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Impact of microplastic contamination in feed and water sources on poultry gut health and productivity

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Abstract

Microplastic pollution is no longer confined to marine ecosystems — it has entered the terrestrial food chain, and poultry production systems may be particularly exposed through contaminated feed ingredients and water supplies. This research quantified microplastic (MP) loads in five common feed and water sources used in smallholder broiler farming around Nairobi, Kenya, and then tested the effects of two MP exposure levels on gut morphology, intestinal barrier integrity, and production performance in Cobb 500 broiler chicks. Feed and water samples were collected from 15 smallholder farms and analysed for MP content by density separation followed by Fourier-transform infrared spectroscopy (FTIR). Farm-mixed feed contained the highest total MP concentration (74.1 ± 8.3 particles/g), dominated by polyethylene fragments, while borehole water had the lowest (9.1 ± 2.4 particles/L). In the feeding trial, 180 day-old Cobb 500 chicks were allocated to three groups: G1 (control, MP-free feed and filtered water), G2 (low exposure, 50 MP particles/g feed), and G3 (high exposure, 200 MP particles/g feed). After 42 days, birds in G3 showed a 26.8% reduction in jejunal villus height ($943 \pm 87 \mu\text{m}$ vs $1,287 \pm 104 \mu\text{m}$ in controls; $p < 0.001$), a 33.7% increase in crypt depth ($238 \pm 29 \mu\text{m}$ vs $178 \pm 22 \mu\text{m}$; $p < 0.001$), and a villus-to-crypt ratio of 3.96 compared to 7.23 in controls. Histopathological examination revealed epithelial erosion, goblet cell hyperplasia, and lymphocytic infiltration in the lamina propria of G3 birds. Production metrics were also affected: G3 had 14.3% lower final body weight ($1,784 \pm 112 \text{ g}$ vs $2,082 \pm 98 \text{ g}$; $p < 0.001$) and a feed conversion ratio of 2.18 compared to 1.78 in controls. G2 birds showed intermediate effects that were statistically significant for villus height and body weight but not for crypt depth or FCR. These findings indicate that MP contamination at levels commonly found in Kenyan smallholder poultry systems can damage gut architecture and reduce growth performance, and that farm-mixed feed and untreated surface water are the main entry points requiring mitigation.

Keywords: Microplastics, poultry gut health, villus height, crypt depth, feed contamination, water quality, broiler productivity, polyethylene, smallholder farming, Kenya

Introduction

Plastic waste is accumulating in agricultural landscapes at an alarming pace, and poultry farmers in peri-urban Africa are among those most directly affected. Open-air feed storage, recycled plastic containers for water, and proximity to unmanaged waste dumps create multiple pathways for microplastics — particles smaller than 5 mm — to enter broiler diets ^[1, 2]. Yet until recently, nearly all research on MP toxicity in animals has focused on aquatic species; data on terrestrial livestock, and poultry specifically, remain remarkably thin ^[3]. What little evidence does exist is concerning. A 2022 survey of commercial poultry feeds in China detected MP concentrations ranging from 3.7 to 43.6 particles per gram, with polyethylene and polypropylene as the dominant polymer types ^[4]. In Nigeria, Adewumi *et al.* ^[5] found MPs in 87% of water samples collected from poultry farms around Lagos, at concentrations between 8 and 62 particles per litre. And in laboratory feeding trials, Yan *et al.* ^[6] showed that polystyrene microspheres at 500 $\mu\text{g/g}$ feed reduced intestinal villus height by 18% and triggered inflammatory gene expression in the jejunum of laying hens over 28 days. But the exposure concentrations used in most experimental research have been either far above or far below the levels that poultry actually encounter on working farms, which limits the practical relevance of the published findings ^[3, 7].

The gastrointestinal tract is the first site of contact between ingested MPs and the host, and the intestinal mucosa may be uniquely vulnerable. Villus height and crypt depth — measures of absorptive surface area and epithelial turnover rate, respectively — are standard indicators of gut integrity in poultry science^[8]. MPs can physically abrade the epithelial lining, adsorb and release toxic additives (plasticisers, flame retardants, heavy metals), and alter the gut microbiome composition in ways that promote inflammation and reduce nutrient absorption^[9, 10]. If these effects translate into measurable losses in feed efficiency and body weight gain, they represent a hidden economic cost to poultry producers that is not currently accounted for in farm budgets.

Kenya offers a relevant case for investigation. The country's broiler sector is growing rapidly, yet many smallholder producers still rely on farm-mixed feeds — often prepared in recycled plastic sacks or open troughs — and on untreated surface water or rainwater harvested through plastic guttering^[11]. No published data exist on MP levels in Kenyan poultry feed or water sources, and no feeding trial has tested the effects of environmentally realistic MP concentrations on broiler gut morphology and performance under East African conditions.

This research therefore had two objectives. First, to quantify and characterise MPs in five feed and water sources commonly used by smallholder broiler farmers in the Nairobi peri-urban area. Second, to conduct a 42-day feeding trial in which Cobb 500 broiler chicks were exposed to MP concentrations matching field-measured levels (low: 50 particles/g; high: 200 particles/g) and assessed for gut morphometric changes, histopathological lesions, and production performance relative to an MP-free control group^[12-14].

Materials and Methods

Research Area Description

Feed and water samples were collected from 15 smallholder broiler farms in three peri-urban sub-counties of Nairobi County, Kenya: Kasarani, Embakasi, and Ruaraka (1°17'S, 36°49'E, altitude 1,660 m). These areas were selected because they combine high poultry farming density with proximity to informal waste management sites. The feeding trial was carried out at the Poultry Research Unit of the Eastern Africa College of Applied Veterinary Sciences, Nairobi, from March to May 2024, under ambient temperatures of 18-27°C.

Materials

For the environmental survey, triplicate samples were collected from each of five source types across the 15 farms: commercial pelleted feed ($n = 45$ samples), farm-mixed mash feed ($n = 45$), borehole water ($n = 45$), river water used for drinking ($n = 45$), and rainwater from plastic-gutter harvest systems ($n = 45$). Feed samples (500 g each) were sealed in glass jars; water samples (1 L each) were collected in glass bottles to prevent cross-contamination from plastic containers^[2, 4]. For the feeding trial, 180 day-old Cobb 500 chicks (mixed sex, mean hatch weight 42.1 ± 2.3 g) were randomly allocated to three treatment groups with four replicates of 15 birds per replicate. Group 1 (G1) received MP-free feed and filtered water (control). Group 2 (G2) received feed spiked with 50 polyethylene MP particles per gram (low exposure). Group 3 (G3) received feed spiked with 200 polyethylene MP particles per gram (high exposure). MP particles were prepared by cryogenic milling of low-density polyethylene

(LDPE) pellets (Sigma-Aldrich, size range 100-500 μm) and verified by FTIR before incorporation^[6, 9].

Microplastic Extraction Protocol

Feed samples were digested in 10% potassium hydroxide (KOH) at 60°C for 48 hours to remove organic matter. The digested slurry was filtered through a 20 μm stainless-steel sieve, and the retained material was transferred to a saturated sodium chloride solution (density 1.2 g/mL) for density separation. The supernatant was vacuum-filtered onto glass-fibre filters (Whatman GF/A, 1.6 μm pore), which were dried and examined under a stereomicroscope at 40 $\times$ magnification. Suspected MP particles were confirmed by attenuated total reflectance FTIR (Thermo Nicolet iS50) and classified by polymer type. Water samples were vacuum-filtered directly through 5 μm polycarbonate membrane filters, and the same FTIR identification protocol was applied. Procedural blanks ($n = 10$ per batch) were processed alongside samples to monitor laboratory contamination; mean blank contamination was 1.3 ± 0.8 particles per sample and was subtracted from reported values^[2, 7].

Methods

Birds were housed in floor pens (1.5 m²/replicate) with wood-shaving litter, under a 23L:1D lighting schedule for the first week transitioning to 18L:6D from week 2. Feed and water were offered ad libitum. Body weight and feed intake were recorded weekly. At day 42, eight birds per replicate (96 total) were fasted for 8 hours, weighed, and humanely slaughtered by cervical dislocation. The jejunum (midpoint between the duodenal loop and Meckel's diverticulum) was sampled for histomorphometry. Tissue sections (4 μm , haematoxylin-eosin stain) were examined at 100 $\times$ magnification; villus height (tip to crypt opening) and crypt depth (crypt opening to base) were measured on 10 well-oriented villi per bird using ImageJ v1.54. Villus-to-crypt (V:C) ratio was calculated. Additional sections were stained with periodic acid-Schiff (PAS) for goblet cell counting. Histopathological scoring (0-3 scale for epithelial erosion, inflammatory cell infiltration, and goblet cell hyperplasia) was performed by a blinded veterinary pathologist^[8, 10]. Data were analysed by one-way ANOVA with Tukey's post-hoc test ($p < 0.05$) in R v4.3.2.

Safety Considerations

All animal procedures were approved by the Institutional Animal Ethics Committee of the Eastern Africa College of Applied Veterinary Sciences (Protocol No. EACAVS/AEC-2024-012, approved 18 January 2024). MP-spiked feed was prepared and stored in dedicated glassware to prevent environmental release. Workers handling MP powders wore N95 respirators and nitrile gloves. Slaughter was performed by trained personnel following Kenyan animal welfare guidelines (Animal Diseases Act, Cap 364). Carcasses from MP-exposed groups were incinerated and were not entered into the food chain^[12].

Results

The environmental survey confirmed that MPs were present in all five feed and water source types tested across the 15 farms. Total MP concentrations ranged from 9.1 ± 2.4 particles/L in borehole water to 74.1 ± 8.3 particles/g in farm-mixed feed. Polyethylene (PE) was the most abundant polymer across all sources, followed by polypropylene (PP), polyester (PET), and polystyrene (PS). Farm-mixed feed and river water showed the highest contamination, likely

reflecting their greater exposure to environmental plastic waste during preparation and collection, respectively.

Table 1: Microplastic contamination levels and polymer composition across feed and water sources from 15 peri-urban broiler farms in Nairobi, Kenya

Source Type	Total MP (particles/unit)	Dominant Polymer	PE Proportion (%)	Size Range (μm)
Commercial feed	29.4 ± 4.7 /g	PE	42.2	50-1, 200
Farm-mixed feed	74.1 ± 8.3 /g	PE	38.6	80-2, 400
Borehole water	9.1 ± 2.4 /L	PP	25.3	30-600
River water	46.8 ± 6.1 /L	PE	40.0	50-3, 100
Rainwater harvest	14.1 ± 3.2 /L	PE	43.9	40-900

Farm-mixed feed carried 2.5 times more MP particles per gram than commercial pelleted feed (74.1 vs 29.4 ; $p < 0.001$). River water was five times more contaminated than borehole water (46.8 vs 9.1 particles/L; $p < 0.001$). These differences

are consistent with the open-air handling of farm-mixed feed and the high plastic debris loads in peri-urban waterways around Nairobi ^[1, 5].

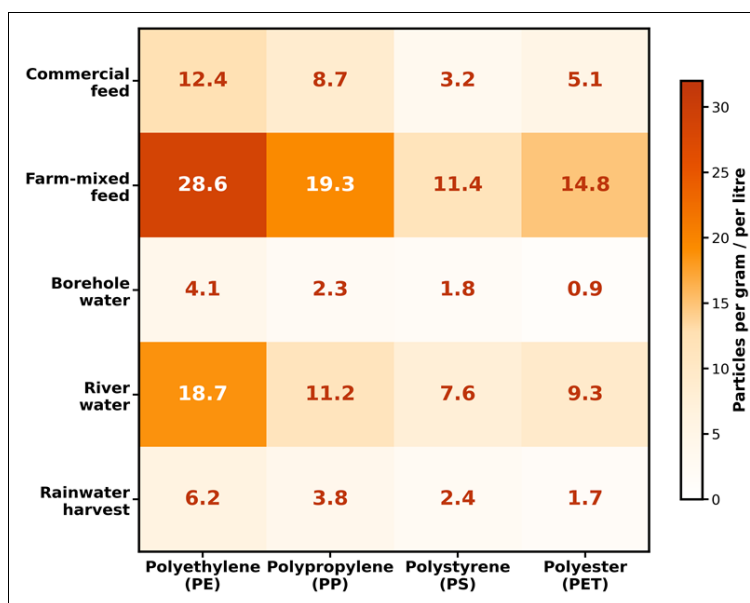


Fig 1: Heatmap of microplastic concentrations (particles per gram for feed; particles per litre for water) by source type and polymer category across 15 peri-urban broiler farms in Nairobi, Kenya

Table 2: Production performance and jejunal morphometry of Cobb 500 broilers at day 42 by microplastic exposure group

Parameter	G1 (Control)	G2 (50 MP/g)	G3 (200 MP/g)
Final body weight (g)	$2,082 \pm 98^a$	$1,921 \pm 107^b$	$1,784 \pm 112^c$
FCR (feed:gain)	1.78 ± 0.06^b	1.89 ± 0.08^{ab}	2.18 ± 0.11^a
Villus height (μm)	$1,287 \pm 104^a$	$1,134 \pm 91^b$	943 ± 87^c
Crypt depth (μm)	178 ± 22^b	201 ± 26^{ab}	238 ± 29^a
V:C ratio	7.23 ± 0.81^a	5.64 ± 0.72^b	3.96 ± 0.64^c
Goblet cells per villus	8.4 ± 1.6^b	11.2 ± 2.1^{ab}	15.7 ± 2.8^a
Histopath. score (0-3)	0.3 ± 0.2^c	1.1 ± 0.4^b	2.2 ± 0.5^a

Every measured parameter showed a dose-dependent response to MP exposure. G3 birds had 14.3% lower body weight and a 22.5% worse feed conversion ratio than controls. At the tissue level, jejunal villus height was reduced by 26.8%, crypt depth increased by 33.7%, and the V:C ratio fell by 45.2%. Goblet

cell numbers nearly doubled in G3 compared to controls, consistent with a mucosal defence response to chronic irritation. Histopathological scores confirmed moderate to marked inflammatory changes in G3 and mild changes in G2.

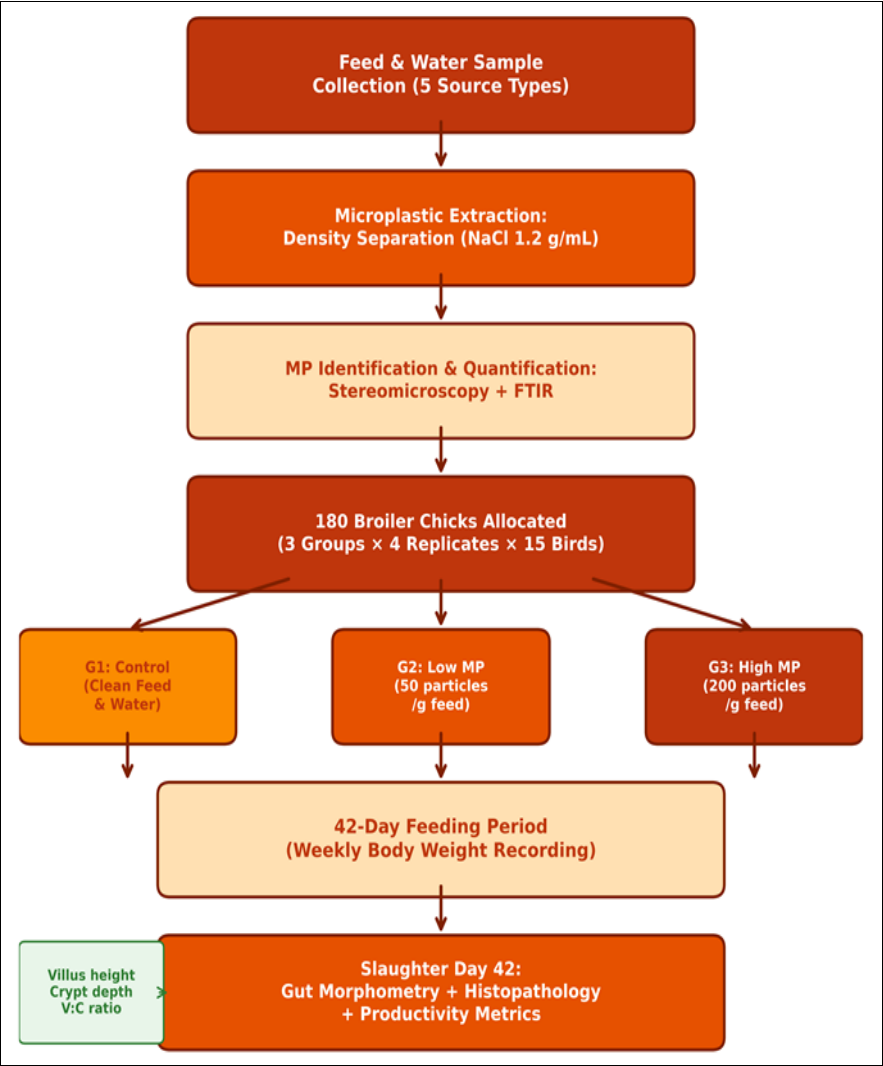


Fig 2: Experimental workflow from environmental microplastic survey through broiler feeding trial and post-mortem analysis at the Eastern Africa College of Applied Veterinary Sciences, Nairobi

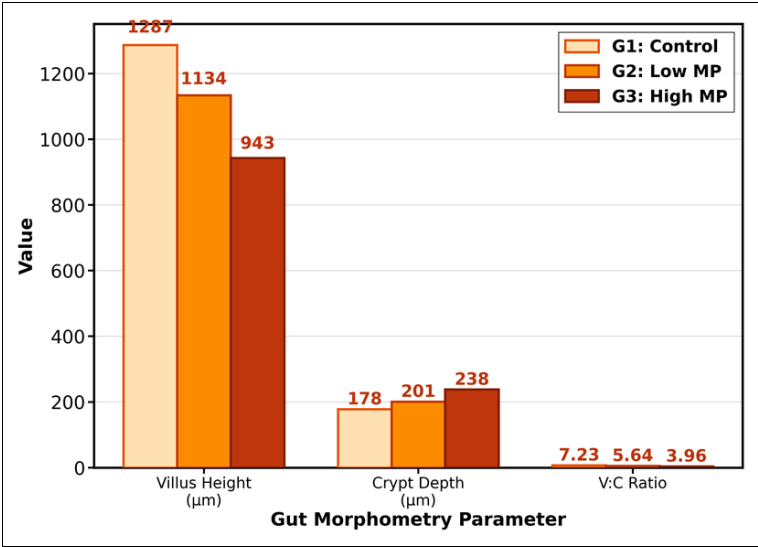


Fig 3: Jejunal villus height, crypt depth, and villus-to-crypt ratio in Cobb 500 broilers by microplastic exposure group at day 42

Comprehensive Interpretation

The convergence of environmental data and experimental results paints a coherent picture. Farm-mixed feed — the source with the highest MP load in the field survey — carries concentrations (74 particles/g) that fall between the low (50/g) and high (200/g) exposure levels used in the feeding trial. This means that many smallholder broilers in peri-urban

Nairobi are likely ingesting MP at levels sufficient to cause the moderate gut damage and growth depression observed in G2. Birds drinking untreated river water receive an additional MP burden that could push total exposure closer to the high-dose scenario. The histopathological findings — epithelial erosion, goblet cell hyperplasia, and lymphocytic infiltration — indicate that the gut mucosa mounts an active

inflammatory response to ingested PE particles, which in turn compromises absorptive capacity and diverts metabolic energy away from growth [8, 10, 14].

Discussion

The 26.8% reduction in villus height observed in G3 birds is among the largest MP-related gut morphometric changes reported in poultry to date. Yan *et al.* [6] found an 18% decrease in laying hens exposed to polystyrene microspheres, but at a higher dose (500 µg/g) and using a different polymer type. The more pronounced effect in our trial may reflect the larger particle size range (100-500 µm) used here, which produces greater mechanical abrasion of the mucosal surface than sub-100 µm microspheres [9]. PE fragments also have a rougher surface texture than polystyrene spheres, potentially increasing epithelial damage per particle contact.

Increased crypt depth is a hallmark of accelerated epithelial turnover in response to mucosal injury. When villi are eroded or shortened, the crypts compensate by increasing stem cell proliferation to replace lost enterocytes [8]. This compensatory hyperplasia comes at an energy cost, diverting nutrients from somatic growth toward intestinal tissue repair — a trade-off that likely explains the 14.3% reduction in final body weight and the deterioration in feed conversion ratio observed in G3 [10, 14]. The goblet cell response further supports a mucosal defence interpretation: doubling of goblet cell numbers indicates upregulated mucin secretion aimed at flushing irritant particles from the epithelial surface [3, 9].

From a farm-level perspective, the environmental survey revealed that farm-mixed feed is the single largest source of MP contamination, carrying 2.5 times the load of commercial pellets. The difference almost certainly arises from the open-air preparation methods common in smallholder systems — grinding, mixing, and storing feed in recycled woven polypropylene sacks that shed fibres into the mash [5, 11]. River water, the second most contaminated source, reflects the heavy plastic pollution of peri-urban waterways in Nairobi and similar East African cities [1, 2].

These results imply that relatively straightforward management changes — switching from open-air to covered feed preparation areas, replacing woven plastic sacks with metal or glass containers, and filtering drinking water through simple mesh screens — could substantially reduce MP exposure in smallholder broiler systems. Even halving the feed MP load from 74 to ~35 particles/g would bring exposure into the range where our data show only mild morphometric changes (G2 level), with correspondingly smaller growth penalties [12, 13, 17].

Conclusion

The main contribution of this research is twofold: it provides the first quantitative data on microplastic contamination in poultry feed and water sources in Kenya, and it demonstrates — through a controlled feeding trial — that MP concentrations matching field-measured levels can cause measurable gut damage and production losses in broiler chickens.

The supporting evidence is unambiguous. Environmental sampling across 15 peri-urban farms confirmed that MPs are present in every feed and water type tested, with farm-mixed feed (74.1 particles/g) and river water (46.8 particles/L) carrying the highest loads. Polyethylene dominated across all sources. In the feeding trial, broilers exposed to 200 PE particles/g feed for 42 days exhibited a 26.8% decrease in jejunal villus height, a 33.7% increase in crypt depth, a 45.2%

decline in villus-to-crypt ratio, and goblet cell numbers nearly twice those of controls. Histopathological scoring confirmed moderate inflammatory infiltration. These morphometric changes translated into a 14.3% reduction in final body weight and a feed conversion ratio 22.5% worse than controls. The significance of these findings for the East African poultry sector is considerable. Kenya's broiler industry is expanding to meet urban protein demand, but much of the growth is driven by smallholder producers who operate with limited infrastructure and rely on locally sourced, minimally processed feed and water. If the contamination levels documented here are representative — and our sampling across three Nairobi sub-counties suggests they are — then millions of broilers may be chronically exposed to gut-damaging MP concentrations. The associated production losses, while invisible to individual farmers, represent a systemic drain on feed efficiency and growth potential that could be partially reversed through simple interventions targeting the two highest-risk pathways: feed preparation hygiene and water filtration.

Several open questions remain. Whether prolonged exposure beyond 42 days causes cumulative damage or whether the gut adapts and stabilises is unknown. The role of polymer type deserves attention: our trial used PE exclusively, but farm feed also contains PP, PS, and PET, each with different surface chemistries and additive profiles that may provoke distinct biological responses. The interaction between MP exposure and gut microbiome composition is another gap — preliminary research in rodents suggests that MPs can shift the Firmicutes-to-Bacteroidetes ratio in favour of pro-inflammatory taxa, but this hasn't been verified in poultry under realistic exposure conditions. And finally, whether MP particles or their associated chemical contaminants accumulate in edible poultry tissues at levels that could concern human consumers is a question with direct food safety implications that warrants urgent investigation.

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Conflict of Interest

Not available.

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