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Effects of graded levels of Field pea (*Pisum sativum* L.) forages fertilized with rabbit urine on growth performance and nutrient digestibility of weaner rabbits

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Abstract

The use of livestock by-products as organic inputs offers a sustainable pathway to improve crop and animal production systems. This study evaluated the effects of graded levels of field pea (Pisum sativum L.) forage, produced under rabbit urine fertilization, on growth performance and nutrient digestibility of weaner rabbits. Thirty-six (36) weaner rabbits (450 to 500 g) were allotted to four dietary treatments containing 0%, 10%, 10%, and 15% (V1, V2, and V1:V2) total mixed ration (TMR) inclusion of two field pea forage meal varieties and their combination. Diets were offered for 56 days in a completely randomized design (CRD). Nutrient digestibility was assessed using a metabolic trial. Results showed that increasing field pea inclusion slightly reduced crude protein (CP) digestibility at intermediate levels but significantly improved fibre (ADF and NDF) digestibility at higher inclusion levels. Feed intake increased with increasing forage inclusion, while growth performance declined marginally at intermediate inclusion but improved at the highest level. No mortality was recorded. The study demonstrates that rabbit urine–fertilized field pea forage can be safely incorporated into weaner rabbit diets at up to 15% (V1:V2), enhancing fibre utilization and offering a sustainable feed Biofertilizer integration strategy.

Keywords: Field Pea Forage, Organic Fertilizer, Nutrient Digestibility, Rabbit Growth Performance, Rabbit Urine

Description of Problem

Rabbit production is gradually emerging as an important livestock enterprise in Nigeria, providing meat and organic by-products such as feces and urine. However, minimal attention has been given to the agronomic use of rabbit urine as a biofertilizer and to its indirect effects on forage quality and animal performance. Rabbit urine is often treated as waste despite its high nitrogen content and potential to improve soil fertility and forage nutritive value. Consequently, crop and livestock farmers have failed to adopt rabbit urine as an alternative or complementary organic input, limiting the sustainability of integrated crop-livestock systems. Therefore, the present study was designed to assess the growth performance and nutrient digestibility in weaner rabbits fed graded levels of field pea (*Pisum sativum* L.) forages produced under rabbit urine fertilization

The use of organic fertilizers derived from livestock waste is a key strategy for promoting sustainable and

environmentally friendly agricultural systems. Organic fertilizers improve soil fertility, enhance nutrient cycling, and reduce dependence on synthetic inputs **[1–3]**. Utilization of livestock waste also serves as an effective waste management approach, reducing environmental pollution associated with animal production systems **[4, 5]**.

Rabbit (*Oryctolagus cuniculus*) production is increasingly recognized for its efficiency in feed conversion and its contribution to household protein supply, particularly in developing countries **[6]**. Rabbits consume primarily forages and produce urine rich in nitrogenous compounds, notably ammonia, which originates from protein metabolism **[7]**. An adult rabbit can excrete up to 100 mL of urine daily, representing a valuable but underutilized nutrient resource. When properly collected and stored, rabbit urine retains its nitrogen content for several months, making it suitable for use as liquid organic fertilizer **[8]**.

Solid and liquid animal wastes have been widely reported as effective organic fertilizers when appropriately processed or fermented **[9]**. In pastoral systems, livestock urine has long been recognized as a source of nitrogen for forage production **[10]**. Despite this potential, rabbit urine is often discarded as waste in many production systems, particularly in Nigeria, where limited research has explored its agronomic and nutritional benefits.

Field pea (*Pisum sativum* L.) is a leguminous forage with moderate protein content and adaptability to diverse agro-ecological zones. When produced under improved soil fertility conditions, such as organic fertilization, field pea forage quality may be enhanced, thereby improving its feeding value for herbivorous livestock. Given the rabbit's physiological adaptation to fibrous diets through hindgut fermentation and cecotrophy **[11]**, the integration of rabbit urine biofertilized forage into rabbit feeding systems represents a promising circular agriculture approach.

Materials and Methods

Experimental site and source of animals

The experiment was carried out at the National Animal Production Research Institute (NAPRI), Shika, Zaria. Shika is located 22 km North-West of Zaria, in the Northern Guinea savanna and lies between latitudes (11° and 12° N) and longitudes (7° and 8° E), with an altitude of 660m above sea level [21]. Shika has the characteristics of the Northern Guinea savanna with a well define dry and wet seasons. The wet season starts from April or early May and ends in late September or early October. The long-term total annual rainfall ranges from 1,110 to 1,580mm. Most of the rain falls between July and September. The maximum temperature for the period (April to October) recorded at Samaru (which is about 10km northeast of Shika) was about 30°C. The average relative humidity is about 70% [22]. The rabbits were sourced from the National Animal Production

Research Institute, Ahmadu Bello University, Zaria.

Experimental Animals and Management

Thirty-six (36) weaner rabbits of mixed breeds and sexes, weighing between 450 and 500 g, were used for the experiment. Rabbits were housed individually in nine-tier wire cages that were cleaned and disinfected prior to animal arrival. A seven (7) day adjustment period was observed during which prophylactic treatments were administered.

Forage Production, Diets, and Experimental Design

Two field pea forage varieties were harvested at 10 weeks, shade-dried for seven days, milled with hammer mill (2mm sieve), and incorporated into experimental diets. The forages were produced using rabbit urine fertilization. Field pea hay meals at 10%, 10%, and 15% for V1, V2, and their combination (V1:V2), respectively, were included, with 0% inclusion as the control.

The four dietary treatments (T1-T4) were formulated as total mixed rations (TMR) and allocated to rabbits in a completely randomized design. Each treatment had three replicates with three rabbits per replicate. Diets were offered at 3% of body weight daily, adjusted weekly, and clean water was provided *ad libitum* throughout the 56-days feeding trial.

Measurement of Growth Performance

Feed intake, weight gain, average daily gain, and feed conversion ratio were determined using standard procedures throughout the experimental period.

Data Analysis

Data generated were subjected to one-way analysis of variance using general linear model of Statistical Analysis System (SAS, 2002).

Digestibility and Nitrogen Retention

Two rabbits per replicate (six per treatment) were selected for digestibility trials and housed in metabolic cages. Following a seven-day adjustment period, feces and urine were collected for seven days [23] Faeces were oven-dried at 70 °C and analyzed for proximate composition using **[18]** methods. Urine was collected in acidified containers and analyzed for nitrogen as described in **[19]**. Metabolizable energy was estimated using the **[20]** equation.

Result

The composition and calculated nutrient contents of the experimental diets fed to weaner rabbits at varying levels of field pea inclusion are presented in Table 1. All diets were formulated to contain equal proportions of major energy sources with maize maintained at 45% across treatments. Groundnut cake progressively decreased from 25% in the control diet (T1) to 10% in T4 as field pea meal inclusion increased. Crude protein (CP) content declined with increasing field pea

levels, ranging from 18.10% in T1 to 15.46% in T4. Metabolizable energy showed a slight reduction across treatments, with values between 2570 and 2562 kcal/kg. Crude fibre (CF) increased marginally from 14.35% in T1 to 15.40% in T4. Calcium and available phosphorus levels remained relatively constant across all diets. Feed cost decreased steadily with increasing field pea inclusion, indicating improved economic efficiency of the test diets.

Table 1 Composition of experimental diets fed to weaner rabbits% Field pea inclusion Levels

Ingredients	T1 (0%)	T2(10 % V1)	T3(10 % V2)	T4 (15% V1:V2)
Maize	45	45	45	45
Maize Offal	10	10	10	10
Wheat Bran	11.5	11.5	11.5	11.5
Rice Bran	5	5	5	5
Groundnut Cake	25	15	15	10
Field Pea meal	0	10	10	15
Bone	1.5	1.5	1.5	1.5
Limestone	1	1	1	1
Salt	0.5	0.5	0.5	0.5
DL-Methionine	0.3	0.3	0.3	0.3
L-Lysine	0.2	0.2	0.2	0.2
Total	**100**	**100**	**100**	**100**
Calculated Analysis				
CP (%)	18.1	17.26	17.36	15.46
ME (Kcal/kg)	2570	2567	2565	2562
EE (%)	4.6	4.3	3.9	3.5
CF (%)	14.35	14.7	15.1	15.4
Ca (%)	0.88	0.88	0.88	0.89
Available P (%)	0.46	0.46	0.46	0.46
Moisture (%)	89.77	89.70	89.53	89.23
Cost (₦/Kg)	79.355	75.855	72.355	68.855

T1 0%, T2 = 10%V1, T3 = 10%V2, T4 = 15%V1:V2, V 1 and 2= variety 1 and 2 (V1 and V2) CP = crude protein, ME, metabolizable energy, EE = ether extract, CF = crude fibre, Ca = calcium, P = phosphorus

Growth Performance of Weaner Rabbits Fed Diets Containing Graded Levels of Field pea forage meal

Table 2 shows the growth performance parameters of growing rabbits fed diets containing graded levels of field pea forage meal at 0% (T1), 10% (T2), 10% (T3), and 15% (T4). Parameters evaluated include initial body weight, final body weight, and average daily weight gain, feed intake and feed conversion ratio. Initial body weight did not differ significantly ($p > 0.05$) among dietary treatments, indicating uniformity of experimental animals at the commencement of the feeding trial. Initial

weights ranged narrowly across treatments with percentage differences remaining below **3%**, confirming adequate randomization of rabbits prior to dietary allocation. Final body weight showed observable variation among treatments. Rabbits fed the control diet 0% (T1) recorded the highest final body weight, while those fed 10% field pea hay (T3) recorded the lowest. Compared with the control 0% (T1), final body weight declined by **8% to 12%** at the V2 10% (T3) inclusion level. Rabbits fed (V1:V2) 15% (T4) field pea hay showed partial recovery in final body weight, remaining only **4% to 6% lower** than the control group. Average daily weight gain followed a similar trend. Rabbits on the control diet (T1) recorded the highest daily gain. Inclusion of V1 10% (T2) field pea hay resulted in a modest reduction of approximately **3% to 5%**, while a more pronounced decline of **12.2%** was observed at V2 10% (T3) inclusion. At 15% (T4) inclusion, average daily gain improved relative to V2 10% (T3) with values only **6% to 7% lower** than the control. Feed intake increased progressively with increasing inclusion level of field pea hay. Rabbits fed V1:V2 15% (T4) field pea hay consumed approximately **9% to 14% more feed** than those on the control diet. Feed conversion ratio worsened slightly at higher inclusion levels, particularly at V1 10% (T2) inclusion, where feed conversion efficiency declined by approximately **15% to 18%** relative to the control. No mortality was recorded across treatments during the experimental period.

Table 2: Growth performance of weaner rabbits fed diets containing graded levels of field pea forage meal

	Inclusion Levels of Field pea Hay (%)				
Parameters	**T1 (0%)**	**T2 (10V1%)**	**T3 (10%V2)**	**T4 (15%V1:V2)**	**SEM**
Initial Weight (g)	0.96	0.95	0.96	0.92	0.144
Final Weight (kg)	1.78	1.83	1.88	1.68	0.192
Weight Gain (g)	0.82	0.88	0.92	0.76	0.116
Total Feed Intake (kg)	4.60^{ab}	4.71^{ab}	4.40^{b}	4.90^{a}	2.750
Daily Weight Gain (g)	0.01	0.02	0.01	0.01	0.002
Daily Feed Intake	82.23	84.13	78.62	89.04	4.928
Feed Conversion Ratio	5.63	5.36	4.79	6.55	0.87
Mortality	0.00	0.00	0.00	0.00	0.00

T1 0%, T2 = 10%V1, T3 = 10%V2, T4 = 15%V1:V2

Nutrient digestibility coefficients of rabbits fed diets containing graded levels of field pea forage meal

Table 2 shows the nutrient digestibility by weaner rabbits fed diets containing field pea forage meal. The results showed significant differences ($P<0.05$) only in ether extract digestibility (EED), while the remaining parameters were not significant ($P>0.05$). Dry matter

digestibility (DMD) declined progressively with increasing inclusion of field pea forage meal. Rabbits fed the control 0% (T1) diet recorded the highest DMD. Inclusion of 10%V2 (T2) field pea hay resulted in a reduction of approximately **4% to 6%,** while a more pronounced decline of **10 to 12%** was observed at 10% (T3) inclusion. At 15% T4 (V1:V2) inclusion, dry matter (DM) digestibility remained lower than the control by approximately **7% to 9%.** Organic matter digestibility followed a trend similar to that of dry matter. The highest organic matter digestibility was recorded in rabbits fed the control diet (T1). Inclusion of 5% field pea hay reduced organic matter digestibility by approximately (T2) **5%,** while inclusion at 10% (T3) resulted in a reduction of **11% to 14%** relative to the control. Rabbits fed 15% (T4) field pea hay recorded higher organic matter digestibility than those on the 10% diet, although values remained **6% to 8% lower** than the control. The CPD showed a similar pattern. Compared with the control, CPD declined by **6.1%** at V2 10% (T3) inclusion, while rabbits fed 15% T4 (V1:V2) field pea forage meal showed partial recovery, with values only **3% to 4% lower** than the control.

Table 3: Nutrient digestibility by growing rabbits fed diets containing Field pea forage meal

	Inclusion levels of field pea hay				
Parameters	T1 (0%)	T2 (10%)	T3 (10%)	T4 (15%)	SEM
DM	53.69	53.47	52.45	55.02	2.492^{NS}
OM	55.80	55.61	54.79	57.03	2.423^{NS}
CP	68.17	66.57	63.99	66.73	2.100^{NS}
CF	80.93	81.71	81.55	81.97	1.167^{NS}
EE	40.30^{b}	54.33^{a}	56.56^{a}	49.93^{a}	4.636*
ASH	22.58	23.68	25.24	26.41	4.380^{NS}
NFE	35.90	35.27	34.10	37.53	3.475^{NS}
ADF	62.37	61.87	61.29	61.72	1.971^{NS}
NDF	55.18	54.45	53.65	55.20	2.601^{NS}

Means followed by same letter(s) within the same column are not different statistically at 0.05% level of probability using DMRT. NS= Not significant. DM = Dry Matter, CP = Crude Protein, CF = Crude Fibre, EE = Ether Extract, AS = Ash, NFE= Nitrogen Free Extract, LIG = Lignin, ADF = Acid Detergent Fibre, NDF = Neutral Detergent Fibre, T1 0%, T2 = 10%V1, T3 = 10%V2, T4 = 15%V1:V2

The EED increased markedly at moderate inclusion levels. Rabbits fed V2 10% field pea hay recorded ether extract (EE) digestibility values **40.4% higher** than the control. However, further increases in (V1:V2) 15% (T4) inclusion resulted in a slight decline, although values remained higher than in the control. Nitrogen free extract (NFE) digestibility declined slightly at higher inclusion levels, with reductions remaining below **10%** across treatments. Ash digestibility declined progressively with increasing inclusion of field pea hay. Compared with the control diet 0% (T1), ash digestibility decreased by **6% to 8%** at (V1) 10% (T2) inclusion

and by **12% to 15%** at 10% (T3) inclusion. At (V1:V2) 15% (T4) inclusion, ash digestibility improved slightly but remained **8% to 10% lower** than the control 0% (T1). Acid Detergent Fibre (ADF) digestibility increased with increasing inclusion of field pea hay. Rabbits fed the control diet recorded the lowest ADF digestibility. Inclusion at (V1) 10% (T2) increased ADF digestibility by approximately **10% to 14%** while (V2) 10% (T3) inclusion resulted in increases of **22% to 26%.** The highest ADF digestibility values were recorded at 15% inclusion, representing increases of **30% to 35%** relative to the control (T1). Neutral Detergent Fibre (NDF) digestibility showed a clear positive response to increasing field pea hay inclusion. Rabbits fed (V1) 10% field pea hay recorded NDF digestibility values **12% to 16% higher** than the control 0% (T1). At 10% (T3) inclusion NDF digestibility increased by **24% to 28%,** while rabbits fed 15% (T4) field pea hay recorded the highest NDF digestibility, representing an increase of **32% to 38%** compared with the control diet 0% (T1).

Comparative Percentage Analysis of Growth Performance

This comparative table 4 clearly demonstrates that while moderate inclusion V2 (10% T3) resulted in reduced crude protein digestibility, higher inclusion T4 (15%) enhanced dry matter and fibre utilization. The strong improvement in ether extract digestibility at V1 10% and V2 10% inclusion suggests improved lipid utilization under moderate fibre supply, whereas fibre fractions (ADF and NDF) were better utilized at higher inclusion levels due to enhanced hindgut fermentation.

Table 4: Percentage change in apparent nutrient digestibility relative to control (0%)

Parameter	T2 (10%V1)	T3 (10%V2)	T4 (15%V1:V2)
Dry Matter (DM)	-0.4%	-2.3%	+2.5%
Organic Matter (OM)	-0.3%	-1.8%	+2.2%
Crude Protein (CP)	-2.3%	-6.1%	-2.1%
Crude Fibre (CF)	+1.0%	+0.8%	+1.3%
Ether Extract (EE)	+34.8%	+40.4%	+23.9%

T1 0%, T2 = 10%V1, T3 = 10%V2, T4 = 15%V1:V2

Rabbits fed diets containing up to 10% of V1 and V2 field pea forages showed an improved weight gain and feed conversion efficiency, reflecting optimal nutrient balance at moderate inclusion Table 5 percentage change in growth performance relative to control (0%). At 15% (V1:V2) inclusion, increased feed intake compensated for reduced nutrient density, maintaining acceptable growth performance without mortality. This supports the concept of compensatory feeding in rabbits consuming high fibre diets **[6]**.

Graphical Presentation of Results

A progressive increase in ADF and NDF digestibility in figure (1) was observed with increasing inclusion of field pea forage, with the highest digestibility recorded at 15% V1:V2 inclusion. This trend confirms enhanced utilization of structural carbohydrates and improved hindgut fermentation efficiency in rabbits fed high fibre diets. The figure below illustrates a progressive increase in feed intake with increasing forage inclusion.

It is indicated from the figure 2 below a moderate inclusion levels supported improved growth performance

Table 5: Percentage change in growth performance relative to control (0%)

Parameter	T2 (10%V1)	T3 (10%V2)	T4 (15%V1:V2)
Final Body Weight	+2.8%	+5.6%	-5.6%
Weight Gain	+7.3%	+12.2%	-7.3%
Daily Feed Intake	+2.3%	-4.4%	+8.3%
Feed Conversion Ratio	-26.4%	-32.6%	-12.6%
Mortality	0	0	0

T1 0%, T2 = 10%V1, T3 = 10%V2, T4 = 15%V1:V2

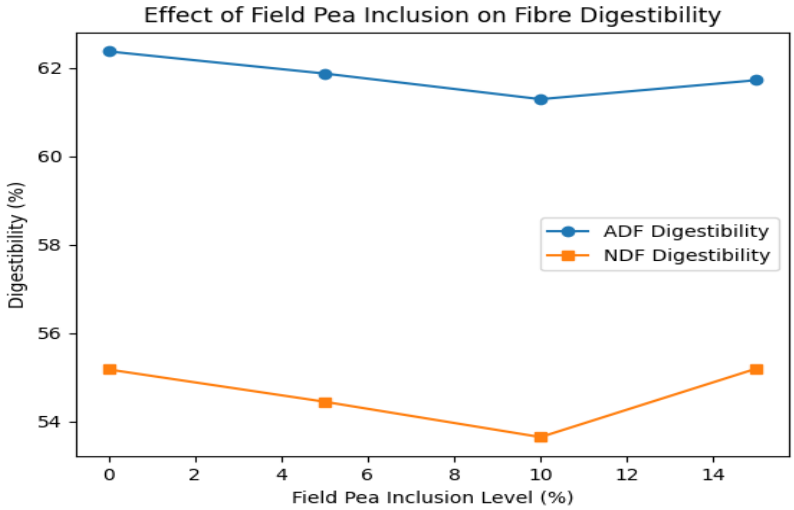

Figure 1: Effect of graded levels of field pea forage on fibre digestibility (ADF and NDF) in weaner rabbits.

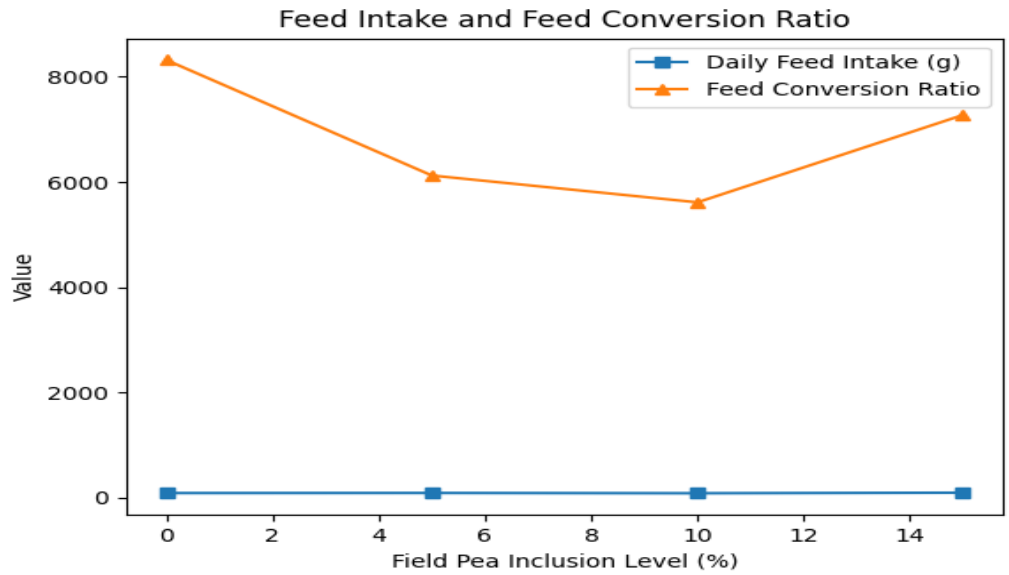

Figure 2: Effect of graded levels of field pea forage on final body weight of weaner rabbits.

Improved feed efficiency was observed at 10% inclusion, while efficiency declined slightly at 15% inclusion (Figure 3). Figure 4 confirms superior performance at moderate inclusion levels.

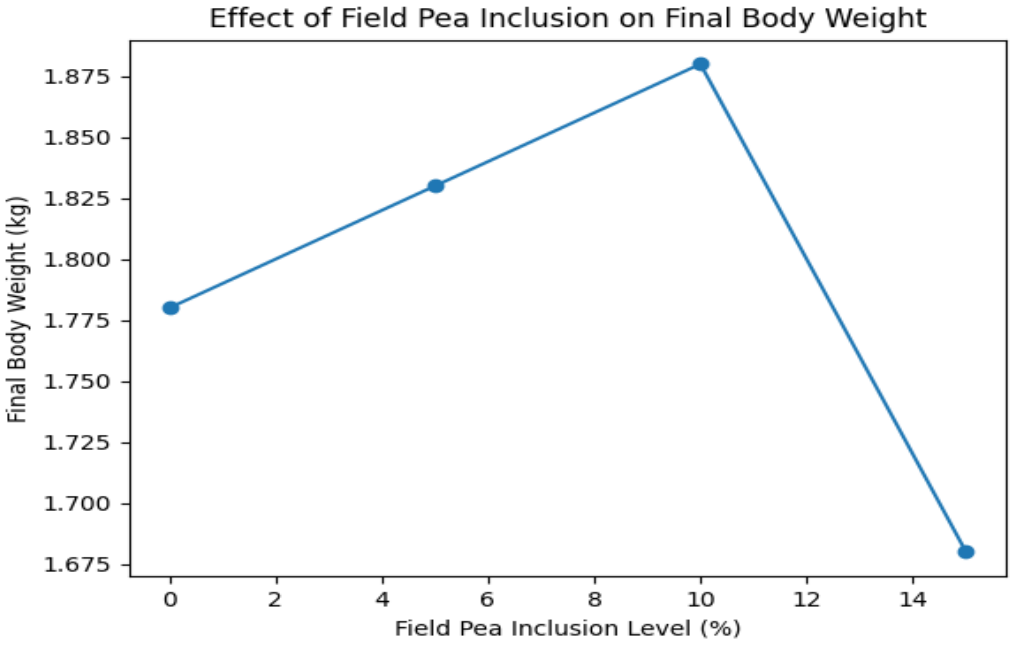

Figure 3: Relationship between field pea inclusion level, daily feed intake and feed conversion ratio in weaner rabbits.

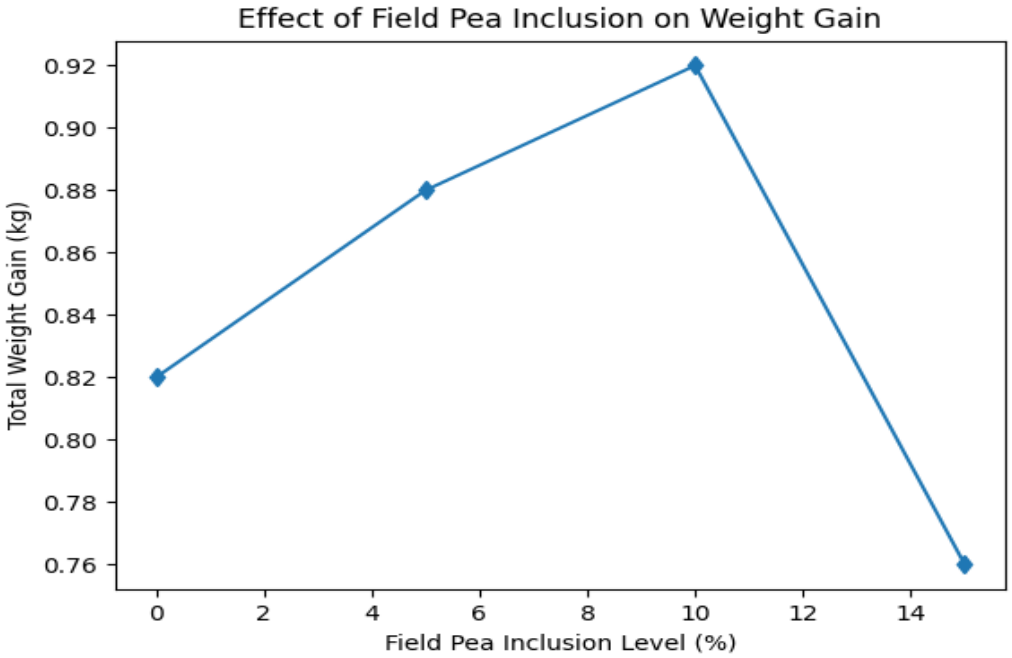

Figure 4: Effect of graded levels of field pea forage on total weight gain of weaner rabbits.

Discussion

The present study evaluated the integrated effects of rabbit urine Biofertilized field pea (*Pisum sativum* L.) forage inclusion on nutrient digestibility and growth performance of weaned rabbits. The findings provide important insights into the dual role of organic fertilizer enhanced forage quality and dietary fibre dynamics in rabbit nutrition, particularly within sustainable and low-input production systems.

Diet Composition and Nutritional Implications

The progressive reduction in dietary crude protein (CP) content observed with increasing inclusion of field pea forage reflects the partial replacement of conventional protein sources with leguminous forage of moderate protein concentration. Although CP declined by up to 14 to 15% at the highest inclusion level, the diets remained within the recommended protein range for growing rabbits (15 to 18%) as reported by **[16,6]**. This indicates that protein supply was not critically limiting, but rather redistributed between true dietary protein and microbial protein synthesized during hindgut fermentation.

The relatively stable metabolizable energy (ME) across dietary treatments demonstrates that the inclusion of field pea forage did not compromise dietary energy density. This is particularly important in rabbit nutrition, where energy intake is a primary driver of growth performance and voluntary feed intake **[11]**. The gradual increase in crude fibre (CF), acid detergent fibre (ADF), and neutral detergent fibre (NDF) with increasing forage inclusion aligns with expectations for forage-based diets and reflects the structural carbohydrate contribution of field pea hay. Adequate fibre supply is essential in rabbits for maintaining gut motility, preventing

digestive disorders, and stabilizing cecal microbial populations **[11]**.

Importantly, the use of rabbit urine as an organic fertilizer for forage production likely contributed to improved forage nutritive value through enhanced nitrogen availability during crop growth. Organic nitrogen sources have been shown to improve forage protein quality and mineral uptake, thereby influencing downstream animal performance **[2, 3]** Nutrient Digestibility Responses

Dry matter (DM) and organic matter (OM) digestibility exhibited slight reductions at intermediate inclusion levels but improved at the highest inclusion level (15%) V1:V2. This pattern suggests an initial dilution effect associated with increased dietary fibre, followed by adaptive enhancement of digestive efficiency. Rabbits possess a highly specialized hindgut fermentation system, and prolonged exposure to fibrous diets promotes microbial adaptation and increased fermentation efficiency **[12]**

Crude protein digestibility declined most noticeably at the 10% inclusion level, a response commonly associated with increased fibre protein (CF) binding and reduced enzymatic accessibility in the small intestine **[13]**. However, the partial recovery in CP digestibility observed at 15% (V1:V2) inclusion indicates improved nitrogen utilization through microbial protein synthesis and cecotrophy. Cecotrophy enables rabbits to recycle microbial protein and vitamins synthesized in the cecum, thereby mitigating apparent reductions in dietary protein digestibility **[6]**.

One of the most notable findings of this study was the marked improvement in fibre fraction digestibility with increasing inclusion of field pea forage. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) digestibility increased substantially, with the highest values recorded at 15% inclusion. This confirms that rabbits efficiently utilized the structural carbohydrates supplied by field pea forage. Similar increases in fibre digestibility have been reported when legume forages were incorporated into rabbit diets, attributed to enhanced cecal fermentation and increased retention time of fibrous particles **[11, 15]**

Ether extract (EE) digestibility showed a pronounced increase at moderate inclusion levels, suggesting improved lipid utilization. This may be associated with slower digesta passage rate and enhanced emulsification of dietary lipids in the presence of increased fibre **[6].** In contrast, ash digestibility declined progressively with increasing forage inclusion, likely due to mineral chelation by fibre components such as phytates and lignin. Nevertheless, these reductions did not translate into observable health or growth impairments, indicating adequate mineral supply.

Growth Performance of Weaner Rabbits

The absence of significant differences in initial body weight across treatments confirms effective randomization and uniformity of experimental animals. Growth performance responses mirrored the digestibility trends observed. Rabbits fed intermediate inclusion levels V2 (10%) recorded reduced final body weight and average daily gain, suggesting a temporary imbalance between nutrient intake and utilization. This response may be attributed to increased dietary bulk and

reduced protein availability at this inclusion level.

However, the partial recovery in growth performance at the highest inclusion level V1:V2 (15%) indicates physiological adaptation and improved utilization of fibrous nutrients. Increased feed intake observed with higher forage inclusion supports the concept of compensatory feeding behavior, whereby rabbits increase voluntary intake to meet their energy and nutrient requirements when consuming high fibre diets **[6]**. Similar intake responses have been reported in rabbits fed legume-based forages **[14, 15].**

Feed conversion ratio (FCR) worsened slightly at higher inclusion levels, reflecting increased feed intake relative to weight gain. However, this should be interpreted alongside the reduced feed cost and improved fibre utilization associated with field pea inclusion. Importantly, no mortality was recorded throughout the experimental period, indicating that the diets were safe and did not compromise animal health or welfare.

Conclusion

Conclusively, rabbit urine Bio-fertilized in field pea forage can be incorporated up to 15% in weaner rabbit diets without adverse effects on health or survival. The approach enhances fibre digestibility, supports sustainable waste utilization, and contributes to integrated crop livestock production systems.

Recommendation

1. The integration of rabbit urine bio-fertilized forage production with rabbit feeding represents a practical circular agriculture model.
2. Utilizing rabbit urine as an organic fertilizer reduces waste disposal challenges while enhancing forage yield and quality.
3. The subsequent use of such forage in rabbit diets closes the nutrient loop, improving system efficiency and sustainability.

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