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Assessment of Biomass, Proximate Composition and Heavy Metal Accumulation in Tropical Vegetable (*Amaranthus hybridus)* Irrigated with Fresh Untreated Abattoir Effluent in Akure, Ondo State, Nigeria

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ABSTRACT: Abattoir waste constitutes a significant environmental concern in Nigeria's peri-urban and urban areas as they often end up in rivers, groundwater and canals, contaminating the environment and increasing human health risks. Therefore, the objective of this paper was to assess the dry biomass, proximate composition and heavy metal accumulation in the Tropical vegetable, *Amaranthus hybridus*, irrigated with fresh untreated abattoir effluent in Akure, Ondo State, Nigeria using standard methods. The results showed that the abattoir effluent increased the vegetable's dry biomass from 7.79 to 23.66 g. Similarly, there was a general increase in the carbohydrate, fibre and moisture contents of the vegetable with increasing concentration of the abattoir effluent, reaching up to 20.42%, 30.42% and 16.41% respectively. However, the protein, fat and ash contents generally decreased in the abattoir effluent irrigated treatments, from 25.38% to 18.23%, 11.38% to 6.70% and 9.63% to 7.34% respectively. This is probably due to the plant variety or metabolic activities of pathogens carried over from the effluent. The four heavy metals analysed (Cadmium, Cd; Lead, Pb; Zinc, Zn; Iron, Fe) were all accumulated in the tissues of the vegetable in amounts well-above the WHO limits, with Fe showing the highest bioaccumulation from 0.22 to 17.20 mg/L. In conclusion, although fresh untreated abattoir effluent can serve as organic fertilizer, it poses huge human health risks due to heavy metal bioaccumulation. Therefore, pre-treating before use to eliminate heavy metals and pathogens is highly recommended, as it would be a relatively cheaper means of growing Tropical vegetables.

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Effluent is a form of wastewater and in general can be defined as liquid waste discharged from a sewage system, factory, nuclear power station or other industrial plant (Department of Environment and Conservation, 2009). Effluent consist of water, nutrients and organic matter which in excess amounts could be detrimental to plant and/or soil health. It also contains pathogens and salts that can pollute the environment and increase public health risks (Department of Environment and Conservation, 2009). Abattoir effluent refers to water laden with waste materials generated from an abattoir and

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potentially hazardous to the environment. Abattoir waste contains high nitrogen content, dissolved and floating solids, fat and hide scraps, detergent, hair, pieces of meat, blood, gut contents, and manure which are biodegradable (Alonge, 1991; Polprasert and Tran, 1992). These substances account for the colour, odour, and other physicochemical and microbiological properties associated with abattoir effluents (Coker *et al.,* 2001). Fresh abattoir effluent contains all the aforementioned materials including metals, minerals and microbes which are reported to scavenge dissolved oxygen (Coker *et al.,* 2001) but differ physically from aged abattoir effluent mainly by the latter's malodorous effect due to putrefaction (Olanrewaju and Olufayo, 2004). The effluent load of blood generated from slaughtered cows, if allowed to discharge directly into sewage systems, is equivalent to the total average sewage produced by 50 people in a day (Aniebo *et al.,* 2009). Although most metals found in abattoir effluent are beneficial (e.g. for plant growth), they may be toxic at elevated concentrations and their toxicity may be increased if the soil is acidic (Raghupathi *et al.,* 2014). Low fertility of native soils in most parts of Nigeria is one of the factors that have increased the use of inorganic fertilizers over the years (Law-Ogbomo *et al.*, 2012). The use of inorganic fertilizer to increase yield has been found to be effective only within few years, demanding consistent use on long-term basis (Ojeniyi *et al.*, 2009). However, as a result of the hazardous environmental consequences (causing soil-hardening after a long period of use) and high cost associated with inorganic fertilizers, this means of improving soil fertility is tagged as unsustainable for rural farmers who dominate the Nigerian agricultural sector (Shiyam and Binang, 2011). The challenges associated with inorganic fertilizers led to an increased interest in organic farming which is reported to be cheaper and more environmentally friendly as organic manure is used in place of synthetic fertilizer (Shiyam and Binang, 2011). Interestingly, a study by Ragupathi *et al.* (2013) reported the use of untreated abattoir effluent as organic-rich irrigation water to grow *Pennisetum purpureum* and *Sinapis alba,* because it was found to contain minerals/metals required for plant growth. Similarly, a comparative study of abattoir wastewater and NPK conducted to determine growth and yield in rice found that abattoir effluent recorded higher grain yield, pH, organic carbon, total nitrogen and available phosphorus content compared to NPK, indicating abattoir wastewater potential to increase soil fertility and rice yield (Ojobor and Egbuchua, 2020). The use of organic manure to restore a poorly fertile land to maximum productivity has been practised for decades in different parts of the world (Shuval *et al.*, 1985). However, the use of abattoir effluent as organic irrigation source is rarely practiced and deserves further investigation to determine its potential use and safety. This organic irrigation source supplies both water and organic matter which potentially improve soil fertility and help reduce the pressure on scarce water resources simultaneously. This suggested approach also has the associated benefit of drastically reducing the amount of hazardous abattoir effluent discharged daily into our waterways (Department of Environment and Conservation, 2009). In Nigeria as well as most other tropical countries of Africa where the daily diet is dominated by starchy staple foods, vegetables are the cheapest and most readily available sources of important proteins, vitamins, minerals, and essential amino acids (Onwordi *et al.*, 2009). According to Law-Ogbomo *et al*. (2012), the mostly consumed vegetables in Nigeria are *Talinum triangulare*, *Telfaria occidentalis*, *Corchorus olitorius*, *Vernonia amygdalina*, and *Amaranthus* species (such as *A. hybridus*, *A. cruentus*, *A. caudatus*, and *A. deflexus*). Due to their low production costs, *Amaranthus* species (Amaranths) are one of the cheapest dark-green leafy vegetables in tropical markets and are often described as the poor man's vegetables (Varalakshmi, 2004).

Therefore, the objective of this paper was to assess the dry biomass, proximate composition and heavy metal accumulation in the Tropical vegetable, *Amaranthus hybridus*, irrigated with fresh untreated abattoir effluent in Akure, Ondo State, Nigeria.

MATERIALS AND METHODS

Study Site: The study was conducted at the premises of the Federal University of Technology, Akure (FUTA), Ondo State, Southwestern Nigeria which lies at latitude $7^0$16' North and longitude $5^0$13' East at an altitude of 351 m above mean sea level. The site used for the study is situated behind the School of Sciences building at the Institution. A screen house was constructed for the purpose of the experiment. The screen house was built with wooden frames by, covered with net on the four sides which has tiny pores to allow for aeration and disallow the entrance of phytophagous insects; a thick transparent nylon was used as the roofing material to shield off rain and allow in sunlight to favour photosynthetic activities.

Collection of materials: Seeds of *Amaranthus hybridus* treated with Tytametrin (an insecticide) and horticultural pots with known dimensions (36.2 cm diameter by 35 cm height) were obtained from Agricultural Development Project (ADP) in Alagbaka, Akure, Ondo State, Nigeria. Loamy soils were collected from a farm situated near the study site at the Federal University of Technology, Akure (FUTA).

Abattoir effluents were collected at an abattoir at Industrial Park, Onyearugbulem, Akure, Ondo State, Nigeria. The abattoir is a major slaughterhouse in Ondo State, Nigeria and accounts for about 65% of the meat supply in the state capital, Akure (Akinro *et al*., 2009). Fresh abattoir effluents were collected every two weeks at 07:00AM in the morning which is around the time the cattle are usually slaughtered. After the slaughtering of the cattle, the blood and other wastes were washed into a drain. The effluents were collected from the drain in a 20L container and transported to the screen house at FUTA immediately. Latex hand gloves, nose mask, safety goggles and an overall were worn to the slaughterhouse for protection against pathogens, parasitic organisms and hazardous materials all through the effluent collection process.

Experimental Procedure: Twenty-four horticultural pots making up six treatments (with four replicates each) were used for the study and arranged in a randomized block design (RBD). Masarirambi *et al*. (2012) reported that *A. hybridus* requires 590 ml of water for maximum growth, and added that further increase of water application led to no corresponding increase in plant growth and biomass. Therefore, the treatments were applied in the following order:

i. Control: 590 ml of fresh water (0 ml of effluent)
ii. Treatment 1: 50ml of effluent + 540 ml of fresh water
iii. Treatment 2: 100 ml of effluent + 490 ml of fresh water
iv. Treatment 3: 200 ml of effluent + 390 ml of fresh water
v. Treatment 4: 400 ml of effluent + 190 ml of fresh water
vi. Treatment 5: 590 ml of effluent (0 ml of fresh water)

The horticultural pots were filled with loamy soil to near brim before the seeds were planted. The tiny seeds were evenly distributed on the soil inside the pots without concentrating on one spot to prevent overcrowding after germination. The abattoir effluents after collection from the abattoir were kept in the screen house and applied every three days; the seeds germinated after four days of planting. A measuring cylinder was used to measure the effluent in different concentrations before application. The pots were irrigated with water and effluent in an alternating fashion for eight weeks: Effluent + water the first week; Water only in the second week, and so on, until the eighth week. Weeding was consistently carried out every two weeks to eliminate potential competitors. The experiment was terminated at the end of the eighth week. All through the experiment, latex hand gloves, safety goggles, nose mask and an overall were worn for protection against potential hazardous materials in the effluent.

Determination of Dry Biomass: After the experiment was terminated, individual plants were carefully harvested from their respective pots without damaging the roots, and separated into two parts with a sterile knife: larger shoots and smaller roots. The larger shoots were placed in big envelopes (30.2 cm by 25 cm) while the smaller shoots were placed in small envelopes (22.3 cm by 14.9 cm). The mean weight for the empty small envelopes was determined prior to loading (23.57 g) as well as that of the empty big envelopes (34.42 g) using a Mettler Toledo PB3002 electronic weighing balance. The loaded envelopes were dried in a Splintex TBSS190182 drying cabinet at 65ºC for 4 days. After drying, the difference in weights between the empty envelopes and the dried loaded envelopes served as the dry biomass for the shoots and roots; these values were added to determine the total plant biomass (TPB).

Determination of Heavy Metal Accumulation: Using the Atomic Absorption Spectrophotometer (AAS) Buck Scientific 210 VGP, fresh untreated abattoir effluent collected for this study was analysed for nine important heavy metals: Cadmium (Cd), Chromium (Cr), Manganese (Mn), Zinc (Zn), Iron (Fe), Copper (Cu), Lead (Pb), Cobalt (Co) and Nickel (Ni). Heavy metal concentrations in the vegetable tissue (whole plant) were also measured at the end of the experimental period using the AAS to account for possible bioaccumulation.

Table 1: Concentrations of heavy metals in untreated fresh abattoir effluent. *Heavy metals with concentrations well above the WHO standard.

Heavy metals	**Concentrations (mg/L)**	**WHO standard (mg/L)**
Cadmium (Cd)	0.01± 0.71*	0.003
Chromium (Cr)	0.09± 0.88	0.05
Manganese (Mn)	0.36± 0.55	2.0
Zinc (Zn)	0.48± 0.88*	0.1
Iron (Fe)	17.20± 1.22*	0.01
Copper (Cu)	0.07± 0.81	0.4
Lead (Pb)	0.20± 0.11*	0.3
Cobalt (Co)	0.03± 0.57	0.07
Nickel (Ni)	0.01± 0.21	0.01

Determination of Proximate Composition: The dried vegetable samples (combined shoots and roots) were analysed for the proximate composition which include moisture, fat, ash, carbohydrate, protein and fibre contents using the AAS.

Data Analysis: The relationship between the dry biomass and proximate composition of each treatment was analysed using Correlation and Pearson as

Correlation Coefficient. Analysis of the dry biomass was carried out using Analysis of Variance (one-way ANOVA) while Duncan Multiple Range Test was the Post Hoc test at 95% confidence level (i.e. P=0.05).

RESULTS AND DISCUSSIONS

Effects of untreated abattoir effluents on the dry biomass of Amaranthus hybridus: Table 2 shows that the untreated abattoir effluents had significant effects ($P<0.05$) on the dry biomass of *Amaranthus hybridus*. Both the root and shoot dry biomass performed better than the control, particularly treatment 5 (590 ml effluent without water), indicating the nutritive contribution of the effluent in promoting plant growth and productivity. Shoot dry biomass seems to be a better means of measuring the contribution of the effluent on *A. hybridus* compared to the root dry biomass. This is supported by the findings of Mohammed *et al.* (2023) who reported that abattoir effluent improved growth and yield in Tomato (*Solanum lycopersicum*) in terms of plant height, number of leaves, flowers and fruits (all components of the shoot system). The same applies to the total plant biomass (TPB, i.e., shoot + root) which showed a significant difference ($P<0.05$) between the control and the treatments, especially between the control (7.79 g) and treatment 5 (23.66 g). This implies that the TPB is perhaps a better approach of measuring growth in *A. hybridus* compared to the shoot dry biomass as it captures the entire plant system. This significant increase in the dry biomass of *A. hybridus* is clearly attributed to the absorption of growth-enhancing nutrient components in the abattoir effluents by the vegetable root as described by Kekere *et al.* (2020) who found that abattoir effluent increased total plant biomass in Tomatoes and Sweet pepper. Similarly, several researchers who worked on other types of organic-based effluents (such as paper and textile effluents) documented that under different concentrations, there were improved seedling lengths of various crops (Orhue *et al*., 2005; Nawaz *et al*., 2006; Akbar *et al*., 2007; Dhanam, 2009).

Table 2: Effects of untreated abattoir effluent on the dry biomass of *Amaranthus hybridus*. *Values are mean ± standard error. Values with the same alphabet(s) within the same column are not significantly different ($P>0.05$). *TPB – Total Plant Biomass.

Treatment (ml)	Mean root weight (g)	Mean shoot weight (g)	Mean TPB (g)
0 (Control)	$2.12^{a} \pm 1.06$	$5.42^{a} \pm 1.44$	$7.79^{a} \pm 1.60$
50	$3.02^{ab} \pm 1.51$	$15.23^{bc} \pm 3.20$	$18.23^{bc} \pm 4.28$
100	$1.77^{a} \pm 0.88$	$11.68^{abc} \pm 3.71$	$13.43^{ab} \pm 4.31$
200	$6.43^{ab} \pm 2.41$	$9.00^{abc} \pm 0.83$	$15.42^{abc} \pm 2.47$
400	$4.49^{ab} \pm 1.22$	$7.83^{ab} \pm 2.38$	$12.32^{ab} \pm 3.10$
590	$7.56^{b} \pm 1.24$	$16.10^{c} \pm 0.72$	$23.66^{c} \pm 1.83$

Effects of untreated abattoir effluents on the proximate composition of Amaranthus hybridus: The proximate composition of *Amaranthus hybridus* was measured at the different treatment levels and the results are shown in Table 3. The parameters analyzed were moisture, fat, ash, fibre, protein and carbohydrate contents. *A. hybridus* irrigated with abattoir effluent showed high amounts of carbohydrates (up to 20.42%), fibre (up to 30.42%) and moisture contents (up to 16.41%) in the tissues, particularly in treatment 5 (590 ml effluent only) compared to the control (0 ml effluent + 590 ml water) with 11.03%, 27.71% and 14.88% of carbohydrates, fibre and moisture contents, respectively. The abattoir effluent generally contains bovine hair, intestinal contents and moisture from water used to wash the slaughtered animal, which explains the increased amount of fibre, carbohydrates and moisture contents accumulating in the vegetable tissues (Nguyen, 2009). These are consistent with the findings of Rehman *et al.* (2013) who reported increase in carbohydrate, fibre and moisture contents in a wide range of vegetables (Cauliflower, Green pepper, Spring onion and Brinjal) irrigated with industrial wastewater compared to those irrigated with fresh water.

In contrast, the protein (ranged from 18.23% - 23.10%), fat (ranged from 6.70% - 10.83%) and ash contents (ranged from 7.34% - 9.21%) in *A. hybridus* irrigated with abattoir effluent interestingly showed lower concentrations compared to the control with 25.38% protein, 11.38% fats and 9.63% ash contents. Abattoir effluent contains blood proteins and therefore, should be rich in Nitrogen as corroborated by Ojobor and Egbuchua (2020) and Bethi *et al.* (2020). Furthermore, a study by Khatoon *et al.* (2018) revealed that a microalgae, *Tetraselmis chuii*, treated with aquaculture wastewater and grown in a Conway medium showed increased levels of proteins, lipids (fat) and carbohydrates compared to the treatment exposed to fresh water only. In addition, Menegassi *et al.* (2020) reported an increase in nitrogen content of Coastcross grass irrigated with slaughterhouse wastewater. However, low levels of protein and ash contents were reported in Cauliflower, Green pepper and Spring onions irrigated with industrial wastewater compared to the fresh water control (Rehman *et al.*, 2013). In the study, the protein content ranged from 26.2% - 32.8% compared to the fresh water control (30.6 - 37.1%) while the ash content ranged from 0.4-1.5% compared to the fresh water control (0.5 - 1.9%), similar to the pattern recorded in this *A. hydridus* study (Table 3). The reason for the low protein was attributed to the fixed nutritional ratios in different plant varieties (Rehman *et al.*, 2013), while some other authors suggested that since pathogens in abattoir effluents are also carried onto the body of the plants (Yahaya *et al.*, 2023), there is the possibility that the protein is being metabolized by the pathogens. According to Ghani *et al*. (2016), any leafy vegetable with protein content within the range of 20.48% to 41.66%, will supply protein higher than the 12% caloric value considered to be a good source of protein. This implies that the protein content range for the abattoir effluent treatments recorded in this study (18.23% - 22.40%) is sufficient to provide enough protein for human growth and development.

As for the ash content, Ukam (2008) suggested that low ash content indicates high nutrient quality of vegetables while Rehman *et al.* (2013) attributed low ash content to environmental conditions while collecting the vegetable samples as well as the specific variety under study. In addition, Kekere *et al.* (2020) reported low fat content in Tomato and Sweet Pepper irrigated with abattoir effluent which was not significantly different from the control. This is consistent with the results obtained in this *A. hybridus* study where the highest fat content in the abattoir effluent treatments (10.83%) and the control (11.38%) were not significantly different at P>0.05, indicating that abattoir effluents generally do not increase the fat content of vegetables.

Figure 1 shows the relationship between the proximate composition and dry biomass of *A. hybridus* irrigated with abattoir effluent at different concentrations. There appears to be a directly proportional relationship between dry biomass and carbohydrate, fibre and moisture contents in the vegetable tissues. This means that as the concentration of the abattoir effluent increases, there is a corresponding increase in the growth and development of the vegetable as well as the carbohydrate, fibre and moisture contents in the tissues. These patterns are similar to the conclusions drawn by a few authors (Nguyen, 2009; Rehman *et al.*, 2013; Matheyarasu *et al.*, 2016; Khatoon *et al.*, 2018). Conversely, there appears to be an inverse relationship between the dry biomass and the protein, fat and ash contents in the vegetable tissue. This implies that as the concentration of the abattoir effluent increases and the vegetable grows, there is a general decrease in the protein, fat and ash contents in the tissues. These observations are consistent with the findings of some other authors (Ukam, 2008; Rehman *et al.*, 2013; Kekere *et al.*, 2020; Yahaya *et al.*, 2023).

Table 3: Effects of untreated abattoir effluent on the proximate composition of *Amaranthus hybridus*. Values with the same alphabet(s) within the same column are not significantly different (P>0.05).

Treatment (ml)	Moisture content (%)	Fat content (%)	Ash content (%)	Fibre content (%)	Protein content (%)	Carbohydrate content (%)
50	12.090^{a}	10.833^{a}	8.591^{bc}	28.325^{a}	23.100^{a}	17.061^{ab}
100	14.864^{ab}	9.421^{abc}	7.343^{c}	27.451^{c}	22.400^{a}	18.521^{abc}
200	15.931^{abc}	7.943^{abc}	8.050^{a}	29.365^{ab}	20.410^{ab}	18.301^{abc}
400	16.313^{c}	6.700^{c}	8.845^{bc}	28.045^{a}	20.405^{ab}	19.692^{bc}
590	16.413^{c}	8.303^{abc}	9.213^{abc}	30.421^{abc}	18.230^{abc}	20.420^{c}
0	14.876^{ab}	11.380^{a}	9.625^{abc}	27.710^{c}	25.380^{c}	11.029^{a}

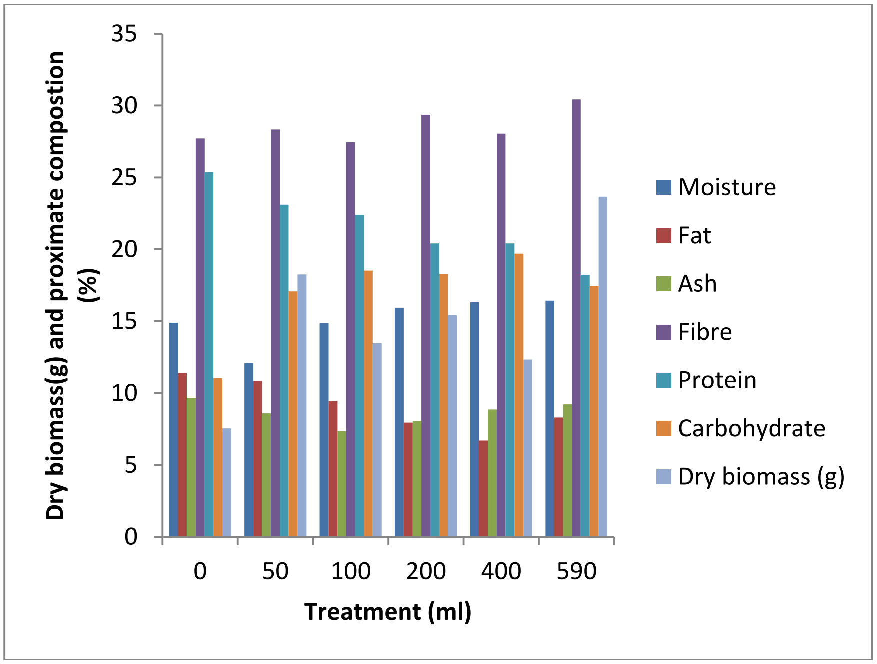

Fig 1: Relationship between proximate composition and dry biomass of *Amaranthus hybridus* irrigated with untreated abattoir effluent.

Effects of untreated abattoir effluents on heavy metal accumulation in Amaranthus hybridus: The heavy metals present in the abattoir effluent include Cadmium (Cd), Chromium (Cr), Manganese (Mn), Zinc (Zn), Iron (Fe), Copper (Cu), Lead (Pb), Cobalt (Co) and Nickel (Ni) (See Table 1). However, only four (Cd, Zn, Fe and Pb) out of the nine detected had concentrations above the WHO standard. Therefore, these four heavy metals were analyzed in the tissues of the vegetables at the end of the experimental period to account for possible bioaccumulation.

The results showed that all the four heavy metals analysed in *A. hybridus* irrigated with abattoir effluent were taken up by the plant roots (See Table 4). It was observed that Cd and Pb were 100% bioaccumulated in the vegetable tissues at concentrations up to 0.01 and 0.20 mg/L, respectively, which are above the WHO limits (0.003 and 0.01 mg/L, respectively). Zn bioaccumulated 79% of the heavy metal in the vegetable tissues at concentrations ranging from 0.02 - 0.38 mg/L, which is above the WHO limit of 0.01 mg/L. Fe on the other hand, bioacccumulated 59% of the heavy metal in the vegetable tissues at concentrations ranging from 5.37 - 10.08 mg/L, which is above the WHO limit of 0.30 mg/L. These findings on heavy metal bioaccumulation in vegetables align with many other works (Sharma *et al*., 2007; Rehman *et al.*, 2013; Osu and Ogoko 2014; Hussain, 2018).
The concentrations of these heavy metals above WHO limit in *A. hybridus* irrigated with abattoir effluent make them unfit for human consumption. This is because these heavy metals have human health risks when consumed at unsafe concentrations. In a particular study, continuous intake of Cd from food and water was observed to results in the accumulation of Cd in the kidneys and consequently causing kidney diseases (ATSDR, 1993). Pb and Cd have been linked to cardiovascular, nervous and bone disorders and found to be readily accumulated by *Amaranthus* sp. (Steenland and Boffetta, 2000). Zn is considered to be relatively non-toxic, especially if taken orally; however, in excessive amounts, system dysfunctions can occur, thereby, resulting in impairment of growth and reproduction (Duruibe *et al*., 2007). The clinical signs of zinc toxicity include vomiting, diarrhea, bloody urine, liver failure, kidney failure and anaemia (Duruibe *et al*., 2007). Fe, which was the highest concentration of heavy metals bioaccumulated in the tissues of *A. hybridus* (due to the presence of blood in the effluent), has shown to catalyze reactions involving the formation of free radicals which can damage biomolecules, cells, tissues and the whole organism (Ryan and Aust, 1992).

The accumulation of toxic heavy metals in plant tissues results in several deficiencies, reduced cell activities and plant growth inhibition (Farooqi *et al*., 2009). They also result in chlorosis and reduction of nutrient (Agarwal, 1999) which may explain why protein and fat contents were reducing with increasing abattoir effluent concentration.

Table 4: Comparison of heavy metal concentration in *Amaranthus hybridus* irrigated with untreated abattoir effluent with WHO limit and concentration in effluent. *ND – Not Detected.

Heavy metals	**WHO**			**In plant tissues (mg/L)**				**In effluent**
	Standard (mg/L)	**0 ml**	**50 ml**	**100 ml**	**200 ml**	**400 ml**	**590 ml**	**(mg/L)**
Cadmium	0.003	ND	ND	ND	0.01	0.01	0.01	0.01
Zinc	0.01	0.02	0.14	0.19	0.29	0.35	0.38	0.48
Lead	0.01	0.01	0.05	0.08	0.10	0.10	0.20	0.20
Iron	0.30	0.22	2.64	5.37	7.22	9.35	10.08	17.20

Conclusions: In this study, abattoir effluent has proven to be a very good source of organic nutrients for the cultivation of *Amaranthus hybridus*. The vegetable biomass increased as well as the carbohydrate, fibre and moisture contents. However, the ash, protein and fat contents reduced with increasing effluent concentration, and these have been attributed to a number of factors including vegetable variety, environmental conditions while sampling the vegetable and the possible metabolism by pathogen carried onto the body of the vegetable. Despite the low levels of protein and fat contents, it has been reported that the range observed in this study is still enough to provide the necessary calories for human development. Furthermore, all four heavy metals analysed (i.e., Cd, Pb, Zn and Fe) accumulated in the vegetable tissue over the experimental period. Therefore, abattoir effluent is recommended as a good source of organic nutrients in agriculture especially in areas experiencing water scarcity or drought, as it has the potential to improve plant yield and reduce environmental pollution.

Declaration of Conflict Of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the first author or corresponding author or any of the other authors.

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