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Impacts of dietary tiger nut on the growth, reproductive and blood constituents of three rabbit breeds

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ABSTRACT

This study assessed the effects of incorporating varying levels (0, 10, 20, and 30 g/kg) of tiger nut (Cyperus esculentus L) into rabbit diets on the growth, reproductive performance, and blood characteristics of three rabbit breeds: New Zealand White, Hyla Max, and Dutch Belted. A total of 420 rabbits (270 does and 150 bucks), originating from 48 mature individuals aged 20–22 weeks and weighing between 2.24 and 2.50 kg, were randomly allocated to the four diets in a 3×4 factorial design. Growth traits such as body weight and linear measurements were taken at 35 days post-kindling. Reproductive performance data included gestation length, litter size at birth and weaning, individual and litter weights, and pre-weaning mortality. Blood samples were collected for haematological and biochemical analyses. Results indicated that dietary inclusion of tiger nut at 20–30 g/kg improved growth and reproductive performance, enhanced milk production and composition, and did not adversely affect health indicators. These findings support the use of tiger nut as a beneficial dietary supplement in rabbit production.

Keywords: rabbit, tiger nut, reproductive traits, growth performance, blood indices, dietary supplementation.

INTRODUCTION

In rabbit farming, it is essential to closely monitor animal performance by accurately estimating their nutritional needs and assessing how different diets impact their genetic potential (Bernabucci et al., 2004). Key economic factors such as litter size and survival rates significantly influence productivity (Szendro et al., 2019). The amount of milk produced during the first three weeks of lactation is particularly important, as it plays a major role in the early growth and survival of kits (Ondruska et al., 2020). According to Bonachera et al. (2017), total milk intake largely determines kit development during this stage, influencing their size and weight rapidly (Chineke et al., 2002; Atansuyi et al., 2011).

Rabbit breeders also focus on the relationship between body weight and linear body traits, as this reveals both feed efficiency and overall performance (Okoro et al., 2010). Improving rabbit genetics is crucial for increasing the availability of animal protein in developing regions (Okoro et al., 2010). Tiger nut (Cyperus esculentus), a tuber crop, is recognized for its high energy content, dietary fiber, and various phytochemicals, including antioxidants and prebiotics, which have shown promising effects as feed supplements in livestock e.g., poultry, swine (Allouh et al., 2015). These properties suggest its potential to enhance nutrient utilization, gut health, and overall performance in livestock.

However, despite a growing interest in sustainable and alternative feed resources for rabbit production, the application of tiger nut in rabbit diets remains largely unexplored. Existing literature on dietary additives for rabbits often focuses on probiotics, prebiotics, synthetic amino acids, or specific plant extracts, e.g., common forage sources or general phytogenic compounds (Belewu et al., 2007). Crucially, there is a paucity of comprehensive studies investigating the multi-trait effects of varying inclusion levels of tiger nut on the integrated performance of rabbits, encompassing not only growth and reproductive parameters but also detailed haematological and serum biochemical profiles across different breeds.

MATERIALS AND METHODS

Study Location

The research was conducted at the Rabbitry Unit of the Livestock Teaching and Research Farm, located within the Federal University of Technology, Akure, Ondo State, Nigeria. The site sits at an elevation of 350.52 meters above sea level, with coordinates 7°17′N and 5°9′E (Mapzoom, 2020). The climate features average temperatures between 28°C and 31°C, and relative humidity around 80% (Climatedata, 2018).

Experimental Design, Animals, and Feeding Regimen

A total of 420 rabbits (270 females and 150 males), derived from 48 sexually mature parent rabbits representing three breeds, New Zealand White, Hyla Max, and Dutch Belted, were used. A standard basal diet was formulated based on INRA (2004) guidelines (see Table 1 for details). The rabbits were housed in wooden cages covered with wire mesh (dimensions: 76×62×42 cm) and elevated 90 cm above concrete flooring in a well-ventilated area. Feed and clean water were provided without restriction. Daily cleaning was maintained throughout the 52-week trial.

Table 1: Composition of Experimental Diets Fed to Pregnant and Lactating Does

Ingredients	Composition
Maize	16.5
Soya Bean Meal	9.5
Rice bran	22.95
Wheat Bran	29.5
Palm kernel cake	18
Limestone	1.7
Bone meal	1
Grower's Premix	0.1
Salt (NaCl)	0.2
L- Lysine	0.15
Dl-Methionine	0.4
Total	100
Calculated Composition	
Nutrient	**Composition**
Digestible energy (Kcal/kg)	2525.35
Crude protein (%)	16.03
Crude fibre (%)	13.09
Calcium (%)	1.02
Total phosphorus (%)	0.51
Lysine (%)	0.94
Methionine (%)	0.68

Composition of premix: 2.5 kg of premix contains: Vit. A (10000000 UI), Vit. D3 (2500000 UI), Vit. E (12000 UI), Vit. B1 (2000 mg), Niacin (15000 mg), Vit.B6 (1500 mg), Vit.B12 (10 mg), Vit. K3 (2000 mg), Biotin (20 mg), Folic Acid (600 mg), Pantothenic Acid (7000 mg), Chlorine Chloride (150000 mg), Manganese (80000 mg), Iron (40000 mg), Copper (10 mg), Zinc (60000 mg), Selenium (150 mg), Iodine (1000 mg), Magnesium (100 mg), Ethoxyquin (500 g), BHT (700 g). 2 Calculated as ME (kcal/kg) =[37×CP (%) +81.8×EE (%) +35.5×NFE (%)] ×0.88= (37×16.08) +(81.8×5.70) +(35.5×51.42) ×0.88=2540 kcal/kg (Pauzenga, 1985)

The basal feed was divided into four parts with tiger nut included at 0, 10, 20, and 30 g/kg of diet, forming Diets 1 to 4, respectively. Each diet was pelletized to a 3 mm diameter. Female rabbits were assigned randomly into four dietary groups, each with four replicates of four does. Bucks were assigned based on genotype for mating purposes. Breeding commenced when does reach 24–26 weeks of age. Milk composition was analysed based on AOAC (2005) procedures. Growth and reproductive data were collected throughout the experiment, with blood sampling for haematological and serum analysis conducted at the end.

Ethical Approval

Ethical clearance was obtained from the Department of Animal Production and Health in line with the institution's research policies, and animal handling followed the EU Directive 2010/63/EU for laboratory animals (European Union, 2010).

Growth and Reproductive Trait Measurement

Body measurements began from day 35 post-kindling and followed humane handling protocols. Using a graduated measuring tape, dimensions were taken at specific anatomical points following Egena et al. (2012). These included:

- Shoulder-to-tail length – from the neck base to tail tip
- Head-to-shoulder length – from the nose tip to shoulder base
- Trunk length – shoulder point to ischial tuberosity
- Height at withers – highest point along the dorsal midline
- Ear length – from ear base to tip
- Heart girth – circumference behind forelimbs
- Fore-limb and hind-limb lengths – from limb attachment points to claw base

Weights and dimensions were recorded in the morning before feeding.

Reproductive Parameters Assessed

Key reproductive indicators included gestation length (GL), litter size at birth (LSB), individual kit birth weight (IKBW), litter birth weight (LBW), pre-weaning mortality (PWM), litter size at weaning (LSW), individual kit weaning weight (IKWW), and total litter weaning weight (LWW). Weights were measured using a Salter Spring balance (Model 235), following FAO (2012) protocols.

Pre-Weaning Performance Indicators

Data included:

- Body weights at days 7, 14, 21, and 28
- Weight changes at days 21 and 28
- Mortality at birth and on days 7, 14, and 21

Blood and Biochemical Assessments

Blood samples were taken from 72 kits across all breeds at the end of the experiment. Samples for haematology were collected in EDTA tubes, while serum samples were collected in plain tubes and centrifuged for analysis. Parameters analysed included PCV, RBC, WBC, Hb, ESR, and differentials like lymphocytes and neutrophils (Lamb, 1981). Serum values such as total protein, albumin, globulin, urea, creatinine, glucose, cholesterol, ALT, AST, and ALP were assessed using kits from Randox Laboratories, UK.

$$ME\ (kcal/kg) = (36 \times \%CP) + (81.8 \times \%EE) + (35.5 \times \%NFE)$$

Statistical Analysis

A two-way ANOVA was used to analyze all data using the General Linear Model in GraphPad Prism 6.01 (2012). The statistical model was:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk},$$

where Y_{ijk} = observation, μ = overall mean, α_i = tiger nut level, β_j = breed, $(\alpha\beta)_{ij}$ = interaction effect, and ε_{ijk} = error term. Differences were considered significant at $\alpha = 0.05$ and compared using Duncan's Multiple Range Test.

RESULTS

Morphometric Traits

Table 2 displays the average values for body measurements of rabbits from the three breeds at five weeks of age. Breed had no statistically significant effect ($p>0.05$) on any morphometric traits assessed. However, dietary treatment significantly influenced ($p<0.05$) body weight (BW), body length (BL), height at withers (HW), heart girth (HG), head-to-shoulder length (HSL), and trunk length (TL). The 20 g and 30 g/kg tiger nut diets showed the most notable differences across these traits. A significant interaction between breed and diet was observed specifically for ear length (EL) and shoulder-to-tail length (ST).

Pre-Weaning Growth Performance

As shown in Table 3, most pre-weaning growth traits were unaffected by breed ($p>0.05$), except for kit weight at birth. New Zealand White rabbits had significantly higher birth weights (0.05 kg) compared to Dutch Belted and Hyla Max, which shared statistically similar values (0.04 kg). Diet significantly influenced ($p<0.05$) birth weight, weight at day 7, day 21, and day 28. Kits fed 20 g and 30 g/kg tiger nut diets generally showed better weight gains compared to those on lower inclusion levels or control.

Reproductive and Milk Traits

Table 4 summarizes reproductive performance and milk yield influenced by breed and diet. While breed had no significant effect ($p>0.05$) on most parameters, New Zealand White rabbits had the highest individual kit birth weight (IKBW). Diet significantly affected IKBW, litter birth weight (LBW), individual kit weaning weight (IKWW), and litter weaning weight (LWW).

The 20 g/kg tiger nut diet led to superior performance in LBW (0.18 kg), IKWW (0.39 kg), LWW (1.18 kg), and IKBW (0.05 kg) when compared to other dietary treatments.

Haematological Indices

As detailed in Table 5, significant breed effects ($p<0.05$) were recorded for several haematological parameters, including packed cell volume (PCV), red blood cell count (RBC), haemoglobin (Hb), lymphocytes (LYM), neutrophils (NEU), monocytes (MON), eosinophils (EOS), mean corpuscular volume (MCV), and mean corpuscular haemoglobin (MCH). Hyla Max had the highest RBC and EOS values, while New Zealand White showed superior PCV, Hb, NEU, and MCV. Dietary inclusion of tiger nut significantly influenced ($p<0.05$) ESR, RBC, LYM, NEU, MON, and MCV, with the 20 g/kg and 30 g/kg diets yielding the most favourable values.

Serum Biochemical Profile

Breed had a marked influence ($p<0.05$) on all serum biochemical parameters measured (Table 6), including total protein (TP), albumin (Alb), globulin (Glo), cholesterol (Chol), urea, ALT, AST, creatinine, and glucose. New Zealand White rabbits showed the highest values for many indices, indicating better protein and metabolic profiles. Although diet had no significant impact ($p>0.05$) on these biochemical traits, trends favoured moderate tiger nut inclusion for stable serum indices.

DISCUSSION

In rabbit production, the relationship between body weight and physical traits is a key indicator of both efficiency and productivity. Linear body measurements have long been used as indirect predictors of body composition and overall performance. This practice is especially valuable in resource-limited settings where weighing scales may be unavailable. These metrics have proven effective in various livestock species, including goats, sheep, cattle, and poultry. However, data on such measurements in rabbit breeds under tropical conditions remain limited.

Among the three breeds studied, Hyla Max consistently showed higher mean values across most performance traits, followed closely by New Zealand White.

Table 2: Least squares mean for body weight (kg) and linear body measurements (cm) of three breeds of rabbit at 5 Weeks of age

Diet	**Breed**	**BW**	**BL**	**HW**	**EL**	**HG**	**ST**	**HSL**	**TL**	**HL**	**RUMP**
	DUT	0.37 ±0.01	25.97 ±0.24	17.38 ±0.17	7.55 ±0.1	15.52 ±0.14	24.56 ±4.42	9.08 ±0.11	5.16 ±0.08	9.88 ±0.09	14.42 ±0.13
	HYLA	0.38 ±0.01	26.26 ±0.22	17.23 ±0.16	7.48 ±0.06	15.66 ±0.14	20.16 ±0.22	9.12 ±0.08	5.25 ±0.06	9.83 ±0.07	14.57 ±0.12
	NZW	0.35 ±0.01	25.82 ±0.2	17.39 ±0.15	7.35 ±0.06	15.34 ±0.12	19.8 ±0.19	9.03 ±0.07	5.31 ±0.06	9.7 ±0.07	14.6 ±0.1
10 g		0.34 ±0.01^{b}	25.51 ±0.21^{b}	17.15 ±0.17^{b}	7.45 ±0.08	15.43 ±0.14^{ab}	25.08 ±5.37	8.98 ±0.1^{b}	5.12 ±0.07^{b}	9.72 ±0.11	14.42 ±0.13
20 g		0.35 ±0.01^{b}	25.62 ±0.23^{b}	16.64 ±0.11^{c}	7.43 ±0.12	15.18 ±0.09 ^{b}	19.8 ±0.23	8.89 ±0.09^{b}	5.23 ±0.06b	9.84 ±0.08	14.4 ±0.14
30 g		0.39 ±0.01^{a}	26.43 ±0.26^{a}	17.71 ±0.2^{a}	7.58 ±0.07	15.52 ±0.19^{ab}	20.27 ±0.25	9.29 ±0.11^{a}	5.53 ±0.09^{a}	9.84 ±0.07	14.56 ±0.15
CNTRL		0.38 ±0.01^{a}	26.39 ±0.29^{a}	17.8 ±0.21^{a}	7.35 ±0.08	15.82 ±0.15^{a}	20.26 ±0.27	9.12 ±0.1^{ab}	5.09 ±0.07^{b}	9.8 ±0.07	14.76 ±0.11
Breed		0.0939	0.2756	0.8172	0.1795	0.2444	0.1162	0.7047	0.3691	0.062	0.481
Diet		0.0002	0.0112	<0.0001	0.3271	0.0499	0.1261	0.0127	0.0005	0.9471	0.2496
Diet* Breed		0.9011	0.5583	0.9948	0.0066	0.5972	0.0366	0.1369	0.341 3	0.5796	0.3646

^{a,b,c} Means on the same column having different superscripts are significantly different (P<0.05).
10g, 20g and 30g = 10grams, 20grams and 30grams Tiger nut inclusion level; HYL = Hyla; NZW = New Zealand White; DUT = DUT;
BW = Body weight; BL = Body length; HW= Height at withers; EL= Ear length; HG = Heart girth; ST= shoulder to tail length;
HSL = Head to shoulder length; FL= Fore limb; TL = Tail length; HL = Head length; RUMP = Rump

Table 3: Least Squares Means (±SEM) of Pre-weaning Performance (kg) of the Kits as Affected by Breed, and Diet

Breed	Diet	Weight at birth	Weight at day 7	Weight at day 14	Weight at day 21	Weight at day 28	Change in weight at day 21	Change in weight at day 28
Dutch		0.04 ±0.00^{b}	0.09 ±0.00	0.15 ±0.00	0.21 ±0.01	0.28 ±0.01	0.16 ±0.01	1.09 ±0.86
Hyla		0.04 ±0.00^{b}	0.09 ±0.00	0.15 ±0.00	0.21 ±0.01	0.29 ±0.01	0.46 ±0.29	0.24 ±0.01
NZW		0.05 ±0.00^{a}	0.10 ±0.01	0.15 ±0.00	0.20 ±0.00	0.26 ±0.01	0.15 ±0.00	0.22 ±0.01
	0g	0.04 ±0.00^{b}	0.10 ±0.01^{a}	0.15 ±0.00	0.21 ±0.01^{ab}	0.29 ±0.01^{a}	0.51 ±0.34	0.25 ±0.01
	10g	0.04 ±0.00^{b}	0.09 ±0.00^{b}	0.15 ±0.00	0.19 ±0.01^{b}	0.26 ±0.01^{b}	0.15 ±0.01	1.36 ±1.14
	20g	0.05 ±0.00^{a}	0.10 ±0.00^{ab}	0.16 ±0.00	0.21 ±0.01^{a}	0.29 ±0.01^{a}	0.17 ±0.01	0.24 ±0.01
	30g	0.04 ±0.00^{b}	0.09 ±0.00^{ab}	0.15 ±0.00	0.19 ±0.01^{ab}	0.26 ±0.01^{b}	0.15 ±0.01	0.22 ±0.01
Breed		0.05	0.15	0.92	0.81	0.29	0.5	0.78
Diet		<0.0001	0.05	0.34	0.04	0.01	0.53	0.87

^{abc} Means within the same column bearing different superscripts are significantly different ($p<0.05$)

Dutch= Dutch belted, Hyla= Hyla max, NZW= New Zealand White, 0g= Diet with no tiger nut, 10g= Diet with 10gram of tiger nut, 20g= Diet with 20gram of tiger nut, 30g= Diet with 30g of tiger nut.

Table 4: Least Squares Means (±SEM) of Reproductive Performance (kg) and Milk Trait as Affected by Breed and Diet

Breed	Diet	GL	LSB	IKBW	LBW	PWM	LSW	IKWW	LWW	MPD
Dutch		30.98 ±0.15	3.53 ±0.21	0.04 ±0.00[b]	0.15 ±0.01	15.97 ±2.86	2.86 ±0.16	0.36 ±0.01	1.02 ±0.07	0.50 ±0.04
Hyla		30.92 ±0.13	3.50 ±0.24	0.04 ±0.00[b]	0.15 ±0.01	13.86 ±2.63	2.92 ±0.2	0.37 ±0.01	1.06 ±0.06	0.52 ±0.04
NZW		31.00 ±0.17	3.51 ±0.21	0.05 ±0.00[a]	0.17 ±0.01	10.46 ±2.64	3.00 ±0.14	0.36 ±0.01	1.11 ±0.06	0.56 ±0.04
	0g	30.84 ±0.16	3.52 ±0.21	0.04 ±0.00[ab]	0.15 ±0.01[b]	13.98 ±3.25	2.90 ±0.15	0.38 ±0.01[a]	1.11 ±0.07[ab]	0.54 ±0.05
	10g	30.97 ±0.17	3.52 ±0.29	0.05 ±0.00[ab]	0.16 ±0.02[ab]	12.04 ±3.03	2.97 ±0.24	0.34 ±0.01[b]	1.02 ±0.07[ab]	0.54 ±0.03
	20g	30.87 ±0.14	3.73 ±0.26	0.05 ±0.00[a]	0.18 ±0.01[a]	15.28 ±3.43	3.07 ±0.22	0.39 ±0.01[a]	1.18 ±0.09[a]	0.56 ±0.05
	30g	31.2 ±0.22	3.30 ±0.25	0.04 ±0.00[b]	0.14 ±0.01[b]	12.58 ±2.98	2.77 ±0.14	0.35 ±0.01[b]	0.95 ±0.07[b]	0.46 ±0.04
Breed		0.91	0.97	<0.0001	0.06	0.15	0.64	0.85	0.59	0.52
Diet		0.75	0.42	0.0006	0.02	0.44	0.79	0	0.05	0.59

[abc] Means within the same column bearing different superscripts are significantly different ($p<0.05$)
GL= Gestation length, LSB= Litter size at birth, IKBW= Individual kit birth weight, LBW= Litter birth weight,
PWM= Pre-weaning mortality, LSW= Litter size at weaning, IKWW= Individual kit weaning at weight, LWW= Litter weight at weaning,
MPD= Milk production of the does, Dutch= Dutch Belted, Hyla= Hyla Max, NZW= New Zealand White, 0g= Diet with no tiger nut,
10g= Diet with 10gram of tiger nut, 20g= Diet with 20gram of tiger nut, 30g= Diet with 30g of tiger nut.

Table 5: Least Squares Means for the Effects of Breed, Diet and their Interaction on Haematological indices of three Breeds of Rabbit

Diet	Breed	ESR (mm/hr)	PCV (%)	RBC (x106 mm)	WBC (x103 mm)	HB (g/100 ml)	LYM (%)	MON (%)	MCHC (%)	MCV (%)
	DUT	4.13 ±0.18	25.32 ±1.15[b]	4.06 ±0.08[b]	1.35 ±0.02	9.2 ±0.12[b]	64.22 ±0.21[a]	7.09 ±0.21[a]	50.53 ±15.5	62.3 ±2.71[b]
	Hyla	3.64 ±0.76	33.38 ±1.42[a]	5.01 ±0.25[a]	1.31 ±0.02	9.85 ±0.65[ab]	62.33 ±0.57[b]	5.38 ±0.24[c]	29.89 ±1.7	67.79 ±2.17[a]
	NZW	3.15 ±0.69	33.83 ±1.41[a]	4.96 ±0.24[a]	1.31 ±0.01	10.94 ±0.5[a]	61.28 ±0.49[c]	6.45 ±0.14[b]	32.31 ±0.59	69.27 ±0.97[a]
10g		2.83 ±0.58[b]	32.49 ±2.14	5.13 ±0.22[a]	1.32 ±0.02	10.42 ±0.66	61.53 ±0.5[b]	6.05 ±0.28[b]	50.06 ±19.03	62.71 ±3.29[b]
20g		3.71 ±0.79[ab]	31.06 ±1.73	4.55 ±0.29[b]	1.36 ±0.02	10.02 ±0.63	62.89 ±0.58[a]	6.33 ±0.28[b]	32.28 ±0.98	69.2 ±1.51[a]
30g		4.50 ±0.81[a]	29.88 ±1.71	4.51 ±0.28[b]	1.31 ±0.02	10.05 ±0.57	63.06 ±0.66[a]	6.65 ±0.23[a]	34.02 ±1.23	67.54 ±2.73[ab]
Control		3.45 ±0.65[ab]	30.53 ±1.60	4.55 ±0.24[b]	1.31 ±0.02	9.81 ±0.48	62.63 ±0.62[ab]	6.37 ±0.28[ab]	32.43 ±0.75	67.37 ±0.9[ab]
Breed		0.72	0.01	0.01	0.16	0.013	<0.0001	<0.0001	0.27	0.03
Diet* Breed	0.06	0.67	0.56	0.67	0.98	0.71	0.45	0.44	0.76	0.12

[ab] Means with different superscripts in the same column are significantly difference (P<0.05). PCV- packed cell volume; RBC – red blood cell; ESR - erythrocyte; WBC – white blood cell; HB- haemoglobin; LYM- lymphocytes; NEU- neutrophils; EOS – eosinophils; MCHC – mean corpuscular haemoglobin concentration; MCV- mean corpuscular volume; MCH - mean corpuscular haemoglobin concentration; BAS – basophil.

Table 6: Least Squares Means for the Effects of Breed, Diet and their Interactions on Serum Biochemical indices of three Breeds of Rabbit

Diet	Breed	T.Prot (g/dl)	Alb (g/dl)	Glo (g/dl)	Chol (mg/dl)	Urea (mg/dl)	ALT (U/L)	AST (U/L)	Creat (mg/dl)	Gluc (mg/dl)
	DUT	6.47 ±0.02^{b}	3.15 ±0.03^{b}	3.34 ±0.01^{b}	36.53 ±0.59^{b}	20.69 ±0.15^{a}	59.70 ±0.29^{a}	64.23 ±0.25^{b}	0.86 ±0.05^{b}	113.94 ±1.34^{b}
	Hyla	6.53 ±0.03^{b}	3.16 ±0.02^{b}	3.18 ±0.02^{c}	35.12 ±1.00^{c}	16.25 ±0.94^{b}	58.35 ±0.37^{b}	61.48 ±0.19^{c}	0.88 ±0.04^{b}	118.22 ±0.78^{a}
	NZW	7.65 ±0.07^{a}	3.43 ±0.07^{a}	4.08 ±0.01^{a}	37.04 ±0.77^{a}	11.20 ±0.00^{c}	54.95 ±0.66^{c}	65.62 ±0.17^{a}	1.08 ±0.02^{a}	118.00 ±1.19^{a}
10g		6.72 ±0.10	3.24 ±0.06	3.35 ±0.01	34.26 ±0.92	16.04 ±1.03	54.76 ±0.69	63.78 ±0.43	0.87 ±0.04	116.46 ±1.51
20g		6.68 ±0.14	3.22 ±0.02	3.53 ±0.06	33.62 ±0.90	16.07 ±1.03	56.67 ±0.63	63.77 ±0.43	0.93 ±0.05	117.92 ±1.30
30g		6.89 ±0.10	3.24 ±0.05	3.43 ±0.03	32.23 ±0.95	16.04 ±1.03	57.55 ±0.66	63.78 ±0.43	0.84 ±0.05	115.75 ±1.34
Control		6.79 ±0.11	3.28 ±0.04	3.50 ±0.08	36.23 ±0.92	16.04 ±1.03	56.44 ±0.60	63.78 ±0.43	0.86 ±0.06	116.75 ±1.34
Breed		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Diet		0.9977	1	1	0.9999	0.9985	1	0.9999	1	0.9851
Diet* Breed		0.9986	1	1	0.9999	0.9985	1	0.9999	1	0.977

[ab] Means with different superscripts in the same column are significantly difference (P<0.05). T. prot = Total protein; Alb = Albumin; Glo = Globulin; Chol = Cholesterol; Creat = Creatinine; Gluc = Glucose; AST = Aspartate aminotransferase; ALT = Alanine aminotransferase.

These results may be attributed to genetic differences and superior maternal qualities, including better milk composition, which enhanced the growth performance of kits. This supports the findings of Abdullah et al. (2003), who emphasized the role of breed and milk quality in offspring development.

Dietary supplementation with tiger nut significantly influenced both body weight and linear traits during the study. The enhanced performance observed with 20 g and 30 g inclusion levels aligns with earlier reports by Belewu and Belewu (2007) and Adejinmi et al. (2007), who noted that fiber-rich diets increased feed intake. This suggests that higher fiber levels, such as those from tiger nut, can support nutrient absorption and positively affect growth performance. Similar conclusions were drawn by Nsa et al. (2010), who observed that tiger nut meal increased fiber content, thereby stimulating feed intake and improving energy utilization.

Breed differences in reproductive traits were minimal, except for individual kit birth weight (IKBW), which was significantly higher in New Zealand White rabbits. This is in agreement with Oke and Iheanocho (2011), who reported that environmental uniformity can mask genetic differences in reproductive traits. New Zealand White's reputation as a reliable maternal breed is supported by its favorable IKBW, consistent with Adeolu et al. (2017). Although this breed also recorded a slightly higher pre-weaning mortality rate, the differences were not statistically significant and may be influenced by litter size or environmental conditions. These findings align with observations by Fayeye and Ayorinde (2010) and Akpo et al. (2008) in similar environments.

The absence of significant dietary effects on traits such as gestation length, litter size, and pre-weaning mortality agrees with earlier findings by Adama et al. (2020), who studied rabbits fed graded levels of tiger nut meal. However, notable improvements in kit birth and weaning weights were recorded in the group fed 30 g/kg of tiger nut. This might be attributed to the higher fat content of the feed, which could have increased milk yield and subsequently enhanced litter growth, as previously described by Kowalska and Bielanski (2004). Similar effects were observed in studies involving tiger nut extract on albino rats and rabbits by Ekaluo et al. (2015) and Adama et al. (2020).

The haematological parameters recorded in this study, namely packed cell volume (PCV), red blood cell (RBC) count, and white blood cell (WBC) count, serve as key indicators of the physiological and health status of animals. The reference ranges for healthy rabbits are as follows: PCV: 35–50%, RBC: 5.0–8.0 × 10^6/µl and WBC: 4.0–10.0 × 10^3/µl (Etim et al., 2014)

In this study, the values obtained for these parameters were generally higher than those reported by Chineke et al. (2006). Although the PCV values for the New Zealand White (NZW) and Hyla breeds 33.38 ± 1.41% and 33.38 ±

1.42% respectively and the 10 g/kg tiger nut dietary group (32.49 ± 2.14%) were slightly below the established lower reference threshold, they still suggest a tendency towards improved erythropoiesis. Elevated PCV levels typically indicate enhanced oxygen-carrying capacity and more efficient aerobic metabolism, which may be attributed to genetic predispositions or nutritional influences (Kopp & Hetesa, 2000).

The erythrocyte sedimentation rate (ESR) values observed were within moderate ranges and are consistent with those reported by Agbede et al. (2011) and Aro et al. (2012). Clinically, ESR is a non-specific indicator of inflammation and is influenced by factors such as diet, hydration, and environmental conditions.

Biochemical indicators play a crucial role in evaluating organ function and nutritional status. The serum total protein concentrations observed in this study ranged between 5.4–7.3 g/dl, which lies within the normal physiological range for rabbits (5.4–7.5 g/dl) as reported by Marai et al. (2006) and Adu et al. (2009). These levels reflect adequate protein synthesis and hepatic function, although they were slightly higher than those reported by Elsiddig (2008), suggesting improved dietary protein availability and utilization. Serum urea concentrations were found to be low, indicative of efficient nitrogen metabolism and possibly enhanced renal function. The standard reference range for rabbits is 10–40 mg/dl (Esonu et al., 2001; Henry et al., 2017). Lower-than-average urea levels may reflect reduced protein catabolism or increased protein retention for growth and tissue repair (Henry et al., 2017).

Serum cholesterol levels, which remained within the normal range of 10–80 mg/dl for rabbits (Bradley, 2001), further support the hypothesis that tiger nut supplementation does not induce hyperlipidemia. This finding implies that tiger nut-based diets may promote the production of leaner meat, which is advantageous from both a consumer and economic standpoint.

While serum protein concentrations remained relatively consistent across the different dietary groups, contrasting with findings by Agbabiaka et al. (2013) in broiler chickens, the results suggest that rabbits are capable of efficiently utilizing moderate levels of tiger nut in their diet.

However, elevated creatinine levels at higher tiger nut inclusions could point to inefficient protein metabolism or possible muscle degradation. The reference range for serum creatinine in rabbits is 0.5–1.5 mg/dl (Udoyong et al., 2010), and increases beyond this threshold may indicate increased muscular turnover or early renal strain.

CONCLUSION

The inclusion of tiger nut in rabbit diets, at levels up to 30 g/kg, was found to be safe and beneficial, with no adverse effects on the animals' health. This was supported by stable haematological and biochemical indices, as well as improved growth and reproductive performance across the tested rabbit breeds. The most consistent and optimal outcomes were observed at the 20 g/kg inclusion level, which enhanced key traits such as body weight, kit survival, and blood quality.

Therefore, incorporating tiger nut at 20 g/kg into rabbit diets is recommended as a practical strategy to improve productivity without compromising the animals' well-being. This dietary supplementation can be applied across different rabbit genotypes for effective and sustainable production outcomes.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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