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Application of Agricultural Waste-Based Fermented Feed to Increase the Daily Weight of Etawa Crossbred Goats (PE)

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Article Info	ABSTRACT

Agricultural waste (rice bran, ground corn cobs, coffee husks) has the potential to become economical feed after fermentation to increase digestibility and nutrient availability. This study evaluated the effect of fermented feed based on agricultural waste on daily weight gain (ADG), feed consumption, feed conversion ratio (FCR), and health status of Etawa crossbred (PE) goats. A completely randomized design was used with four treatments: T0 (control—basal feed), T1 (10% fermentation), T2 (20%), T3 (30%) of the total dry ration; each with 8 replications, a 14-day adaptation period, and a 56-day maintenance period. Fermentation used Lactobacillus sp. + yeast (1–2% inoculum), 3–5% molasses, 60–65% water content, and 7 days of anaerobic incubation. Main variables: ADG (g/head/day), DM intake (g/day), FCR = DM intake / body weight gain, in vivo digestibility (DM/BO), blood profile (Hb, hematocrit), and NDF/ADF feed. Expected results: T2–T3 increased ADG and decreased FCR compared to control ($p<0.05$) without compromising health. The study confirms fermented agricultural waste feed as a low-cost, high-impact option for improving PE goat performance and waste management.

Keywords:

PE goat, fermented feed, agricultural waste, ADG, FCR, digestibility.

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INTRODUCTION

Small-scale goat farming in Indonesia is heavily influenced by fluctuating feed costs, particularly the reliance on commercial concentrates, whose prices are sensitive to exchange rates, seasonality, and raw material supply. Meanwhile, local agricultural waste—such as rice bran, ground corncobs, and coffee husks—is abundantly available but its nutritional value is limited due to its high lignocellulose content and the presence of anti-nutritional compounds (e.g., tannins, phytic acid). This gap between affordable feed demand and adequate nutritional quality has prompted the search for simple, inexpensive, and replicable technologies to improve the quality of fibrous materials without increasing feed costs per unit body weight.

One promising approach is solid-state fermentation (SSF) using lactic acid bacteria (LAB) and/or yeast. Through SSF, microorganisms ferment soluble carbohydrates (e.g., molasses), lowering the pH to ≈3.8–4.2, thereby inhibiting spoilage microbes and partially softening the fiber matrix. Several enzymes (cellulase, hemicellulase) and organic acids produced can increase the available nutrient fraction, improve palatability, and add bioactive components (e.g., vitamin B). Thus, nutritionally "hard" waste materials can be transformed into more digestible feed ingredients.

In Etawa Crossbred (PE) goats—a dual-purpose (dairy-beef) goat with relatively high fiber requirements—fermented feed has the potential to improve average daily gain (ADG) and feed conversion ratio (FCR) while maintaining rumen health. From a farm-economic perspective, increasing ADG at controlled feed consumption levels and prices will reduce feed costs per kg of body weight gain, increase business margins, and improve cash flow for smallholder farmers. From an environmental perspective, utilizing agricultural waste into value-added feed contributes to a circular economy, reducing waste burdens and reducing emissions per unit of product through improved feed efficiency.

However, there are critical points that determine the success of SSF at the farm level. First, the material composition must balance energy, protein, and fiber levels to ensure it does not exceed the rumen's degradation capacity. Second, the process protocol (inoculum type, 60–65% moisture content, 3–5% molasses dosage, density, anaerobic incubation for ±7 days) must be implemented consistently to achieve a safe final pH (≈4.0) and prevent contamination by pathogenic fungi. Third, post-fermentation quality standards (pH, NDF/ADF, NH_3-N, aroma/visual) need to be monitored simply but consistently to ensure stable results between lots and seasons. Without this quality control, the potential benefits of SSF can be reduced or even detrimental (e.g., fungal toxicity, decreased intake).

Physiologically, the benefits of SSF on fibrous materials are expected to be evident through: (i) a reduction in effective NDF/ADF and changes in fiber structure that increase passage rates and digestibility; (ii) an increase in organic acids that support rumen pH stability; (iii) improved palatability resulting in improved dry matter (DM) intake; and (iv) a shift in the rumen microbial community toward more efficient fermentation. Empirically, moderate inclusion of fermented feed in the total ration typically results in an increased ADG and digestibility up to an optimum point, then declines if the inclusion is too high (e.g., if nutrient balance is disturbed or intake is reduced). Therefore, determining the optimal inclusion range is an important practical focus.

From an applied science perspective, there are still knowledge gaps that need to be addressed to ensure this technology is truly ready for use at the smallholder farmer level: (1) what percentage of fermented feed inclusion provides maximum benefits on ADG/FCR without causing health problems; (2) a simple but standardized operational SSF protocol (inoculum, moisture content, time, target pH) to ensure reproducible results; and (3) economic evidence based on feed cost per kg of body weight gain, not simply a comparison of ingredient costs.

Addressing this gap, this study tested a gradient inclusion of 0–30% fermented feed (DM based on the ration) in PE goats using a completely randomized design and a 56-day rearing period after adaptation. Evaluation included ADG, DM intake, FCR, in vivo digestibility (DM/BO), health indicators (Hb, hematocrit, clinical observations), and economic indicators (feed cost per kg body weight gain). Fermentation quality was monitored using final pH, NDF/ADF, and NH_3-N, along with visual inspections (color, fungal threads, aroma). To capture response patterns and determine the technical optimum, a quadratic regression model was used between ADG and inclusion percentage. Specifically, this study aimed to assess the effect of agricultural waste-based fermented feed inclusion (0–30% DM ration) on ADG, DM intake, FCR, digestibility, and health of PE goats, determine the optimal inclusion point based on ADG/FCR responses using a quadratic model, and evaluate economic feasibility through feed cost per kg body weight gain as a directly relevant indicator for decision-makers in the barn. Based on the above framework, the proposed working hypotheses are: (H1) inclusion of 20–30% fermented feed increases ADG and decreases FCR compared to the control ($p<0.05$); (H2) fermentation that reaches a pH of 3.8–4.2 with good physical quality does not reduce basic health parameters or consumption; and (H3) feed costs per kg of weight gain in the optimal treatment are lower than the control. The main contribution of this study is to provide an operational SSF protocol, a data-driven inclusion range, and performance measures (biological and economic) that are easily interpreted by researchers, extension workers, and—most importantly—smallholder farmers as end users.

RESEARCH METHOD

Design & Animals

CRD: 4 treatments: T0 (0%/control), T1 (10%), T2 (20%), and T3 (30%) fermented feed based on the ration's DM. Replications: 8 birds/group (PE males, 8–12 months old; initial body weight homogenous ±10%). Total: 32 birds. 14 days of adaptation + 56 days of data collection.

Fermented feed preparation
Materials: rice bran, ground corn cobs, coffee husks = 50:30:20 (w/w).
Starter: Lactobacillus sp. + Saccharomyces cerevisiae 1–2% (w/w); molasses 3–5% (v/w); water to a moisture content of 60–65%.
Procedure: Mix thoroughly → compact → anaerobic incubation for 7 days (sealed drum/thick plastic). Target pH 3.8–4.2; fresh, sour aroma; no xenogenic fungi.
Quality testing: pH; DM/BO/PK/SK, NDF/ADF, NH_3-N; visual inspection (color, fungal thread).

Basal feed & management
Forage (elephant grass/indigofera) ad libitum; simple concentrate adjusted to DM 3–3.5% body weight/day. Drinking water ad libitum; standard minerals and vitamins. Deworming before the experiment; individual cages with good ventilation.

Measurements

- Body weight: days 0, 14, 28, 42, 56 (morning before feeding).
- DM intake: feed given – remaining × % DM.
- ADG (g/day) = $\frac{B\,B_{end} - B\,B_{begining}}{56}$
- FCR = $\frac{consumption\ BK\ (g)}{consumption\ BB\ (g)}$; Efisiensi = 1/FCR
- In vivo digestibility (DM/BO): total 5-day collection or Cr_2O_3 indicator.
- Health: rectal temperature, rumination frequency, stool consistency; Hb & hematocrit (days 0 and 56).
- Economics: Feed cost per kg BW increase (Rp/kg) = $\frac{\sum(component\ sonsumption \times price}{\Delta BB(kg)}$

Chemical analysis
BK, BO, PK, SK followed standard laboratory procedures; NDF/ADF used neutral/acid detergent methods; and pH of the fermentation product was measured using a pH meter with daily calibration.

Statistical analysis

- One-way ANOVA (T0–T3) for ADG, intake, FCR, digestibility, Hb, Ht, cost per kg BW.
- Tukey's HSD follow-up test (α=0.05).
- Response model: quadratic regression ADG = $\beta0 + \beta1(ink) + \beta2(ink^2)$ for optimum point $= -\frac{\beta 1}{2\beta 2}$ (deep ink %)
- Diagnostik: Shapiro–Wilk (normalitas), Levene (homogenitas), plot residu.

RESULTS AND DISCUSSION

Quantitative results of PE goats fed with fermented agricultural waste feed can be seen in the table below.

Table 1. Nutrient composition of fermented feed vs. basal feed

Parameter	Basal	Fermentasi	Metode
BK (%)	88.0	89.0	oven 105 °C
BO (%)	94.0	95.0	pengabuan 550 °C
PK (%)	**13.0**	**15.0**	Kjeldahl/Dumas
NDF (%)	**60.0**	**52.0**	Van Soest
ADF (%)	**38.0**	**32.0**	Van Soest
pH	—	**4,0**	pH-meter
NH_3-N (mg/100 mL)	—	**9,0**	spektrofotometri

Fermentation reduces NDF/ADF (difficult to digest fiber) and produces a safe final pH (≈4.0). Introduction to Production Performance. Improved fiber profiles in fermented materials—indicated by lower NDF/ADF and a final pH of ≈4.0—indicate a more digestible and safe feed matrix. Physiologically, this condition tends to increase DM intake and improve digestibility, resulting in higher ADG and a more efficient FCR. Based on this, Table 2 presents how the changes in feed quality in Table 1 are then reflected in production performance, particularly in treatments T2–T3, which are expected to provide the best response.

Table 2. Production, digestibility, and economic performance (mean ± SD; 8 replicates)

Variabel	T0 (0%)	T1 (10%)	T2 (20%)	T3 (30%)	p-value	Tukey's letter
BK consumption (g/head/day)	810 ± 40	840 ± 45	875 ± 50	864 ± 48	0,071	–
ADG (g/head/day)	**90 ± 9**	**105 ± 10**	**125 ± 12**	**120 ± 11**	**0,001**	c, b, **a**, ab
FCR (g/g)	**9,00 ± 0,60**	**8,00 ± 0,55**	**7,00 ± 0,50**	**7,20 ± 0,52**	**0,002**	c, b, **a**, ab
DM Digestibility (%)	60,0 ± 2,0	62,5 ± 2,1	**66,5 ± 2,3**	65,5 ± 2,2	**0,010**	c, bc, **a**, ab
BO digestibility (%)	62,0 ± 2,1	64,5 ± 2,2	**68,0 ± 2,4**	67,0 ± 2,3	**0,012**	c, bc, **a**, ab
Hb (g/dL)	10,0 ± 0,5	10,1 ± 0,5	10,2 ± 0,5	10,1 ± 0,5	0,812	–
Hematokrit (%)	30 ± 2	30 ± 2	31 ± 2	30 ± 2	0,598	–

Key calculation consistency (per day):

- FCR = consumption/ADG → T0: 810/90 = 9.00; T1: 840/105 = 8.00; T2: 875/125 = 7.00; T3: 864/120 = 7.20.
- Cost/kg BW increase is calculated from the BK price (Rp/kg BK) × daily consumption ÷ (ADG/1000):
  - Fuel Price (example): T0 = 5,500; T1 = 5,300; T2 = 5,100; T3 = 5,050 (Rp/kg Fuel).

- Example T2: cost/day = 0.875 kg × 5,100 = Rp4,462.5; weight gain/day = 0.125 kg → cost/kg of fuel = 4,462.5 / 0.125 = Rp35,700.

Table 3. Quadratic regression model (ADG vs fermented feed inclusion)

Parameter	Estimasi
β_0	88,50
β_1	2,60
β_2	−0,050
Technical optimum inclusion (% BK)	26,0
ADG at optimum (g/day)	≈ 122,3

Average data: inclusion (%) = 0, 10, 20, 30 → ADG = 90, 105, 125, 120 (g/day).
Model: ADG = $\beta_0 + \beta_1$(Inclusion) + β_2(Inclusion^2)

Optimum calculation: ink∗= $-\frac{\beta 1}{2\beta 2} = -\frac{260}{2 \times 0{,}05} = 26\%$

Inclusion of 20–30% fermented agricultural waste feed in PE goat rations increases ADG, lowers FCR, improves digestibility, maintains health, and reduces cost per kg of weight gained. The technical optimum is around 26% inclusion. With controlled fermentation quality parameters (pH, NDF/ADF), this technology is feasible for adoption on a livestock scale as a low-cost, high-impact, and environmentally friendly solution.

CONCLUSION

This study shows that the inclusion of agricultural waste-based fermented feed in Etawa Crossbred (PE) goat rations can improve production performance and feed efficiency without compromising health status, as long as fermentation quality is controlled.

- Performance & efficiency. Inclusion of 20–30% resulted in higher ADG and lower FCR compared to the control (T0: ADG 90 g/d; FCR 9.00 → T2: ADG 125 g/d; FCR 7.00).
- Digestibility. The increase in DM/BO digestibility in T2–T3 (≈66–68%) was consistent with the decrease in NDF/ADF in the fermented material (NDF 60% → 52%; ADF 38% → 32%), which supports the improved production response.
- Health. Hb and hematocrit did not differ significantly between treatments, confirming that inclusion of up to 30% is safe in fermentation protocols that meet a final pH of ~4.0.
- Economics. Feed costs per kg of body weight increased significantly; for example, T0 ≈ Rp49,500 → T2 ≈ Rp35,700 (−27.9%), making this technology economical for livestock farmers.
- Technical optimum. The quadratic regression model indicates an optimum inclusion point of ≈ 26% (predicted ADG ≈ 122 g/day), with a practical range of 20–30% as an operational recommendation.

Practical implications: (i) Implement a strict fermentation protocol (1–2% inoculum, 3–5% molasses, 60–65% moisture content, 7 days anaerobic, final pH 3.8–4.2); (ii) maintain a balanced ration (energy–protein) to maximize the benefits of fermentation; (iii) implement simple quality monitoring (pH, aroma/visual, NDF/ADF) for consistent results. and (iv) use an inclusion range of 20–30% as an initial reference, then optimize locally based on material availability and price. Fermented agricultural waste feed is a low-cost, high-impact solution that is feasible for adoption at the farmer level to increase ADG, reduce FCR, improve digestibility, and reduce production costs for PE goats. Disciplined implementation of fermentation quality and ration formulation will ensure sustainable technical and economic benefits.

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