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***Corresponding author**

Otitoloju Kekere
E-mail
otito.kekere@aaua.edu.ng
Phone
+2348067646215

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Assessment of Growth, Yield and Fruit Nutritional Composition of Tomato and Sweet Pepper Irrigated with Abattoir Wastewater

Otitoloju Kekere*, Agnes Funmilayo Babatunde, Olumakinde Akinbuwa

Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria

Abstract

Recycling of organic-based wastewater for crop production has received worldwide acceptability as a promising alternative to fertilizer use. Hence, this research evaluated growth, yield and nutritional quality of tomato and sweet pepper irrigated with abattoir wastewater (AWW) with the aim of assessing recycling liquid effluent from slaughterhouses for crop production. Each vegetable was cultivated in experimental pots irrigated with 0 (control), 20, 40, 60, 80 and 100% AWW. In tomato, AWW improved plant height, number of branches and leaves, and relative growth rate (RGR) with the maximum values recorded at 100% AWW. Root and shoot dry mass, total biomass and root/shoot ratio were also increased in plants treated with undiluted AWW. In sweet pepper, values of plant height, number of leaves and branches, root length and RGR were higher under AWW treatments than the control with peak values recorded at 100% concentration. The root mass of sweet pepper was increased but the root/shoot ratio was reduced at all AWW concentrations with the highest impact found when AWW was not diluted. While AWW resulted in an increased number of fruits in both crops with the best performance when undiluted, the differences with control were only significant in tomato. Fresh and dry mass of fruit was also significantly increased by AWW in both crops with the highest values recorded at 100% concentration. AWW increased fruit nutrient and heavy metal contents of both vegetables but this increase was nonsignificant compared to control. In conclusion, the application of 20-80% AWW is capable of increasing tomato and sweet pepper production but growing them with undiluted AWW irrigation was the most effective alternative source of fertilizers for improved growth, yield and nutritional quality of vegetables.



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Introduction

Tomato (*Lycopersicon esculentum* L.) is a vegetable crop grown worldwide, which ranks third in global vegetable production [1]. Its global production, which was over 159 million tons in 2011 [2] dropped to 27.3 metric tons, according to the Global Tomato Industry Report in 2018, and 37.5 million metric tons in 2019 [3]. Over 80% of tomatoes grown throughout the world are processed into a variety of products for consumption [4]. Similarly, sweet pepper (*Capsicum annum* L.) is a vegetable with high nutritive value occupying an important position in daily diets in Sub-Saharan Africa. Nigeria is one of the major producers in the world accounting for about 50% of African production [5]. The meat-processing industry uses about 35% to 40% of world production and it is the spice mostly used on Nigerian dishes [6]. In recent times, the production of vegetables has not been able to meet demand by the growing human population. [6, 7]. For example, it was reported by the Horticultural Institute of Nigeria in 2017 that tomato national production stands at 2.3 metric tons as against 3 million metric tons of national demand. The yield reduction due to soil infertility has been a major factor thus bringing about serious concerns of many small-scale African farmers [6, 7]. Although chemical fertilizers can improve crop yield, they are most often not readily available and expensive [8]. This has brought about increased advocacy for alternative sources of nutrients in infertile soils such as recycling of organic-based wastewater for crop production [1, 9-17].

Slaughterhouses are an important component of meat for the common people and meat processing industry that produce large volumes of abattoir wastewater (AWW) from the cleaning of slaughterhouses and facilities [18-22]. The total amount of waste produced per animal slaughtered is approximately 35% of its weight [23]. This is usually released in large quantities directly into the ecosystems without adequate treatment process [24-25]. In addition, it is not uncommon to locate abattoirs near aquatic environments to ensure water availability; hence the wastes generated are discharged into the water bodies [26-28]. According to Omole and Longe [29], AWW could increase the level of nitrogen, phosphorus and total solids in receiving water bodies, which could encourage the rapid growth of algae leading to eutrophication. It is a rich source of nutrients even after primary treatment [30]. In comparison with other

wastewater sources, AWW possesses the highest concentration of organic load, with a high volume of COD (8000 mg/L), proteins (70%) and suspended solids of 15–30 mg/L [31]. Masse and Masse [32] stated that AWW can act as a source of major nutrients (N and P) and micronutrients such as calcium, sodium, magnesium, sulfur and iron. Irrigation with wastewater is a potential low-cost approach to wastewater management and a good source of nutrients for infertile soils [33-34]. Castrol et al. [35] also stated that irrigation with AWW had positive impacts on plant growth and development. Sparling et al. [36] observed that AWW irrigation significantly increased the annual and total herbage production. Roy et al. [37] recorded a significant increase in plant height, number of leaves, leaf area, number of fruits, number of flowers and total fruit weight of plants grown in soil added with slaughterhouse wastes.

Discharge of untreated AWW has been widely reported to bring about surface water contamination, general environmental pollution and public health concerns [38-43]. As such, most research on it has focused largely on their characteristics and associated public health concerns [18-19, 21, 41-44]. There is not enough data available regarding plant responses to different concentrations or levels of AWW. Besides, vegetables like tomato and sweet pepper are grown largely in-home gardens in South-Western Nigeria have a high possibility of having direct contact with wastewater from abattoirs situated near residential areas or from runoff of those disposed of in gullies. Hence, the aim of this research was to assess growth, yield and fruit nutritional quality of tomato and sweet pepper, which are important vegetables in high demand for daily diets in Nigeria. We hypothesized that recycling it for crop production might produce positive results, which could enhance sustainable management of the effluent and contribute to food security.

Materials and Methods

It was a greenhouse research carried out from March to April 2019 at the Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria (latitude 7°37'N and longitude 5°44'E). Seedlings of locally grown tomato and sweet pepper were raised separately in perforated polyethylene pots (15 cm diameter × 12 cm height) filled with 5 kg soil with pre-determined physicochemical parameters [45]. The AWW used for this experiment was obtained

from slaughterhouses at different locations in Akungba-Akoko, Ondo State, Nigeria. The wastewaters were thoroughly mixed and some characteristics determined following the standard procedure of AOAC [46]. The data are shown in Table 1. Concentrations of 20, 40, 60, 80 and 100% AWW were prepared in plastic kegs just before each treatment by dilution with tap water to make the desired concentrations while the tap water without AWW served as the control (0% concentration). Seedlings in each pot were thinned to remain one per pot in such a way that the seedlings for each vegetable were of relatively equal size and treatments commenced at one month after planting. Each pot was irrigated with 250 ml (volume enough to keep the soil moist) 3 times in a week. Pots were laid out in a completely randomized design (CRD) with 5 single-plant replicates per treatment. The tomato was treated for 9 weeks and sweet pepper for 12 weeks before the experiment was terminated due to different maturity time.

Plant height and root length were measured by meter rule, and stem girth with a digital Vernier caliper (model 0-200 mm) at the 5 cm point from the stem base. The leaves and branches produced were manually counted. Fruits and other plant parts were measured for fresh weight before oven-drying to constant weight for dry mass determination with Metler PC 180 weighing balance. The root dry mass was divided by that of the shoot to get root/shoot ratio. Dried fruit samples were digested using 10 ml of 20% sulfuric acid. Na⁺ and K⁺ were analyzed by

flame photometry while Mg²⁺ and Ca²⁺ were by EDTA titration method [46]. Cu, Zn, Pb and Cr were assayed by the atomic absorption spectrophotometer (Buck 210). Phosphorous was determined calorimetrically using Spectronic 20 (Gallenkemp, UK) while crude protein, lipid, carbohydrate, fiber and ash contents of the dry tomato and sweet pepper fruit powders were determined using the standard laboratory procedures provided by AOAC [46]. Data were subjected to one-way ANOVA and means were separated with the Tukey HSD Test at the 5 % level of probability using SPSS ver. 24.0 statistical software (SPSS, Chicago, IL).

Results

Tomato plants grown in soil irrigated with AWW had improved growth over the ones irrigated with water devoid of AWW (Table 2). Statistical analysis revealed that the plant height differed significantly compared to control (68.2 cm) at 40-100% concentrations of AWW (87.3-97.3 cm) but it was highest at 100% concentration (97.30 cm). Likewise, the number of branches and relative growth rate (22.7 and 0.014 g/g dry weight, respectively) differed significantly at 60-100% concentrations of AWW compared to control (34.7-39.0 and 0.02-0.08 g/g dry weight respectively) with the best performance when treated with undiluted AWW. The number of leaves significantly differed from the control (126.8 cm) at 80-100% concentrations of AWW (172-182) with the maximum value recorded at 100% concentration. No significant differences were; however, obtained in stem girth and root length between the control and AWW-treated tomato plants. Similarly, sweet pepper grown under AWW irrigation had root length and relative growth rate that increased significantly at all treatment levels (5.1-8.5 cm and 0.042-0.046 g/g dry weight, respectively) compared to their respective control with peak valued obtained under undiluted AWW (100%). The increase in plant height, number of leaves and number of branches were highest at 100% concentrations (66 cm, 104.7 and 13.7, respectively) in comparison to their respective control and other treatments. Only the stem girth did not show any significant difference among different treatments in sweet pepper (Table 2). The results showed that dry mass of above- and below-ground plant parts as well as total biomass were increased by the different concentrations of AWW applied to both plants (Table 3). In tomato, root and shoot dry

Table 1 Some characteristics of the abattoir wastewater used for the experiment.

Parameters	Value
BOD (mg/l)	647.62
COD (mg/l)	1187.65
Cond (µS cm ⁻¹)	320
pH	8.0
TDS (mg/L)	3224
Temperature (°C)	27.7
TOC (mg/l)	1342
TSS (mg/l)	910
Turbidity (VTU)	252
K (mg/l)	1.27
Nitrate (mg/l)	36
Phosphate (mg/l)	17
Sulphate (mg/l)	49
Cr (mg/l)	0.19
Cu (mg/l)	0.19
Pb (mg/l)	0.29
Zn (mg/l)	0.22

Table 2 Impact of abattoir wastewater irrigation on some growth parameters of tomato and sweet pepper.

Plant species	Growth parameter	Quantity of abattoir wastewater applied (%)					
		0	20	40	60	80	100
Tomato	Plant height (cm)	68.17 ^b	78.70 ^{ab}	91.73 ^a	95.93 ^a	94.83 ^a	97.30 ^a
	Number of leaves	126.67 ^b	120.67 ^b	121.33 ^b	132.33 ^{ab}	175.30 ^a	182.00 ^a
	Number of branches	22.67 ^b	28.67 ^{ab}	29.67 ^{ab}	34.67 ^a	35.33 ^a	39.00 ^a
	Stem girth (cm)	8.92	9.13	9.82	9.82	10.34	10.46
	Root length (cm)	6.52	8.78	10.56	10.78	10.67	10.89
	Relative growth rate (g/g dry weight)	0.014 ^c	0.015 ^c	0.016 ^c	0.020 ^b	0.022 ^b	0.08 ^a
Sweet pepper	Plant height (cm)	30.20 ^b	56.25 ^{ab}	47.30 ^{ab}	45.03 ^{ab}	52.60 ^{ab}	66.00 ^a
	Number of leaves	57.00 ^b	61.33 ^b	50.33 ^b	54.67 ^b	62.00 ^b	104.67 ^a
	Number of branches	7.00 ^b	7.67 ^b	7.00 ^b	6.33 ^b	10.00 ^{ab}	13.67 ^a
	Stem girth (cm)	5.08	6.33	5.15	5.66	6.71	6.90
	Root length (cm)	3.45 ^b	6.26 ^b	5.10 ^a	7.18 ^a	8.20 ^a	8.47 ^a
	Relative growth rate (g/g dry weight)	0.030 ^b	0.045 ^a	0.046 ^a	0.042 ^a	0.043 ^a	0.043 ^a

Each value is a mean \pm S.E of 5 replicates. For each value, means with the different letter(s) in superscript on the same row are significantly different at $P \geq 0.05$ (Tukey HSD test).

Table 3 Impact of abattoir wastewater irrigation on dry mass and root/shoot ratio of tomato and sweet pepper.

Plant species	Dry matter	Quantity of abattoir wastewater applied (%)					
		0	20	40	60	80	100
Tomato	Root dry mass (g)	0.30 ^{bc}	0.43 ^b	0.60 ^b	1.23 ^a	1.20 ^a	1.37 ^a
	Shoot dry mass (g)	3.57	5.00	5.73	7.67	8.23	8.30
	Total biomass (g)	3.89 ^b	5.42 ^{ab}	6.35 ^{ab}	8.89 ^a	9.48 ^a	9.55 ^a
	Root/shoot ratio	0.08 ^{ab}	0.09 ^{ab}	0.10 ^{ab}	0.16 ^a	0.15 ^a	0.17 ^a
Sweet pepper	Root dry mass (g)	1.33 ^b	2.77 ^a	2.23 ^a	2.77 ^a	2.50 ^a	2.97 ^a
	Shoot dry mass (g)	1.8 ^c	3.50 ^{bc}	3.61 ^{bc}	5.40 ^b	10.40 ^a	10.77 ^a
	Total biomass (g)	3.33 ^c	6.26 ^{bc}	5.80 ^{bc}	8.19 ^b	13.40 ^a	13.74 ^a
	Root/shoot ratio	0.74 ^b	0.79 ^b	0.62 ^b	0.33 ^a	0.23 ^a	0.27 ^a

Each value is a mean \pm S.E of 5 replicates. For each value, means with the different letter(s) in superscript on the same row are significantly different at $P \geq 0.05$ (Tukey HSD test).

mass as well as total biomass and root/shoot ratio increased at a significant level under 60-100% concentrations of AWW (1.2-1.4, 7.7-8.3 and 8.9-9.5 g, respectively) in comparison to their respective control treatments (0.3, 3.6 and 3.9 g, respectively), while the shoot dry mass was not significantly affected by AWW treatments. It was; however, found that the best performance occurred in plants irrigated with undiluted AWW. On the other hand, sweet pepper root dry mass increased significantly when treated with AWW (2.23-2.97 g) while the root / shoot ratio was found to be reduced significantly in comparison with the control (0.74) at 60-100% concentrations of AWW (0.27-0.33). It was; however, obvious that the performance was better under 100% AWW concentration.

From the results presented in Table 4, it was revealed that the application of AWW improved yield in both vegetables. Irrigation of tomato with AWW had no significant effect on the number of fruits produced per plant with 4.33 fruits in the control and 5.00-7.33 under AWW treatments. AWW application; however, significantly increased the fruit fresh (20.6-36.8 g) and dry mass (4.4-7.9 g) relative to the control (13.7 and 2.2 g, respectively).

In sweet pepper, on the other hand, the number of fruits per plant (3.3-8.2), fruit fresh (7.4-15.8 g) and dry mass (2.5-7.3 g) were significantly increased over the control (1.1, 2.6 and 1.1 g, respectively). Summarily, the overall yield performance was best in plants irrigated with undiluted AWW. Table 5 shows that the fruits produced by tomato and sweet pepper plants treated with different concentrations of AWW had all the nutritional and proximate parameters with higher values than in the control. However, no statistical differences were found when comparisons were made between each of the nutritional and proximate parameters under AWW and the control treatments. Table 6 shows an increased concentration of heavy metals (Cu, Zn and Pb) in the fruits of plants grown with AWW irrigation while that of Cr was not influenced by AWW application relative to the control treatment. Statistical analysis; however, revealed that even where differences were recorded between the control and AWW-treated plants, the differences were not significant. Cu, Zn, Pb and Cr were 0.18, 0.37, 0.29 and 0.04%, respectively in the control but ranged 0.20-1.24, 0.82-0.83, 0.41-0.54 and 0.02-0.05%, respectively under AWW treatments.

Table 4 Impact of abattoir wastewater irrigation on some yield parameters of tomato and sweet pepper.

Plant species	Yield parameters	Quantity of abattoir wastewater applied (%)					
		0	20	40	60	80	100
Tomato	Number of fruits/plant	4.33	6.00	5.00	5.33	6.33	7.33
	Fruit fresh mass (g)	13.70 ^b	31.38 ^a	20.63 ^a	26.23 ^a	29.07 ^a	36.83 ^a
	Fruit dry mass (g)	2.20 ^b	7.20 ^a	7.90 ^a	6.57 ^a	4.40 ^a	4.97 ^a
Sweet pepper	Number of fruits/plant	1.10 ^c	3.33 ^{ab}	3.50 ^{ab}	6.89 ^a	7.33 ^a	8.23 ^a
	Fruit fresh mass (g)	2.56 ^c	7.47 ^b	8.60 ^b	10.98 ^b	15.87 ^a	19.75 ^a
	Fruit dry mass (g)	1.12 ^c	2.53 ^b	3.67 ^b	4.13 ^b	7.27 ^{ab}	13.87 ^a

Each value is a mean \pm S.E of 5 replicates. For each value, means with the different letter(s) in superscript on the same row are significantly different at $P \geq 0.05$ (Tukey HSD test).

Table 5 Impact of abattoir wastewater irrigation on fruit proximate and nutritional composition of tomato and sweet pepper.

Plant species	Nutritional and proximate composition (%)	Quantity of abattoir wastewater applied (%)						
		0	20	40	60	80	100	
Tomato	N	1.38	1.49	1.61	1.63	1.87	1.91	
	P	0.04	0.06	0.10	0.09	0.17	0.19	
	K	0.67	1.02	0.85	0.96	1.21	1.32	
	Ca	0.16	0.23	0.21	0.23	0.24	0.23	
	Mg	0.23	0.18	0.18	0.34	0.47	0.32	
	Na	0.21	0.24	0.27	0.27	0.29	0.30	
	Ash	0.69	0.85	0.83	0.87	0.97	0.52	
	Fiber	1.27	1.29	1.35	1.31	1.29	1.32	
	Protein	8.31	9.31	10.06	10.19	11.69	9.88	
	Lipid	0.94	0.94	0.86	0.93	0.91	0.89	
	Nitrogen free extract	8.60	7.73	7.10	7.90	8.24	8.60	
	Sweet pepper	N	0.48	0.53	0.52	0.65	0.79	0.77
		P	0.07	0.08 ^a	0.08	0.07	0.10	0.13
K		0.63	0.91	0.90	0.95	0.95	0.94	
Ca		0.43	0.47	0.49	0.71	0.77	0.75	
Mg		0.16	0.19	0.21	0.24	0.33	0.31	
Na		0.19	0.24	0.33	0.37	0.42	0.47	
Ash		4.59	4.63	4.65	4.71	5.32	5.44	
Fiber		9.98	10.46	10.78	10.55	10.49	10.59	
Protein		0.30	0.32	0.30	0.39	0.39	0.37	
Lipid		1.79	1.82	1.94	1.93	2.00	2.00	
Nitrogen free extract		0.68	0.71	0.77	0.80	0.79	0.80	

Each value is a mean \pm S.E of 3 replicates. For each value, means with the different letter(s) in superscript on the same row are significantly different at $P \geq 0.05$ (Tukey HSD test).

Discussion

This study revealed that all concentrations of the wastewater generally enhanced the growth parameters of the two vegetables. This result is in conformity with the ones obtained from experiments conducted on *Solanum lycopersicum*, *Solanum melongena* and *Capsicum annuum* by Roy et al. [37]. They found a significant increase in plant height, number of leaves, leaf area, number of fruits, number of flowers and total fruit weight of plants grown in soil mixed with slaughterhouse wastes used as organic fertilizer. It also agrees with research on *Pennisetum purpureum*, *Sinapis alba*, *Helianthus annuus* and *Medicago sativa* where plant growth was improved by abattoir wastewater [15]. Similarly, Castrol et al. [35] also reported that AWW irrigation had positive impacts on plant

growth and development. Growth improvement can be attributed to an increase in soil fertility following AWW application as confirmed by Matheyarasu and Bolan [47] who applied AWW to low-fertility soils and found an increase in soil fertility status. The presence of essential nutrients for plant growth in the AWW used for this study (Table 1) must have increased soil fertility, thereby bringing about better growth than in the control. This experiment also revealed that AWW enhanced the root and shoot dry masses as well as the total biomass of both plants. In a previous study, Nissim et al. [48] showed that irrigation with municipal wastewater had a positive effect on willow growth and biomass yield. Likewise, Misra et al. [10] observed that *Solanum lycopersicum* irrigated with domestic wastewater obtained higher nutrient uptake and biomass at the flowering stage when compared to

tap water. Gupta et al. [13] reported that plants irrigated with domestic wastewater resulted in a significant increase in biomass and green fodder yield of sorghum as compared to well water. Zema et al. [12] investigated the biomass yield of *Typha latifolia* and found it to be increased by irrigation with urban wastewater.

In this study, apart from the biomass, fruit yield of the vegetables was improved by AWW particularly at 100% concentration relative to other treatments. This concurs with the previous study of Bedbabis et al. [14] that municipal wastewater irrigation of olive trees resulted in significant yield increase when compared to yields from the plot using well water. Qaryouti et al. [1] concluded that the irrigation using raw wastewater from food industry increased significantly tomato growth and yield parameters, as well as cucumber plant height and fruit yield. Day et al. [9] also compared the effect of irrigation with municipal wastewater and pump water on wheat. They discovered that wastewater irrigation produced taller plants, heavier seeds and higher grain yields than pump water. Similar results were also recorded by Juwarkar et al. [49] on *Arachis hypogaea*. Furthermore, yield improvement in plants grown in wastewater treated soil conforms to that of Matheyarasu and Bolan [47] who found about 70% lower yields in *Pennisetum purpureum*, *Medicago sativa*, *Sinapis alba* and *Helianthus annuus* grown under tap water compared to the abattoir wastewater irrigation. Similarly, in a pot experiment, fertilizer produced from abattoir waste products was found to significantly increase biomass yield of AberMagic grass (*Lolium perenne*) and wheat (*Triticum aestivum*) compared with the Nil treatment pots [17]. They reported more grain production in wheat and AberMagic grass when AWW was applied and concluded that it is a sustainable alternative to conventional fertilizers. Yield improvement could

be linked to an increase in the number of leaves that provided more surface area for photosynthetic activities, which produced more photosynthates for fruit production. Mg in the wastewater is an integral part of chlorophyll, which when absorbed by plants could enhance chlorophyll synthesis which is a factor in yield production.

This study also revealed increased fruit nutritional composition in both plants at all levels of AWW when compared with the control. Similarly, Al-Jaloud et al. [50] reported raised levels of N, Ca, Mg and Na in leaves of sorghum when the crop was irrigated with domestic wastewater. Moreover, Vasquez-Montiel et al. [11] found that irrigation of maize (*Zea mays* L.) with treated domestic wastewater resulted in increased N, P, K and Mg concentration in the leaves. Fonseca et al. [51] reported similar results in a greenhouse experiment on AWW on maize. In a previous study, concentrations of nutrients, including N, P, K, Ca, Mg and Na were found higher in *Lolium perenne* and *Triticum aestivum* grown in soil treated with fertilizer produced from abattoir wastes [17]. Also, Matheyarasu and Bolan [47] reported the application of AWW to cause an abundance of nutrient accumulation in *Pennisetum purpureum*, *Medicago sativa*, *Sinapis alba* and *Helianthus annuus*. The increase in the nutrients is as a result of their increased concentration in the soil with AWW.

Increase in proximate composition as a result of AWW treatment in this study is in agreement with that of Babyshakila et al. [52] who recorded higher lipid, ash and protein content at 50% and 75% concentrations of AWW in the leaf samples of mung bean compared to the control. Achuba and Iserhienrhien [53] also obtained more chlorophyll, β -carotene, amino acids, protein and sugar in the leaves of cowpea seedlings exposed to AWW relative to the control. The activities of α -amylase

Table 6 Impact of abattoir wastewater irrigation on the fruit-heavy metal content of tomato and sweet pepper.

Plant species	Heavy metal concentration (%)	Quantity of abattoir wastewater applied (%)					
		0	20	40	60	80	100
Tomato	Cu	0.18	0.20	0.29	1.08	1.07	1.24
	Zn	0.37	0.83	0.82	1.51	1.65	1.17
	Pb	0.29	0.41	0.40	0.42	0.45	0.54
	Cr	0.04	0.02	0.04	0.03	0.04	0.05
Sweet pepper	Cu	3.97	4.63	4.91	4.90	4.99	4.98
	Zn	8.78	10.46	10.87	11.01	12.03	13.44
	Pb	0.21	0.32	0.45	0.74	0.73	0.82
	Cr	0.97	0.82	0.85	0.99	0.98	0.97

Each value is a mean \pm S.E of 3 replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at $P \geq 0.05$ (Tukey HSD test).

and starch phosphorylase in the leaves of cowpea seedlings were also observed to be increased by AWW treatments over the control [53]. It was explained by Matheyarasu and Bolan [47] that AWW application increases the population of microorganisms for improved mineralization of organic matters in the soil and some of the microorganisms play important roles in the fixation of atmospheric nitrogen. Increased nutrient availability in the soil, enhanced enzymatic and microbial activities in the presence of AWW might have contributed to improved yield and nutritional quality of the fruits. This was further confirmed by Achuba and Iserhienrhien [53] who concluded that abattoir wastewater is a good source of organic manure containing essential nutrients like nitrate and phosphate.

The increase in concentrations of heavy metals in fruits of pepper and tomato treated with AWW is in accordance with that of Masse and Masse [32] who stated that AWW can act as a source of major nutrients, micronutrients and trace amount of heavy metals. In a recent study, Darch et al. [17] found higher values of heavy metals like As, Cd, Cr, Ni, Mo, Co, Fe, Al, Cu and Pb in *Lolium perenne* and *Triticum aestivum* grown with fertilizer produced from abattoir wastes than in those grown without it. This could be as a result of the presence of heavy metals in wastes generated from slaughterhouses, which is evident in the results of the AWW analysis in this study (Table 1). The presence of heavy metals in wastes generated from slaughterhouses has also been confirmed by many researchers and the metals were reported to be part of metal accumulation in body tissues of animals from their feeds and also from cleaning of facilities for meat processing in slaughterhouses [20-21, 47].

Conclusion

In this study, irrigation of tomato and sweet pepper with 100% abattoir wastewater was the best treatment for their production and is, therefore, recommended as a substitute source of fertilizer for enhanced growth, yield and nutritional quality of the vegetables. Meanwhile, concentrations of 20-80% can also lead to yield improvements in the vegetables. It is recommended that abattoir wastewater should be channeled for reuse in home gardens or stored in a septic system for crop irrigation. There is; however, the need for further studies on the environmental impacts associated with AWW reuse and investigate the public acceptance of the concept.

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Conflict of Interest

The author declares no conflict of interest in this study.

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