

Irrigation Water Source Influences the Nutritional and Biochemical Qualities of Vegetables

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Abstract

Farmlands are typically irrigated by groundwater and surface water. Research works on the effects of irrigation water on crop quality abound, but it is desirable to have information on the comparative effects of groundwater and surface water irrigation on the nutritional quality of harvested crops. Hence, in this study, we compared the nutritional and biochemical qualities of vegetable crops harvested from groundwater-irrigated farmland and surface water-irrigated farmland, situated within the same vicinity. *Telfairia occidentalis*, *Amaranthus hybridus* and *Corchorus olitorius* were harvested from the two farm types, and evaluated for nutritional and biochemical parameters, using the spectrometric technique. Data were analysed using One-way ANOVA, and the mean differences were considered significant at $p < 0.05$. Vegetables irrigated with groundwater had higher values of all the assessed parameters, except carbohydrate and total energy. *C. olitorius* was highest in moisture ($27.83 \pm 0.08\%$), while *A. hybridus* recorded the highest ash ($24.15 \pm 0.05\%$), both significant at $p < 0.05$. *T. occidentalis* had higher values of protein ($21.66 \pm 0.05\%$), crude fibre ($12.45 \pm 0.06\%$) and fat ($3.40 \pm 0.05\%$). The result of the biochemical analysis showed that *A. hybridus* grown on groundwater-irrigated farmlands had higher values of starch, reducing sugar and total sugar, relative to those grown on surface water-irrigated farmland. Since the vegetables grown on groundwater water-irrigated farmland showed improved nutritional qualities, we recommend sustainable groundwater irrigation practices for the production of quality vegetables.

Keywords: *Amaranthus hybridus*, *Corchorus olitorius*, Irrigation, *Telfairia occidentalis*, Vegetables,

1.0 Introduction

Agricultural productivity and sustainable food production are key activities needed to address the issue of hunger. However, in the face of an ever-growing global population size, accelerating pace of urbanization, and effects of climate change, there is more pressure on the limited natural resources for agriculture [1]. Water availability is a major limiting environmental factor affecting crop production. In arid and semi-arid regions, plants are often subjected to periods of drought [2, 3]. Interventions such as irrigated agriculture have played a vital role in maintaining food productivity and security in developing countries

[4]. At present, irrigated agriculture utilises more than two-thirds of the total available freshwater for about 20% of the total arable land [5].

Irrigated agriculture is essential to attaining food security, as conventional rain-fed farming does not suffice to cope with the current food demand. Two major sources of water for irrigation are groundwater and surface water. Water from rain and surface is stored in underground spaces between rock particles, as it moves slowly through geologic formations of soil, sand and rocks, called aquifers [6]. Access to the stored water could either be via natural means such as from springs or manmade methods [6].

Groundwater is generally less prone to contamination, having passed through layers of filtration. The choice of water for irrigation could be influenced by the sensitivity of plants to water-related environmental contamination and the quality of plant produce. Global withdrawals of freshwater have created uncertainty on the volumes and spatial distribution of groundwater [7, 8]. Inadequate protection of surface water from contamination raises concerns, as do the global climate impact, accessibility, and affordability issues stemming from artificial means of accessing groundwater for irrigated agriculture, as well as the quality of food produced by groundwater irrigation.

Vegetables are an important portion of the culinary diet, as they serve as a functional food and a major source of vitamins, minerals, proteins and dietary fibre [9]. Vegetables are enjoyed by different ethnicities, and some hold cultural significance. However, vegetable cultivation presents a unique challenge due to its perishability and high sensitivity to environmental factors such as the quality of the irrigation water and its susceptibility to contamination during growth [10]. Several human health issues are tied to diet,

and this calls for the need to investigate the effect of water sources on vegetable cultivation. This study aimed to compare the nutritional and biochemical quality of three tropical leafy vegetables important to West Africa's culinary – *Telfairia occidentalis* (Ugwu), *Amaranthus hybridus* (Tete), *Corchorus olitorius* (Ewedu), each cultivated on plots of surface water irrigated farm and groundwater irrigated farm.

2.0 Materials and Methods

2.1 Experimental Site and Plant Collection

Seeds of selected tropical leafy vegetables, *Telfairia occidentalis*, *Amaranthus hybridus*, and *Corchorus olitorius* (Table 1), collected from local farmers, were grown in sections on two experimental farm plots irrigated with groundwater and surface water, within the premises of an educational institution in Lagos, Nigeria. The vegetables were harvested on maturity from each plot and cleaned under running tap water. The edible portions of the leaves were detached from the stalk, air-dried and packed in zipper plastic bags. Samples were taken for analysis at the Federal Institute of Industrial Research Oshodi (FIIRO) laboratory.

Table 1: Names of Selected Green Leafy Indigenous Vegetables

Species	Family	Common name (English)	Local name (Dialect)
<i>T. occidentalis</i> Hook. F.	Cucurbitaceae	Fluted pumpkin	Ugwu (Igbo), Ikong-ubong (Efik)
<i>A. hybridus</i> Linn.	Amaranthaceae	African spinach	Tete (Yoruba), Inyangafia (Efik)
<i>C. olitorius</i> Linn.	Tiliaceae	Bush okra, Vegetable juts	Ewedu (Yoruba), Etinyung (Efik)

2.2 Proximate analysis

The Proximate analysis was determined using the protocols of the Association of Official Analytical Chemist and other standard procedures. Moisture, crude protein, ash, crude fibre and crude lipid content were measured using the oven-dry (105°C), Kjeldahl nitrogen, dry ashing (600°C), digestion, and Soxhlet extraction methods, respectively. Protein was calculated from the total nitrogen value of the Kjeldahl result using the conversion factor of 6.25, while the Carbohydrate and Total Energy were determined by difference and Atwater factor, respectively. All analyses were performed in triplicates.

2.3 Moisture Content

The moisture content of vegetables was determined using the AOAC method [11, 12].

Porcelain cups were dried for 30 minutes in an oven at 110°C, the cups were cooled in a desiccator and weighed (W1). Two grams of each sample were added to the known weight of porcelain cups (W2) and heated in an oven at 105°C until a constant weight was obtained (W3). The percentage moisture content was calculated as;

$$\text{Moisture content (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

2.4 Crude Protein Content

The crude protein of each vegetable sample was determined using the Kjeldahl Nitrogen method. Two grams of each sample with two tablets of digestion catalyst were subjected to a reaction with 15ml sulphuric in a Kjeldahl tube. The tubes were set up in a digestion block heater (370°C)

until a clear green colour was obtained. The organic nitrogen in the sample was converted to ammonium sulphate. The digest was cooled to room temperature and diluted to 100ml with distilled water, which was further distilled in an alkaline condition of 40% sodium hydroxide. The liberated ammonium hydroxide was trapped in a 2% boric acid solution and titrated against a 0.1 N hydrochloric acid solution [13, 14]. The crude protein was calculated from the total nitrogen in the sample using the conversion factor 6.25, based on the assumption that the average protein contains about 16% nitrogen.

2.5 Total Ash Content

Ash Content was determined using the AOAC method as described by Olajire et al. [13]. Lab crucibles were dried in the oven to a constant weight at 110°C for 10 min, cooled in a desiccator and weighed (W1). Two grams of vegetable samples were added to pre-weighed crucibles (W2) and heated in a muffle furnace at 600°C for 6 hours to ensure proper ashing. The crucibles containing ashes samples were cooled in desiccators and reweighed (W3). The percentage ash content was calculated as;

$$\text{Ash content (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

2.6 Crude Fiber Content

To analyze the dietary fibre of the vegetables, two grams of samples was defatted with n-hexane and placed in a crucible of known weight. The sample was left to heat in an extraction unit and digest for 30 minutes with 100ml of the solution containing 1.25% sulphuric acid. The condenser was allowed to cool. The solution was filtered and the filtrate was washed with boiling distilled water to remove the remaining acid. The filtrate was digested for 30 minutes with 100ml of alkaline solution (1.25% sodium hydroxide) to dissolve alkaline-soluble matter from the sample. The final residue was washed with water, oven-dried at 105°C, cooled in a desiccator and weighed (W1). The weighed sample was incinerated in a muffle furnace at 550 °C for 2 h, and the crucible and ash were cooled in a desiccator and weighed (W2) [15, 16]. The percentage of crude fibre was calculated as;

$$\text{Crude fibre content (\%)} = \frac{W2 - W1}{\text{Initial Sample Weight}} \times 100$$

2.7 Crude Lipid

Exhaustive Soxhlet extraction was used to determine the crude lipid/fat with petroleum ether using a modified version of the Zaklouta et al. [17] protocol. Two grams of the sample were put into preweighed thimbles and covered in a wad of cotton. A Soxhlet extraction cup was weighed and 150ml of petroleum ether was added into each flask fitted with Soxhlet extraction units and condenser. The heating mantle was switched on with cool tap water circulation in the connected condenser. The heating rate was adjusted until the solvents were refluxing at a steady rate. Extraction was carried out for 6 h, after which the solvent was evaporated. The extraction cup was removed and placed in an oven for drying at 105°C. The extraction cup was removed from the oven after 60 minutes, allowed to cool in desiccators and then weighed. The lipid was measured by re-weighing the extract cup and the crude lipid content was determined by percentage difference.

2.8 Carbohydrate Content and Total Energy Determination

The nitrogen-free extract (carbohydrate) was determined with the equation;

$$\text{Total Carbohydrate (\%)} = 100 - (\text{moisture} + \text{protein} + \text{fat} + \text{crude fibre} + \text{ash})$$

While, the water factors of 4, 9 and 4 kcal were employed to calculate the caloric value by summing the multiplied values for crude protein, crude lipid and carbohydrate respectively as:

Energy value (kcal/100 g) =

$$(\text{crude protein} \times 4) + (\text{crude lipid} \times 9) + (\text{total carbohydrate} \times 4).$$

2.9 Determination of Reducing Sugar Content, Total Sugar and Starch Content

Reducing sugars of vegetable extracts were estimated using the dinitrosalicylic acid (DNS) method. Samples were centrifuged at 3,500 rpm for 5 min and diluted with distilled water. DNS reagent was further added to the mixture and incubated in a boiling water bath for 5 minutes. The optical density was read at 540 nm wavelength and the absorbance was correlated to the concentration of reducing sugar using a standard glucose curve [18]. Total soluble sugars and starch were estimated according to the

anthrone-sulphuric acid reported by Sung et al. [19] with some modifications. 0.2% anthrone in concentrated H_2SO_4 was used as a reagent. The tubes were cooled under tap water and the optical density was read using 660 nm wavelengths. The concentration of total sugar was calculated using the concentration factor using glucose as standard. The concentration of starch was determined by multiplying the obtained value by 0.9 for converting the glucose value to starch content.

2.10 Chlorophyll a, b & Total Chlorophyll

Chlorophyll contents of vegetables were extracted with 15ml of 80% acetone (v/v) per gram of samples and homogenized using the Phillip-type harmonizer at 1000 rpm for one minute. The homogenate was filtered and centrifuged at 5000 rpm for ten minutes. The absorbance of the supernatant was read with a UV spectrophotometer at 663 nm and 645nm wavelength [20, 21]. The chlorophyll a and chlorophyll b contents were calculated with the equation below, while total chlorophyll content is the sum of the contents of chlorophylls a and b.

$$\text{Chlorophyll a (Ca)} = 12.7 (\text{A663}) - 2.69 (\text{A645})$$

$$\text{Chlorophyll b (Cb)} = 22.9 (\text{A645}) - 4.68 (\text{A663})$$

2.11 Statistical Analysis

The data generated from the study were subjected to One Way ANOVA, to check the differences in

nutritional and biochemical values of sampled vegetables irrigated with groundwater and surface water, using SPSS v 26 statistical software (IBM Corp., USA). Statistical significance was determined at the level $P \leq 0.05$. Results were presented as mean $\pm$ SD for all variables. The graphs were plotted using Graph PadPrism 8.0.1.

3.0 Results

3.1 Proximate composition of vegetables irrigated with groundwater and surface water

The proximate composition of *Telfairia occidentalis*, *Amaranthus hybridus* and *Corchorus olitorius* irrigated with groundwater and surface water is shown in Table 2. Generally, vegetables irrigated with groundwater recorded marginally higher nutritional values, relative to those irrigated with surface water. *C. olitorius* had the highest moisture ($27.83 \pm 0.08\%$), which was statistically significant ($p < 0.05$). *A. hybridus* recorded significantly ($p < 0.05$) higher ash ($24.15 \pm 0.05\%$) than other vegetables. *T. occidentalis* had the highest value $21.66 \pm 0.05\%$, $12.45 \pm 0.06\%$ and $3.40 \pm 0.05\%$ for protein, crude fibre and fat respectively, and were all statistically significant ($p < 0.05$). The total energy values of the vegetables ranged from 176.94 to 217.44 kcal/100g, and the highest range was observed in *T. occidentalis* (214.8 to 217.44 kcal/100g).

Table 2: Proximate composition of vegetables irrigated with groundwater and surface water

Proximate (%)	<i>Telfairia occidentalis</i>		<i>Amaranthus hybridus</i>		<i>Corchorus olitorius</i>	
	GW	SW	GW	SW	GW	SW
Moisture	25.45 ± 0.05^c	25.20 ± 0.05^d	23.65 ± 0.05^c	23.35 ± 0.05^f	27.83 ± 0.08^a	27.30 ± 0.05^b
Protein	21.66 ± 0.05^a	20.41 ± 0.05^b	15.43 ± 0.04^c	15.11 ± 0.05^c	13.24 ± 0.04^d	12.76 ± 0.05^e
Ash	12.65 ± 0.05^d	12.35 ± 0.05^d	24.15 ± 0.05^a	23.90 ± 0.05^b	20.80 ± 0.05^c	20.40 ± 0.05^c
Crude Fibre	12.45 ± 0.06^a	12.09 ± 0.05^b	9.34 ± 0.02^c	9.16 ± 0.02^d	8.26 ± 0.02^e	8.11 ± 0.02^f
Crude Lipid	3.40 ± 0.05^a	3.20 ± 0.05^b	1.10 ± 0.05^d	0.90 ± 0.05^c	1.35 ± 0.05^c	1.20 ± 0.05^d
Carbohydrate	24.39 ± 0.28^d	26.75 ± 0.16^c	26.33 ± 0.05^{bc}	27.58 ± 0.04^b	28.52 ± 0.01^{ab}	30.23 ± 0.13^a
Total Energy (kcal/100g)	214.8	217.44	176.94	178.86	179.19	182.76

GW=groundwater irrigated; SW=Surface water irrigated. Each value was expressed as the mean $\pm$ standard deviation (n=3), different superscripts across the same row imply statistical significance at $p < 0.05$.

3.2 Reducing sugar contents of vegetables irrigated with groundwater and surface water

Groundwater-irrigated and surface water-irrigated *A. hybridus* had reducing sugar values of 8.413 ± 0.165 mg/100g and 7.427 ± 0.083 mg/100g, respectively. Surface water-irrigated *C. olitorius*

had significantly ($p < 0.05$) higher reducing sugar 6.45 ± 0.070 mg/100g compared to groundwater irrigated (5.940 ± 0.095 mg/100g). *T. occidentalis* was characterized with the lowest reducing sugar: 4.217 ± 0.081 mg/100g and 3.553 ± 0.070 mg/100g for the groundwater and surface water-irrigated *T. occidentalis*, respectively (Figure 1).

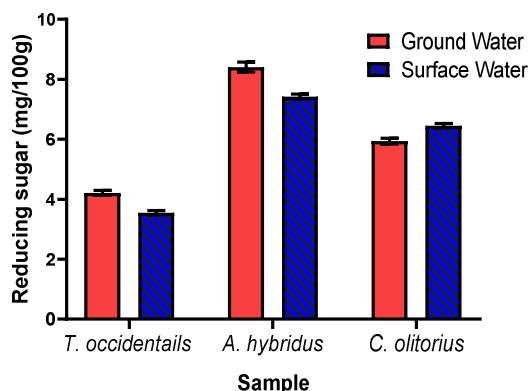


Figure 1: Reducing sugar contents of vegetables irrigated with groundwater and surface water

3.3 Starch contents of vegetables irrigated with groundwater and surface water

Vegetables irrigated with groundwater generally recorded higher starch content, relative to those irrigated with surface water. Groundwater irrigated *A. hybridus* had the highest starch content of 25.5 ± 0.5 mg/100g, which was statistically significant at $p < 0.05$ (Figure 2).

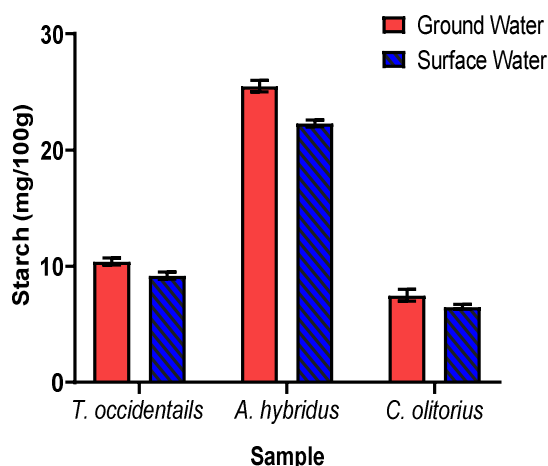


Figure 2: Starch contents of vegetables irrigated with groundwater and surface water

3.4 Total sugar contents of vegetables irrigated with groundwater and surface water

Groundwater irrigated vegetables had higher total sugar contents. Groundwater and surface water irrigated *A. hybridus* had total sugar contents of 24.66 ± 0.22 mg/100g and 22.95 ± 0.15 mg/100g, respectively. *T. occidentalis* and *C. olitorius* irrigated with ground water had total sugar contents of 19.540 ± 0.303 mg/100g and 20.46 ± 0.145 mg/100g, respectively, which was significantly higher than the corresponding surface water irrigated vegetables (Figure 3).

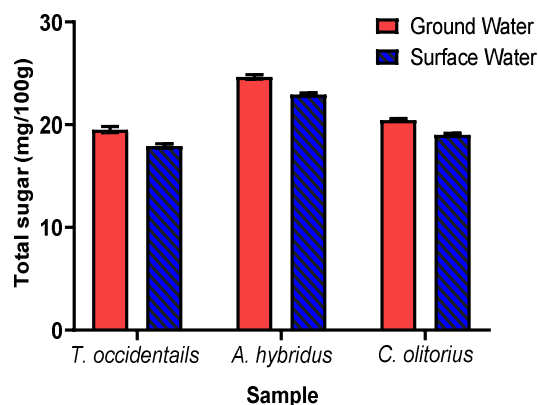


Figure 3: Total sugar contents of vegetables irrigated with groundwater and surface water

3.5 Chlorophyll a, b and total chlorophyll of vegetables irrigated with groundwater and surface water

Figure 4 shows the concentration of chlorophyll a, b and total chlorophyll in *T. occidentalis*, *A. hybridus* and *C. olitorius* grown on groundwater and surface water irrigated farms. Chlorophyll a, chlorophyll b, and total chlorophyll in vegetables were generally lower in vegetables irrigated with surface water. The concentrations of chlorophyll a in *T. occidentalis* irrigated with groundwater (62.98 ± 0.36 mg/100g) and surface water were (53.31 ± 0.48 mg/100g) were significantly higher ($p < 0.05$) than in the other vegetables. *A. hybridus* irrigated with groundwater and surface water recorded the lowest chlorophyll a concentration (44.10 ± 0.40 mg/100g and 42.55 ± 0.45 mg/100g, respectively).

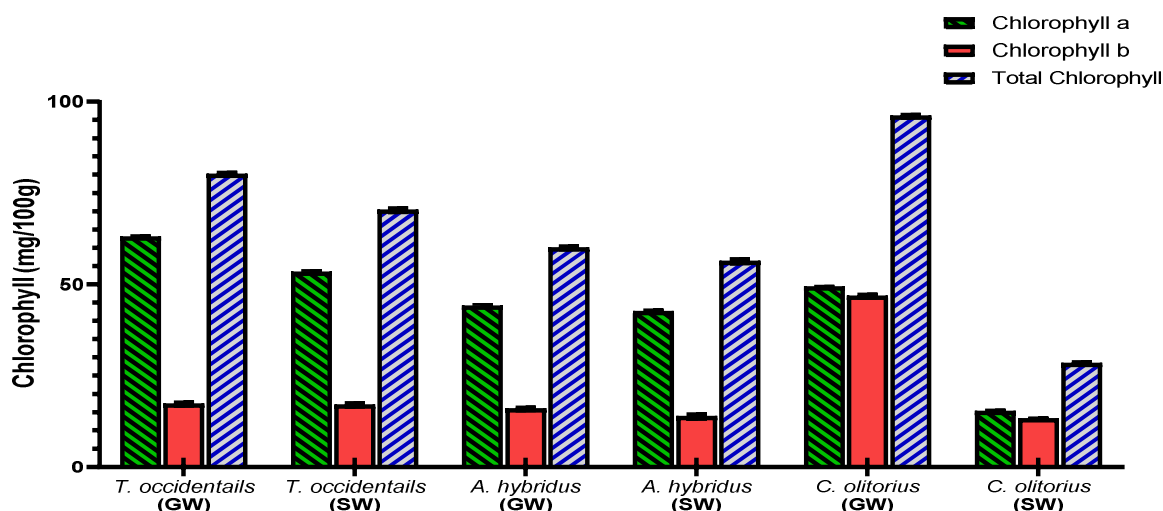


Figure 4: Chlorophyll a, b and total chlorophyll of vegetables irrigated with groundwater and surface water

4.0 Discussion

Green leafy vegetables play a vital role in diets, especially among the populace of many developing countries suffering from hunger and malnutrition. The consumption of indigenous vegetables thus serves as an affordable and important source of protein, amino acids, minerals, vitamins and dietary fibre, which are beneficial in the maintenance of good health and prevention of diseases [22,23].

Our study showed a considerable stable range of moisture content among all the species of vegetable, which could indicate that they were all subjected to similar environmental factors. While the high moisture content of vegetables could be an indicator of freshness, it could also facilitate spoilage through microbial activities, often observed in most vegetables with very short shelf life [24]. The result of the protein content for *T. occidentalis* and *C. olitorius* in our study is similar to the range reported by Arowosegbe et al. [25]. Protein is important in the diet for growth, especially in children. Protein is also needed for the constant replacement of worn-out tissues [25].

In this study, the concentrations of crude lipid/fat and fibre of *C. olitorius* were less, and ash content was higher; this compared favourably with the findings of Arowosegbe et al. [25]. Dietary fibres aid digestion in the bowel while creating the feeling of satisfaction and preventing constipation. It is worth noting that vegetables generally contain low sugar and calories, which is

beneficial in treating disease conditions such as obesity.

While the green pigmentation in most vegetables is attributable to the presence of chlorophyll, their productivity and photosynthetic rate are directly dependent on the quantity and concentration per unit area of the chloroplast [26]. In this study, the high chlorophyll concentration in *T. occidentalis* directly correlated with its high protein value. However, *A. hybridus* generally had lower chlorophyll concentrations, but high concentrations of reducing sugar, total sugar and starch. These variations in parameters could be explained by the different mechanisms of conversion of primary products by different plant species.

Since the vegetables grown on groundwater water-irrigated farms showed improved nutritional qualities, we recommend increased production of these vegetables through sustainable groundwater irrigation practices. This is because *C. olitorius*, *A. hybridus*, and *T. occidentalis* among others, play important roles in traditional medical practice, in addition to their use as sources of food [24, 27]. Vegetables have been identified as rich sources of sources of vitamin E, iron, anti-inflammation, anti-ageing, and anti-cancer agents [27, 28, 29].

5.0 Conclusion

We compared the nutritional and biochemical qualities of vegetable crops harvested from groundwater-irrigated farmland and surface

water-irrigated farmland, situated within the same proximity. Our research underscores the importance of environmental factors (irrigation water) in vegetable quality. Vegetables irrigated with groundwater generally recorded increased nutritional values. Given the enhanced nutritional profiles observed in vegetables from groundwater-irrigated farms, there's a compelling case for expanding sustainable irrigation practices.

6.0 Recommendation

We recommend increased production of these vegetables through sustainable groundwater irrigation. Research for optimized cultivation techniques for sustainable groundwater irrigation is also recommended. More so, farmers should be educated on the best methods of expansion of sustainable irrigation systems.

7.0 Conflict of Interest

The authors declare that there are no conflicts of interest associated with the research presented in this paper.

8.0 References

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