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EFFECTS OF GRADED SKIM MILK POWDER INCLUSION IN DIETS CONTAINING 0.4% TURMERIC FLOUR (*CURCUMA DOMESTICA*) ON GROWTH PERFORMANCE, FEED CONSUMPTION, AND PROTEIN UTILIZATION EFFICIENCY OF NEW ZEALAND WHITE RABBITS

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ABSTRACT

Turmeric (Curcuma domestica) and milk-derived by-products are increasingly explored as natural, antibiotic-free feed additives for rabbit production, yet evidence on graded inclusion of a milk-derived protein source within a turmeric-containing diet remains limited, particularly for New Zealand White rabbits reared under smallholder tropical conditions. This study evaluated the effect of graded skim milk powder inclusion (0%, 5%, and 10%) in a diet containing a fixed level of turmeric flour (0.4%) on the growth performance, feed consumption, feed conversion ratio (FCR), and protein efficiency ratio (PER) of growing New Zealand White rabbits. A Completely Randomized Design (CRD) was used with three dietary treatments — P0 (0.4% turmeric flour, 0% skim milk powder), P1 (0.4% turmeric flour, 5% skim milk powder), and P2 (0.4% turmeric flour, 10% skim milk powder) — each replicated six times, over a six-week observation period that followed a two-week adaptation. Body weight gain was highest in P2 (21.30 ± 4.94 g/rabbit/day), which differed significantly from P0 (14.00 ± 2.37) but not from P1 (16.70 ± 3.78) ($p < 0.05$). Feed consumption was also highest in P2 (96.11 ± 12.66 g/rabbit/day) relative to P1 (76.72 ± 7.84) and P0 (73.54 ± 13.42) ($p < 0.01$). FCR (4.60–5.30) and PER (0.97–1.10) did not differ significantly among treatments ($p > 0.05$), with the numerically lowest FCR in P2 and the numerically highest PER in P1. These findings indicate that increasing skim milk powder inclusion up to 10% within a diet containing 0.4% turmeric flour increases growth rate and feed intake, whereas feed conversion ratio and protein efficiency ratio were not significantly affected.

Keywords : *Curcuma domestica; skim milk powder; growth performance; feed conversion ratio; New Zealand White rabbit.*

1. Introduction

Rabbits (Oryctolagus cuniculus) are gaining recognition as an efficient alternative livestock commodity for animal protein production because of their short generation interval, high reproductive rate, and the favorable nutritional profile of their meat, which is characterized by high protein and low fat content. Realizing this potential, however, depends heavily on feed formulation strategies that support optimal growth, efficient feed utilization, and product quality while remaining economically accessible to smallholder farmers (Gugołek and Kowalska, 2022; Placha *et al.*, 2022). Rising concerns over antibiotic growth promoters have shifted attention in monogastric and rabbit nutrition research toward natural, plant- and dairy-derived feed additives that can support performance without the residue and resistance risks associated with antibiotics (Wang *et al.*, 2024). In Indonesia specifically, regulatory restriction of antibiotic growth promoters in livestock feed has intensified interest in locally available herbal and natural alternatives capable of sustaining production performance (Sugiharto, 2021).

Turmeric (Curcuma domestica, synonymous with Curcuma longa) contains curcuminoids, bioactive polyphenolic compounds capable of modulating multiple cellular signaling pathways relevant to inflammation, oxidative stress, and microbial growth (Zhang, 2024), including a documented antibacterial action against Gram-positive pathogens such as Staphylococcus aureus (Teow and Ali, 2016). In meat rabbits, dietary curcumin supplementation has been reported to improve body weight gain, average daily feed intake, and nutrient digestibility by supporting intestinal morphology and digestive enzyme activity (Li *et al*., 2023). Similarly, graded inclusion of turmeric powder in crossbred rabbit diets improved feed intake, daily body weight gain, and feed conversion ratio compared with unsupplemented diets (Pujiawati *et al*., 2021), and turmeric supplementation has been shown not to compromise — and in some cases to enhance — growth performance in rabbits under other production systems (Okanlawon *et al*., 2020). These findings position turmeric as a promising phytogenic feed additive, although reported responses vary with inclusion level, rabbit genotype, and rearing conditions, indicating that its effects are not yet fully generalizable.

In parallel, milk-derived by-products such as skim milk and whey powder are valued as sources of highly digestible protein, energy, lactose, and minerals that can support the growth of young, rapidly developing animals; comparable evidence in other young monogastric and pre-ruminant species indicates that skim milk powder is a nutritionally suitable and growth-supportive protein-energy source when included at an appropriate level (Huuskonen, 2016). In growing rabbits, graded dietary inclusion of whey powder has been shown to improve final body weight, body weight gain, feed conversion ratio, protein efficiency ratio, and relative growth rate compared with a basal diet, with the highest inclusion level tested producing the best performance outcomes (Kishawy *et al*., 2018). It should be noted that whey powder and skim milk powder differ in composition—whey powder is comparatively higher in lactose and lower in protein, whereas skim milk powder retains the caseins—so findings for whey powder are cited here as related, indicative evidence rather than as direct equivalents for skim milk powder. Milk-derived proteins and fats have also been proposed to influence the solubility and gut-level handling of co-ingested bioactive compounds, since curcumin itself is characterized by poor intrinsic bioavailability arising from limited aqueous solubility, rapid intestinal and hepatic metabolism, and rapid systemic elimination (Hewlings and Kalman, 2017).

Despite this body of evidence, most existing studies have examined turmeric supplementation and milk-derived protein supplementation in rabbits as separate, single-factor interventions. Comparatively little empirical work has evaluated a fixed level of turmeric flour combined with graded levels of a milk protein source within a single controlled trial, and reports specifically involving New Zealand White rabbits raised under Indonesian smallholder-type management remain scarce. This represents a clear knowledge gap: it is not established how graded inclusion of skim milk powder affects growth performance and feed efficiency within a diet containing a fixed level of turmeric flour, particularly in New Zealand White rabbits under Indonesian smallholder-type management. Addressing this gap is practically urgent, because rabbit farming in tropical smallholder systems requires feed strategies that are simultaneously effective, natural, and based on locally accessible ingredients such as turmeric and dried or waste milk powder.

The present study was therefore designed to evaluate the effect of graded skim milk powder inclusion (0%, 5%, and 10%) within a diet containing a fixed level of turmeric flour (0.4%) on the growth performance (body weight gain and feed consumption) and feed utilization efficiency (feed conversion ratio and protein efficiency ratio) of New Zealand White rabbits. It was hypothesized that higher skim milk powder inclusion within the turmeric-containing diet would be associated with improved growth performance and feed efficiency, providing evidence-based guidance for the practical formulation of natural, growth-supportive rabbit diets.

2. Materials and Methods

2.1 Experimental Animals, Design, and Treatments

The study used a Completely Randomized Design (CRD) with three dietary treatments and six replications (one rabbit per replicate), giving a total of 18 experimental units. Eighteen weaned New Zealand White rabbits of the same sex, aged approximately 8 weeks and of uniform initial body weight and confirmed clinically healthy prior to enrolment;

they were randomly allocated to individual cages and treatments. The three dietary treatments were formulated to maintain a constant turmeric flour inclusion of 0.4% while varying the level of skim milk powder as follows: P0 - 0.4% turmeric flour without skim milk powder; P1 - 0.4% turmeric flour with 5% skim milk powder; and P2 - 0.4% turmeric flour with 10% skim milk powder. This design allowed the effect of graded skim milk powder inclusion to be evaluated within a constant 0,4% turmeric flour background.

2.2 Housing and Adaptation

Rabbits were housed individually in cages measuring 60 cm (length) × 50 cm (width) × 50 cm (height), each equipped with a nipple drinker to ensure ad libitum water access. Prior to data collection, all rabbits underwent a two-week adaptation period during which they were acclimatized to the housing environment and experimental diets, and received routine health monitoring and, as needed, supportive treatment to minimize environmental and handling stress. The subsequent observation period lasted six weeks.

2.3 Feed Preparation and Feeding Protocol

Experimental diets were formulated from rice bran, wheat pollard, soybean meal, copra meal, molasses, grass meal, premix, salt, turmeric flour, and skim milk powder to meet the nutrient requirements of growing rabbits (de Blas & Wiseman, 2020), weighed according to the treatment formulation and mixed into uniform pellets to ensure even distribution of the turmeric flour and other ingredients. The ingredient composition of each treatment is presented in Table 1, the calculated and analysed nutrient composition in Table 2, and the proximate composition of the finished pellets in Table 3. Skim milk powder was included by substitution against a fixed 0.40% turmeric flour background, replacing mainly wheat pollard and rice bran as its level increased from 0% (P0) to 5% (P1) and 10% (P2). Feed was offered twice daily (07:00 and 16:00) at 140 g/rabbit/day (70 g per feeding) at the start of the trial, increasing to 175 g/rabbit/day by the fifth week to match the animals' increasing energy requirements as body weight increased. Feed offered and feed refusals were recorded daily to determine actual feed intake.

Table 1. Ingredient composition of the experimental diets (P0, P1, P2)

Feed ingredient	**P0**	**P1**	**P2**
	.... % (as-fed)		
Rice bran	27.00	23.00	23.00
Wheat pollard	30.00	27.00	19.00
Soybean meal	7.20	7.20	8.20
Copra meal	24.00	24.00	26.00
Molasses	3.00	3.00	3.00
Grass meal	5.00	7.00	7.00
Premix	1.90	1.90	1.90
Salt	1.50	1.50	1.50
Turmeric flour	0.40	0.40	0.40
Skim milk powder	0.00	5.00	10.00
Total	**100.00**	**100.00**	**100.00**

Skim milk powder was included by substitution: as its level increased from 0% (P0) to 5% (P1) and 10% (P2), it proportionally replaced mainly wheat pollard and rice bran so that each formulation totalled 100%. Turmeric flour was held constant at 0.40% across all treatments. Formulated by trial-and-error using a spreadsheet.

Table 2. Calculated and analysed nutrient composition of the experimental diets

Nutrient	P0	P1	P2	Requirement‡
Crude protein (%)	19.60	20.10	20.70	15–18
Crude fibre (%)†	2.87	4.07	4.12	14–16
Crude fat (%)	7.30	8.10	9.30	5–6
Calcium (%)	0.40	0.40	0.40	0.5
Phosphorus (%)	0.90	0.90	0.80	0.7–0.9
DE (kcal/kg)	2417.14	2486.75	2495.19	2100–2500

Values for crude protein, crude fat, calcium, phosphorus, and DE were calculated from the ingredient composition (NRC, 1994; Central Laboratory, Universitas Padjadjaran, 2024). †Crude fibre is reported from proximate analysis (dry-matter basis; Laboratory of Non-Ruminant Nutrition, Faculty of Animal Husbandry, Universitas Padjadjaran, 2024). ‡Nutrient requirement for grower rabbits (de Blas & Wiseman, 2020). Because skim milk powder replaced energy/fibre ingredients, dietary crude protein, crude fat, and DE increased with skim milk powder level; the diets were therefore not isonitrogenous or isoenergetic across treatments.

Table 3. Proximate composition of the experimental pelleted diets (%)

No.	Proximate assay	P0	P1	P2			
		As-fed	DM	As-fed	DM	As-fed	DM
1	Moisture	6.47		9.49		11.20	
2	Crude protein	19.60	19.60	20.10	20.10	21.70	21.70
3	Crude fat	9.68	10.35	7.06	7.80	8.79	9.90
4	Crude fibre	2.87	3.07	4.07	4.50	4.12	4.64
5	Ash	3.09	3.30	2.83	3.12	4.50	5.07

As-fed and dry-matter (DM) basis. Source: proximate analysis, Laboratory of Non-Ruminant Nutrition, Faculty of Animal Husbandry, Universitas Padjadjaran, 2024.

2.4 Measured Parameters

The following growth performance and feed efficiency parameters were recorded weekly (body weight) or daily (feed intake) throughout the six-week observation period:

Body Weight Gain (BWG): BWG = (Final body weight − Initial body weight) / number of observation days (42), expressed as g/rabbit/day.

Feed Consumption: Feed consumption = Feed offered (g) – Feed refusal (g), recorded and expressed as g/rabbit/day.

Feed Conversion Ratio (FCR): FCR = Feed consumption (g) / Body weight gain (g). A lower FCR indicates higher feed efficiency.

Protein Efficiency Ratio (PER): PER = Body weight gain (g) / Protein consumption (g), reflecting how efficiently dietary protein is converted into body mass.

2.5 Statistical Analysis

Data for each parameter were analyzed using one-way Analysis of Variance (ANOVA) appropriate to the Completely Randomized Design. Where treatment effects were statistically significant, Duncan's Multiple Range Test (DMRT) (Duncan, 1955) was used as a post-hoc test to identify differences between treatment means, following the procedures described by Steel and Torrie (1980). Differences were considered statistically significant at $p < 0.05$, and highly significant at $p < 0.01$. Results are presented as treatment means ± standard deviation (SD).

3. Results and Discussion

3.1 Body Weight Gain

Body weight gain (BWG) is the primary indicator used to assess overall growth performance in rabbits, as it directly reflects how effectively a diet supports tissue accretion. The observed BWG values across replicates and treatments are presented in Table 4.

Table 4. Body weight gain of New Zealand White rabbits fed turmeric flour with graded levels of skim milk powder (g/rabbit/day)

Replication	P0	P1	P2
1	12.26	17.86	30.36
2	12.98	20.24	15.95
3	13.81	18.57	19.88
4	12.62	14.52	18.33
5	18.69	18.81	22.02
6	13.81	10.00	21.31
Mean ± SD	14.00 ± 2.37^{a}	16.70 ± 3.78^{ab}	21.30 ± 4.94^{b}

Superscripts (a, b) within the mean row that differ indicate a significant difference (p < 0.05) based on Duncan's Multiple Range Test.

Average BWG ranged from 14.00 g/rabbit/day in P0 to 21.30 g/rabbit/day in P2, a 52% increase associated with the addition of 10% skim milk powder on top of the constant 0.4% turmeric flour inclusion. One-way ANOVA indicated a significant treatment effect ($p < 0.05$; $F = 5.52$). Duncan's test showed that P0 and P1 did not differ significantly, whereas P2 differed significantly from P0, indicating that the growth-promoting effect became statistically detectable only at the higher (10%) level of skim milk powder inclusion under the conditions of this trial.

This pattern is consistent with the graded, dose-dependent improvement in growth performance reported when whey powder was included at increasing levels in growing rabbit diets, where the highest inclusion level produced the greatest body weight gain (Kishawy *et al*., 2018), indicating that a significant growth response was observed only at the 10% skim milk powder inclusion level under the conditions of this trial; because only three inclusion levels were tested and no formal dose–response or threshold analysis was performed, this should not be interpreted as evidence of a defined threshold. The result also aligns with observations that graded turmeric powder inclusion improves daily body weight gain in crossbred rabbits (Pujiawati *et al*., 2021), suggesting that the constant 0.4% turmeric background in the present study may have contributed a baseline antioxidant and digestive-supportive effect across all treatments, upon which the graded milk powder level acted additively. Mechanistically, the curcuminoids in turmeric are considered to reduce oxidative stress and support nutrient absorption (Li *et al*., 2023), and in poultry, dietary curcumin has been shown to enhance growth performance partly through favorable modulation of gut microbiota composition and microbiota-derived metabolites together with reduced expression of inflammation-related genes (Chen *et al*., 2024), a mechanism that plausibly extends to the hindgut-fermenting digestive physiology of rabbits. In parallel, the protein and readily available energy supplied by skim milk powder can directly support the substrate requirements of muscle protein synthesis, particularly in young, rapidly growing rabbits. Taken together, these results are most appropriately interpreted as the response to graded skim milk powder inclusion within a diet containing a fixed 0.4% turmeric flour level. Because turmeric was held constant in all treatments and no turmeric-free or skim-milk-only group was included, the present design cannot determine the independent effect of either ingredient or any interaction between them.

3.2 Feed Consumption

Feed consumption reflects both the palatability of the diet and the animal's physiological demand for nutrients and energy. Observed feed consumption values are presented in Table 5.

Table 5. Feed consumption of New Zealand White rabbits fed turmeric flour with graded levels of skim milk powder (g/rabbit/day)

Replication	P0	P1	P2
1	68.88	76.48	117.02
2	71.55	80.93	93.14
3	58.31	72.40	96.98
4	63.17	75.93	93.10
5	92.50	88.90	98.73
6	86.83	65.69	77.71
Mean ± SD	73.54 ± 13.42^{a}	76.72 ± 7.84^{a}	96.11 ± 12.66^{b}

Superscripts (a, b) within the mean row that differ indicate a significant difference ($p < 0.05$) based on Duncan's Multiple Range Test.

Feed consumption ranged from 73.54 g/rabbit/day in P0 to 96.11 g/rabbit/day in P2. ANOVA revealed a highly significant treatment effect ($p < 0.01$; $F = 6.69$), and Duncan's test grouped P0 and P1 together, with P2 significantly higher than both. This pattern of higher intake at the highest skim milk powder level is consistent with reports that whey powder inclusion increases feed intake in growing rabbits (Kishawy *et al*., 2018), likely reflecting improved palatability associated with the lactose, fat, and protein content of milk-derived ingredients. It is also consistent with the general observation that turmeric supplementation can support feed intake in rabbits through improved digestive comfort and nutrient handling (Okanlawon *et al*., 2020), which may have provided a shared baseline effect across all three treatments while the graded milk powder level drove the differences between them.

Notably, the higher intake in P2 occurred alongside the highest BWG (Table 1) rather than at its expense, indicating that the additional feed consumed in P2 was being converted into growth rather than simply representing wasted or unproductive intake — a pattern that is further clarified by the feed conversion ratio results in Section 3.3.

3.3 Feed Conversion Ratio

Feed conversion ratio (FCR) expresses the amount of feed required to produce a unit of body weight gain, and therefore reflects the overall efficiency of nutrient utilization. Table 6 presents the FCR values recorded across treatments.

Table 6. Feed conversion ratio of New Zealand White rabbits fed turmeric flour with graded levels of skim milk powder

Replication	P0	P1	P2
1	5.62	4.28	3.85
2	5.51	4.00	5.84
3	4.22	3.90	4.88
4	5.01	5.23	5.08
5	4.95	4.73	4.63
6	6.29	6.55	3.53
Mean ± SD	5.27 ± 0.71	4.78 ± 1.00	4.64 ± 0.84

FCR ranged from 4.64 in P2 to 5.27 in P0, and ANOVA indicated no statistically significant treatment effect ($p > 0.05$). Although not significant, the numerically lowest (most efficient) FCR in P2 is directionally consistent with reports that curcumin supplementation can improve feed conversion in meat rabbits by supporting nutrient digestibility and intestinal function (Li *et al.*, 2023), and with the improved feed conversion ratio observed with graded turmeric powder inclusion in crossbred rabbits (Pujiawati *et al.*, 2021). The relatively high within-treatment variability (SD of 0.71–1.00) evident in Table 6, combined with the modest number of replicates (n = 6) typical of small-animal feeding trials, likely limited the statistical power available to detect a treatment effect on FCR even where a numerical trend was present. This underscores a broader methodological point: a parameter can show a biologically meaningful directional pattern without reaching conventional statistical significance, particularly when replicate variability is high relative to the treatment differences involved.

3.4 Protein Efficiency Ratio

Protein efficiency ratio (PER) evaluates how effectively dietary protein is converted into body mass and is particularly informative when comparing diets that differ in their protein source, as in the present study. Table 7 presents the PER values recorded.

Table 7. Protein efficiency ratio of New Zealand White rabbits fed turmeric flour with graded levels of skim milk powder (g body weight gain/g protein consumed)

Replication	P0	P1	P2
1	0.90	1.20	1.30
2	0.90	1.20	0.80
3	1.20	1.30	1.00
4	1.00	1.00	1.00
5	1.00	1.10	1.00
6	0.80	0.80	1.40
Mean ± SD	0.97 ± 0.14	1.10 ± 0.18	1.08 ± 0.22

PER ranged from 0.97 in P0 to 1.10 in P1, with no statistically significant difference among treatments ($p > 0.05$). The numerically highest PER was recorded in P1 rather than P2, and neither FCR nor PER differed significantly among treatments; the modestly higher PER in the skim-milk-containing diets relative to P0 is directionally consistent with the improved protein efficiency ratio reported when whey powder was included in growing rabbit diets, attributed to the high digestibility and favorable amino acid profile of milk-derived protein relative to plant-based protein sources alone (Kishawy *et al.*, 2018). It is also plausible that curcumin's antioxidant activity contributed indirectly to protein utilization by limiting oxidative damage to intestinal tissue and thereby preserving absorptive capacity (Hewlings and Kalman, 2017), although this mechanism was not directly measured in the present trial and should be interpreted as a hypothesis rather than a confirmed pathway. As with FCR, the absence of statistical significance for PER should be interpreted in light of the modest replicate number and considerable inter-individual variability characteristic of rabbit feeding trials, rather than as definitive evidence of no biological effect.

3.5 Integrated Discussion and Study Limitations

Considered together, the four parameters describe a coherent pattern: increasing the level of skim milk powder from 0% to 10%, against a constant 0.4% turmeric flour background, significantly increased both body weight gain and feed consumption, while feed conversion ratio and protein efficiency ratio showed favorable but statistically non-significant numerical trends toward greater efficiency at the higher milk powder inclusion level. This is compatible with a scenario in which skim milk powder primarily increased the quantity of nutrients ingested and available for growth, while turmeric may have contributed a background antioxidant and digestive-support effect common to all treatments; the data from this trial do not allow the two ingredients' contributions to be statistically disentangled, since turmeric level was not varied factorially alongside milk powder level.

Three limitations should be acknowledged. First, and most fundamentally, turmeric flour was maintained at 0.4% in all treatments; consequently the individual effects of turmeric and skim milk powder, and any interaction between them, cannot be determined from this design, and all effects reported here are attributable to graded skim milk powder inclusion within a turmeric-containing diet. Moreover, because skim milk powder replaced energy- and fibre-supplying ingredients rather than being added iso-nutritionally, dietary crude protein, crude fat, and digestible energy increased with skim milk powder level (Table 2); the diets were therefore not isonitrogenous or isoenergetic, and the observed responses reflect the combined effect of skim milk powder inclusion and the accompanying shift in dietary nutrient density. Second, carcass composition (meat, bone, and fat percentages) and meat oxidative quality were not measured in this trial, even though such traits are frequently reported alongside growth performance in comparable rabbit nutrition studies and turmeric supplementation has itself been shown to influence the physical characteristics and oxidative status of rabbit meat post-slaughter (Li *et al*., 2023; Mancini *et al*., 2015); consequently, no carcass- or meat-quality-related conclusions are drawn here, and these parameters are recommended as priorities for future work using the same treatment structure. Third, the modest number of replicates per treatment (n = 6), while consistent with common practice in small-animal CRD trials, constrains the statistical power available to detect moderate effects on FCR and PER; larger-scale or multi-cohort replication would help clarify whether the numerical trends observed here for these two parameters reflect real, biologically meaningful differences.

From an applied perspective, these findings indicate that raising skim milk powder inclusion to 10% within a diet containing 0.4% turmeric flour increased growth rate and feed intake in New Zealand White rabbits, with no significant change in feed conversion ratio or protein efficiency ratio. Because efficiency was unchanged and only three inclusion levels were tested, the present data are not sufficient to support a specific feeding recommendation; confirmation with a factorial design and economic evaluation is warranted before practical adoption.

4. Conclusion

Within a diet containing a fixed 0.4% turmeric flour level, increasing skim milk powder inclusion to 10% (P2) significantly improved body weight gain and feed consumption relative to the diet without skim milk powder (P0), whereas feed conversion ratio and protein efficiency ratio did not differ significantly among treatments. These results indicate that graded skim milk powder inclusion within a turmeric-containing diet can support growth in New Zealand White rabbits; however, because turmeric was not varied, the contribution of turmeric itself cannot be established from this study. Further research incorporating carcass composition, nutrient digestibility, blood biochemical profiling, larger replicate numbers, and a factorial design that varies both turmeric and milk powder levels independently is recommended to confirm these findings, clarify the relative contribution of each ingredient, and establish the optimal combined dosage for long-term application in rabbit farming.

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