Research

Characterization and Supplementing of PVA-curcumin Nanofibers on the Initial Week Performance of Broiler Growth

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ABSTRACT

Broiler chickens are a vital global commodity, known for their rapid growth and efficiency, but their productivity has historically relied on Antibiotic Growth Promoters (AGP), necessitating the development of safe alternatives. This study aimed to assess the efficacy of Polyvinyl Alcohol (PVA)-curcumin nanofibers as a potential substitute for Antibiotic Growth Promoters (AGP) in improving the growth performance of broiler chickens. The nanofibers were synthesized via the electrospinning technique at varying PVA concentrations of 5%, 10%, and 15%, and their morphology was characterized by Scanning Electron Microscopy (SEM). The in vitro assay evaluated curcumin release profiles were measured in phosphate buffer (PBS, pH 7,4) at 37 °C. A seven-day in vivo experiment involving 30 broiler hens categorized into 5 groups to assess the impact of supplementation on body weight, feed intake, and feed conversion ratio (FCR). The synthesized PVA-curcumin nanofibers exhibited optimal dimensions (100–135 nm), with gradual curcumin release measuered at 43,5–51,5% at 5 minutes and 49,27–64,5% at 120 minutes. While statistical analysis showed no significant difference ($p > 0,05$). The treatment group showed higher average daily gain (ADG) (99,49–115,4 g) and feed intake (FI) (118,76–129,11 g), resulting in better feed conversion ratio (FCR) (0,921–1,00) compared to the control group. In conclusion, PVA-curcumin nanofibers were successfully synthesized, demonstrating their potential to improve growth performance, and are suitable as an alternative non-antibiotic growth promoter in broilers.
Keywords: AGP, broiler chickens, curcumin, nanofiber, performance

ABSTRAK

Ayam broiler merupakan komoditas global yang penting, dikenal dengan pertumbuhan pesat dan efisiensinya, namun produktivitasnya secara historis bergantung pada Antibiotik Pemacu Pertumbuhan (AGP). Hal ini mendorong pengembangan alternatif yang aman. Penelitian ini bertujuan untuk mengevaluasi efektivitas nanofiber polivinil alkohol (PVA)-kurkumin sebagai pengganti potensial AGP dalam meningkatkan kinerja pertumbuhan ayam broiler. Nanofiber disintesis menggunakan teknik elektrospinning dengan variasi konsentrasi PVA 5%, 10%, dan 15%, serta morfologinya dikarakterisasi dengan Mikroskopi Elektron Pemindai (SEM). Pengujian in vitro mengevaluasi profil pelepasan kurkumin yang diukur dalam buffer fosfat (PBS, pH 7,4) pada suhu 37 °C. Uji in vivo selama tujuh hari menggunakan 30 ayam broiler yang dibagi menjadi 5 kelompok untuk menilai dampak suplementasi terhadap berat badan, konsumsi pakan, dan rasio konversi pakan (FCR). Nanofiber PVA-kurkumin yang disintesis menunjukkan dimensi optimal (100–135 nm), dengan pelepasan kurkumin secara bertahap, yaitu 43,5–51,5% pada 5 menit dan 49,27–64,5% pada 120 menit. Meskipun analisis statistik tidak menunjukkan perbedaan signifikan ($p > 0,05$), kelompok perlakuan menunjukkan peningkatan rata-rata pertambahan bobot badan harian (ADG) (99,49–115,4 g) dan konsumsi pakan (*feed intake*) (118,76–129,11 g), yang menghasilkan rasio konversi pakan (FCR) yang lebih baik (0,921–1,00) dibandingkan dengan kelompok kontrol. Sebagai kesimpulan, nanofiber PVA-kurkumin berhasil disintesis, menunjukkan potensinya untuk meningkatkan kinerja pertumbuhan, dan cocok sebagai alternatif promotor pertumbuhan non-antibiotik pada broiler.
Kata kunci: AGP, ayam broiler, kurkumin, nanofiber, pertumbuhan

INTRODUCTION

Nanotechnology holds the possibility of completely transforming bioactive compound delivery systems using nanoparticle platforms in poultry. Its application in feed nutrition interventions, such as nanocurcumin supplementation for promoting growth (Moniruzzaman & Min, 2020) and nanominerals for enhancing nutrient absorption and disease resistance (Zaheer *et al.,* 2024), expands its applications and promises significant socio-economic impacts through more effective, efficient, and environmentally friendly products (Martien *et al.,* 2012; Zaheer *et al.,* 2024).

Broiler chickens, characterized by their high productivity, rapid growth, and superior feed efficiency, are a vital poultry commodity, supplying economical animal protein in Indonesia (Listyasari & Purnama, 2022). Their substantial dominance is evidenced by a national population of 3.148 billion broiler chickens (BPS, 2024). Since 1970, productivity has relied on Antibiotic Growth Promoters (AGP), with an estimated annual industrial requirement of 1.02 million tons (Soeharsono, 2010; Nahrowi *et al.,* 2021). This dependence has resulted in a sustainability challenge within the national poultry sector.

Long-term AGP use has caused a global antimicrobial resistance epidemic that affects human health. To address this serious threat, the European Union and Indonesia (Ministry of Agriculture Regulation No. 14/2017) have banned the inclusion of antibiotics in animal feed (Markovic *et al.,* 2009; Soeharsono, 2010; Hidayat *et al.,* 2018), forcing the development of safe, sustainable alternatives. Curcumin, the primary component of curcuminoids, emerges as a viable AGP alternative in poultry farming due to its established antioxidant, immunomodulatory, antibacterial, and hypolipidemic characteristics. However, conventional methods have low bioavailability due to inefficient absorption, fast biotransformation, and quick systemic clearance (Sundari *et al.,* 2014; Hidayat, 2018). Therefore, nanotechnology is a rational way to improve pharmaceutical performance.

Previous studies have demonstrated that nanocurcumin increases bioavailability by about 60 times and enhances tissue distribution (Rahmani *et al.,* 2018), thus nearing the efficacy of AGP while improving broiler meat quality (Sundari *et al.,* 2013; Hidayat *et al.,* 2018). Electrospinning-based PVA-curcumin nanofibers emerge as innovative feed additives and potential growth promoters. This study aims to synthesize these nanofibers and test their applicability in broiler chickens, addressing a research gap. The working hypothesis is that nanoparticle curcumin can effectively replace AGP. Therefore, this study aims to synthesize, characterize, and evaluate the potential of PVA-curcumin nanofibers as an AGP substitute in improving broiler chicken growth performance

MATERIALS AND METHOD

Time and Location of Research

The research was conducted from December 2023 to April 2024 at various locations, including the Pharmacy Installation of Ratu Zalecha Regional General Hospital, the Pharmaceutical Laboratory of FMIPA and Integrated University of Lambung Mangkurat, the PT Mikro Material Laboratory in Bogor, and Chicken Coop Berkah Usaha Pendi (Figure 1A; 3°24′47.0″S, 114°47′32.0″E) in partnership with CV. BAJA.

Tools and Materials

Equipment utilized in this study included a dissolution tester (TDT-208L), a UV-Vis spectrophotometer (Genesys 10S), an analytical balance (Ohaus

Figure 1. Map of the location and condition of the research cage for (A) position on Google Map, (B) conditions outside the cage, and (C) conditions inside the cage

PA224), and preparation devices (mini grinder, Mollar; blender, Maspion). Materials comprised PVA (Sigma, P1763), curcumin (Merck, S8350354), and 30 vaccinated Day-Old Chicks (DOC) of the Cobb strain (Nobilis COR4+IB+ND+EDS, PT SHS Int). The feeding regimen consisted of basal feed (Hi-Pro-Vite CP 511), as detailed in Table 1, supplemented with premix (Masamix-Bro).

Production of PVA-curcumin Nanofibers

PVA–curcumin solutions (at concentrations of 5%, 10%, and 15%) were prepared by homogenization at 850 rpm for 24 hours (Wirahadikesuma *et al.,* 2024). These solutions were then electrospinned at a distance (spinneret-collector) of 3–5 cm, a flow rate of 10 mL/hour, and a voltage of 20 kV DC. The resulting nanofiber filaments were sectioned to a thickness of 2–4 mm, milled with a modified razor grinder (Gillette, Goal), and homogenized with the base feed before administration to the test animals.

Characterization of PVA-curcumin Nanofibers

The morphology of the filament fibers was analyzed using Scanning Electron Microscopy (SEM) and *ImageJ software*. The release profile of curcumin from the nanofibers was assessed by a dissolution test in Phosphate-Buffered Saline (PBS) at pH 7.4 and 37°C, with UV absorbance measurement at a wavelength of $\lambda = 427$ nm, according to Konain *et al.* (2023).

Broiler Chicken Growth Performance Test

The broiler chicken growth performance testing was conducted *in vivo* for 7 days, starting at 1 day of age, in accordance with ethical approval No. 589/UMB/KE/IX/2023. The research employed a Completely Randomized Design (CRD) with six test subjects per group. A total of thirty DOC chickens were used, in accordance with Federer's calculations. Rearing was carried out in raised cages in boxes (60x40x30 cm) according to CV. BAJA technical standards and under the supervision of the technical team (Figure 1B-C).

The five treatment groups were designated as follows:

- P1: Basal feed without additions (negative control)
- P2: Basal feed with pure curcumin (positive control)
- P3: Basal feed with PVA5%-curcumin
- P4: Basal feed with PVA10%-curcumin
- P5: Basal feed with PVA15%-curcumin

Supplementation (in pure form or PVA-curcumin nanofiber) was given at a dose of 33.33 mg/kg feed, which is equivalent to a total of 100 mg/3 kg in feed.

- Body Weight Gain (BWG, g) = Final body weight (g) – Initial body weight (g)
- Feed Intake (FI, g) = Feed given (g) – Remaining feed left (g)

$$\text{Conversion Feed Ratio (FCR)} = \frac{\text{Total increase in body weight (g)}}{\text{Total accumulated feed consumption (g)}}$$

Statistical Analysis

Nanofiber characterization data were analyzed descriptively, while chicken performance data were analyzed using ANOVA statistics.

Table 1. Composition and nutrient content of basal ration

| Product Name	Hi-Pro-Vite CP 511
Type	Complete granular feed for the broiler starter phase
Nutrient Composition	Specification
Moisture	Maximum 13%
Crude Protein	21,5–23,8%
Crude Fat	Maximum 5%
Crude Fiber	Maximum 5%
Ash	Maximum 7%
Calcium (Ca)	Minimum 0,9%
Phosphorus (P)	Minimum 0,6%
Aflatoxin	Maximum 50 ppb
Metabolizable Energy (ME)	3025–3125 kcal/kg
Ingredients	Maise (corn), rice bran, soybean meal, broken wheat, corn gluten meal, meat, and bone meal, calcium, phosporus, vitamins, trace minerals

RESULTS

Characteristic Results: Scanning Electron Microscope (SEM) and Dissolution Test

SEM examination (Figure 2): PVA10%/Cur has a nanofiber shape (135 ± 0,002 nm), PVA5%/Cur is mostly beads (100 ± 3,1 nm), and PVA15%/Cur is porous (1480 ± 3,1 nm). Figure 3 shows curcumin release profiles at 5 min (F1 = 50,9%, F2 = 51,5%, F3 = 43,5%) and at 120 min (64,5%) compared to other formulations.

Supplementation Results

The results of supplementation for 7 days (Table 2; Figure 4, and Figure 5) showed no significant differences (p>0.05) in ADG, FI, and FCR.

The relationship between the synthesized nanofiber properties, their drug release kinetics, and the resultant in vivo biological response in broiler chickens is comprehensively summarized in Table 3.
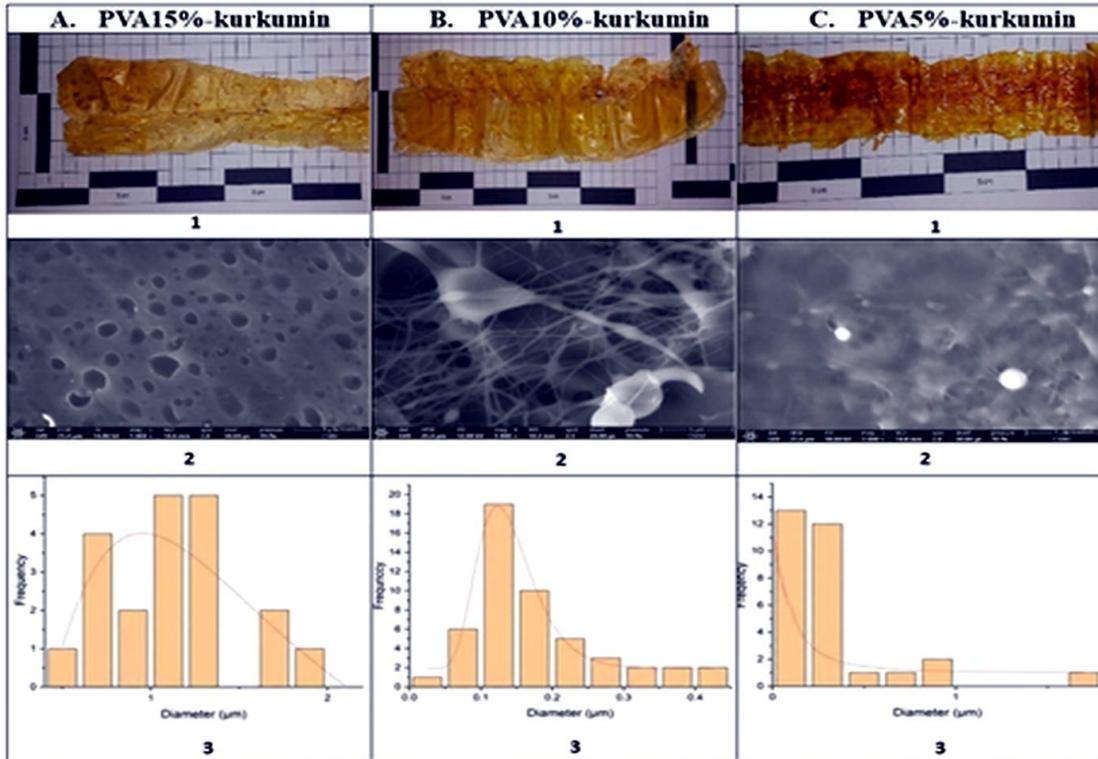
Note: (1) A/B/C = PVA-curcumin filament; (2) SEM image 5000X magnification; (3) ImageJ nanofiber size distribution graph; PVA-curcumin fiber morphology at various PVA concentrations: (A) 15%, (B) 10%, and (C) 5%; (1) Based on macroscopic photos; (2) SEM image; (3) diameter histogram; the most ideal nanofiber formation was formed at a PVA10% concentration; PVA15% porous film concentration; PVA5% dominated by beads.

Figure 2. Morphology of PVA-curcumin in the form of filament/film photos, SEM, and diameter for (A) PVA15%/Cur, (B) PVA10%/Cur, and (C) PVA5%/Cur
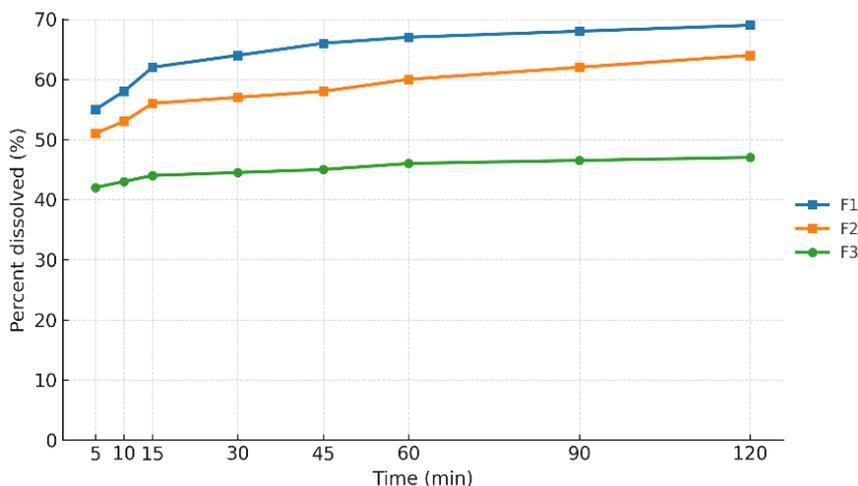

Figure 3. Graph of the percentage of curcumin dissolved in the sample with time

Table 2. Performance of broiler chickens in the 1st week of treatment for 7 days

Perfor- mance vari- ables	Treatment Groups					ANOVA Analysis	
	P1	P2	P3	P4	P5	F	Sig.
ADG (g)	107,06± 44,6	115,4± 59,2	108,11± 48,0	99,49± 33,6	108,01± 35,0	0,526	0,717
FI (g)	112,2± 66,5	128,07± 71,2	126,8± 64,3	118,76± 64,9	129,11±61,1	0,086	0,986
FCR	1,167± 0,52	1,0±0,43	0,921± 0,23	0,984± 0,34	0,922± 0,23	0,110	0,978

Notes: Values are mean ±SD. P1 = negative control, P2= curcumin, P3= treatmen 1 (PVA 5% + curcumin); P4= treatmen 2 (PVA 10% + curcumin). ADG = Average Daily Grain; FI= Feed Intake; FCR = Feed Conversion Ratio.
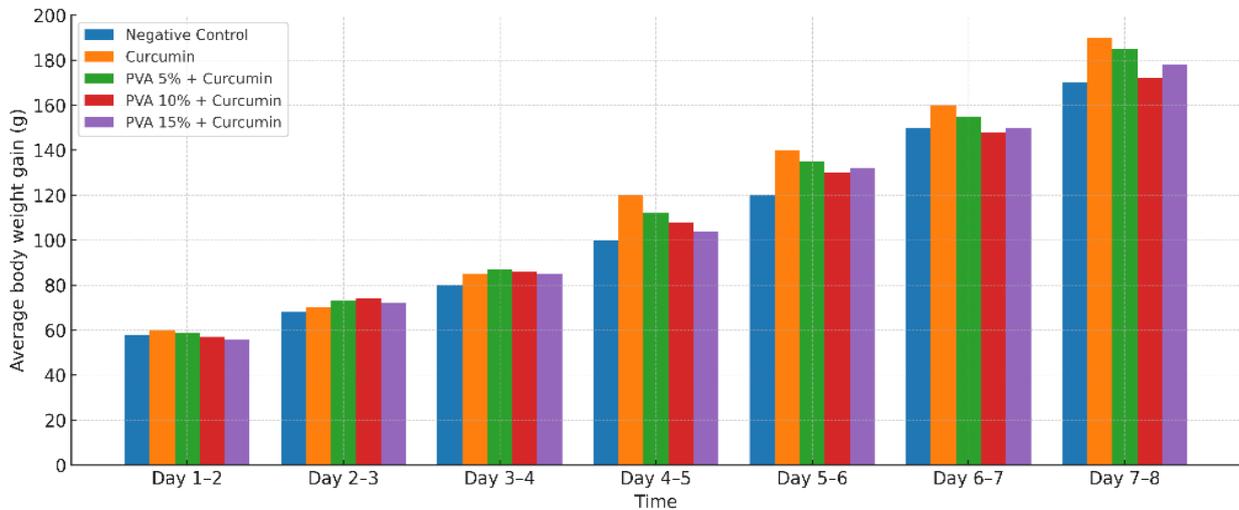

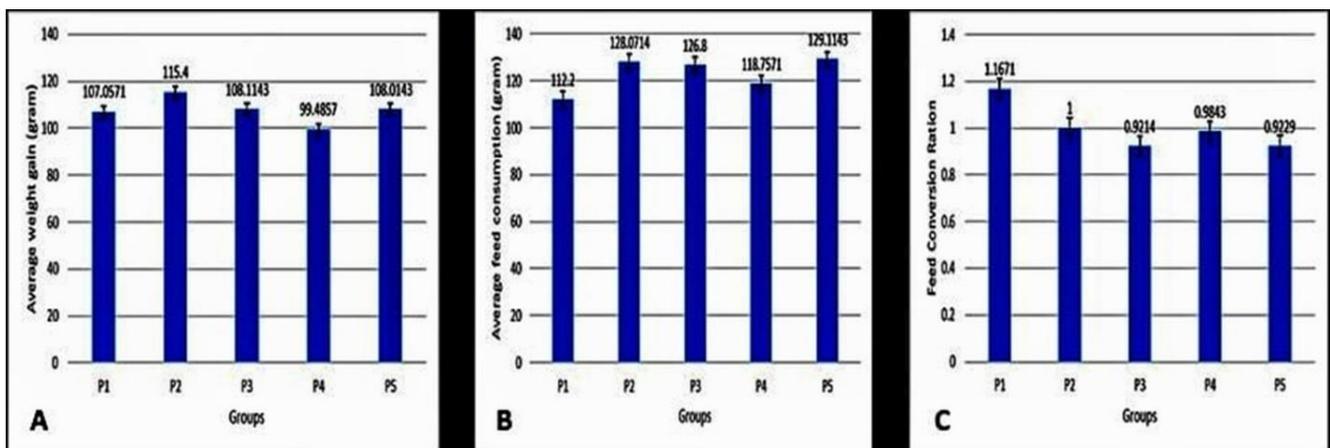Figure 4. Graph of average daily body weight of chickens during treatment (7 days)

Figure 5. Average graph of broiler chicken growth performance in week 1 including (A) graph of average daily body weight growth of broiler chickens, (B) graph of average daily feed consumption, and (C) FCR (*Feed Conversion Ratio*)

Table 3. Relationship PVA– curcumin nanofiber morphology, dissolution test results (5 and 120 minutes), and broiler growth performance (for 7 days)

Treatment Group (P1–P5)	Supplementation	Nanofiber	Dissolution Test		Growth Performance
		Morphology (SEM)	Cumulative Curcumin Released, 5 min (%)	Cumulative Curcumin Released, 120 min (%)	ADG; FI; FCR (mean±SD)
P1	Control negative (without curcumin)	—	—	—	ADG: 107,05 ± 44,57 FI: 112,2 ± 66,5 FCR: 1,17 ± 0,52
P2	curcumin without nanofiber	—	—	—	ADG: 115,4 ± 59,17 FI: 128,1 ± 71,17 FCR: 1,00 ± 0,43
P3	PVA 5%-curcumin	Beads dominant	50,9	63,35	ADG: 108,11 ± 48,01 FI: 126,8 ± 64,3 FCR: 0,921 ± 0,23
P4	PVA 10%-curcumin	uniform/fairly ideal fiber	51,5	64,5	ADG: 99,49 ± 33,56 FI: 118,76 ± 64,93 FCR: 0,984 ± 0,34
P5	PVA 15%-curcumin	Porous film	43,5	49,27	ADG: 108,01 ± 35,03 FI: 129,11 ± 61,1 FCR: 0,922 ± 0,23

Notes: Values are mean ±SD. P1 = negative control, P2= curcumin, P3= treatmen 1 (PVA 5% + curcumin); P4= tratmen 2 (PVA 10% + curcumin). ADG = Average Daily Grain; FI= Feed Intake; FCR = Feed Conversion Ratio; Min= Minutes

DISCUSSION

Relationship between Characterization and Growth Performance

SEM analysis revealed that a 10% PVA concentration produced optimal nanofibers with a diameter of 135 ± 0,002 nm, while 5% PVA resulted in beads (100 ± 3,1 nm) due to a high flow rate (10 mL/h) affecting jet stretching (Wirahadikesuma *et al.*, 2024; Aung *et al.*, 2021). Electrospinning parameters, including the spinneret-collector distance, influenced the solvent evaporation time, directly impacting fiber morphology (Kumarage *et al.*, 2022). Conversely, the 15% PVA concentration failed to form nanofibers but instead created a macroporous matrix (1480 ± 3,1 nm) due to high viscoelasticity, which inhibited jet stretching.

The linear relationship between PVA concentration and viscosity explains the macroporous structure of 15% PVA and the beaded fibers of 5% PVA (Kumarage *et al.*, 2022). Figures 2C1, 2B1, and 2A1 showed a decrease in yellow color intensity with increasing PVA concentration, indicating better curcumin integration in the PVA nanofiber matrix (Martien *et al.*, 2012; Zaheer *et al.*, 2024). Despite surface aggregation, PVA-curcumin compatibility is maintained at the nanometer scale.

In vitro PVA-curcumin release assay

Formulation F3, a nanofiber of PVA 15%-curcumin (PVA 15%/Cur), shown in Figure 3, exhibits the slowest curcumin release kinetics profile with the highest retention (50,73% at the 120th minute) due to matrix density and strong drug-polymer interactions (Chou and Woodrow, 2017; Alkarri *et al.*, 2024). The controlled release characteristics, influenced by variations in PVA concentration through polymer-curcumin interactions, are expected to make pharmaceutical preparations candidates for gradual delivery systems with high stability and bioavailability (Mahmud *et al.*, 2020; Liu *et al.*, 2020; Konain *et al.*, 2023).

Growth performance of broiler chickens aged 1–7 days (in vivo)

In vivo testing was conducted for 7 days on Day-old Chickens (DOC) to evaluate the influence of PVA-curcumin supplementation. This dose selection considers the safety and optimal bioavailability of nanocurcumin, in accordance with the effectiveness of a dose of 10–100 mg/kg of feed in improving broiler performance (Zhang *et al.*, 2024; Hernández-García *et al.*, 2025). Treatment during this first period, which begins on Sunday, is based on the critical phase mentioned, where there is 20–25% of total growth with an increase in body weight of up to

total growth with an increase in body weight of up to 300% and a rapid maturation of the digestive system (Ravindran & Abdollahi, 2021). Nutritional response during this period is a strong predictor of long-term performance, making it an ideal indicator for early evaluation of supplementation effectiveness (Lamot, 2017).

Among the treatment groups, Group P2 had the highest average daily gain (ADG) at 115,4 g/head, while Group P5 recorded the highest feed intake (FI) at 129,11 g/head, resulting in feed conversion ratios (FCR) between 0,921 and 1,16. Although these differences were not statistically significant (P>0,05), optimal growth during the starter period is crucial for development until harvest (Listyasari & Purnama, 2022; Umaternate & Horhoruw, 2023). Figure 5B shows that Group P5 also achieved the highest feed consumption in favorable conditions (Oktavia et al., 2021; Sultan et al., 2023). Additionally, the raised cage system enhances comfort by reducing manure vapor exposure (Irwan et al., 2022). The FCR range of 0,921–1,16 indicates better efficiency than the reports of Irwan et al. (2022) and Sultan et al. (2023), which has important economic implications, considering that feed contributes 60–70% of production costs.

These findings are consistent with research by Rahmani et al. (2017), which confirmed that significant differences between free curcumin and nano formulations are often undetectable in short-term studies. The critical relevance of the starter phase as a predictor of harvest performance is reflected in its contribution of 20–25% of total growth, with a 300% increase in weight and rapid maturation of the digestive system (Ravindran & Abdollahi, 2021; Lamot, 2017). The positive trend in first-week performance (especially FCR in the nanofiber group) indicates that curcumin intervention in the starter phase has the potential to maximize long-term feed efficiency, in line with the review by Martinez et al. (2022), which stated a strong correlation between increased body weight gain (BWG) in the early phase and improved final FCR.

Pharmacokinetically, free curcumin is more soluble, rapidly absorbed, and produces peak plasma levels earlier. Conversely, curcumin in nanofiber form exhibits sustained release characteristics, which lead to a periodic release of curcumin and provide a more consistent pharmacological effect, although this results in a slower onset (Liu et al., 2020; Moniruzzaman & Min, 2020).

This delayed response explains why the effects of curcumin nanofibers were not statistically optimal in the first week, as the sustained release system requires a longer duration to reach optimal therapeutic concentrations (Zhang et al., 2024). This indicates that the slow-release system in nanofibers/nanoparticles causes a delayed onset of action, while free curcumin has a rapid onset but a shorter duration of effect. This delayed response suggests that nanofibers are more suitable for prolonged or chronic effects rather than rapid effects in the starter phase of chickens (Mahmud et al., 2020; Konain et al., 2023; Zhang et al., 2024).

Previous studies indicate that curcumin and nanocurcumin improve broiler growth, immunity, and health by enhancing nutrient digestibility and digestive enzyme secretion (Badran et al., 2020; Sundari et al., 2013). They can modulate growth gene expression (IGF-1, GHR), suppress inhibitory genes (MSTN, leptin), and boost immune responses (Hafez et al., 2022; Ashry et al., 2022). Nanocurcumin's higher bioavailability and gastrointestinal stability lead to optimized long-term physiological effects (Badran et al., 2020; Ashry et al., 2022; Hafez et al., 2022).

PVA-curcumin nanofiber morphology modulates curcumin release and impacts broiler chicken growth performance

The PVA-curcumin nanofiber morphology directly modulates curcumin release and its impact on broiler chicken growth performance (Table 3). The 10% PVA-curcumin formulation (supplementation group P4), with its relatively ideal nanofiber morphology, proved most effective in releasing curcumin in a controlled manner, in line with the basic principles of drug delivery systems to enhance bioavailability (Liu et al., 2020). The implications of these results are reflected in broiler performance, where data indicate that nanofiber supplementation did not result in the highest average daily body weight gain (ADG). Nevertheless, this technology did numerically improve feed efficiency, although the results were not statistically significant. This increased efficiency was evident by the lower feed conversion ratio (FCR) compared to the negative control. This increased efficiency is thought to occur due to the slow and steady release of curcumin in the gastrointestinal tract, which optimally maintains the health and integrity of the intestinal epithelium, possibly mediated by molecular pathways supporting cell proliferation (Konain et al., 2023). This research confirms that the advantages of nanotechnology are not only the potential to stimulate growth but also to increase nutrient utilization to achieve higher production efficiency.

From a One Health perspective, this finding represents valuable *proof of concept* demonstrating that PVA-curcumin nanofibers are a safe and sustainable technology platform as an AGP alternative with biological activity in the form of a better FCR trend. For livestock farmers, this technology promises long-term feed efficiency, which is the largest component of production costs (60–70%). It is highly feasible to develop by optimizing the dosage of a preventive solution for antimicrobial resistance, which threatens human, animal, and environmental health (Irwan *et al.,* 2022; Umatenerte & Horhoruw, 2023).

PVA-curcumin nanofibers (100–135 nm) released 43,5–51,5% at minute 5 and 49,27–64,5% at minute 120 after synthesis and analysis. In the initial part of the 7-day *in vivo* assessment, all nanofiber groups showed a numerically higher feed efficiency trend (FCR 0,921–0,984) compared to the negative control, although the results were not statistically significant ($p > 0,05$). The 10% PVA formulation, which demonstrated the optimal morphology and maximal release rate, is identified as the best candidate AGP alternative formulation. PVA-curcumin nanofibers were created, characterized, and tested as AGP replacements for broiler growth during proof-of-concept. Only if the trial time is extended to the harvest phase and dose-frequency adjustment is used may meaningful impacts be expected to meet objectives and not exceed expectations.

Nanofibers' functional superiority over pure curcumin must be confirmed by demanding its nanotechnology model, extending *in vivo* testing to the harvest phase, and measuring the gradual release effect and dose optimization.

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