels. H1=harvesting at 4 weeks after transplanting, H2=harvesting at 6 weeks after transplanting, H3= harvesting at 8 weeks after transplanting. N1= 0 kg N/ha, N2 = 55.5 kg N/ha, N4 =166.6 kg N/ha.

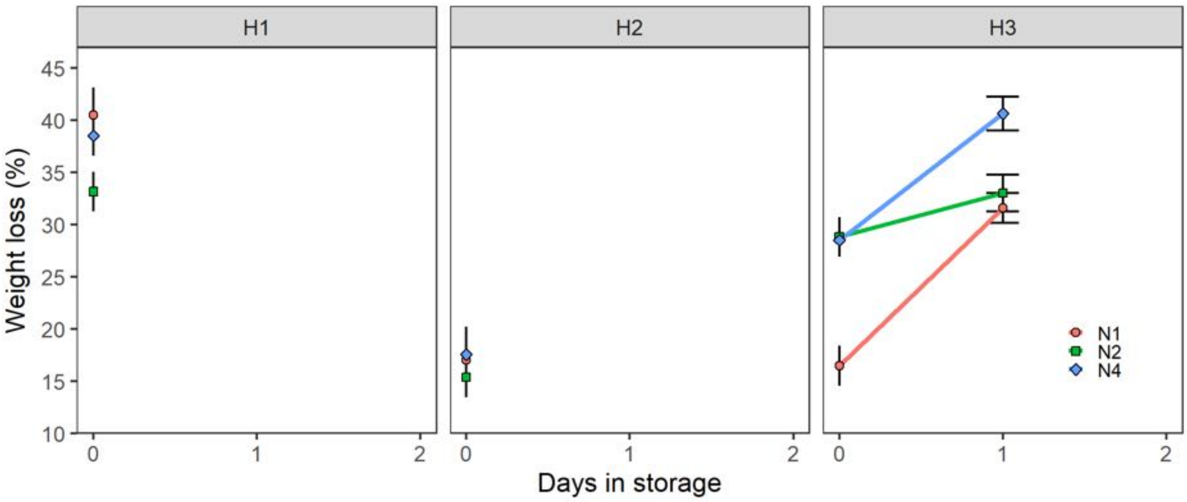

Figure 2: Cumulative weight loss of black nightshade as affected by different harvest stages and nitrogen levels. H1=harvesting at 4 weeks after transplanting, H2=harvesting at 6 weeks after transplanting, H3= harvesting at 8 weeks after transplanting. N1-0 kg N/ha, N2-30 kg N/ha, N4-90 kg N/ha.

Wilting

Increase in wilting index was observed with increase in storage days in both black nightshade and collard irrespective of the harvest stage and nitrogen level. Harvest stage had a significant ($p<0.05$) effect on the wilting index of collard (Figure 3). Collard harvested at 4 weeks after transplanting and 6 weeks after transplanting reached their end stage at two days compared to those harvested at 8 weeks after transplanting, which reached their end stage at three days. Collard harvested at 4 weeks after transplanting and 6 weeks after transplanting had the highest wilting index (33.3%) whereas collard harvested at 8 weeks after transplanting resulted in the lowest wilting index (11.1%) at day two of storage. The nitrogen treatments affected wilting in collard whereby 116.6 kg N/ha resulted in the highest wilting index (33.3%) at 8 weeks after transplanting followed by 55.5 kg N/ha (22.2%) and 0 kg N/ha which had the lowest wilting index (11.1%).

Nitrogen level had no significant effect on wilting index of black nightshade (Figure 4). Black nightshade harvested at 4 weeks and 6 weeks after transplanting reached an end stage on day 1 compared to those harvested at 8 weeks after transplanting that had reached an end stage at day 2. Nitrogen level influenced the wilting index of black nightshade whereby 90 kg N/ha had the highest wilting index (33.3%) whereas 30 kg N/ha had the lowest wilting index of 22.2% at both 4 weeks and 6 weeks after transplanting. Loss of saleable weight and wilting in leafy vegetables was mainly attributed to water loss. Water loss is the main cause of wilting and loss in saleable weight in stored vegetables [24]. High water loss evident in black nightshade with high nitrogen level (90 kg N/ha) was attributed by large surface area therefore exposing the leaf to the environment causing more loss of moisture through transpiration [25]. Vegetables appear wilted and unmarketable when they lose 5-10% fresh weight [24]. When vegetables lose water, they not only lose their physical quality but also lose their nutritional components such as vitamin C [26]. The shorter shelf life evident in vegetables harvested in harvest stage one was attributed to high water content of harvested leaves which leads to high water loss compared to those harvested in harvest stage three (8 weeks after transplanting) that were fibrous and had a more developed membrane [27]. In addition, immature harvested leaves have a relatively high respiration rate compared to mature leaves which leads to faster deterioration of quality [28].

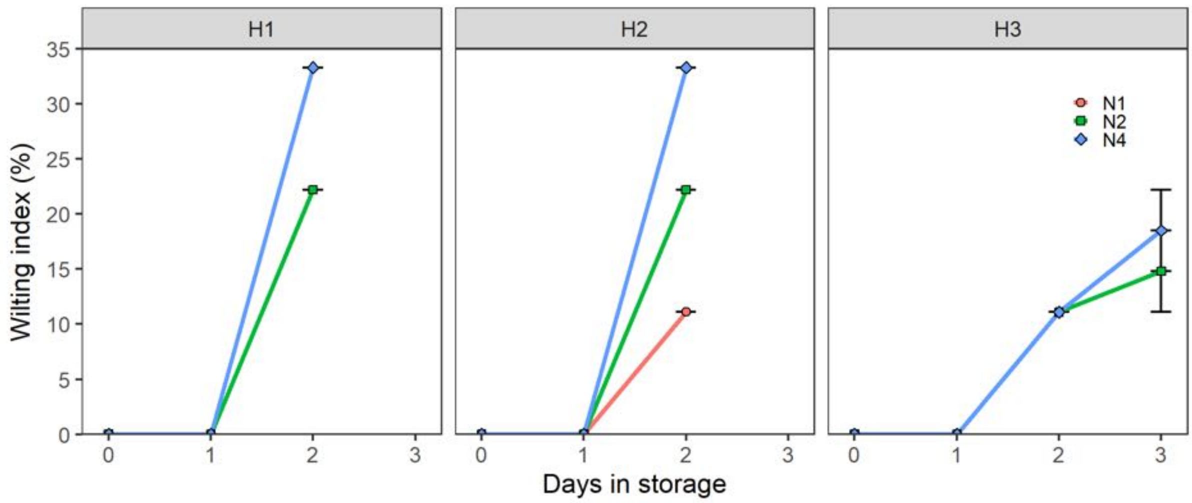

Figure 3: Wilting indices of collard as affected by different harvest stages and nitrogen levels. H1=harvesting at 4 weeks after transplanting, H2=harvesting at 6 weeks after transplanting, H3= harvesting at 8 weeks after transplanting. N1-0 kg N/ha, N2-55.5 kg N/ha, N4-166.6 kg N/ha.

https://doi.org/10.18697/ajfand.111.22085

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

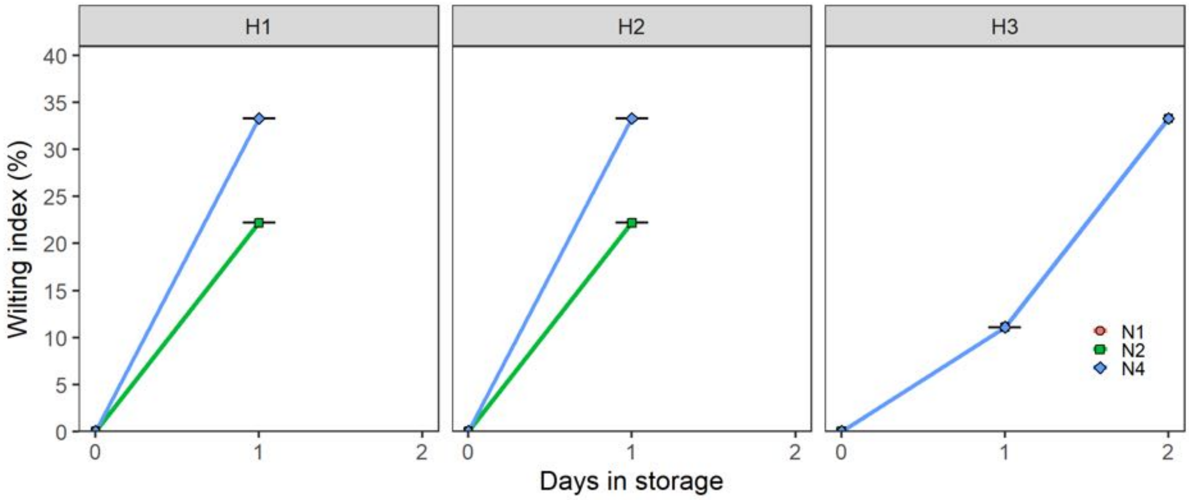

Figure 4: Wilting indices of black nightshade as affected by different harvest stages and nitrogen levels. H1=harvesting at 4 weeks after transplanting, H2=harvesting at 6 weeks after transplanting, H3= harvesting at 8 weeks after transplanting. N1-0 kg N/ha, N2-30 kg N/ha, N4-90 kg N/ha.

Color change

There was a decrease in hue angle of both collard and black nightshade with increase in storage duration. Collard that received 55.5 kg N/Ha and harvested at 8 weeks after transplanting had the highest hue angle (139°) at day 0 whereas collard that received 166.6 kg N/ha and harvested at 6 weeks after transplanting had the lowest hue angle (111.8°) at day 2 (Figure 5). Collard at 8 weeks after transplanting maintained green color (139°) through the storage days compared to those harvested 4 weeks and 6 weeks after transplanting. Black nightshade recorded the highest hue angle (145°) at 6 weeks after transplanting on day 0 which decreased to 131.9° at nitrogen level of 90 kg N/ha (Figure 6). Nitrogen treatments had no significant effect on color change of black nightshade. Interaction between harvest stage and nitrogen level on color change was highly significant ($p<0.05$) on day 1 in black nightshade. It seems that collard responded well to nitrogen fertilization compared to black nightshade. High chlorophyll is a major component contributing to the green color in collard and black nightshade [28]. Green color retention is an indicator of leafy vegetable quality which has a great impact in consumer selection [29]. Nitrogen is one of the main constituents of the chlorophyll structure. High nitrogen application on vegetables enhances chlorophyll retention therefore enhancing green color retention in vegetables [10]. The difference in color change in storage time is brought about by loss in chlorophyll content [21]. Excess rates of nitrogen application have been associated with color discoloration during storage of cabbage [20]. Research shows that the browning rate of overmature lettuce leaves was higher than that of immature lettuce leaves (*Lactuca sativa*) due to degradation of chlorophyll pigments leading to formation of other pigments [20].

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

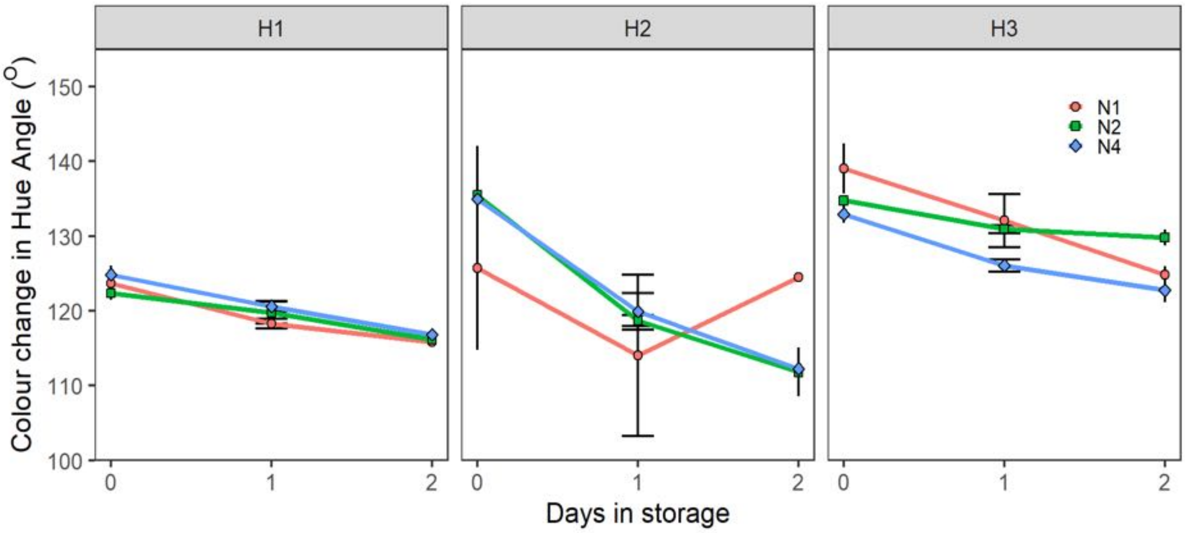

Figure 5: Color change of collard as affected by different harvest stages and nitrogen levels. H1=harvesting at 4 weeks after transplanting, H2=harvesting at 6 weeks after transplanting, H3= harvesting at 8 weeks after transplanting. N1-0 kg N/ha, N2-55.5 kg N/ha, N4-166.6 kg N/ha.

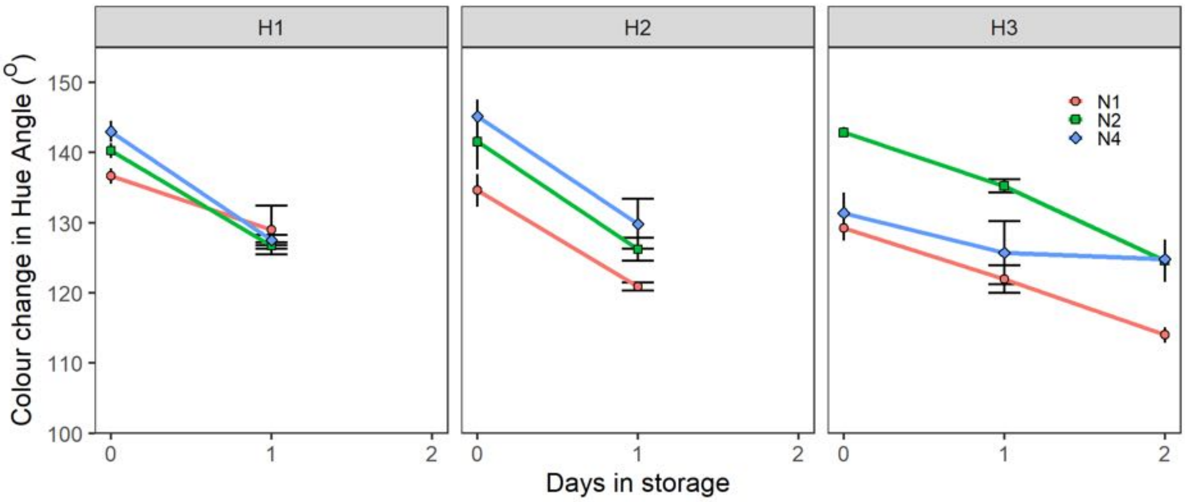

Figure 6: Color change of black nightshade as affected by different harvest stages and nitrogen levels. H1=harvesting at 4 weeks after transplanting, H2=harvesting at 6 weeks after transplanting, H3= harvesting at 8 weeks after transplanting. N1-0 kg N/ha, N2-30 kg N/ha, N4-90 kg N/ha.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 6
August 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Figure 7: Collard and black nightshade harvested at 6 weeks and stored in ambient room. Collard at day 0 (A) and day 1 (B). Black nightshade at day 0 (C) and day 1 (D)

CONCLUSION

The study demonstrates that nitrogen fertilization and harvest stage affected the quality and shelf life of collard and black nightshade. Quality related parameters such as wilting, color change and saleable weight deteriorated over time in storage. High nitrogen fertilization enhanced high cumulative weight loss. Collard and black nightshade harvested at the 8 weeks after transplanting had a longer shelf life of three days in both collard and black nightshade compared to the those harvested at 4 weeks and 6 weeks after transplanting which had a shorter shelf life of one day. However, low nitrogen fertilization affected color, when compared to high nitrogen fertilization. This was evident by the overall best color (145°) recorded in black nightshade that was achieved with 90 kg N/ha application at 6 weeks after transplanting. In addition, application of 30 kg N/ha in black nightshade and 55.5 kg N/ha in collard reduced cumulative weight loss and wilting and led to good keeping quality. Black nightshade showed better postharvest response with nitrogen application at storage than collard as they showed less wilting and weight loss. However, there is need for more study on the biochemical and physiological changes that occur during storage of leafy vegetables as well as good agricultural practices and postharvest technologies that will enhance quality of stored leafy vegetables for longer period so as to meet the increased demand of consumers.

ACKNOWLEDGEMENTS
The authors acknowledge the National Research Fund (NRF-Kenya) for financial support received and awarded to Prof. Jane Ambuko of the University of Nairobi. The authors are grateful to the University of Nairobi Field Station leadership for provision of an experimental site.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 22 No. 6 August 2022 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

REFERENCES

1. **Horticultural Crops Directorate (HCD).** Kenya Validated Report 2016-2017.

2. **Abukutsa-Onyango MO** Unexploited potential of indigenous African vegetables in Western Kenya. Maseno Journal of Education Arts and Science. 2003;**4(1)**:103-222.

3. **Steiner F, Zuffo AM, De Moraes Echer M and VF Guimarães** Collard green yield and nutritional quality with mineral and organic fertilization. Semina: Ciências Agrárias. 2019 Sep 1:2165-2178.

4. **Tanielle T and J Tuquero** Growing Kale (*Brassica oleraceaea*). Cooperative Extension & Outreach, College of Natural & Applied Sciences, University of Guam. 2019.

5. **Abukutsa-Onyango MO, Adipala E, Tusiime G and JG Majaliwa** Strategic repositioning of African indigenous vegetables in the Horticulture Sector. In Second RUFORUM biennial regional conference on "Building capacity for food security in Africa", Entebbe, Uganda 2010 Sep 20; 1413-1419.

6. **Edmonds JM and JA Chweya** Black nightshades: Solanum nigrum L. and related species. Bioversity International; 1997.

7. **Kitinoja L and AA Kader** Measuring postharvest losses of fresh fruits and vegetables in developing countries. PEF white paper. 2015 Sep; 15:26.

8. **Kirigia D, Kasili R and H Mibus** African Leafy Vegetables Pre-harvest and Post-harvest constrains and Technologies for losses reduction along the field to consumer chain. African Journal of Horticultural Science. 2017 Aug 7; **12:**51-60.

9. **Ramjan MD and MT Ansari** Factors affecting of fruits, vegetables and its quality. J. Med. Plants. 2018; **6:**16-18.

10. **Lazar T, Taiz L and E Zeiger** Plant physiology. 3rd edition. 2003: 068-086.

11. **Lerna A, Mauro RP, Leonardi C and F Giuffrida** Shelf life of bunched carrots as affected by nitrogen fertilization and leaf presence. Agronomy. 2020 Dec 16;**10(12)**:1982.

12. **Hewett EW** An overview of preharvest factors influencing postharvest quality of horticultural products. International Journal of Postharvest Technology and Innovation. 2006 Jan 1;**1(1)**:4-15.

13. **Porat R, Lichter A, Terry LA, Harker R and J Buzby** Postharvest losses of fruit and vegetables during retail and in consumers' homes: Quantifications, causes, and means of prevention. Postharvest biology and technology. 2018 May 1; **139:**135-149.

14. **Kader AA** Increasing food availability by reducing postharvest losses of fresh produce. In International Postharvest Symposium 682. 2004 Jun 6; 2169-2176.

15. **Kader AA** Postharvest biology and technology: An overview. Postharvest technology of horticultural crops. 1992.

16. **Michieka DO** Soils of the valley bottom of Kabete Vet. Labs, Nairobi. Site evaluation report. Kenya soil survey, Nairobi. 1977.

17. **McLellan MR, Lind LR and RW Kime** Hue angle determinations and statistical analysis for multiquadrant Hunter L, a, b data. Journal of food quality. 1995 Jun;**18(3)**:235-240.

18. **Bonasia A, Conversa G, Lazzizera C and A Elia** Preharvest nitrogen and Azoxystrobin application enhances postharvest shelf life in Butterhead lettuce. Postharvest biology and technology. 2013 Nov 1; **85:**67-76.

19. **Miceli A and C Miceli** Effect of Nitrogen Fertilization on the Quality of Swiss Chard at Harvest and during Storage as Minimally Processed Produce. Journal of food quality. 2014;**37(2):**125-134.

20. **Mampholo BM, Maboko M, Soundy P and D Sivakumar** Postharvest responses of hydroponically grown lettuce varieties to nitrogen application rate. Journal of Integrative Agriculture. 2019 Oct 1;**18(10):**2272-2283.

21. **Kirakou S** Evaluation of the quality attributes of selected local Cowpea accessions and their response to Postharvest treatments. PhD diss., University of Nairobi; 2017.

22. **Martínez-Sánchez A, Luna MC, Selma MV, Tudela JA, Abad J and MI Gil** Baby-leaf and multi-leaf of green and red lettuces are suitable raw materials for the fresh-cut industry. Postharvest Biology and Technology. 2012 Jan 1;**63(1)**:1-10.

23. **Cantwell M, Hong G, Fibriyanti A, Ara J and K Albornoz** Postharvest handling considerations for kale as intact and fresh-cut product. Respiration. 2012;**25(30)**:35.

24. **Ambuko J, Wanjiru F, Chemining'wa GN, Owino WO and E Mwachoni** Preservation of postharvest quality of leafy amaranth (Amaranthus spp.) vegetables using evaporative cooling. Journal of Food Quality. 2017;1-7.

25. **Liu F and H Stutzel** Leaf expansion, stomatal conductance, and transpiration of vegetable amaranth (Amaranthus sp.) in response to soil drying. Journal of the American Society for Horticultural Science. 2002;**127(5)**:878-883.

26. **Acedo Jr AL** Postharvest technology for leafy vegetables: AVRDC-ADB postharvest projects-RETA 6208/6376. AVRDC-The World Vegetable Center; 2010.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 22 No. 6 August 2022 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

27. **Osei R** Effect of Age of transplants, spacing, supplementary application of sulphate of ammonia and harvesting intervals on growth, yield and some postharvest qualities of chilli pepper. (*C. annum*) VAR. LEGION 18. PhD diss., Kwame Nkrumah University of Science and Technology, Kumasi, Ghana .2013.

28. **Albornoz K** Postharvest Characterization of Kale (Brassica oleracea L. var acephala DC.): A Study of the Impact of Leaf Maturity, Fresh-Cut Preparation and Storage Conditions. University of California, Davis; 2014.

29. **Agüero MV, Ponce AG, Moreira MR and SI Roura** Lettuce quality loss under conditions that favor the wilting phenomenon. Postharvest Biology and Technology. 2011;**59(2)**:124-131.