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IMPACT OF HEAVY METALS ON SAFETY OF CATTLE MEAT SOLD IN OWERRI METROPOLIS, IMO STATE, NIGERIA

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Abstract

The concentrations of Copper (Cu), cadmium (Cd), manganese (Mn) and lead (Pb) in liver, kidneys and red meat of cattle slaughtered in selected abattoirs in Owerri metropolis, Nigeria were studied using atomic absorption spectroscopy (AAS). This was performed in relation to their concentrations in a forage grass, *Panicum maximum* randomly harvested from roadsides of Owerri-Onitsha and Owerri-Aba expressways. Results obtained showed that cattle meat samples contained all heavy metals studied. Their mean concentrations (mg/kg ± standard deviation) were 0.040 ± 0.018, 0.039 ± 0.031 and 0.044 ± 0.048 for Pb; 0.0088 ± 0.005, 0.0078 ± 0.0058 and 0.010 ± 0.011 for Cd; 0.013 ± 0.008, 0.013 ± 0.008 and 0.011 ± 0.006 for Cu; and 0.020 ± 0.008, 0.020 ± 0.017 and 0.015 ± 0.007 for Mn, in red meat, liver and kidneys respectively. The general order of concentrations observed was Pb>Mn>Cu>Cd. Their concentrations in various organs of cattle were in the order; kidneys>liver>red meat for Pb and Cd and liver>kidneys>red meat for Cu and Mn. These were far below the World Health Organization/Food and Agricultural Organization/European Commission maximum permissible/allowable limits (MPLs) for the heavy metals. The concentrations in *Panicum maximum* were in the order Pb>Cu>Mn>Cd in samples collected from Owerri-Aba expressway, while in samples from Owerri-Onitsha expressway, the order was Mn>Cu>Pb>Cd. The order of estimated daily intake (EDI) for meat samples was Pb>Mn>Cu>Cd, being below the tolerable daily intake (TDI). Statistical analysis showed that there was no correlation between the concentrations of these heavy metals in meat and plant samples.

Key words: cattle meat, heavy metal, liver, red meat, safety

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1. Introduction

Meat is an essential component of human diet as it supplies nutrients necessary for normal metabolic activities (Khalafalla et al., 2015). In Nigeria, cattle meat is the most consumed source of animal protein with 90,000 cattle slaughtered daily (Eze, 2017). Being ruminant, cattle meat may contain certain toxic substances like heavy metals consumed via feeding on contaminated fodders (Khalafalla et al., 2015). In Nigeria, most of these cattle, if not all, are herded. Thus, they indiscriminately consume forages as well as water from sources that may be contaminated with heavy metals. Studies have revealed increasing cases of soil contamination by heavy metals due to applications of pesticides, fertilizers, industrial processes and exhaust gases from automobiles (Ekundayo and Fatoba, 2020; Hoha et al., 2014). Plants which serve as food and fodders are known to absorb heavy metals from the soil. However, factors

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such as soil physicochemical properties, availability and type of metal in soil, cropping practices, type of plant, and solubility of metals in soil affect the concentrations of heavy metals in both plants and soils (Dheri et al., 2007; Sinha et al., 2006).

Heavy metal is any metal with a specific weight greater than 5g.cm^{-3} (Akan et al., 2010; Enemugwem et al., 2016). They are ubiquitous in both abiotic and biotic components of the ecosystem in which they play diverse roles (Alturiqi and Albedair, 2012; Harmanescu et al., 2011). Eventhough heavy metals like Cu, cobalt (Co), iron (Fe), zinc (Zn) and magnesium (Mg) have essential functions in human metabolism, their deficiency and excessiveness have been associated with chronic metabolic disturbances (Katnoria et al., 2011; Wang et al., 2012). On the other hand, non-essential heavy metals such as Pb, Cd, mercury (Hg), chromium (Cr), nickel (Ni) and arsenic (As) can cause profound biochemical and neurological changes in the body, even at low concentrations (Schroeder, 1991). Consequently, they should be completely excluded from food meant for human and animal consumption (Economic Commission (EC), 2001; World Health Organization (WHO), 2000, 2001).

Consumption of heavy metals contaminated food is the most implicated route of human exposure to heavy metals. This poses great threat in view of their toxicity, bioaccumulation potentials, as well as biomagnification along food chains (Halliwell et al., 2000; Liu et al., 2013; Zwolak et al., 2019). Emerging reports of contamination in meat samples by heavy metal call for serious concern for food safety and human health (D'Mello, 2003; Khalafalla et al., 2015; Santhi et al., 2008). Therefore, there is a need to regularly evaluate food and meat sources to ascertain their safety. Moreover, efforts should be strived towards identifying major routes of contamination of cattle and other meats so as to check them.

In this context, the main objective of our paper was to assess the effect of vehicular traffic and associated exhaust fumes on the composition and concentrations of heavy metals in a forage grass, *Panicum maximum*, growing on two major roads in Imo State; as well as the impact of consumption of the grass by cattle on the safety of their meat sold in Owerri metropolis. This was undertaken because most cattle in Nigeria are herded, hence feed on grasses growing generously on roadsides.

2. Material and methods

2.1. Study location and samples collection

Beef samples used in the study were collected on different days from abattoirs in Obinze, Relief market and Afor–Ogbe market in Owerri Zone, Imo State, Nigeria. These abattoirs operate on daily basis and supply beef and other meat products to people within Owerri locality. On each occasion, twelve (12) fresh cattle meat samples comprising of 4 samples of red meat, 4 samples of liver and 4 samples of kidneys were collected immediately after they were slaughtered. Two batches of samples were collected from each abattoir at 3 weeks intervals. The collected samples were packaged in pre-cleaned waterproof bags and then moved to the laboratory for processing and analyses.

Also, at each location of the roadsides studied, 3 samples of *Panicum maximum* leaf were randomly collected. This was repeated at 9 locations at different distances from the roadsides. Similar number of samples was collected from each of Owerri-Onitsha and Owerri-Aba expressways. Each sample was carefully packaged in cleaned polythene bag and then labeled accordingly. The leaves were cut into smaller pieces, completely air dried and ground to powder with thoroughly cleaned pestle and mortar. All the samples were then stored in air tight containers for further analysis.

2.2. Digestion and analysis of cattle meat samples

Digestion and analysis of all meat samples followed a modified method of Akinyele and Shokunbi (2015). Then concentrations of Pb, Cd, Cu and Mn in the digested samples were determined using Atomic Absorption Spectrophotometer (AAS)

2.3. Digestion and analysis of Panicum maximum leaf samples

Wet digestion of *Panicum maximum* leaf samples was done with a mixture of acids: 0.0125M HNO_3: 0.05M HCl (3:1), according to a modified method of Akinyele and Shokunbi (2015). Afterward, the concentrations of heavy metals, including Pb, Cd, Cu and Mn were obtained using the AAS (Buck Scientific 210 VGP).

2.4. Statistical procedures

A total of 72 meat samples were collected from the 3 abattoirs in 2 batches, each with 4 replicates for red meat, liver and kidneys on each occasion. Similarly, 9 samples of *Panicum maximum* leaf were collected at 9 different locations with 3 replicates at each location of Owerri-Aba and Owerri-Onitsha expressways. This gives a total of 27 samples for each road. The mean and standard deviation of the concentration of each heavy metal in the samples studied were calculated.

3. Results and discussion

3.1. Heavy metals concentration in meat samples

Generally, heavy metal concentrations in red meat, liver and kidneys were in the order Pb>Mn>Cu>Cd. Moreover, their concentrations in the various organs of cattle were in the order kidneys>liver>red meat for Pb and Cd, and liver>kidneys>red meat for Cu and Mn as shown in Fig. 1.

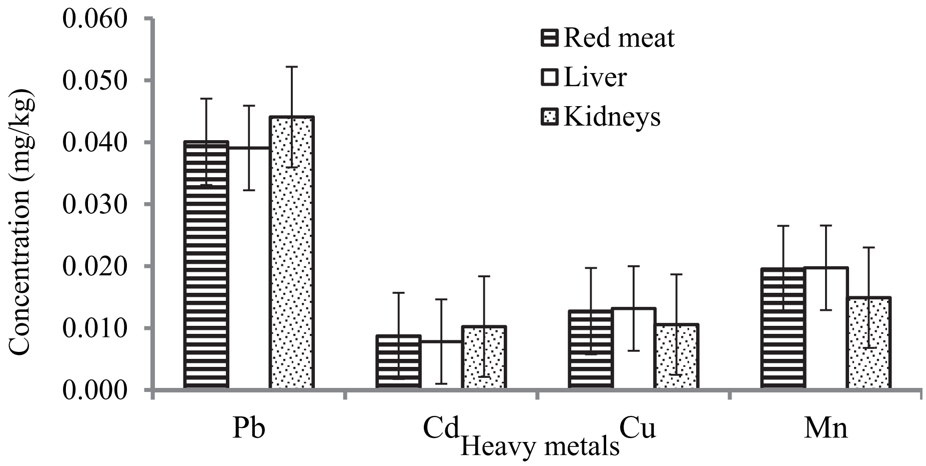

Fig. 1. Average concentrations of heavy metals in different cattle meat samples

This is similar to some published reports (Akoto et al., 2014; Iwegbue, 2008). There was no significant difference (p>0.05) between the concentrations of the heavy metals among the three meat samples studied. Also, this is in line with another report (Akoto et al., 2014). Conversely, Khalafalla et al. (2015) observed significant difference in the concentrations of heavy metals in the various organs studied at (p>0.05).

Lead is a toxic metal. Thus, the concentration must always be low in foods and additives to guarantee the safety of consumers. Results obtained indicated that average concentration (mg/kg) (± standard deviation) of lead (Pb) was 0.040 ± 0.018, 0.039 ± 0.031 and 0.044 ± 0.048 in red meat, liver and kidneys. These values are much similar to the results earlier reported (Bamuwamye et al., 2015; Orisakwe et al., 2017). Nevertheless, comparably higher concentrations of Pb have also been reported in similar samples (Akan et al., 2010; Alturiqi et al., 2012). Conversely, Lukáčová et al. (2014) reported lower concentration of Pb in their study. The highest average concentration Pb was found in kidneys. However, these concentrations of Pb are well below the maximum permissible limits (MPLs) for food (World Health Organization/Food and Agricultural Commission (WHO/FAO, 2007).

Cadmium is another toxic heavy metal which plays no known vital metabolic functions. The concentrations (mg/kg) (± standard deviation) were 0.0088 ± 0.005, 0.0078 ± 0.0058 and 0.010 ± 0.011 respectively in red meat, liver and kidneys for cadmium (Cd). This corroborates the results earlier published (Bamuwamye et al., 2015; Di Bella et al., 2020; Orisakwe et al., 2017). Elsewhere, higher concentrations of the heavy metals have been reported (Akan et al., 2010; Alturiqi et al., 2012; Khalafalla et al., 2015). Kidney is known to accumulate lead which is implicated in many cases of poisoning among domestic animals, like cattle. When absorbed, lead and cadmium are mainly stored in the liver and kidney where they accumulate (Khalafalla et al., 2015). The highest average concentration of Cd was found in red meat, though it is also below 0.5 mg/kg MPL (WHO/FAO, 2007).

On the other hand, copper is a micronutrient required in plants and animals for normal metabolic activity. In this study, the concentrations of copper (mg/kg) (± standard deviation) were 0.013 ± 0.008, 0.013 ± 0.008 and 0.011 ± 0.006 in red meat, liver and kidneys respectively. These were lower than the values reported by some other researchers (Akan, 2010; Alturiqi and Albedair, 2012; Iwegbue, 2008; Khalafalla et al., 2015). Red meat and liver samples showed highest average concentration of copper. However, the concentrations are far below the 3mg/kg MPL (EC 178, 2002; FAO, 2002). This low concentration may imply that Cu is deficient in the meat samples (Bamuwamye et al., 2015) which can cause clinical symptoms (Hoha et al., 2014).

The concentrations of manganese (mg/kg) (± standard deviation) were 0.020 ± 0.008, 0.020 ± 0.017 and 0.015 ± 0.007 in red meat, liver and kidneys, respectively. Although the results of this study for liver showed lower concentration of manganese than those reported by some other researchers (Akan et al., 2010; Iwegbue, 2008), the results for kidneys are comparable to those earlier reported (Iwegbue, 2008). Similarly, these concentrations are significantly below the 55.5 mg/kg MPL of WHO (Ahmad et al., 2017). Manganese is one of the bioessential metals needed in plants and animals for maintenance of normal metabolic activity (Iwegbue, 2008).

3.2. Heavy metals concentrations in Panicum maximum samples

The concentrations (mg/kg) of heavy metals ranged from 0.5 ± 0.6 – 5.5 ± 0.3 for Cd, 0 ± 0.0 – 26 ± 8.3 for Cu, 0 ± 0.0 – 1.5 ± 0.7 for Mn and 0 ± 0.00 - 30.5 ± 3.4 for Pb in *P. maximum* leaf samples from Owerri-Aba expressway. However, the concentrations (mg/kg) ranged from 0.5 ± 0.9 to 3.3 ± 0.6 for Cd, 5.7 ± 1.4 to 38.4 ± 9.2 for Cu, 10.9 ± 6.3 to 56.2 ± 16.4 for

Mn and 6.4 ± 2.6 to 34.2 ± 7.7 for Pb, for samples from Owerri-Onitsha expressway. This gives the order, Pb>Cu>Mn>Cd in the *Panicum maximum* samples collected from roadsides of Owerri-Aba expressway, but Mn>Cu>Pb>Cd in samples from roadsides of Owerri-Onitsha expressway. Nimyel et al. (2015) had reported a similar order Mn>Fe>Zn>Cu>Cd in cabbage and Fe>Cu>Mn>Ni in spinach. Capability of plants to stabilize heavy metals has been reported for *Ludwigia stolonifera*, *Ceratophyllum demersum* reed and *Panicum maximum* (Anuforo et al., 2020).

Moreover, samples from Owerri-Onitsha expressway contained higher heavy metals concentrations than those from Owerri-Aba expressway. The difference is as shown in Figs. 2- 3. This could be attributed to the higher traffic on the Owerri-Onitsha expressway which results in increased release of exhaust fumes (Ekundayo and Fatoba, 2020; Rolli et al., 2019). It is noteworthy that Owerri-Onitsha expressway witnesses more traffic than Owerri-Aba expressway. Moreover, dynamics of heavy metals is dependent on properties of the soil, including its organic and inorganic matter contents. This determines the bioavailability of heavy metals in the soil and their absorption by plants (Zwolak et al., 2019).The concentrations of the selected heavy metals in the samples studied were higher than (Opaluwa et al., 2012) reported in their study. They also reported that Cu had the highest concentration than other heavy metals studied which excluded Mn. On the average, Pb and Cd concentrations exceeded the minimum permissible limits (WHO/FAO, 2007). This observation calls for serious concern especially as the use of leaded petrol has been banned in the country. It implies that there exist some factors that are responsible for these high concentrations of Pb and Cd. Statistical analysis showed that there was no correlation between the concentrations of the heavy metals in the plant samples with those in the meat. This implies that *P. maximum* is not the only source of the heavy metals load in the meat samples. Other sources, including drinking of heavy metals polluted run off water from roads and other flood water while being herded may be implicated.

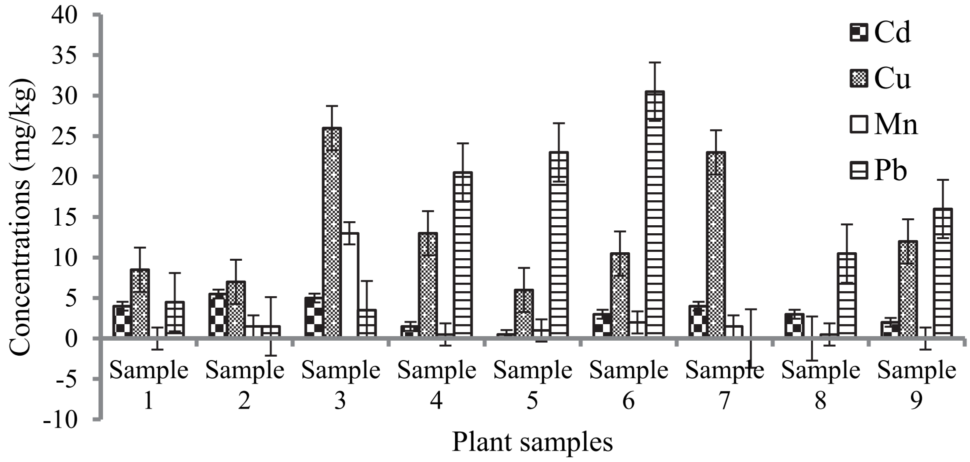

Fig. 2. Heavy metals concentrations in *Panicum maximum* samples from Owerri-Aba expressway

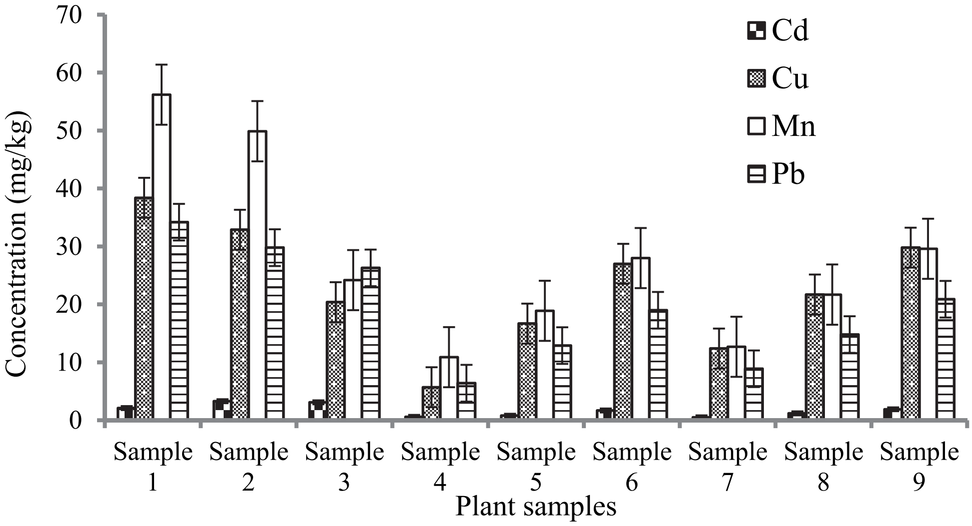

Fig. 3. Heavy metals concentrations in *Panicum maximum* samples from Owerri-Onitsha expressway

3.3. Estimated Daily Intake (EDI)

The computation for *EDI* was done as shown in Eq. (1) using the results of heavy metals analysis, rate of consumption of meat in Nigeria, and average body weight of Nigerian adults (Bamuwamye et al., 2015; United States Enviornmental Protection Agency (USEPA), 2010).

$$EDI = \frac{CxIR}{BWa} \tag{1}$$

where *C* represents heavy metal concentration in the sample (mg/kg wet weight), *IR* refers to rate of consumption of cattle meat and *BWa* is the average body weight of adult Nigerians.

The estimated daily intake of cattle meat was computed using data obtained from reports of Eze (2017) that 90,000 cattle with average carcass weight of 123.7kg (FAO, 2019) are slaughtered daily in Nigeria with an estimated population of 200 million. Using average body weight of 70 kg for adults (Ekhator et al., 2017), the *EDI* ranged from 0.007 – 0.032µg/kg-bw/day for red meat, 0.006 – 0.031µg/kg-bw/day for liver and 0.0082 – 0.035µg/kg-bw/day for kidneys as shown (Table 1). Generally, the order for *EDI* for all the meat samples was Pb>Mn>Cu>Cd. The computed *EDIs* for the heavy metals in all cattle meat samples were well below the 0.025, 0.007, 3.5, and 5.6 $mgkg^{-1}$-body weight/week limits for Pb, Cd, As, Cr, Cu, Zn, and Fe, respectively (Stanković et al., 2011). This is similar to results of a study in Italy which showed that estimated weekly intake (*EWI*) (µg/kg BW) of 0.01 and 0.34 for Cd and Pb respectively, through beef, for adults, as well as target hazard quotient (*THQ*) of 0.00 and 0.00 for Cd and Pb respectively (Di Bella et al., 2020). However, due to the bioaccumulation potentials of heavy metals, their concentrations should regularly be checked, especially for Pb.

Table 1. Estimated daily intake (*EDI*) ($\mu g kg^{-1} day^{-1}$) of heavy metals in Nigeria through consumption of cattle meat

	Red meat	*Liver*	*Kidneys*	*TDI*
Pb	0.032	0.031	0.035	3.57
Cd	0.007	0.006	0.008	1.00
Cu	0.010	0.011	0.008	500
Mn	0.016	0.016	0.012	300

TDI: Tolerable daily intake.

3.4. Hazard Ratio (HR) and Hazard Index (HI)

The assessment of risk associated with consumption of cattle meat was done in line with the guidelines of USEPA (2010). The *EDI* obtained was compared to the recommended reference doses (*RfD*) (0.001 mg/kg/day for Cd and 0.004 mg/kg/day for Pb) (USEPA, 2010) to determine the non-carcinogenic effects using (Eq. 2).

$$HR = \frac{EDIx10^3}{RfD} \tag{2}$$

where: *EDI* is the intake of heavy metals via consumption of red meat, liver and kidney of cattle and *RfD* is the estimated rate of safe cattle meat consumption in terms of heavy metal. The *HR* was 0.00002 for Cu, 0.009 for Pb, 0.007 for Cd and 0.0001 for Mn in red meat. Further, *HR* was 0.00002 for Cu, 0.006 for Cd, 0.009 for Pb and 0.0001 for Mn in liver meat. In kidneys, it was 0.00002 for Cu, 0.01 for Pb, 0.008 for Cd and 0.00001 for Mn.

HI was generated by using the relationship as shown in Eq. (3).

$$HI = \sum HRi \tag{3}$$

where *i* stands for each heavy metal. When *HR* and/or *HI* is greater than 1 (*HR* or *HI* >1), there is a possible risk to human health. When it is lower than 1 (≤1), there is no possible risk of adverse health effects.

The hazard ratio (*HR*) and hazard index (*HI*) for the cattle meat samples were <1. This implies that cattle meat sold in Owerri metropolis is safe for consumption. This could be attributable to low density of industries and their associated pollution in Imo State and Nigeria in general as well as ban on use of leaded petrol. Thus the ban should be retained. Similar findings have also been reported (Darwish et al., 2015), unlike the reports (Bamuwamye et al., 2015) which were >1 for all their samples studied.

4. Conclusions

This study assessed the effect of vehicular traffic and associated exhaust fumes on the heavy metals concentrations of a forage crop, *Panicum maximum* and the possible correlation with its concentration in meat derived from herded cattle sold in Owerri Metropolis, Nigeria. Cattle meat samples studied contained all the heavy metals with their average concentrations in red meat, liver and kidneys in the order Pb>Mn>Cu>Cd. Their concentrations in the various organs of cattle were in the order kidneys>liver>red meat for Pb and Cd, and liver>kidneys>red meat for Cu and Mn. The concentrations were far below the WHO/FAO/EC maximum permissible/allowable limits (MPLs) for the heavy metals. The order of concentrations of the heavy metals in *Panicum maximum* was Pb>Cu>Mn>Cd in samples collected from Owerri-Aba expressway, while it was Mn>Cu>Pb>Cd in samples from Owerri-Onitsha expressway.

The concentrations of the heavy metals in plant samples from Owerri-Onitsha expressway were found to be higher than those in samples from Owerri-Aba expressway. Thus, this could be associated with higher vehicular traffic witnessed by Owerri-Onitsha expressway than Owerri-Aba expressway. Moreover, only the concentrations of Pb and Cd in *Panicum* *maximum* exceeded the MPL. This implies that wear and tear of vehicular parts beside leaded fuel may be significantly releasing heavy metals to roadside soil. The estimated daily intake (*EDI*) of the cattle meat ranged from 0.007 – 0.032μg/kg-bw/day for red meat, 0.006 – 0.031μg/kg-bw/day for liver and 0.0082 – 0.035μg/kg-bw/day for kidneys, which are well below the *TDI*. However, the *EDI* is in the order Pb>Mn>Cu>Cd for all the meat samples. The results of *HR* and *HI* which are less than 1 indicate that meat samples sold in Owerri metropolis are safe for consumption. The concentration of heavy metals in meat sample showed no correlation with their concentrations in *Panicum maximum* samples. Although these concentrations are presently low, there is a need for continuous monitoring to ensure maintenance of the status and guarantee public health.

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