

Energy partitioning for growth by rabbits fed groundnut and stylo santhes forages supplemented with concentrate

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Abstract

Forty eight crossbred (California X New Zealand White) rabbits were used to evaluate energy partitioning of rabbits fed forages supplemented with concentrate. The rabbits were randomly allocated to three treatments consisting of sole Stylosanthes hamata (stylo),sole Arachis hypogea (groundnut) haulms and 50:50 mixture of both forages (mixed), and four class groups: weaners, 6-8 weeks old (0.79kg), growers, 11-12 weeks old (1.15kg), pubertal, 15-16 weeks old (1.36kg) and adult, >16 weeks old (1.55kg) in a completely randomized design (3 x 4 factorial experiment). The rabbits were individually housed and offered 150g forage and 50g concentrate diet in separate feeders at 08.00hr. Feeding sole or mixed forages did not significantly affect daily gain or body composition of rabbits. DE intake, DE retention as protein, fat and growth, DE requirement for maintenance, protein synthesis, fat synthesis and for growth were similar for sole and mixed forages. Efficiency of utilization of DE for growth was significantly higher for mixed forage than sole stylo and ranged between 0.41-0.43. DE intake was similar for all classes of rabbits. Weaners had significantly higher retained energy as protein, fat and growth, DE requirement for protein and fat synthesis and for growth and efficiency of DE utilization for growth than growing, pubertal and adult rabbits. Efficiency of DE utilization for growth ranged between 0.39-0.47. Retained energy as protein, fat and for growth were similar for weaner and grower rabbits on mixed forage but higher than for pubertal and adult rabbits. For sole stylo, weaner rabbits retained more energy as protein, fat and growth than grower, pubertal and adult rabbits while for sole groundnut haulms, weaner and pubertal rabbits retained more energy as protein, fat and growth than grower and adult rabbits. DE utilization was better for mixed than stylo. It is concluded that feeding a mixture of groundnut and stylo forages slightly increased gain and improved efficiency of DE utilization resulting in better performance of the rabbits.

Keywords: concentrate, energy, forages, groundnut, partitioning, rabbit, Stylosanthes.

Introduction

Rabbits are pseudo ruminant animals which do not compete with man for food. The greatest potential for using rabbits is in areas where forages are readily available. Rabbits can be raised on diets consisting entirely of forage and cereal by-products as main sources of protein and energy with high level of production (Cheeke, 1986). In addition to supply of proteins and energy, forages supply fibre which aid proper digestion. Rabbits on verano stylo forage had similar performance with those on all concentrate diet (Bamikole and Ezenwa 1999).

Growth in animals involves increase in body size and mass (Close, 1980) The environment within which animals are maintained determines the extent to which digestible energy or metabolizable energy is utilized for maintenance and thermoregulation on one hand and energy retention or growth on the other (Close,

1980). Genetic and environmental controls regulate the set of metabolic events that regulate growth (Marai *et al*., 2002). Rabbits in the tropics are raised at ambient temperatures ranging between 27-44°C which is outside their comfort zone of 21-23°C.

Energy is derived from the synthesis of carbohydrate, protein and lipids. The energy requirement of rabbits is usually the proportion of the diet in terms of MJ Kg^{-1} of the feed. Animals in good health condition normally consume sufficient feed to meet their energy requirements (Pargi Bini and Xiccato, 1998). Voluntary feed intake is proportional to metabolic live weight ($LW^{0.75}$) and in growing rabbits it is about 900 - 1000 KJ digestible energy (DE) day^{-1} kg^{-1} $LW^{-0.75}$. This study was conducted to evaluate the partitioning of energy for growth by growing rabbits fed groundnut and stylosanthes forages supplemented with concentrate.

Materials and Methods

Location

The experiment was conducted at the Rabbitry Unit, National Animal Production Research Institute (NAPRI), Shika- Zaria, Nigeria. Shika is located in the Northern guinea Savanna, on latitude 11^0 12'N of the equator and longitude $7^0$33' with altitude of about 610mm and 1200mm, temperature ranges between 14.5°C during the early dry season (November-January) and 39.3°C which are usually expected during the late dry season (February to April). (Osinowo *et al*., 1991).

Experimental animals and housing

Crossbred rabbits obtained from mating between California and New Zealand White were used for this study. The rabbits were individually housed in metal cages with dimensions of 120 x 60 x 50 cm. The cages were placed in a well-ventilated house completely walled with wide, open windows covered with wire mesh and screened using mosquito netting. The rabbits were prophylactically treated with subcutaneous injection of ivomectine (Pantex® Holland) at the rate of 0.2ml/rabbit against both internal and external parasites and amprolium against coccidiosis.

Forage harvesting and handling

Stylosanthes hamata cv *Verano* was harvested from the Forage and Crop Residue Research Programme (FCRRP), NAPRI demonstration plot and air dried in a room (under shade) to maintain its greenish colour and quality while groundnut haulms were planted and harvested from the Rabbit Research Unit's groundnut farm and air dried in a shade. The forages were chopped to about 7mm length and bagged ready for use.

Experimental procedure

Forty eight (48) rabbits were allocated to three treatments consisting of *Stylosanthes hamata* (stylo), *Arachis hypogea* (groundnut) haulms and 50:50 mixture of both forages, and four class groups: weaners, 6-8 weeks old (0.79kg), growers, 11-12 weeks old(1.15kg), pubertal, 15-16 weeks old (1.36kg) and adult, >16 weeks old(1.55kg) in a 3 x 4 factorial experiment in a randomized complete block design. The rabbits were individually offered 150g forage and 50g rabbit diet (concentrate) in separate feeders in the morning at 08.00hr. Water was supplied *ad-lib* daily in earthen pots. The concentrate (22% CP and 2600kcal ME/kg), contained (%): maize 39.24, groundnut cake 42.26, maize offal 15.00, bone meal 3.0, salt 0.25, and vitamin/mineral premix 0.25. Table.1 shows the nutrient composition of the concentrate and forages fed. The study lasted six weeks with an initial one week adjustment period

Digestibility study was conducted using

Table 1: Analysed Nutrient composition (%DM) of concentrates and forages fed to rabbits

	DM	ASH	EE	CF	NFE	CP
Concentrate feed	96.57	6.68	12.61	10.13	48.64	21.94
Groundnut haulms	96.22	18.42	9.98	24.29	35.39	11.92
Stylosanthes forage	95.67	6.19	10.83	40.23	30.67	12.08
Mixed (stylo + groundnut) forage	94.87	8.96	11.98	32.26	35.68	11.12

thirty six rabbits (n= 12, for stylo, groundnut haulms and mixed), in the 6th week of the feeding trial. Faecal samples were collected for four days and stored in a refrigerator at -20°C during collection. At the end of the collection period, faecal samples were bulked for each rabbit. Feed and faecal samples were analyzed for proximate composition according to the procedure of AOAC (1980).

Data computation and Statistical analysis:

Data on live weight, weight gain, feed intake, nutrient digestibility were used to compute the composition of body gain, protein content of gain, retained energy as protein and fat, protein and digestible energy intake, requirement for maintenance and growth, protein synthesis and fat synthesis. Reference data from works by other authors given as; empty body gain (EBG) of 0.87 LWgain, EBG composition: water, 0.61 ; protein, 0.21; fat, 0.15; ash, 0.03, caloric value of body protein of 23.2 KJ g^{-1}, caloric value of body fat of 35.6 KJ g^{-1}, efficiency of DE utilization for retained energy (RE) as protein of 0.04, and efficiency of DE utilization for RE as fat of 0.65 (Garcia *et al*., 1996, Motta Ferrira *et al*., 1996, Fernandez and Fraga, 1996, Fraga, 1998, Parigini Bini and Xiccato, 1998) was used in computation of the parameters as indicated below.

Empty body gain (EBG) = 0.87 LW gain
EBG Composition: Water, 0.61 ; Protein, 0.21; Fat, 0.15; Ash, 0.03
Caloric Value of body protein = 23.2 KJ g^{-1}
Caloric value of body fat = 35.6 KJ g^{-1}
Efficiency of DE utilization for retained energy (RE) as protein = 0.40
Efficiency of DE utilization for retained energy (RE) as fat =0.65
Efficiency of DE utilization for growth=0.50

For computation

Estimation of Digestible Energy (DE) requirements and efficiency of utilization:
Metabolic Live Weight gain(MWG) =Final Weight – Initial Weight($^{-0.75}$)
Metabolic Live Weight (MLWT) = $LWT^{0.75}$
Empty Body Gain (EBG) =0.87 x Daily Live Weight gain
Protein gain = Empty body gain x Protein Content of gain
Fat Gain = Empty body gain x Fat content of gain
Retained Energy as Protein (RE_p) = Protein Gain x Caloric value of body protein
Retained Energy as fat (RE_f) = Fat gain x Caloric value of body fat
Total Retained Energy (RE_g) = RE_p + RE_f
Digestible Energy requirement for maintenance (DE_m) =430 KJ day^{-1} kJ^{-1} $LWT^{-0.75}$
DE requirement for RE_p (DE RE_p)= *REp/Efficiency of DE utilization for RE as Protein*
DE requirement for RE_f (DE RE_f) = *REf/Efficiency of DE utilization for RE as fat*

Table 2: Weight gain and body composition of gain of growing rabbits fed forages hays supplemented with concentrate

Parameter	Mixed	Stylo	Groundnut	SEM	P level
Initial weight (kg)*	1.16	1.21	1.24	0.11	0.17
Final weight (kg)*	1.48	1.45	1.54	0.13	0.32
Weight gain (kg)*	0.32	0.24	0.31	0.13	0.33
Metabolic weight gain($WG^{0.75}$)	0.42	0.33	0.39	0.12	0.33
Ave. daily gain (g)*	7.69	5.80	7.26	0.61	0.33
Empty body gain (g/d)	6.69	5.05	6.32	0.57	0.33
Water (g/d)	3.93	2.97	3.72	0.44	0.33
Protein (g/d)	1.42	1.07	1.34	0.26	0.33
Fat (g/d)	1.14	0.86	1.08	0.24	0.33
Ash (g/d)	0.19	0.14	0.18	0.10	0.34

Mixed (stylosanthes + Groundnut) forage. *Iyeghe-Erakpotobor (2009).

Total Digestible Energy requirement for growth (DE_g) = DE RE_p + DE RE_f
Efficiency of DE utilization for growth = *Total REg/DEg*
Total DE requirement = DE_m +DE_g

Data collected were subjected to analysis of variance using GLM procedure for a for factorial experiment in a completely randomized design while pair- wise difference method was used to separate significant means (SAS, 1987)

Results

Effect of forage type

Final weight, daily gain and body composition of rabbits were not significantly (P>0.05) affected by feeding stylo and groundnut forage hays either sole or mixed (Table 2). Digestible energy intake (Table 3) was similar for rabbits on sole stylo and groundnut haulms and mixed

Table 3: Digestible energy retention, requirement and efficiency of retention of growing rabbits fed forages hays supplemented with concentrate

Parameter	Mixed (stylo + Groundnut)	Stylo	Groundnut	SEM	P level
DE intake (kcalDM/d)	598.91	617.38	593.34	2.81	0.57
DE intake (kJDM/d)	2506	2583	2482		-
Retained energy as protein RE_p (kJ/d)	33.05	24.94	31.23	1.27	0.33
Retained energy as fat RE_f (kJ/d)	40.48	30.55	38.25	1.41	0.33
Retained energy for growth RE_g (kJ/d)	73.53	55.50	69.48	1.90	0.33
Maintenance energy requirement DE_m (kJ/d)	179.24	142.39	169.26	2.54	0.25
Energy requirement for protein synthesis DE RE_p (kJ/d)	82.63	62.36	78.08	2.01	0.33
Energy requirement for fat synthesis DE RE_f (kJ/d)	62.27	47.00	58.85	1.74	0.33
Energy requirement for growth DE_g (kJ/d)	144.90	109.36	136.93	2.66	0.33
Total digestible energy requirement DE (kJ/d)	324.14	251.74	306.19	3.68	0.29
Efficiency of DE utilization for growth	0.43^a	0.41^b	0.42^{ab}	0.06	0.05

^{ab}Means with the same superscript along rows are significantly different .DE= Digestible Energy

Table 4: Weight gain and body composition of gain of different classes of rabbits fed forages hays supplemented with concentrate

Parameter	Weaners	Growers	Pubertal	Adult	SEM	P level
Initial weight (kg)	0.78[a]	1.15[b]	1.36[c]	1.52[d]	0.08	<0.001
Final weight (kg)	1.30[a]	1.42[a]	1.58[b]	1.68[b]	0.10	<0.001
Weight gain (kg)	0.52[a]	0.27[b]	0.22[b]	0.16[b]	0.09	<0.001
Metabolic weight gain($WG^{0.75}$)	0.60[a]	0.36[b]	0.31[bc]	0.25[c]	0.09	<0.001
Ave. daily gain (g)	12.33[a]	6.35[b]	5.22[b]	3.77[b]	0.61	<0.001
Empty body gain (g/d)	10.73[a]	5.52[b]	4.54[b]	3.28[b]	0.43	<0.001
Water (g/d)	6.32[a]	3.25[b]	2.68[b]	1.93[b]	0.33	<0.001
Protein (g/d)	2.28[a]	1.18[b]	0.97[b]	0.70[b]	0.20	<0.001
Fat (g/d)	1.83[a]	0.94[b]	0.77[b]	0.56[b]	0.18	<0.001
Ash (g/d)	0.30[a]	0.16[b]	0.13[b]	0.09[b]	0.07	<0.001

[ab]Means with the same superscript along rows are significantly different

forages. Retention of energy in gain as protein, fat and growth and also energy requirement for maintenance, protein synthesis, fat synthesis and for growth were similar for the sole and mixed forages. Efficiency of utilization of DE for growth was significantly ($P<0.05$) higher for mixed than stylo and ranged between 0.41-0.43. Total digestible energy required for growth, protein and fat synthesis was higher for mixed and groundnut forages and lower for stylo fed rabbits.

Effect of class of rabbit

Initial weight was significantly different for all classes of rabbits (Table 4). However, final weight was similar for weaners and grower and significantly lower ($P<0.001$) than pubertal and adult rabbits. Weight gain was significantly higher for weaners than grower, pubertal and adult rabbits. Metabolic weight gain decreased with the age of the rabbits from weaners to adults. Empty body gain, water, protein, fat and ash content of body gain were significantly higher ($P<0.001$) for weaners than grower, pubertal and adult rabbits.

Digestible energy intake was similar for all the classes of rabbits (Table 5). Weaner rabbits had significantly ($P<0.001$) higher retained energy as protein, fat and growth, energy requirement for protein and fat synthesis and total DE requirement for growth than growing, pubertal and adult rabbits. Maintenance energy requirement and efficiency of DE utilization for growth were also significantly higher for weaners than grower and pubertal rabbits while adult rabbits had the lowest value. Efficiency of energy utilization for growth ranged between 0.39-0.47.

Effect of forage type and class of rabbit

Empty body gain, water, protein, fat and ash content of gain (Table 7) decreased from weaner to adult. Empty body gain of rabbits was higher for weaner and pubertal rabbits

Table 5: Digestible energy retention, requirement and efficiency of retention of different classes of rabbits fed forages hays supplemented with concentrate

Parameter	Weaners	Growers	Pubertal	Adult	SEM	P level
DE intake (kcalDM/d)	616.54	574.82	620.64	600.85	2.11	0.42
DE intake (kJDM/d)	2580	2405	2597	2514		
Retained energy as protein RE_p (kJ/d)	53.02^{a}	27.29^{b}	22.45^{b}	16.20^{b}	1.05	<0.001
Retained energy as fat RE_f (kJ/d)	64.93^{a}	33.42^{b}	27.50^{b}	19.84^{b}	1.05	<0.001
Retained energy for growth RE_g (kJ/d)	117.95^{a}	60.72^{b}	49.95^{b}	36.04^{b}	1.42	<0.001
Maintenance energy requirement DE_m (kJ/d)	259.26^{a}	154.72^{b}	134.55^{bc}	105.99^{c}	1.91	<0.001
Energy requirement for protein synthesis DE RE_p (kJ/d)	132.55^{a}	68.23^{b}	56.13^{b}	40.50^{b}	1.51	<0.001
Energy requirement for fat synthesis DE RE_f (kJ/d)	99.90^{a}	51.43^{b}	42.31^{b}	30.53^{b}	1.31	<0.001
Energy requirement for growth DE_g (kJ/d)	232.45^{a}	119.66^{b}	98.44^{b}	71.03^{b}	2.00	<0.001
Total digestible energy requirement DE (kJ/d)	491.70^{a}	274.38^{b}	232.99^{b}	177.01^{b}	2.76	<0.001
Efficiency of DE utilization for growth	0.47^{a}	0.42^{b}	0.41^{bc}	0.39^{c}	0.04	<0.001

^{ab}Means with the same superscript along rows are significantly different. *DE (kJDM/d) =Kcal DM/d *4.185.

Table 6: Effect of forage type and class of rabbit on weight and weight gain of rabbits fed forages hays supplemented with concentrate

Forage	*Class*	Initial weight (kg)	Final weight (kg)	*Metabolic weight* ($LW^{0.75}$)	Weight gain (kg)	Metabolic weight gain($WG^{0.75}$)	Ave. daily gain (g)
Mixed	Weaner	0.68^{a}	1.20^{a}	1.14^{b}	0.52^{a}	0.60^{a}	12.30^{a}
	Grower	1.09^{b}	1.46^{b}	1.33^{a}	0.37^{a}	0.47^{a}	8.93^{a}
	Pubertal	1.35^{c}	1.57^{b}	1.40^{a}	0.22^{b}	0.33^{b}	5.36^{b}
	Adult	1.52^{d}	1.70^{b}	1.49^{a}	0.17^{b}	0.27^{b}	4.16^{b}
Stylo	Weaner	0.81^{a}	1.26^{a}	1.18^{b}	0.45^{a}	0.54^{a}	10.71^{a}
	Grower	1.14^{b}	1.40^{ab}	1.29^{ab}	0.26^{b}	0.35^{b}	6.25^{b}
	Pubertal	1.35^{c}	1.45^{b}	1.32^{a}	0.10^{b}	0.18^{b}	2.38^{b}
	Adult	1.52^{d}	1.69^{b}	1.48^{a}	0.16^{b}	0.25^{b}	3.87^{b}
Groundnut	Weaner	0.84^{a}	1.42^{a}	1.30^{a}	0.59^{a}	0.66^{a}	13.98^{a}
	Grower	1.22^{b}	1.39^{a}	1.28^{ab}	0.16^{b}	0.25^{b}	3.87^{b}
	Pubertal	1.38^{c}	1.72^{b}	1.50^{a}	0.33^{a}	0.44^{a}	7.93^{a}
	Adult	1.50^{d}	1.64^{b}	1.45^{a}	0.14^{b}	0.22^{b}	3.27^{b}
	SEM	0.03	0.03	0.28	0.03	0.03	0.15
	P level**	<0.001	0.39	0.43	0.27	0.19	0.27

^{ab}Means with different superscripts along columns are significantly different ($p<0.05$). Gnut= groundnut haulms. **P level for interaction effect.

Table 7: Effect of forage type and class of rabbit on body composition of gain of rabbits fed forages hays supplemented with concentrate

Forage	*Class*	Empty body gain (g/d)	Water (g/d)	Protein (g/d)	Fat (g/d)	Ash (g/d)
Mixed	Weaner	10.70[a]	6.30[a]	2.28[a]	1.82[a]	0.30[a]
	Grower	7.77[a]	4.57[a]	1.66[a]	1.32[a]	0.22[a]
	Pubertal	4.66[b]	2.74[b]	0.99[b]	0.79[b]	0.13[b]
	Adult	3.62[b]	2.13[b]	0.77[b]	0.61[b]	0.10[b]
Stylo	Weaner	9.32[a]	5.49[a]	1.98[a]	1.59[a]	0.26[a]
	Grower	5.43[b]	3.20[b]	1.16[b]	0.92[b]	0.15[b]
	Pubertal	2.07[b]	1.22[b]	0.44[b]	0.35[b]	0.06[b]
	Adult	3.37[b]	1.98[b]	0.71[b]	0.57[b]	0.09[b]
Groundnut	Weaner	12.17[a]	7.17[a]	2.59[a]	2.07[a]	0.34[a]
	Grower	3.37[b]	1.98[b]	0.71[b]	0.57[b]	0.09[b]
	Pubertal	6.90[a]	4.07[a]	1.47[a]	1.17[a]	0.19[a]
	Adult	2.85[b]	1.68[b]	0.60[b]	0.48[b]	0.08[b]
	SEM	0.14	0.11	0.07	0.06	0.02
	P level**	0.27	0.27	0.27	0.27	0.29

[abc]Means with different superscripts along columns are significantly different ($p<0.05$). **P level for interaction effect.

on groundnut haulms than mixed forages and sole stylo fed rabbits while it was higher for growers on mixed forages and lowest for those on groundnut haulms. For adult rabbits, empty body gain was higher for mixed forages and stylo fed rabbits and lower for rabbits on groundnut haulms.

Digestible energy intake of rabbits was similar for all classes of rabbits on the forage hays (Table 8). Retained energy as protein, retained energy as fat and retained energy for growth was similar for weaner and grower rabbits on mixed forage but slightly higher than for pubertal and adult rabbits. For stylo, weaner rabbits retained more energy as protein, fat and growth than grower, pubertal and adult rabbits while for groundnut haulms, weaner and pubertal rabbits retained more energy as protein, fat and growth than grower and adult rabbits.

The same trend was observed for digestible energy required for protein and fat retention, digestible energy (Table 9), required for maintenance, growth, total digestible energy and for efficiency of DE utilization of digestible energy for growth. Efficiency of DE utilization ranged between 0.36-0.46 and was lowest for pubertal rabbits on stylo forage.

Discussion

Feeding of stylo and groundnut forage hays either sole or mixed did not significantly affect the daily gain or body composition of rabbits however, empty body gain and content of gain were significantly higher for weaners than growers, pubertal and adult rabbits. This could be as a result of changes in body mass and composition in weaners and growers who were actively growing compared with pubertal and adult rabbits that were at the stage of declining growth. Fraga (1998) reported higher content of body fat and energy and lower water content in fast growing rabbits. Heusner (1985) also reported that in the later phase of growth, body composition and form tend to remain constant while mass continues to increase by accumulation of fat and retention of water.

Digestible energy intake of rabbits on sole and mixed forages was not statistically different though DE intake for sole stylo forage was 3-3.9% higher than mixed and sole groundnut forage. This could probably

Table 8: Effect of forage type and class of rabbit on digestible energy intake, retention and requirement of rabbits fed forage hays supplemented with concentrate

Forage	*Class*	*DE intake (kcalDM/d)*	*Retained energy as protein RE_p (kJ/d)*	*Retained energy as fat RE_f (kJ/d)*	*Retained energy for growth RE_g (kJ/d)*	*Energy reqd for protein synthesis DE RE_p (kJ/d)*	*Energy reqd for fat synthesis DE RE_f (kJ/d)*
Mixed	Weaner	639.49	52.88	64.76	117.64	132.20	99.64
	Grower	554.91	38.39	47.02	85.41	95.98	72.34
	Pubertal	631.44	23.02	28.19	51.22	57.56	43.38
	Adult	569.81	17.91	21.93	39.84	44.76	33.74
Stylo	Weaner	622.23	46.06	56.40	102.46	115.14	86.78
	Grower	590.21	26.86	32.90	59.75	67.15	50.61
	Pubertal	633.09	10.23	12.53	22.76	25.58	19.28
	Adult	624.00	16.63	20.36	36.99	41.57	31.33
Ground nut	Weaner	587.91	60.12	73.63	133.76	150.31	113.28
	Grower	579.35	16.63	20.36	36.99	41.57	31.33
	Pubertal	597.38	34.11	41.77	75.88	85.27	64.26
	Adult	608.75	14.07	17.23	31.30	35.17	26.51
	SEM	7.02	0.32	0.35	0.47	0.50	0.44
	P level**	0.82	0.27	0.27	0.27	0.27	0.27

[abc]Means with the same superscript along columns are significantly different ($p<0.05$). **P level for interaction effect.

indicate that sole stylo was more palatable to rabbits than the mixed forages or sole groundnut haulms. Digestible energy intake was also similar for all the classes of rabbits because of similar feed intake. Parigi Bini and Xiccato (1998) explained that total quantity of energy ingested by rabbits daily tend to be constant because appetite regulation in rabbits was mostly controlled by chemostatic mechanisms.

Similar DE retention in protein and fat, and energy requirement for protein and fat synthesis with sole and mixed forages indicates a better utilization of energy by rabbits on these forages. This is indicated by the higher efficiency of digestible energy utilization for growth observed for mixed and sole groundnut in this study. Higher retained energy as protein, fat and growth observed in weaner rabbits than growing, pubertal and adult rabbits could be as a result of their higher weight gain and hence faster growth.

DE retention in protein, fat and growth, requirement for maintenance, protein and fat synthesis and growth decreased from weaner to adult rabbits for the sole and mixed forages. This indicates a reduction in DE utilization as the rabbits aged. Heusner (1985) reported a positive correlation between energy metabolism and body mass. Webster (1977) reported that the amount of food energy required for maintaining energy balance increases throughout growth as does ratio of maintenance requirement to *ad lib.* Intake, therefore, DE intake that is not retained as protein or fat in the body is lost as heat.

In this study, DE required for maintenance obtained ranged from 142.39 kJ/d for stylo forage, 169.26 kJ/d for groundnut forage and 179.24 KJ/d for the mixed forages

Table 9: Effect of forage type and class of rabbit on digestible energy intake, requirement and efficiency of utilization of rabbits fed forages hays supplemented with concentrate

Forage	Class	DE intake (kJDM/d)*	Maintenance energy reqt DE_m (kJ/d)	Energy reqt for growth DE_g (kJ/d)	Total digestible energy reqt DE (kJ/d)	Efficiency of DE utilization for growth
Mixed	Weaner	2676	258.56^{a}	231.84^{ab}	490.39^{a}	0.47
	Grower	2322	203.56^{a}	168.31^{b}	371.88^{b}	0.45
	Pubertal	2642	139.64^{b}	100.93^{bc}	240.58^{b}	0.41
	Adult	2384	115.18^{b}	78.50^{c}	193.69^{b}	0.40
Stylo	Weaner	2603	233.98^{a}	201.91^{ab}	435.89^{a}	0.46
	Grower	2469	151.66^{bc}	117.76^{b}	269.41^{b}	0.41
	Pubertal	2649	76.47^{c}	44.86^{c}	121.33^{c}	0.37
	Adult	2611	107.43^{bc}	72.90^{c}	180.33^{bc}	0.39
Ground nut	Weaner	2460	285.23^{a}	263.59^{a}	548.82^{a}	0.47
	Grower	2424	108.94^{bc}	72.90^{c}	181.84^{b}	0.39
	Pubertal	2499	187.53^{ab}	149.53^{b}	337.06^{b}	0.44
	Adult	2547	95.34^{bc}	61.68^{c}	157.02^{b}	0.38
	SEM	-	0.64	0.67	0.92	0.01
	P level**	-	0.20	0.27	0.23	0.16

^{abc}Means with the same superscript along columns are significantly different ($p<0.05$). **P level for interaction effect

which is lower than that obtained by Brody (1945), when he multiplied 70 kcals/$W^{0.75}$ kg or 292 kJ/$W^{0.75}$kg the basal metabolism by a factor of two to obtain the DE requirement for maintenance. The values obtained when converted to requirement per metabolic weight per day of 134 kJ DE for stylo, 108 kJ DE for groundnut and 123 kJ DE for mixed are also lower than 377 kJ day^{-1} kg^{-1} $LW^{0.75}$ in New Zealand white rabbits (Partridge *et al*., 1989) and 552 KJ DE day^{-1} Kg^{-1} $LW^{0.75}$ in Giant Spanish growing rabbits (de Blas *et al*., 1985). This could be because of the high forage intake of the rabbits as it formed the bulk of the feed consumption. Maintenance DE requirement was significantly higher for weaners than grower and pubertal rabbits while adult rabbits had the lowest value. Heusner (1985) reported a positive correlation between energy metabolism and body mass but observed that the relationship between body weight and energy metabolism was not linear over a large weight range.

Decreasing trend in digestible energy required for growth, protein and fat synthesis of rabbits from weaner to adults indicates the fact that growing rabbits require more energy than rabbits that are approaching, or have attained maturity. According to Parigi Bini and Xiccato (1998), an increase in the level of dietary energy intake affects the composition of body gain and the partition of energy retained as protein and fat. Joyce *et al.* (1971) reported that the DE requirement per kilogram of live weight gain falls within the range of 20,920KJ to 24,686 KJ (that is 20.92-24.69 kJ/g of live weight gain). DE requirement for growth of 251.74 KJ/d (43.40 KJ/g live weight gain) for stylo, 306.19 KJ/d (42.17 KJ/g live weight gain) for groundnut and 324.14 kJ (42.15 KJ/g live weight gain) for mixed forages obtained in this study is twice that recommended by Joyce *et al*. (1971). This

further indicates the effect of thermal stress on reducing energy utilization for growth in the tropics.

Efficiency of DE utilization for growth was significantly higher for mixed forages and groundnut than stylo and for weaners than grower and pubertal rabbits while adult rabbits had the lowest value. This indicates higher utilization of energy for growth as a result of faster growth rate in weaners then the other classes. Thyroxin a hormone necessary for cellular metabolism and energy utilization, plays an important role as a growth promoter and acts in the metabolism of protein, fat, carbohydrates and minerals (Marai *et al*., 2002).

At a given level of intake in the tropics, increase in environmental temperature above the upper critical temperature leads to increase in energy requirement for maintenance and a decrease in energy available for growth (Close, 1980). Lower efficiency of energy utilization in this study compared with temperate regions could be as a result of thermal stress. The National Academy Press (1981) reported that metabolizable energy for production is available after the maintenance needs of the animal are met, but because of heat production as a result of inefficiencies of product synthesis, energy available for production, as well as the costs of retaining or expelling the product is not entirely incorporated into animal products, be it retained in tissue growth or fattening.

Heat loss in mammals is reported to be proportional to body surface area and heat production per unit weight and is greater in small than large animals (Heusner, 1985). Considering the fact that reference data from studies conducted under temperate conditions were used for computing digestible crude protein requirements and digestible energy requirements in these studies, it is possible that some degree of over- or under-estimation of the values might have occurred.

Conclusion

The result revealed that DE utilization was better for mixed than stylo forage. DE intake was similar for all the classes of rabbits however, weaner rabbits had significantly ($P<0.01$) higher retained energy as protein, fat and growth, energy requirement for protein and fat synthesis, total DE requirement for growth than growers, pubertal and adult rabbits. This indicates the potentials of feeding groundnut and stylo forages to weaner, grower and pubertal rabbits by farmers to reduce cost of production.

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