Trop J Nat Prod Res, May 2024; 8(5): 7315-7320 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

# Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

*Original Research Article*

# Effect of Variety, Fertilizer Combinations, and Harvest Age on Biochemical Qualities of Carrot (*Daucus carota* L.) in a Tropical Environment

Eugenia A. Njoku[1], Uchenna N. Ukwu[1]*, Chukwunyere C. Anozie[1], Kayode P. Baiyeri[1], Bonaventure C. Echezona[1,2]

[1]*Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka.*
[2]*Center for Entrepreneurship and Rural Development, University of Nigeria, Nsukka*

ARTICLE INFO

*Article history:*
Received 07 April 2024
Revised 20 April 2024
Accepted 30 April 2024
Published online 01 June 2024

**Copyright:** © 2024 Njoku *et al*. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

ABSTRACT

The increasing global concern about ecologically unsafe agricultural practices calls for an investigation of how fertilizer combinations and harvest age interact to influence the biochemical qualities of crops. The study objective was to determine the biochemical responses of three carrot varieties to fertilizer composition, and harvest-age interactions. Three carrot varieties, Graffas, Carrot Touchon, and Nantes; four fertilizer compositions, 10 t/ha of poultry manure + 200 kg of NPK 15:15:15 ($PM_{10}$ + $NPK_{200}$), 20 t/ha of pig manure + 200 kg of NPK 15:15:15 ($PIG_{20}$ + $NPK_{200}$), 350 kg of NPK 15:15:15 ($NPK_{350}$), and 0 t/ha (control); and three harvest-age, 10, 12, and 14 weeks after planting (WAP) were evaluated in a 3 x 4 x 3 factorial in randomized complete block design with 3 replications. Variations in biochemical concentrations of carrot roots with variety, fertilizer type, and harvest-age interactions were recorded. Proximate qualities were generally higher in Nantes and Graffas varieties grown with the combined use of organic and inorganic fertilizers harvested at 10 WAP. Phytochemical quality was higher in Graffas and Carrot Touchon grown with $PM_{10}$ + $NPK_{200}$ when harvested at 14 WAP. Nantes variety grown with $NPK_{350}$ and harvested at 12 WAP had higher vitamin contents. Root weight had a positive correlation with saponin (0.22), carbohydrate (0.31), alkaloid (0.33), vitamin E (0.26), and fiber (0.19). Vitamin C displayed positive correlations with vitamin B (0.43), vitamin E (0.56), alkaloid (0.67), tannin (0.31), saponin (0.32), and carbohydrate (0.35), while beta-carotene exhibited positive correlations with vitamin A (0.42) and tannin (0.38).

***Keywords***: Fertilizer combinations; proximate qualities, phytochemicals, safe agricultural foods, correlation

## Introduction

The modest but nutrient-rich root vegetables of the *Daucus carota* L. species (carrots) have long been a mainstay in global diets and play a significant role in global agriculture.[1] They are a top research target due to their adaptability in culinary applications and significant contribution to dietary health. Carrot plays important health and nutritional roles in human life. The healing properties of carrots have been used throughout history for a variety of medicinal purposes including the prevention of vitamin A deficiency, relieving diarrhea, promoting urine, and improving premenstrual symptoms.[2,3] Carrot is a good source of antioxidants that rejuvenate the human system from some damage caused by excessive deposition of oxidative materials.[2,3] Nutritionally, carrot helps in the supply and maintenance of our daily body needs through the provision of beta-carotene, vitamin K, and fiber.[4] Varietal difference (genotype) appears to be a vital aspect that can easily be manipulated by the farmer to adjust the dietary, health, and sensory aspects of carrots.[5] Carrot is a two-yearly temperate vegetable crop but is grown yearly for its fleshy root consumption. Carrot root yield and quality can be significantly affected by environmental factors such as soil structure and texture, fertilizer type or rate, moisture content[6,7], and genotype.[8-11] These traits could be positively affected when supplemental fertilizer addition does not exceed the saturation level. Potassium (K) and nitrogen (N) minerals are reported as the most critical essential elements required for carrot production.[12] Carrot yield per unit area in developing nations falls short of the recommended world average.[13] Consequently, farmers in these regions apply heavy doses of inorganic fertilizers to boost growth and yield[14] which may be unsafe and cost ineffective. Environmental and human health safety, groundwater contamination, and soil acidity are some of the problems that have been implicated in the inappropriate use of chemical fertilizers.

There is an increasing global concern about ecologically unfriendly agricultural practices[15] that are unsafe, unhealthy, insecure, and bereft of quality which calls for careful investigation of how fertilizer inputs and age at harvest interact to influence biochemical indices of crops. Results of the successes of sole applications of organic, inorganic, or different combinations of organo-mineral fertilizers on the improvement of carrot growth and yield attributes are not in short supply. For instance, in a study conducted in southwest Nigeria, Agbeda[3] observed a significant increase in the growth and yield traits of carrots treated with different fertilizer amendments. He reported corresponding increases of 43, 24, 46, and 76% in fresh carrot yield with applications of NPK, biochar, poultry manure, and their combinations, respectively. In a related study conducted in South Africa, Mbatha *et al*.[16] observed a significant increase in growth and yield indices of carrots with increased rates of organic manure applications. However, carrot roots treated with organic manure recorded significantly reduced root total soluble solid, dry mass, and quality as the organic fertilizer rate increased.

This study aims to contribute to the existing knowledge by investigating how the harvest age of carrots interacts with variety and fertilizer

***Corresponding author.** E mail: uchenna.ukwu@unn.edu.ng
Tel: +234 7036370853

**Citation:** Njoku EA, Ukwu UN, Anozie CC, Baiyeri KP, Echezona BC. Effect of Variety, Fertilizer Combinations, and Harvest Age on Biochemical Qualities of Carrot (*Daucus carota* L.) in a Tropical Environment. Trop J Nat Prod Res. 2024; 8(5): 7315-7320. https://doi.org/10.26538/tjnpr/v8i5.38

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria



© 2024 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

composition to affect the biochemical parameters of carrots. The study hypothesized that fertilizer type, harvest age, and variety could affect biochemical attributes of carrots. The objective of this study was to determine the biochemical responses of three carrot varieties to fertilizer composition and harvest-age interactions. Biochemical indices were quantified to be able to estimate how these traits are affected by the interplay of fertilizer type, harvest date, and variety. The implications of these findings could improve the awareness of sustainable agricultural practices, increase the nutritional quality of carrot, and advance the continuing discussion about the environmental impact of contemporary farming.
1 – 1

## Materials and Methods

*Study Site, Treatments and Experimental Design*
The study was conducted at the research farm and laboratory of the Department of Crop Science, University of Nigeria, Nsukka located in the derived Savanna agro-ecological Zone (latitude 06° 52`N; longitude 07° 24`E, with an altitude of 447.26 m above sea level). The annual rainfall distribution ranges from 1155 - 1955 mm with a mean annual temperature of 29 - 30 °C and relative humidity of 69 - 79%. The seeds of three carrot varieties (Carrot Touchon, Graffas, and Nantes) were sourced from Jos, Nigeria in June 2021. The organic manure was sourced from a deep litter poultry and pig Farm of the Department of Animal Science, UNN. The field experiment was a 3 x 4 x 3 factorial laid out in a randomized complete block design (RCBD) replicated three times. Factor A comprised three carrot varieties - Carrot Touchon, Graffas, and Nantes while factor B consists of four fertilizer combinations, 10 t/ha of poultry manure + 200 kg of NPK 15:15:15 ($PM_{10}$ + $NPK_{200}$), 20 t/ha of pig manure + 200 kg of NPK 15:15:15 ($PIG_{20}$ + $NPK_{200}$), 350 kg of NPK 15:15:15 ($NPK_{350}$), and 0 t/ha (control). Factor C consists of the three harvest ages (10, 12, and 14 weeks after planting) of the carrot roots in the same experiment. Data were collected on proximate, vitamins, and phytochemical attributes of carrots after harvest.

*Determination of proximate qualities and vitamin contents*
"Standard procedures of the association of official analytical chemists (AOAC) were used for the determination of proximate qualities of carrot samples. Moisture content and crude fiber were determined according to AOAC method 934.01. Samples were dried at 105°C until constant weight. Ash content was determined by AOAC method 942.05. Carrot samples were incinerated in a muffle furnace at 550°C for 6 hours. Protein content was determined by multiplying total nitrogen content from the Kjeldahl method by 6.25 according to method 960.52 of the AOAC International. Fat content was determined by Soxhlet extraction using petroleum ether as solvent following the AOAC method 963.15. Carbohydrate content was determined by difference [100 - (% moisture + % ash + % protein + % fat)].[17] Vitamins A, B, C, and E were determined using a high-performance liquid chromatography (HPLC) approach. Vitamins were extracted from the sample matrix, were separated and quantified using reverse phase HPLC with UV-visible detection". Vitamin A was detected at 325 nm, vitamin B at 270 nm, vitamin C at 254 nm, and vitamin E at 292 nm.[9,17]

*Determination of Phytochemicals*
"Phytochemical contents of carrot roots were determined following the procedure used by Subramaniam et al. [18] The fresh fruits were dried in shade for about 3 weeks and ground to a coarse powder using a mixer. 100 g of powdered material was soxhlet extracted with different solvents, like ethanol, chloroform, and aqueous (12 hours each). All the extracts were evaporated in a vacuum under reduced pressure and stored in sterile glass bottles at room temperature until screened. Total Phenols were determined using the Spectro-photometric method. The reaction mixture was prepared by mixing 0.5 ml of ethanol extract, 2.5 ml of 10% Folin-Ciocalteu's reagent dissolved in water, and 2.5 ml of 7.5% $NaHCO_3$. Blank was concomitantly prepared, containing 0.5 ml ethanol, 2.5 ml 10% Folin-Ciocalteu's reagent dissolved in water, and 2.5 ml of 7.5% of $NaHCO_3$. The samples were thereafter incubated in a thermostat at 45°C for 45 min. The absorbance was determined using a spectrophotometer at λmax= 765 nm. The samples were prepared in triplicate for each analysis and the mean value of absorbance was obtained. The same procedure was repeated for the standard solution of Gallic acid and the calibration line was taken. Based on the measured absorbance, the concentration of phenolics was read (mg/ml) from the calibration line; then the content of phenolics in the extract was expressed in terms of Gallic acid equivalent (mg of GA/g of extract). Flavonoids were determined by extracting 10 g of the sample repeatedly with 100 ml of 80% aqueous ethanol at room temperature. The whole solution was filtered through Whatman filter paper No 42 (125 mm). The filtrate was later transferred into a crucible and evaporated into dryness over a water bath and weighed to a constant weight. Tannin was determined by weighing 500 mg of the sample into a 50 ml plastic bottle. 50 ml of distilled water was added and shaken for 1 hour in a mechanical shaker. This was filtered into a 50 ml volumetric flask and made up to the mark. Then 5 ml of the filtrate was pipetted out into a test tube and mixed with 2 ml of 0.1M $FeCl_3$ in 0.1N HCl and 0.008M potassium ferrocyanide. The absorbance was measured at 120 nm within 10 minutes. Alkaloids were determined by weighing 5 g of the sample into a 250 ml beaker and 200 ml of 10% acetic acid in ethanol was added. The beaker was covered and allowed to stand for 4 hours. It was then filtered and the extract was concentrated in a water bath to one-quarter of the original volume. Concentrated ammonium hydroxide was added dropwise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected and washed with dilute ammonium hydroxide (2M) and then filtered. The residue is the alkaloid which is then dried and weighed. Saponins were determined by extracting 20 g of each sample into a conical flask followed by the addition of 100 ml of 20% aqueous ethanol. They were then heated over a hot water bath for 4 hours with continuous stirring at about 550ºC. The mixture was filtered and the residue was re-extracted with another 200 ml of 20% ethanol. The combined extracts were reduced to 40 ml over a water bath at about 900ºC. The concentrate was transferred into a 250 ml separatory funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated. 60 ml of n-butanol was added. The combined n-butanol extracts were washed twice with 10 ml of 5% aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the samples were dried in the oven to a constant weight. Saponin content was calculated as a percentage".
Data were analyzed using the R software version 4.2.1 GUI 1.79, High Sierra build, and R Studio IDE version (2022.12.0+ 353).

## Results and Discussion

*Effect of Variety on Biochemical Composition of Carrot*
The carrot varieties exerted varying influences on the biochemical properties of the vegetable. Within this study, Carrot Touchon demonstrated higher concentrations of tannin (0.94) and flavonoids (0.79) compared to other carrot varieties, while Graffas exhibited notably lower levels (as shown in Figure 1). In contrast, Nantes influenced elevated concentrations of vitamin B, vitamin C, ash, protein, and beta carotene, registering values of 1.03, 1.09, 1.12, 1.12, and 1.15, respectively. Graffas, on the other hand, recorded the lowest quality in these aspects. Nantes also displayed superior attributes in moisture and vitamin A content, whereas Carrot Touchon exhibited relatively lower quality in these categories. The vitamin E content of Graffas (0.78) surpassed that of the other varieties, while Carrot Touchon lagged at -1.13. Graffas stood out with higher concentrations of saponin, carbohydrates, alkaloids, fats, and fiber (0.58, 1.15, 1.12, and 1.07) compared to the other varieties. In terms of root weight, Carrot Touchon (0.66) outperformed Nantes, which had the least root weight (-1.15).
This study confirms the established notion that carrots are abundant sources of vital compounds, including carbohydrates, carotenes, antioxidants, and flavonoids, as recognized by earlier studies[19,2]. These inherent qualities position carrots as valuable contributors to daily nutritional needs by providing essential elements such as beta carotene, vitamin K, fiber, and antioxidants, thereby bolstering overall health[4]. The observed variations in the biochemical composition of the three


© 2024 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

carrot varieties can be attributed to their genetic makeup, as genetically distinct genotypes tend to express different qualities [11]. This finding aligns with Scalzo and Mezzetti's observation[20] that attributes related to quality are chiefly governed by major genes and that the magnitude of bioactive components is influenced by crop genotypes. Graffas variety excelled in concentrations of carbohydrates, fats, fiber, alkaloids, saponins, and vitamin E. This is significant, as the higher fiber content in Graffas holds value in relieving constipation[21]. Saponins, found in greater abundance in Graffas, are recognized as dietary supplements and nutraceuticals, contributing to cancer prevention and the regulation of cholesterol levels in the body[22]. The higher Vitamin E concentration of the Graffas variety could play a vital role in therapeutic medicine, especially in cardiological ailments, in addition to its antioxidant properties[2].

In contrast, Nantes enhanced higher concentrations of ash, protein, moisture, beta carotene, vitamin A, vitamin B, and vitamin C. The higher levels of beta carotene and vitamin A recorded in the Nantes variety are crucial for improving vision, supporting ocular health, enhancing the immune system, and promoting mucous membrane health, among other benefits. This could prove pivotal in addressing vitamin A deficiency in Nigeria, aligning with the United Nations' sustainable development goals[9]. The high Vitamin C content in Nantes could have multifaceted roles in various biological processes, including skin and soft tissue maintenance, bile acid synthesis, redox reactions within cells, and the mitigation of neuronal ailments such as Parkinson's and Alzheimer's[23-25]. The elevated moisture content in Nantes enhances its suitability for rehydration. It's noteworthy that this finding contradicts Eze[26], which indicated insignificant variations in proximate content, particularly moisture, among the considered carrot varieties. Carrot Touchon excelled with higher tannin and flavonoid contents, which are crucial antioxidants, known for their efficacy in treating conditions like diarrhea[27].

*Effect of Fertilizer Combinations on Biochemical Composition of Carrot*

The effects of different fertilizer combinations on the biochemical characteristics of carrot roots are shown in Figure 2. Among the various fertilizer amendments, the combination of PM$_{10}$ and NPK$_{200}$ demonstrated a pronounced impact on several parameters, leading to higher carbohydrate (1.37), tannin (1.30), and root weight (0.97). It was followed by PIG$_{20}$ and NPK$_{200}$, while carrot roots that received no fertilizer treatment recorded the lowest values in these categories (-0.92, -1.14, and -1.29, respectively). Roots treated with PIG$_{20}$ and NPK$_{200}$ displayed higher levels of fats (0.73), moisture (1.28), and vitamin E (1.13), outperforming other fertilizers. In contrast, the control group exhibited the poorest quality in these parameters (-1.48, -1.16, and -1.20, respectively). Carrot roots treated with NPK$_{350}$ influenced a higher concentration of vitamin B (0.93) compared to those treated with PIG$_{20}$ and NPK$_{200}$, PM$_{10}$ and NPK$_{200}$, and the control group. The NPK$_{350}$-treated roots also displayed higher levels of vitamin A (0.90) and beta carotene (1.41), while those treated with PM$_{10}$ and NPK$_{200}$ had the least content. The control group, surprisingly, showed higher ash (0.95) and alkaloid (1.50) quality than the treated roots, while NPK$_{350}$ performed relatively poorly in these aspects. PM$_{10}$ and NPK$_{200}$ were superior in the concentrations of flavonoids (1.17), fiber (0.78), protein (0.78), and saponins (0.69), while pig manure exhibited the least quality in these parameters.

Fertilizer treatment has emerged as a pre-harvest agronomic practice that significantly influences the biochemical quality of various horticultural crops[9], a phenomenon observed in studies concerning passion fruit[28] and carrots[29]. The effects of specific fertilizer compositions are evident, with PM$_{10}$ and NPK$_{200}$ treatment notably boosting carbohydrate, fiber, tannin, and flavonoid contents. In contrast, the PIG$_{20}$ and NPK$_{200}$ treatments enhanced the fat, moisture, and vitamin E contents in carrot roots. Conversely, untreated roots displayed higher ash, protein, alkaloid, saponin, and vitamin C content. Roots treated with NPK$_{350}$ exhibited increased beta-carotene, vitamin A, and vitamin B contents. This underscores the significance of supplemental fertilizer applications and soil fertility in plant nutrition, aligning with earlier studies[6,7]. The results correspond with the findings of Anozie and Baiyeri[30] and Turhan and Ozmen[31], who reported significant improvements in yield and quality of carrot and tomato plants when treated with fertilizers compared to untreated plants.

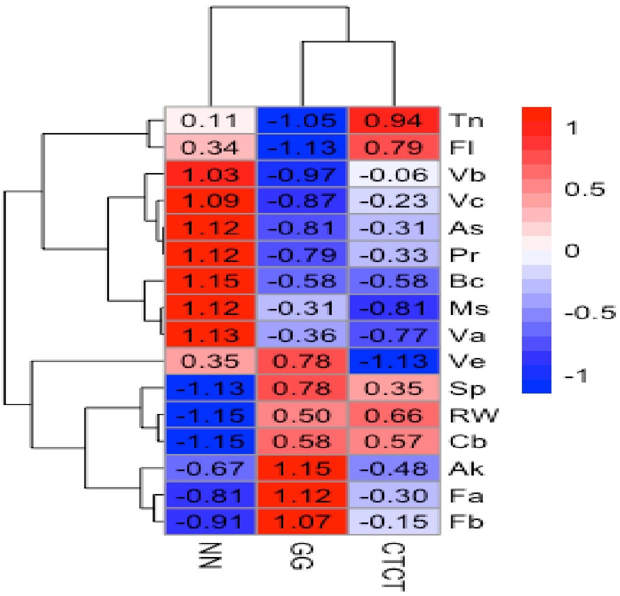


**Figure 1:** Heat map of biochemical contents of carrot roots as influenced by variety. CTCT = Carrot Touchon, NN = PIG (20 t) + Nantes, GG = Graffa, RW = Root Weight, Ms = Moisture, As = Ash, Fa = Fat, Fb = Fiber, Pr = Protein, Cb = Carbohydrate, Ak = Alkaloid, Tn = Tanin, Sp = Saponin, Bc = Beta Carotene, Fl = Flavonoid, Va = Vitamin A, Vb = Vitamin B, Vc = Vitamin C, Ve = Vitamin E.

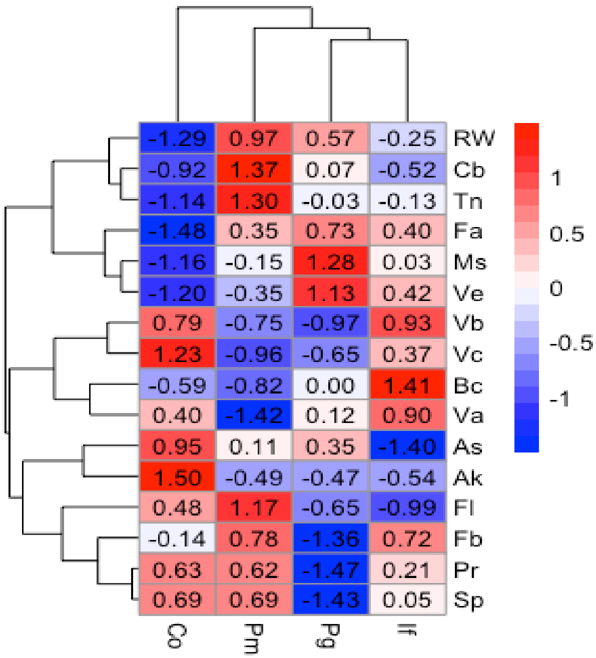


**Figure 2:** Heat map of biochemical contents of carrot roots as influenced by fertilizer rates. Pm = PM10 + NPK200, Pg = PIG(20 t) + NPK(200 kg), If = NPK(350 kg), Co = Control, RW = Root Weight, Ms = Moisture, As = Ash, Fa = Fat, Fb = Fiber, Pr = Protein, Cb = Carbohydrate, Ak = Alkaloid, Tn = Tanin, Sp = Saponin, Bc = Beta Carotene, Fl = Flavonoid, Va = Vitamin A, Vb = Vitamin B, Vc = Vitamin C, Ve = Vitamin E.


© 2024 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

*Effect of Harvest Age on Biochemical Composition of Carrot*

The biochemical attributes of carrot roots varied with harvest age (Figure 3). Carrots harvested at 12 WAP displayed higher vitamin C (0.84), vitamin E (0.96), and carbohydrate (0.85) content, while those harvested at 10 WAP exhibited the poorest quality. Harvesting at 14 WAP resulted in higher root weight (1.07), vitamin B (1.02), alkaloid (0.78), tannin (0.65), protein (0.70), and saponin (0.71) content. Conversely, carrots harvested at 10 WAP displayed the lowest quality in these parameters (-0.91, -0.97, -1.12, -1.15, -1.14, and -1.14, respectively). The highest value for ash (0.79) and vitamin A (0.61) was observed in carrots harvested at 12 WAP, with a decline in ash and vitamin A concentration for carrots harvested at 14 WAP. Harvesting at 12 weeks resulted in higher fat (1.14) and flavonoid (0.91) concentrations compared to 10- and 14-week harvests, whereas harvesting at 14 weeks recorded higher beta carotene (1.13) content. The moisture content of carrots exhibited a sharp decline from 1.11 at 10 WAP to -0.84 at 12 WAP.

Harvest age and maturity stage emerge as pivotal factors influencing the nutritional quality of crop produce, as corroborated by Kader[32]. In this study, harvesting at different ages yielded distinct variations in the biochemical composition of carrot roots. The observed variability in the biochemical constituents of carrot roots as a function of harvest age corroborates earlier reports that the nutritional quality of carrot roots varies with harvest age [33,34]. The corresponding increase in fiber content with an increase in harvest age is consistent with the findings of Paltrinieri[35] who observed that produce harvested too late accumulates excessive fiber.

*Interaction Effect of Variety, Fertilizer, and Harvest Age on Biochemical Concentrations of Carrot*

The interaction effect of variety, fertilizer, and harvest age on the biochemical contents of carrot is shown in Figure 4. The biplot explained 41.11% of the variation in biochemical content. The interaction of Graffas, poultry manure, and 10 WAP (T1); Graffas, NPK, and 14 WAP (T9); Nantes, pig manure, and 14 WAP (T30); Carrot Touchon, NPK, and 14 WAP (T21); Carrot Touchon, NPK, and 12 WAP (T20); Graffas, Control, and 14 WAP (T12); Carrot Touchon, Control, and 12 WAP (T23); Carrot Touchon, poultry manure, and 14 WAP (T15); Carrot Touchon, pig manure, and 10 WAP (T16); and Graffas, NPK, and 10 WAP (T7) accounted for the higher proportion of the variation.

The combined effect of Graffas, Control, and 14 WAP (T12) gave higher protein, saponin, tannin, vitamin E, and vitamin C content, while the combined effect of Carrot Touchon, NPK, and 14 WAP (T21), and Carrot Touchon, NPK, and 12 WAP (T20), gave higher content of Vitamin B and alkaloid. T9 gave more beta carotene and vitamin A. Although, T1 and T7 appeared in the same section of the plot with the following treatments T9, T19, T25, T10, and T28, they influenced higher moisture and fat contents respectively than the referenced treatments. T31 gave more flavonoid and ash than the rest treatments that appeared in the same section of the plot, although, it does not differ much from T4 in ash content. The vertex treatment combinations that appeared at the outer polygon also gave a reasonable proportion of all the biochemical components considered but not as much as those that appeared within the different sections with the respective biochemical parameters considered.

*Correlation among Proximate, Vitamins, and Phytochemical Attributes of Carrot*

The intricate relationships among yield and various biochemical parameters of carrot roots are highlighted in Figure 5. Vitamin A exhibited a positive and highly significant correlation (r = 0.42, P < 0.001) with various parameters. Notably, vitamin A displayed negative correlations with root weight (-0.04) and all biochemical parameters, including fiber (-0.02), protein (-0.11), vitamin B (0.02), vitamin E (-0.07), alkaloid (-0.11), vitamin C (0.05), carbohydrate (-0.02), saponin (-0.24), ash (0.13), flavonoid (-0.29), moisture content (0.12), fat (0.15), and tannin (0.12). A positive correlation (0.43) was established between moisture and fat content, with moisture content demonstrating an inverse relationship with all other parameters.

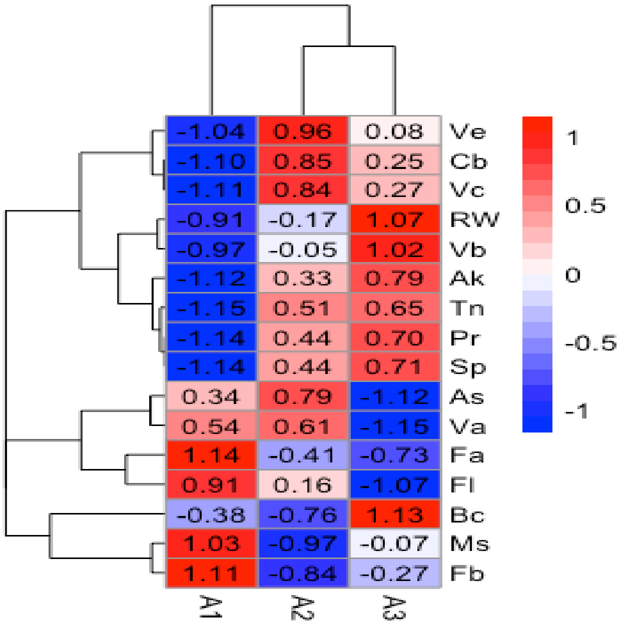


**Figure 3:** Heat map of biochemical contents of carrot roots as influenced by age of harvest. A1 = 10 WAP, A2 = 12 WAP, A3 = 14 WAP, WAP = Weeks after planting, RW = Root Weight, Ms = Moisture, As = Ash, Fa = Fat, Fb = Fiber, Pr = Protein, Cb = Carbohydrate, Ak = Alkaloid, Tn = Tanin, Sp = Saponin, Bc = Beta Carotene, Fl = Flavonoid, Va = Vitamin A, Vb = Vitamin B, Vc = Vitamin C, Ve = Vitamin E.

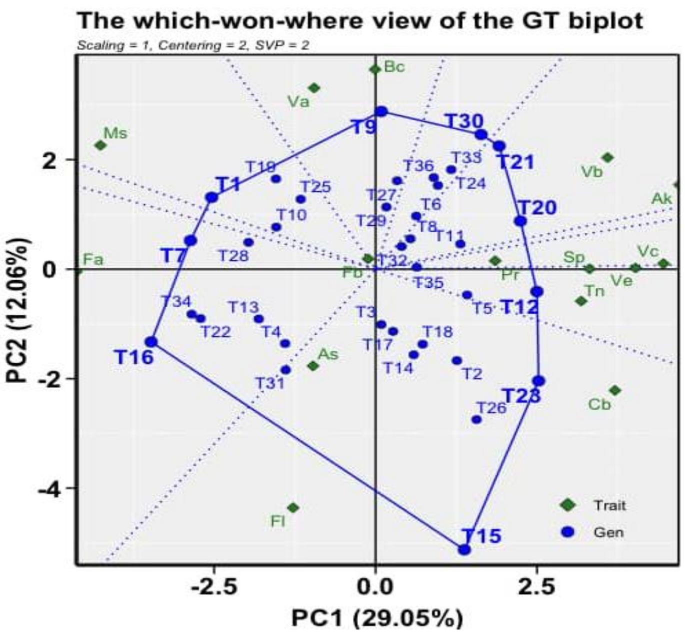


**Figure 4:** Biplot analysis of variety and age of harvest by biochemical component

T1 = Graffas × poultry manure × 10 WAP, T2 = Graffas × poultry manure × 12 WAP, T3 = Graffas × poultry manure × 14 WAP, T4 = Graffas × pig manure × 10 WAP, T5 = Graffas × pig manure × 12 WAP, T6 = Graffas × pig manure × 14 WAP, T7 = Graffas × NPK × 10 WAP, T8 = Graffas × NPK × 12 WAP, T9 = Graffas × NPK × 14 WAP, T10 = Graffas × Control. × 10 WAP, T11 = Graffas × Control × 12 WAP, T12 = Graffas × Control × 14 WAP, T13 = Carrot Touchon × poultry manure × 10 WAP, T14 = Carrot Touchon × poultry manure × 12 WAP, T15 = Carrot Touchon × poultry manure × 14 WAP, T16 = Carrot Touchon × pig manure × 10 WAP, T17 = Carrot Touchon × pig manure × 12 WAP, T18 = Carrot Touchon × pig manure × 14 WAP, T19 =


© 2024 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

Carrot Touchon × NPK × 10 WAP, T20 = Carrot Touchon × NPK × 12 WAP, T21 = Carrot Touchon × NPK × 14 WAP, T22 = Carrot Touchon × Control × 10 WAP, T23 = Carrot Touchon × Control × 12 WAP, T24 = Carrot Touchon × Control × 14 WAP, T25 = Nantes × poultry manure × 10 WAP, T26 = Nantes × poultry manure × 12 WAP, T27 = Nantes × poultry manure × 14 WAP, T28 = Nantes × pig manure × 10 WAP, T29 = Nantes × pig manure × 12 WAP, T30 = Nantes × pig manure × 14 WAP, T31 = Nantes × NPK × 10 WAP, T32 = Nantes × NPK × 12 WAP, T33 = Nantes × NPK × 14 WAP, T34 = Nantes × Control. × 10 WAP, T35 = Nantes × Control × 12 WAP, T36 = Nantes × Control × 14 WAP. Ms = Moisture, As = Ash, Fa = Fat, Fb = Fibre, Pr = Protein, Cb = Carbohydrate, Ak = Alkaloid, Tn = Tanin, Sp = Saponin, Bc = Beta Carotene, Fl = Flavonoid, Va = Vitamin A, Vb = Vitamin B, Vc = Vitamin C, Ve = Vitamin E

Root weight exhibited positive correlations with saponin (0.22), carbohydrate (0.31), alkaloid (0.33), vitamin E (0.26), and fiber (0.19). Vitamin C displayed positive correlations with vitamin B (0.43), vitamin E (0.56), alkaloid (0.67), tannin (0.31), saponin (0.32), and carbohydrate (0.35), while beta carotene exhibited positive correlations with vitamin A (0.42) and tannin (0.38). Of all the parameters considered, the most substantial negative and positive correlation was recorded between moisture and carbohydrate (-0.83) and vitamin C and alkaloid (0.67), respectively. This study has established a positive correlation between beta-carotene and vitamin A content, implying that factors promoting the accumulation of beta-carotene will also enhance vitamin A levels, as most vitamin A synthesis directly derives from beta-carotene. This is particularly significant given the various health benefits associated with both nutrients. Additionally, the positive correlation between moisture content and fat aligns with previous findings[36] and suggests an interesting interplay between these two attributes. On the contrary, the negative correlation between moisture content and carbohydrates underscores the importance of moisture management, as higher moisture content can compromise root quality and promote the activity of rot-causing pathogens.

## Conclusion

The challenges facing carrot production in Southeast Nigeria, including variety selection, soil fertility, fertilizer availability, and optimal harvest timing, are critical. This study has provided insights into the complex interplay of these factors on the nutritional quality of carrot roots. As no single variety emerged as superior in all attributes, the results serve as valuable guidance for carrot farmers and consumers regarding variety selection, fertilizer application, and harvest timing.
For improved proximate content, it is recommended to grow Nantes and Graffas varieties treated with a combination of organic and inorganic fertilizers and harvest at 10 WAP. To enhance phytochemical content, Graffas and Carrot Touchon varieties should be grown with $PM_{10}$ and $NPK_{200}$ treatment and harvested at 14 weeks after planting. For higher vitamin content, Nantes varieties treated with $NPK_{350}$ should be harvested at 12 WAP. Future research could explore additional factors influencing carrot quality, such as soil health and environmental conditions, and investigate optimal combinations of fertilizers and harvest timing to maximize both yield and nutritional quality.

## Conflict of Interest

The authors declare no conflict of interest.

## Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

## Acknowledgments

The authors are grateful to Dr. Emeka Okechukwu for his assistance with the heat maps and correlograms

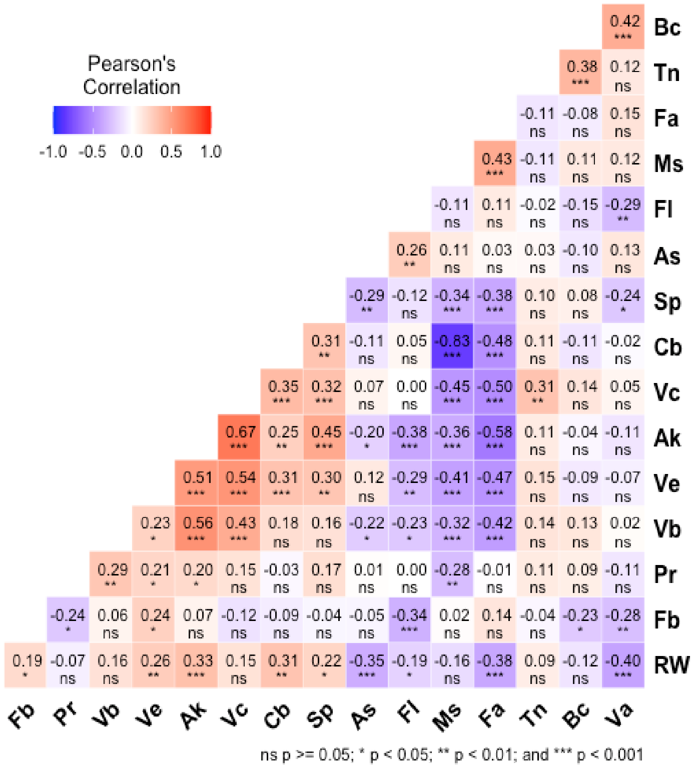


**Figure 5:** Corregram showing the correlation of yield and biochemical content of carrot roots. RW = Root Weight, Ms = Moisture, As = Ash, Fa = Fat, Fb = Fiber, Pr = Protein, Cb = Carbohydrate, Ak = Alkaloid, Tn = Tanin, Sp = Saponin, Bc = Beta Carotene, Fl = Flavonoid, Va = Vitamin A, Vb = Vitamin B, Vc = Vitamin C, Ve = Vitamin E.

## References

1. FAOSTAT. Food and Agricultural Organization of the United Nations (FAO) Statistical Database 2020. https://www.fao.org/faostat/en/#home. Accessed October 26, 2023.
2. Tavares A C, Goncalves M J, Cavaleiro C, Cruz M T, Lopes M C, Canhoto J, Salgueiro L R. Essential oil of *Daucus carota* subsp. halophilus: composition, antifungal activity, and Cytotoxicity. J Ethnopharmacol. 2008; 119(1): 129-134. https://doi.org/10.1016/j.jep.2008.06.012
3. Agbede T M. Effect of tillage, biochar, poultry manure, and NPK 15-15-15 fertilizer, and their mixture on soil properties, growth and carrot (*Daucus carota* L.) yield under tropical conditions, Heliyon 2021; 7(6): e07391. https://doi.org/10.1016/j.heliyon.2021.e07391.
4. Sharma K D, Karti S, Singh N, T and Attri S A. Chemical composition, Functional properties and processing of carrot-a review. J Food Sci. Technol. 2012; 49(1): 22-32. https://doi.org/10.1007/s13197-011-0310-7
5. Baardseth P, Rosenfeld H J, Sundt T W, Skrede G, Lea P and Slnde E. Evaluation of Carrot Varieties for Production of deep fried carrot chips- II Sensory Aspects. Food Res Int. 1996; 28(6): 513-519. https://doi.org/10.1016/0963-9969(95)00036-4
6. Ihejiofor P N, Ukwu U N and Adeoye G. Determination of Kolgrace Bio-fertilizer Rate for Optimum Greengram (Vigna radiata L. Wilczek) Production in Ibadan, Southwest Nigeria. Agro-Science 2022; 21(1): 82-87. https://doi.org/10.4314/as.v21i1.13
7. Ihejiofor PN, Ukwu UN Adeoye GO. Comparative effects of different levels of kolgrace organic fertilizer on the growth


© 2024 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License

 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

and yield attributes of Green gram (*Vigna radiata* (L) Wilczek) in the screenhouse. Asian J Res Agric For. 2020; 6(3): 1-7. https://doi.org/10.9734/ajraf/2020/v6i330104
8. Ukwu N U and Olasanmi B. Crossability among five Cassava (*Manihot esculenta* Crantz) Varieties. Modern Concepts and Development in Agronomy 2018; 2(4): 1–6. http://dx.doi.org/10.31031/mcda.2018.02.000543
9. Muojiama S O, Nwune U C, Ugo G O, Ezeh M C and Ukwu U N. Growth performance and nutritional concentrations of two kale (Brassica oleracea var Acephala) varieties in response to fertilizer types in Awka, Southeast Nigeria. Int. J. Recycl. Org. Waste Agric. 2023; 12(4): 723-733 https://doi.org/10.30486/ijrowa.2023.1979246.1591
10. Ukwu U N, Agbirionwu A C, Dauda N, Adewuyi S O, Osadebe V O and Anozie C C. Response of mungbean (Vigna radiata L Wilczek) genotypes to different spacing types in derived savannah agroecology of southeast Nigeria. Nigerian J Biotechnol. 2023; 40(1): 77-85. http://dx.doi.org/10.4314/njb.v40i1.9.
11. Ukwu U N, Oburu B N, Muojiama S O, Osadebe V O, Dauda N, Adewuyi S O. Morphology and agronomic evaluation of ten mungbean (Vigna radiata L.) accessions in derived savanna agroecology of southeast Nigeria. Asian J Biol Sci. 2023; 16(2): 110-120. https://doi.org/10.3923/ajbs.2023.110.120
12. Ali M A, Hossain M A, Mondal Md F and Farooque A M. Effect of Nitrogen and Potassium on Yield and Quality of Carrot. Pakistan J Biol. Sci. 2003; 6: 1574-1577. https://doi.org/10.3923/pjbs.2003.1574.1577
13. FAO. Food and Agriculture Organization Production Year Book (51st ed.). 1999; Rome, Italy. https://www.fao.org/food-agriculture-statistics/resources/publications/statistical-yearbook-and-pocketbook/en/. Accessed October 12, 2023.
14. Dauda S N, Ajayi F A, Ndor E. Growth and yield of watermelon (*Citrullus lanatus*) as affected by poultry manure application J Agric Soc Sci. 2003; 4: 121-124
15. Umesha S, Manukumar H M G, Chandrasekhar B. Sustainable Agriculture and Food Security. In: Biotechnology for Sustainable Agriculture, Ram Lakhan Singh and Sukanta Mondal Editions, Chapter 3, Woodhead Publishing. 2018; Pp 67-92. https://doi.org/10.1016/B978-0-12-812160-3.00003-9.
16. Mbatha A N, Ceronio G M and Coetzer G M. Response of carrot (Daucus carota L.) yield and quality to organic fertilizer. South African J Plant Soil. 2014; 31(1): 1–6. http://dx.doi.org/10.1080/02571862.2013.862309
17. AOAC. Official Methods of Analysis of the Association of Official Analytical Chemists International. In: Horwitz, W. Led. 17th ed., Arlington, VA, USA. AOAC Press. 2007.
18. Subramaniam P A, Seedar D and Gopal V. Quantitative phytochemical analysis of some edible fruits from Boda and Kolli hills. J. Pharm. Phytochem. 2017; 6(5): 2002-2005.
19. Gopalan C, Ramasastry B V, Balasubramanian S C. Nutritive value of Indian foods. Hyderabad: National Institute of Nutrition. 2014; p. 47
20. Scalzo J and Mezzetti B. Biotechnology and Breeding for Enhancing the Nutritional Value of Berry Fruit. In: Biotechnology in Functional Foods and Nutraceuticals. Bagchi D, Lau F C & Ghosh D K (Eds) (2010), CRC Press Inc. 2010. https://doi.org/10.1201/9781420087123
21. Van der Schoot A, Drysdale C, Whelan K, Dimidi E. The Effect of Fiber Supplementation on Chronic Constipation in Adults: An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials. Am J Clin Nutr. 2022; 116(4):953-969. https://doi.org/10.1093/ajcn/nqac184
22. Elekofehinti O O, Iwaloye O, Olawale F, Ariyo E O. Saponins in Cancer Treatment: Current Progress and Future Prospects. Pathophysiology. 2021; 28(2): 250–272. https://doi.org/10.3390%2Fpathophysiology28020017
23. Fotopoulos V and Kanellis A K. Altered apoplastic ascorbate redox state in tobacco plants via ascorbate oxidase overexpression result in delayed dark-induce senescence in detached leaves. Plant Physiol Biochem. 2013; 73:154-160. https://doi.org/10.1016/j.plaphy.2013.09.002
24. Gest N, Gautier H, and Stevens R. Ascorbate as seen through plant evolution: The rise of a successful molecule. J Exp Bot. 2013; 64(1): 33-53. https://doi.org/10.1093/jxb%2Fers297
25. Ahmad T, Cawood M, Iqbal Q, Arino A, Batool A, Tariq R M S, Azam M and Akhtar S. Phytochemicals in Daucus carota and Their Health Benefits. Foods. 2019; 8(9): 424 https://doi.org/10.3390/foods8090424
26. Eze F O. Growth, Yield and Postharvest Evaluation of Four Genotypes of Carrot (*Daucus carota* L.) Under Three Rates of Poultry Manure. An M. Sc. Dissertation Submitted to The Department of Crop Science, University of Nigeria, Nsukka. 2018.
27. Han RM, Zhang JP and Skibsted L H. Reaction dynamics of flavonoids and carotenoids as antioxidants. Molecules 2012; 17(2): 2140–2160. https://doi.org/10.3390/molecules17022140
28. Ndukwe O O and Baiyeri K P. Influence Genotype and Poultry Manure Rate on Phenology and Fruit Yield of Yellow Passion Fruit. Acta Horti. 2018; 1225(18): 139-144. https://doi.org/10.17660/actahortic.2018.1225.18
29. Seljasen R, Kristensen H L, Lauridsen C, Wyss G B, Kretzschmar U, Birlouez-Aragone I and Kahl J. Quality of Carrots as Affected by Pre- and Postharvest Factors and Processing. J Sci Food Agric. 2013; 93 (11). Retrieved from https://www.researchgate.net 2018-02-18.
30. Anozie C C and Baiyeri K P. Effect of Tillage Methods and Poultry Manure Rates on the Production of Carrot (*Daucus carota* L.) in Nsukka, Southeast Nigeria. *J Horticul For*. 2022; 14(4): 42-48. https://doi.org/10.5897/JHF2022.0691
31. Turhan A and Ozmen N. Effect of Chemical and Organic Fertilizer Treatment on Yield and Quality Traits of Industrial Tomato. J Terkirdag Agric Facul. 2021; 18(2): 213-221. https://doi.org/10.33462/jotaf.741367
32. Kader AA. Perspective flavor quality of fruits and vegetables. J Sci Food Agric. 2008; 88(11): 1963-1968. https://doi.org/10.1002/jsfa.3293
33. Shanmugavelu K G. Production technology of vegetable crops. Oxford & IBN Publishing Co. New Delhi. 1989; Pp. 397-420.
34. Mohanta HC, Hossain M M, Islam MS and Saha S R. Effect of Harvesting Time on Yield and Quality of Carrot. Ann Bangladesh Agric. 2017; 21(1 & 2): 79-87
35. Paltrinieri G. Handling of Fresh Fruits and Vegetables and Root Crops.: Agricultural Marketing Improvement. A Traning Manual for Grenada. 2001. (FAO of UN). https://www.fao.org
36. Fanlegue CL, Abdoulaye T, Ambroise C, Adama C N and Renes S Y. Physiochemical and Nutritional Properties of Varieties of Carrot (*Daucus carota* L.) Grown in Region of Korhogo, North of Cote d'Ivoire. Int J Environ Agric Biotechnol (IJEAB) 2018; 3(3): 792-798. https://doi.org/10.22161/IJEAB%2F3.3.11


© 2024 the authors. This work is licensed under the Creative Commons Attribution 4.0 International License