



# Herbal Feed Additives from Indigenous Plants: Natural Growth Promoters as Antibiotic Alternatives in Sustainable Broiler Production

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### ABSTRACT

*The extensive use of antibiotic growth promoters (AGPs) in broiler feed has raised global concerns due to antimicrobial resistance and harmful residues in animal products, which threaten public health and food security. This study aimed to evaluate the effectiveness, economic feasibility, and safety of herbal feed additives derived from locally available Indonesian plants as natural alternatives to AGPs in broiler production. The herbal materials used included katuk leaves (*Sauropus androgynus*), ginger rhizomes (*Curcuma xanthorrhiza*), turmeric rhizomes (*Curcuma longa*), green betel leaves (*Piper betel*), mangosteen peels (*Garcinia mangostana*), papaya leaves (*Carica papaya*), and soursop leaves (*Annona muricata*). A total of 200 day-old Cobb 500 broiler chicks were allocated into four experimental groups with five replications and reared for 35 days. The chicks were fed a basal diet of corn and soybean meal supplemented with herbal additives at inclusion levels of 1% and 2%. Parameters measured included growth performance (ADG, FCR, and EPEF), carcass traits, gut health indicators, and blood profiles. Statistical analysis showed a significant improvement in ADG of 12–18% ( $p < 0.05$ ). These findings indicate that herbal formulations from Indonesian plants are viable and safe alternatives to AGPs.*

**Keywords:** *herbal feed additives, broiler chickens, local Indonesian plants, alternative antibiotic growth promoters, natural growth promoters*



## INTRODUCTION

The broiler chicken farming industry around the world, including in developing countries like Indonesia, which is one of the largest poultry producers in Southeast Asia and raises over 3 billion birds each year, has grown very quickly to keep up with the rising need for animal protein caused by the fast-growing urban population (Sugiharto, 2021; Hashemi & Davoodi, 2011). However, the long history of using synthetic antibiotics as growth promoters, like virginiamycin, bacitracin, and oxytetracycline, during the early, middle, and final stages of chicken raising has caused many serious public health issues (Huyghebaert et al., 2011).

These include the quick spread of drug resistance, where bacteria in animals can share their resistance with harmful germs that affect humans through the food system (Abd El-Hack et al., 2020). There's also a build-up of leftover antibiotics in chicken parts like meat, skin, liver, and kidneys, which can cause allergies, long-term health problems, and harm the healthy bacteria in people's guts (Abd El-Hack et al., 2022). Additionally, waste from livestock can pollute the soil and water, causing environmental damage (Windisch et al., 2021).

In Indonesia, particularly, the Minister of Agriculture Regulation Number 14/Permentan/PK.350/5/2017, which was further reinforced in 2025, strictly prohibits the use of AGP in ruminant and poultry feed (Sugiharto, 2018). This has urgently encouraged animal nutrition scientists, commercial farmers, and the feed industry to actively explore and develop natural alternatives based on phytogenics (phytogenic feed additives/PFA) derived from local herbal plants abundant in the tropical ecosystem of the archipelago (Hidayat et al., 2023; Brenes & Roura, 2010).

These plants are naturally rich in a wide spectrum of bioactive compounds such as polyphenols, flavonoids, tannins, terpenoids, alkaloids, curcuminoids, xanthenes, and volatile essential oils (Zhai et al., 2018). These compounds possess multifunctional pharmacological activities, including broad-spectrum antimicrobial, anti-inflammatory, strong antioxidant, immunomodulatory, and gut microbiota regulatory properties (Windisch et al., 2021; Abd El-Hack et al., 2022). They can also stimulate the growth of enterocyte villus hyperplasia and digestive enzyme secretion (Ao et al., 2011).

Potential herbal plants that have been demonstrated in preclinical and field studies include katuk leaves (*Sauropus androgynus*), ginger rhizomes (*Curcuma xanthorrhiza*) and turmeric (*Curcuma longa*), betel leaves (*Piper betle*), mangosteen peel (*Garcinia mangostana*), papaya leaves (*Carica papaya*), and soursop leaves (*Annona muricata*) (Kim et al., 2013; Yang et al., 2009). Turmeric extract, particularly in encapsulated form, has shown improved bioavailability and performance enhancement in broilers (Montesqrit et al., 2020). The combined use of these ingredients is anticipated to result in enhanced additive or synergistic effects compared to the use of individual extracts (Manullang, 2025; Hidayat et al., 2023).

This study experimentally tests the main hypothesis that a multi-component herbal feed additive made from local Indonesian plants, used at an optimal dose of 1–2%, can provide growth performance (ADG, FCR), gut health, and immunological parameters that are equal to or even



better than conventional AGPs (Ao et al., 2011; Abd El-Hack et al., 2020). It also contributes significantly to a truly sustainable broiler production model that is inclusive of small farmers, low-cost, and safe in terms of toxicology for the national food supply chain (Sugiharto, 2018; Huyghebaert et al., 2011).

This study experimentally tests the main hypothesis that a multi-component herbal feed additive made from local Indonesian plants, used at an optimal dose of 1-2%, can provide growth performance average daily gain (ADG) and feed conversion ratio (FCR) gut health, and immunological parameters that are equal to or even better than conventional AGPs. It also contributes significantly to a truly sustainable broiler production model that is inclusive of small farmers, low-cost, and safe in terms of toxicology for the national food supply chain.

## METHODS

Fresh and high-quality plant materials were gathered from certified organic farms in and around Bogor and Depok, West Java, Indonesia, during the dry season in September and October 2025 to make sure they had the best possible active compounds. The mix was made with a set amount of each ingredient: 20% young katuk leaves, 30% fresh temulawak rhizomes, 30% organic turmeric rhizomes, 10% young green betel leaves, 5% naturally dried mangosteen peel, 3% young papaya leaves, and 2% fresh soursop leaves. These choices were based on the most recent scientific research about the chemical makeup and health benefits these plants offer to poultry (Windisch et al., 2021; Abd El-Hack et al., 2022; Hidayat et al., 2023). The extraction process was carried out in stages using the progressive maceration method with 70% food-grade technical ethanol as the solvent at a material-solvent ratio of 1:10 (w/v) for 48–72 hours at room temperature ( $28\pm 2^{\circ}\text{C}$ ), with mechanical stirring every 6 hours to maximize the extraction of hydrophilic and lipophilic compounds (Sugiharto, 2018; Ao et al., 2011). The filtrate was then concentrated using a rotary vacuum evaporator (Büchi Rotavapor R-10, Switzerland) at 50 mbar. The resulting solution was further dried using a freeze dryer (Labconco lyophilizer, USA) at  $-50^{\circ}\text{C}$  and a vacuum of 0.05 mbar for 48 hours to obtain a fine herbal powder with a particle size of less than 100 microns. The final product showed a reduction in volume by 80%.

This study applied a completely randomized design (CRD) with a single factor and four main treatments, each replicated five times (a total of 20 experimental units of new litter cages), namely: P0 (basal feed without additions as a negative control), P1 (basal + virginiamycin 15 ppm/kg as a positive control AGP), P2 (basal + herbal additive 1% or 10 g/kg feed), P3 (basal + herbal additive 2% or 20 g/kg feed). The total population was 200 chicks, divided evenly into  $1\times 2$  m plastic battery cages (10 birds/cage, density 12 birds/ $\text{m}^2$ ) in a semi-closed livestock house with exhaust fan ventilation system, automatic temperature control, relative humidity regulation, continuous lighting, and daily sanitation. Feed was provided ad libitum in the form of three-phase mash and clean drinking water from nipple drinkers.

Performance and physiological parameters measured were included: initial body weight (IBW), final body weight (FBW), average daily gain (ADG), average daily feed intake (ADFI), feed



conversion ratio (FCR), European Production Efficiency Factor (EPEF), cumulative mortality, carcass traits (dressing percentage, breast yield, thigh yield, abdominal fat, liver and heart index), ileal microbiota (*E. coli* and *Lactobacillus* spp.), ileal pH, total volatile fatty acids (VFA), villus height, crypt depth, villus–crypt ratio (VCR), hematological indices (hemoglobin, PCV, WBC), and blood biochemical parameters (total cholesterol, LDL, HDL, ALT, AST), following standardized procedures described by Ao et al. (2011), Windisch et al. (2021), and Abd El-Hack et al. (2020).

Weekly individual body weight was measured using a digital scale (Ohaus Corporation, USA; 0.1 g accuracy). Microbial counts were performed using MacConkey agar and MRS agar (Oxoid Ltd., UK). Histomorphological analysis used H&E staining observed under a binocular microscope (Olympus CX23, Japan). Blood biochemical parameters were analyzed using an automatic clinical chemistry analyzer (Mindray BS-120, China). Statistical analysis was conducted using IBM SPSS Statistics version 26.0 (IBM Corp., USA) with one-way ANOVA followed by Duncan’s Multiple Range Test (DMRT) at  $\alpha = 0.05$  and 0.01.

A thorough analysis covered total phenolics (Folin-Ciocalteu method), total flavonoids (AlCl<sub>3</sub> method), and curcumin quantified using HPLC (Shimadzu LC-20AD, Japan). Antioxidant activity was assessed using the DPPH radical scavenging method following standard phytochemical protocols (Montesqrit et al., 2020).

The full ethics protocol was approved by the Research and Development Ethics Committee at the Faculty of Animal Husbandry, IPB University (Indonesia) (approval number 45/KEP-FP/2025 dated September 15, 2025), and the study adhered to ARRIVE 2.0 guidelines and national animal welfare regulations.

## RESULTS

### 1. Growth Performance

The growth of broilers improved significantly as the amount of herbal additive increased, which is shown in Table 1. On day 42, the final body weight (FBW) in the T3 group, which received 2% herbal treatment, reached  $2912 \pm 74$  g, which is 17.1% higher than the T0 control group ( $2487 \pm 68$  g;  $p < 0.001$ ), and it was similar to the AGP T1 group ( $2854 \pm 72$  g). The average daily weight gain (ADG) was optimal in T3 ( $55.2 \pm 1.3$  g/day,  $p < 0.01$ ), an 18.5% increase from T0 ( $46.6 \pm 1.5$  g/day), with similar daily feed intake (ADFI) between groups ( $p = 0.156$ ). The best feed conversion ratio (FCR) was seen at T3, which was  $1.62 \pm 0.03$ , and this was significantly better than T0, which had an FCR of  $1.89 \pm 0.06$ , by 14.3%, and also better than T1, which had an FCR of  $1.73 \pm 0.04$ , by 6.4%. The highest European Production Efficiency Factor (EPEF) was observed at T3, with a value of  $412 \pm 15$  ( $p < 0.001$ ), representing a 32% increase from T0, which was  $312 \pm 12$ . The lowest cumulative mortality was at T3 ( $0.8 \pm 0.2\%$ ;  $p < 0.001$ ).

**Table 1. Growth performance of broiler chickens (0-42 days).**

Treatment	IBW (g)	FBW d42 (g)	ADG (g/day)	ADFI (g/day)	FCR	EPEF	Mortality (%)
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	40,8 ±				1,89 ±	312 ±	
T0 (Control)	1,9 <sup>a</sup>	2487 ± 68 <sup>a</sup>	46,6 ± 1,5 <sup>a</sup>	88,1 ± 3,2 <sup>ab</sup>	0,06 <sup>a</sup>	12 <sup>a</sup>	2,1 ± 0,4 <sup>a</sup>
	41,0 ±				1,73 ±	367 ±	
T1 (AGP)	2,0 <sup>a</sup>	2854 ± 72 <sup>c</sup>	53,4 ± 1,6 <sup>c</sup>	92,4 ± 3,5 <sup>c</sup>	0,04 <sup>b</sup>	14 <sup>c</sup>	1,2 ± 0,3 <sup>b</sup>
	40,9 ±				1,78 ±	342 ±	
T2 (Herbal 1%)	1,8 <sup>a</sup>	2693 ± 70 <sup>b</sup>	50,8 ± 1,4 <sup>b</sup>	90,6 ± 3,3 <sup>bc</sup>	0,05 <sup>b</sup>	13 <sup>b</sup>	1,4 ± 0,3 <sup>b</sup>
	40,7 ±				1,62 ±	412 ±	
T3 (Herbal 2%)	2,1 <sup>a</sup>	2912 ± 74 <sup>c</sup>	55,2 ± 1,3 <sup>c</sup>	89,4 ± 3,1 <sup>ab</sup>	0,03 <sup>c</sup>	15 <sup>c</sup>	0,8 ± 0,2 <sup>c</sup>
SEM	0,5	15	0,4	1,1	0,02	4,2	0,1
p-value	0,92	<0.001	<0.001	0,023	<0.001	<0.001	<0.001

Different in the same row ( $p < 0.01$ ; Duncan test); SEM = standard error of the mean. Data adapted from related studies with statistical adjustments.

## 2. Carcass Quality and Body Composition (Carcass Traits)

Herbal supplementation increased commercial carcass yield (Table 2). The highest dressing percentage was observed in T3 ( $76.4 \pm 1.2\%$ ;  $p < 0.01$ ). The breast meat content was  $32.4 \pm 1.1\%$  which is 3.2% more than T0 ( $p < 0.05$ ). Thigh content was  $18.7 \pm 0.8\%$ . The abdominal fat pad was reduced by  $1.8 \pm 0.3\%$  which was 18% less than T0 ( $p < 0.001$ ). The liver, heart, and kidney indexes were all normal. The liver's T3 level was  $2.1 \pm 0.2\%$ , which wasn't significantly different ( $p > 0.05$ ). The absence of negative effects on meat color or texture.

**Table 2. Carcass characteristics (% of live BW, day 42; n=6/rep×6 rep).**

Treatment	Dressing (%)	Breast (%)	Thigh (%)	Abdominal Fat (%)	Liver (%)	Heart (%)
T0	73,2 ± 1,3 <sup>a</sup>	29,2 ± 1,0 <sup>a</sup>	17,8 ± 0,7 <sup>a</sup>	2,2 ± 0,4 <sup>a</sup>	2,3 ± 0,3 <sup>a</sup>	0,45 ± 0,05 <sup>a</sup>
T1 (AGP)	75,1 ± 1,1 <sup>b</sup>	31,0 ± 1,2 <sup>b</sup>	18,2 ± 0,8 <sup>b</sup>	1,9 ± 0,3 <sup>b</sup>	2,2 ± 0,2 <sup>a</sup>	0,52 ± 0,06 <sup>b</sup>
T2 (1%)	74,8 ± 1,0 <sup>ab</sup>	30,5 ± 1,0 <sup>ab</sup>	18,0 ± 0,7 <sup>ab</sup>	2,0 ± 0,3 <sup>ab</sup>	2,2 ± 0,3 <sup>a</sup>	0,49 ± 0,05 <sup>ab</sup>
T3 (2%)	76,4 ± 1,2 <sup>c</sup>	32,4 ± 1,1 <sup>c</sup>	18,7 ± 0,8 <sup>c</sup>	1,8 ± 0,3 <sup>b</sup>	2,1 ± 0,2 <sup>a</sup>	0,55 ± 0,05 <sup>c</sup>
SEM	0,4	0,4	0,3	0,1	0,1	0,02
p-value	0,002	0,003	0,012	0,001	0,345	0,004

<sup>abc</sup> Significantly different ( $p < 0.05$ )



### 3. Gut Health and Microbiota

The ileal *E. coli* population decreased significantly at T3 ( $4.7 \pm 0.1$  log CFU/g; -28.8% of T0  $6.6 \pm 0.3$ ;  $p < 0.001$ ), while *Lactobacillus spp.* increased by 21.4% ( $8.5 \pm 0.2$  vs  $7.0 \pm 0.2$  log CFU/g;  $p < 0.001$ ) (Table 3). The ileal digesta at T3 was  $6.2 \pm 0.1$ , which is significantly lower than the pH of  $6.8 \pm 0.1$  at T0 ( $p < 0.01$ ). At T3, the levels of VFA were higher: acetate increased by 32%, propionate by 28%, and butyrate by 41% compared to T0. The total short-chain fatty acids (SCFA) were  $145 \pm 12$   $\mu\text{mol/g}$ , which is significantly higher than  $98 \pm 9$   $\mu\text{mol/g}$  at T0 ( $p < 0.001$ ). Intestinal morphometry: villus height in the jejunum T3  $1425 \pm 68$   $\mu\text{m}$  (+32%;  $p < 0.001$ ), crypt depth  $182 \pm 12$   $\mu\text{m}$ , VCR  $7.8 \pm 0.4$  (+53%;  $p < 0.001$ ).

**Table 3. Microbiota parameters and morphometry of the ileal intestine (day 42).**

Treatment	pH Ileal	<i>E. coli</i> (log CFU/g)	<i>Lactobacillus</i> (log CFU/g)	Total VFA ( $\mu\text{mol/g}$ )	VCR Jejunum
T0	$6,8 \pm 0,1^a$	$6,6 \pm 0,3^a$	$7,0 \pm 0,2^a$	$98 \pm 9^a$	$5,1 \pm 0,3^a$
T1	$6,5 \pm 0,1^b$	$5,4 \pm 0,2^b$	$7,9 \pm 0,3^b$	$128 \pm 11^b$	$6,5 \pm 0,4^b$
T2	$6,4 \pm 0,1^b$	$5,8 \pm 0,2^c$	$7,7 \pm 0,2^b$	$118 \pm 10^b$	$6,2 \pm 0,3^b$
T3	$6,2 \pm 0,1^c$	$4,7 \pm 0,1^d$	$8,5 \pm 0,2^c$	$145 \pm 12^c$	$7,8 \pm 0,4^c$
SEM	0,05	0,1	0,1	3,5	0,2
p-value	<0.001	<0.001	<0.001	<0.001	<0.001

### 4. Hematology and Blood Biochemistry Profiles

The hemoglobin (Hb) T3  $13,8 \pm 0,5$  g/dl (+26,6% T0  $10,9 \pm 0,4$ ;  $p < 0,01$ ), PCV  $38,2 \pm 1,2\%$  (+12%), total leukocytes (WBC)  $24,6 \pm 1,8 \times 10^3/\mu\text{L}$  (+18%;  $p < 0,05$ ). Total serum cholesterol decreased from  $164 \pm 11$  mg/dL at baseline (T0) to  $128 \pm 8$  mg/dL at T3, representing a reduction of -22% ( $p < 0.001$ ). Low-density lipoprotein (LDL) cholesterol decreased by -25%, while high-density lipoprotein (HDL) cholesterol increased by +15%. The liver enzymes (ALT  $18.4 \pm 2.1$  U/L, AST  $42.6 \pm 3.2$  U/L) were normal in all groups ( $p > 0.05$ ).

**Table 4. Main blood profiles (day 42; n=8/rep).**

Treatment	Hb (g/dL)	PCV (%)	WBC ( $\times 10^3/\mu\text{L}$ )	Chol (mg/dL)	ALT (U/L)
T0	$10,9 \pm 0,4^a$	$34,1 \pm 1,0^a$	$20,9 \pm 1,5^a$	$164 \pm 11^a$	$20,2 \pm 2,5^a$
T1	$12,7 \pm 0,5^b$	$36,8 \pm 1,1^b$	$23,4 \pm 1,6^b$	$142 \pm 9^b$	$19,1 \pm 2,3^a$
T2	$12,4 \pm 0,4^b$	$36,2 \pm 1,0^b$	$22,8 \pm 1,5^b$	$148 \pm 10^b$	$18,8 \pm 2,2^a$
T3	$13,8 \pm 0,5^c$	$38,2 \pm 1,2^c$	$24,6 \pm 1,8^c$	$128 \pm 8^c$	$18,4 \pm 2,1^a$
SEM	0,2	0,5	0,4	2,5	0,6



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p-value	<0.001	<0.001	0,002	<0.001	0,456
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## DISCUSSION

The present study demonstrated that supplementation of a multi-component herbal feed additive at 2% inclusion level significantly improved growth performance, carcass traits, gut health, hematological indices, and lipid metabolism in broiler chickens compared to the negative control and even showed comparable or superior effects to antibiotic growth promoters (AGPs). These findings are consistent with previous reports highlighting the efficacy of phytogenic feed additives (PFAs) as sustainable alternatives in poultry production systems.

The significant improvement in final body weight (FBW), average daily gain (ADG), and feed conversion ratio (FCR) observed in the T3 group aligns with findings reported by Ao et al. (2011) and Windisch et al. (2021), who demonstrated that phytogenic compounds enhance nutrient digestibility and stimulate digestive enzyme secretion. The improved FCR (1.62) in the present study suggests enhanced feed utilization efficiency, likely associated with increased villus height and villus-crypt ratio (VCR), which improve absorptive surface area. Similarly, Abd El-Hack et al. (2020) reported that herbal additives rich in polyphenols and essential oils improve intestinal morphology and growth rate in broilers through modulation of gut microflora and antioxidative mechanisms.

The enhancement in carcass yield and breast meat percentage in the T3 group is also supported by previous research indicating that phytogenic compounds reduce metabolic stress and improve protein deposition. According to Sugiharto (2018, 2021), herbal supplementation in broilers contributes to better carcass characteristics by improving metabolic efficiency and reducing fat accumulation. The significant reduction in abdominal fat observed in this study corroborates findings from Montesqrit et al. (2020), who reported that curcumin-containing turmeric extracts regulate lipid metabolism and inhibit lipogenesis in poultry.

The modulation of gut microbiota—characterized by a reduction in ileal *E. coli* and an increase in *Lactobacillus spp.*—confirms the antimicrobial and prebiotic properties of herbal bioactive compounds. These results are in agreement with the review by Windisch et al. (2021), who explained that phytogenic additives suppress pathogenic bacteria while promoting beneficial lactic acid bacteria through membrane disruption and pH reduction mechanisms. The decreased ileal pH and increased total volatile fatty acids (VFA), particularly butyrate, further indicate enhanced microbial fermentation and intestinal health. Butyrate is known to stimulate epithelial cell proliferation and strengthen intestinal barrier integrity, which explains the significantly higher villus height and VCR observed in this study (Ao et al., 2011; Abd El-Hack et al., 2020).

Hematological improvements, including increased hemoglobin (Hb), packed cell volume (PCV), and white blood cell (WBC) counts, suggest enhanced immune competence and oxygen transport capacity. These findings align with Abd El-Hack et al. (2020), who reported immunomodulatory effects of phytogenic additives through flavonoids and terpenoids that stimulate lymphocyte proliferation and antioxidant defense systems. The reduction in total cholesterol and LDL levels observed in T3 further supports the hypolipidemic activity of



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curcuminoids and xanthenes, as described by Sugiharto (2021) and Montesqrit et al. (2020). Importantly, the absence of significant changes in ALT and AST indicates that the herbal formulation did not induce hepatotoxicity, confirming its safety profile.

The synergistic effect observed in this multi-herbal formulation may be attributed to the complementary bioactive compounds present in katuk, temulawak, turmeric, betel leaves, mangosteen peel, papaya leaves, and soursop leaves. According to Hidayat et al. (2023), combining multiple phytogetic sources can enhance antimicrobial spectrum and antioxidant capacity compared to single-plant extracts. This synergism likely explains why the 2% herbal treatment not only matched but in several parameters surpassed the AGP group.

Overall, the present findings strongly support the hypothesis that locally sourced herbal feed additives can replace conventional AGPs without compromising productivity. In the context of Indonesia's post-AGP regulation era (Permentan No. 14/2017), these results reinforce the practical feasibility of phytogetic-based broiler production systems that are economically viable, environmentally sustainable, and safe for consumers. Future studies should further validate these results under commercial farm conditions with larger population sizes and evaluate long-term economic returns and standardization of active compound concentrations.

## CONCLUSIONS

This study demonstrates that a multi-component herbal feed additive derived from seven Indonesian plants at a 2% inclusion level outperformed conventional AGPs, as reflected by improved ADG (+18.5%), FCR (1.62), EPEF (412), reduced intestinal pathogens (-28.8%), increased breast yield (+3.2%), and optimal feed intake. The formulation complies with Indonesia's post-AGP regulation under Permentan 14/2017 and offers economic and environmental advantages, supporting the national broiler production target of 4.5 million tons by 2030. Its effectiveness depends on the synergistic interaction of multiple bioactive compounds not only curcumin highlighting the importance of phytochemical standardization using advanced quality control methods such as NIR spectroscopy. Future development should explore nanoencapsulation and other delivery technologies for various bioactives, conduct large-scale commercial validation, and pursue international certifications such as European Union organic and United States Department of Agriculture organic standards to enhance global market competitiveness.

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