Litter indices of primiparous rabbit does subjected to feed restriction during pregnancy with or without vitamin E inclusion

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ABSTRACT

Background and Objectives: Rabbits are characterized by high reproductive efficiency (number of offspring produced per doe per annum). Excessive overweight in rabbits has been reported to impair reproductive efficiency. Therefore, different feeding strategies have been explored to maintain body conditions of does. Thus, this study evaluates litter indices of rabbits does subject to feed restriction during pregnancy with or without vitamin E inclusion.

Methodology: Seventy-five (75) rabbits consisting of 60 primiparous rabbit does of 5 months old (1.7–2.0 kg) and 15 mature bucks of 6–7 months old, of mixed breeds (Chinchilla, Dutch, and New Zealand White) were randomly assigned into 12 treatments of 5 replicates each. Rabbit does were placed on two levels of quantitative feed restriction (0 and 15%) at three gestation periods (15–19, 20–24, and 25–29 days) with or without vitamin E inclusion (0 and 300 mg/kg). Data obtained on litter indices were subjected to a three-way analysis of variance in a completely randomized design.

Main Results: The overall interactive effect shows that significantly (P = 0.04), the highest average litter weight at birth, 354 ± 78.8 g was obtained from does fed *ad libitum* with vitamin E inclusion at 15–19 days compared to other treatments. The higher weight of kits at birth was obtained from rabbit does fed *ad libitum* with vitamin E inclusion for 15–19 (61.06 ± 0.32 g), 20–24 (62.03 ± 8.56 g), and 25–29 (60.86 ± 0.34 g) days compared to other treatments. While litter weight at weaning was statistically (P = 0.03) highest (3,170 ± 214 g) from rabbit does on feed restriction with vitamin E inclusion at 15–19 days of gestation.

Conclusions: *Ad libitum* feeding with vitamin E inclusion during pregnancy resulted in higher litter weight and kit weight at birth than the restricted group. Therefore, for better kit weight and viability during kindling, vitamin E should be incorporated in the diet of pregnant rabbit does.

Keywords: Reproductive indices, vitamin E, feed restriction, litter indices

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INTRODUCTION

In commercial rabbit production, it is a common practice to feed rabbit does *ad libitum* directly after mating and during gestation. However, *ad libitum* feeding of these rabbit does can lead to low embryonic survival with subsequent reduction in the number of newborn rabbits, which can be associated with excessive fatness in rabbit does (Fortun-Lamothe and Lebas, 1996). Excessive fatness can enhance subsequent difficulty in parturition and impair reproductive efficiency or performance (Partridge *et al.,* 1986). Therefore, feed restriction was suggested in pregnant rabbit does by Maertens (1992). Hartmann and Petersen (1995) reported improved fertility at second parity from the group of rabbit does raised on the 85% of the *ad libitum* feeding level. Feed restriction can be applied at different periods or different levels (restriction percentage in relation to free intake; Di Meo *et al*., 2007). Therefore, rabbit producers and nutritionists are trying different feeding strategies capable of reducing digestive disorders and enhancing the body condition of reproductive does, thereby increasing their reproductive performances and longevity (Parigi Bini and Xiccato, 1998). Vitamin E deficiency can cause infertility in all farm animals. This has been discovered particularly in rodents and has resulted in vitamin E sometimes being called the "fertility vitamin" (Bowen, 2003). Supplementation of vitamin E in the diet of farm animals has been observed to enhance fertility and immunity. Vitamin E, a dietary essential, fat-soluble vitamin, can enhance animal performance when provided in amounts above minimal requirements (Roger, 1999). Hence, this study aims to determine the impact of feed restriction with or without vitamin E inclusion on the reproductive indices of pregnant rabbit does.

MATERIALS AND METHODS

All rules guiding animal welfare and procedures were strictly followed following the rules and regulations of the Animal Welfare Committee of the College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta.

Experimental Site

The experiment was conducted at the Rabbitry Unit of the Directorate of University Farms, Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State. The site is located in South-Western Nigeria's rain forest vegetation zone on latitude 7°13'49.46" N, longitude 3°26'11.98" E, and altitude 76 m above sea level. The climate is humid, with a mean annual rainfall of 1,037 mm and mean temperature and humidity of 34.7°C and 83%, respectively (Google Earth, 2015).

Experimental Animals and Management

Seventy-five (75) rabbits consisting of sixty (60) 5 months old does of mixed breeds (Chinchilla, California, Dutch, and New Zealand White) with an initial live weight of 1.7–2.0 kg and fifteen (15) mature bucks with an initial live weight of 2.0–2.5 kg were used for this experiment. The cages were disinfected before the commencement of the experiment.

Experimental Animals Allotment

The young nulliparous does were divided into two groups of thirty (30) rabbits, each after balancing for weight, and housed individually in hutches of dimension 0.8 × 0.5 × 0.6 m. The rabbit bucks that were used for mating were similarly housed individually.

Mating Process

Each doe was carried into the buck's hutch for mating, and after successful natural mating, each doe was returned to its hutch. The mating process was carried out in the morning and 10 hours after the 1st mating to ensure fertilization. All the females were mated on the same day (24 hours). The mating ratio was a buck to five does.

Palpation Method and Procedure

Ten days after mating, the rabbit was palpated and checked for pregnancy. Each doe was held around the ears and in front of the shoulders using the right hand. The left hand was placed under the rabbit's body between the hind legs, in front of the pelvis, and checked for growing embryos.

Experimental Design

Treatments consisted of two levels of quantitative feed restriction (0 and 15%) fed at three periods (15–19, 20–24, and 25–29 days) during the pregnancy period with or without vitamin E inclusion (0 and 300 mg/kg). The rabbit does were divided into 12 groups of 5 replicates of 1 rabbit each. The composition of the concentrate diet fed to the nulliparous rabbits is shown in Table 1. The treatment arrangements were made in the following order: 0% restriction (control) was fed 100 g/rabbit/day (*ad libitum* feeding), and 15% restriction was fed 85 g/rabbit/day. Vitamin E inclusion at 300 mg/kg of feed is according to the recommendation of Gy *et al.* (2008) in rabbits.

Feeding Procedures

Rabbits on 0% restriction were offered 100 g of feed with or without vitamin E inclusion daily throughout the experimental period of 32 days. Rabbits on 15% restriction were offered 100 g of feed daily with or without vitamin E inclusion before and after the restriction periods. In contrast, 85 g of feed was offered during the periods of quantitative feed restriction.

Table 1 Composition of concentrate breeder diets

Composition	Diet A	Diet B
Ingredients (%)		
Maize	47.50	47.50
Fish meal	2.00	2.00
Soybean meal	3.00	3.00
Wheat offal	23.00	23.00
Groundnut cake	12.00	12.00
Rice husk	7.00	7.00
Bone meal	3.00	3.00
Oyster shell	2.00	2.00
Salt	0.25	0.25
Vitamin and mineral premix*	0.25	0.25
Total	100	100
Vitamin E (mg/kg)	0	300
Determined analysis		
Metabolizable energy (kcal/kg)	2,578.80	2,578.80
Ash (%)	2.74	2.74
Crude fiber (%)	10.65	10.65
Crude protein (%)	16.20	16.20
Nitrogen free extract (%)	42.50	42.50

Note: * Premix contained: vitamin A 8,000 IU, vitamin D3 2,000 IU, vitamin E 4,000 IU, vitamin K 2 mg, riboflavin 4.20 mg, vitamin B12 0.01 mg, pantothenic acid 5 mg, nicotinic acid 20 mg, folic acid 5 mg, choline 300 g, Mn 56 mg, Fe 20 mg, Cu 10 mg, and Zn 50 mg. Diet A = composition of breeder diet fed without vitamin E inclusion, Diet B = composition of breeder diet fed with vitamin E inclusion. The nulliparous does were also offered 100 g of *Tridax procumbens* forage to meet up with the fiber requirement of the rabbits once a week across the dietary treatments.

Kindling Preparation

On the 21st day of pregnancy, after successful mating and palpation, nest boxes (0.5 × 0.5 × 0.3 m) were introduced into the maternity hutches (0.9 × 0.6 × 0.6 m) of each pregnant doe to enhance proper preparation of this does for kindling.

Data Collection

Data were collected on litter size at birth (LSB), litter weight at birth (LWTB), average kit weight at birth (AWTB), litter size at weaning (LSW), kit weight at weaning (KWTW), litter weight at weaning (LWTW), and pre-weaning weight gain of kits (PWWT). The does were fed *ad libitum* without vitamin E as indicated in Table 1, from the kindling date till the time of weaning. Extra feeders were provided in each hutch two weeks after kindling to ensure the kits had access to feed. Litter size at birth was taken immediately after kindling by counting the number of kits per doe. Litter weight at birth was the live weight of all kits at birth within the litter. Average kit weight at birth was calculated by dividing the total live weight of the kits per doe by the number of kits. Litter size at weaning was determined by counting the number of kits that were alive at weaning age. Kit weight at weaning was the live weight of each of the kits at 6 weeks of weaning. Litter weight at weaning was measured by taking the weight of all kits per doe during weaning.

Statistical Analysis

The experimental layout was in a 2 × 3 × 2 factorial arrangement, and data collected were subjected to three-way analysis (SAS, 1999). Significantly ($P < 0.05$) different means were separated using Duncan's multiple range test of SAS (1999) statistical packages. The experimental model was:

$$y_{ijkl} = \mu + V_i + P_j + R_k + VP_{ij} + VR_{ik} + PR_{jk} + VPR_{ijk} + \varepsilon_{ijkl}$$

where y_{ijkl} is the observed value of dependent variables, μ is the overall mean value, V_i is the effect of i^{th} vitamin E inclusion, P_j is the effect of j^{th} period of feed restriction, R_k is the effect of k^{th} feed restriction, VP_{ij} is the effect of interaction between i^{th} vitamin E inclusion and j^{th} period of feed restriction, VR_{ik} is the effect of interaction between i^{th} vitamin E inclusion and k^{th} feed restriction, PR_{jk} is the effect of interaction between j^{th} period of feed restriction and k^{th} feed restriction, VPR_{ijk} is the effect of interaction between i^{th} vitamin E inclusion, j^{th} period of feed restriction and k^{th} feed restriction, and ε_{ijkl} is the residual error.

RESULTS AND DISCUSSION

Table 2 shows the effect of feed restriction levels, periods of feed restriction, and vitamin E inclusion during pregnancy on litter performance. The average weight of kit at birth was significantly ($P < 0.05$) influenced by the levels of feed restriction. A higher (57.12 ± 5.41 g/kit) mean value for the kit weight at birth was obtained for non-restricted gestating rabbits compared to 50.30 ± 2.50 g/kit obtained for restricted gestating rabbit does. The significant effect obtained on the kit weight at birth could be attributed to feed restriction applied on the does. This result is in contrast with the work of Brecchia *et al.* (2012), who reported that the weight of individual kit was not affected by levels of feed restriction. However, litter size, litter weight at birth, litter size at weaning, litter weight at weaning, kit weight at weaning, and pre-weaning weight gain were not significantly ($P > 0.05$) influenced by the levels of feed restriction. The no significant ($P > 0.05$) difference obtained in litter size at birth is in line with the result of Rommers *et al.* (2004), who reported that feeding levels during gestation did not affect litter size at birth. The result obtained on litter weight at birth and litter size at weaning further agrees with the work of Menchetti *et al.* (2015), who reported that litter weight at birth and litter size at weaning of rabbit does were not affected by feeding levels.

The periods of feed restriction significantly ($P < 0.05$) influenced litter weight at birth, litter size at weaning, kit weight at weaning, and pre-weaning weight gain. Litter weight at birth decreases as the period of restriction increases across dietary treatments. This could be attributed to the period at which restriction was applied. These results are in agreement with the work of Brecchia *et al.* (2012), who reported that litter weight at birth was significantly affected by the periods of feed restriction. Pre-weaning weight gain was heavier (504 ± 169 g/kit) from rabbit does restricted at 20–24 days of gestation, while lighter (402 ± 90 g/kit) weight was obtained from rabbit does restricted at 15–19 days of gestation. The highest mean values (637 ± 180 g/kit) for kit weight at weaning were obtained at 20–24 days of gestation, while the least (523 ± 102 g/kit) was obtained at 15–19 days of gestation. Kit weight at weaning and pre-weaning weight gain were significantly influenced by the periods of feed restriction. The results obtained in this study contrast with the work of Nafeaa *et al.* (2011), who reported that feed restriction during the second half of gestation significantly decreased the pre-weaning weight gain of kits. The heavier kit weight at weaning obtained during the periods of feed restriction might be due to the ability of the kits to suckle well. However, litter size at birth, kit weight at birth, and litter weight at weaning were not significantly ($P > 0.05$) influenced by the periods of feed restriction.

Vitamin E inclusion significantly ($P < 0.05$) influenced litter weight at birth, average weight of kit at birth, litter size at weaning, and kit weight at weaning. Means for litter weight at birth, average weight of kit at birth, and litter size at weaning were statistically higher with does fed with vitamin E inclusion compared with results obtained from does fed without vitamin E inclusion. Higher litter weight at birth obtained from those fed vitamin E during pregnancy could be attributed to the inclusion of vitamin E in the diet. This result agrees with the findings of Abdul-Khalek (2008), who reported heavier litter weight at birth with vitamin E inclusion during pregnancy than the control groups. The average weight of kits at birth was significantly influenced by vitamin E inclusion. This could be attributed to vitamin E inclusion in the diet of the rabbit does during pregnancy, and this agreed with the work of Shaibu (2014), who reported heavier body weight with vitamin E inclusion compared to the control groups. Kit weight at weaning was significantly influenced by vitamin E inclusion, and this is in agreement with the work of Abdul-Khalek (2008), who reported a significant difference in heavier weaning weight from rabbit does without vitamin E than rabbit does with vitamin E inclusion.

Table 3 shows the interactive effect between levels and periods of feed restriction during pregnancy on litter performances of rabbit does. Significant ($P < 0.05$) differences were obtained for the average weight of kit at birth, litter size at weaning, kit weight at weaning, and pre-weaning weight gain. The average weight of kit at birth was significantly ($P < 0.05$) influenced by the levels and periods of feed restriction. The heavier weight of the kit at birth was obtained from rabbit does on 0% restriction during pregnancy compared to the lighter weight of the kit at birth obtained from rabbit does on the 15% restriction. Significant differences obtained in the average weight of the kit at birth for levels and periods of feed restriction could be attributed to feed restriction applied during pregnancy, which decreased the fetus's weight. This agreed with the work of Fortun-Lamothe and Lebas (1994), who recorded a significant decrease in the weight of fetuses carried by does subjected to different degrees of feed restriction maintained for various periods during gestation. Litter size at weaning of rabbit does subjected to 0 and 15% restriction at 15–19 days of gestation was statistically higher than that of the others, while the smallest litter size was obtained in the group subjected to 0% restriction between 20–24 days. This result could not be attributed to the treatment effect. This result is in contrast with the work of Brecchia *et al.* (2012), who reported no significant difference in litter size at weaning for does subjected to varying levels and periods of feed restriction.

Table 2 Effects of feed restriction levels, periods of feed restriction and vitamin E inclusion during pregnancy on litter performances of rabbit does

Parameters	Levels of feed restriction		Periods of feed restriction			Vitamin E inclusion	
	0%	15%	15–19 days	20–24 days	25–29 days	-Vit. E	+Vit. E
LSB (kit)	5.03 ± 1.44	5.23 ± 1.56	5.75 ± 1.58	4.85 ± 1.59	4.80 ± 1.15	4.80 ± 1.29	5.46 ± 1.63
LWTB (g)	289 ± 92	264 ± 86	311 ± 90^{a}	263 ± 100^{ab}	256 ± 69^{b}	243 ± 67^{b}	311 ± 97^{a}
AWTB (g/kit)	57.12 ± 5.41^{a}	50.30 ± 2.50^{b}	53.87 ± 4.50	54.02 ± 6.60	53.18 ± 5.10	50.64 ± 2.70^{b}	56.74 ± 5.70^{a}
LSW (kit)	4.56 ± 1.27	4.86 ± 1.35	5.40 ± 1.23^{a}	4.30 ± 1.50^{b}	4.45 ± 0.94^{b}	4.33 ± 1.12^{b}	5.10 ± 1.39^{a}
LWTW (g)	2,602 ± 459	2,640 ± 537	2,752 ± 503	2,568 ± 525	2,541 ± 455	2,586 ± 507	2,655 ± 490
KWTW (g/kit)	601 ± 166	561 ± 117	523 ± 102^{b}	637 ± 180^{a}	585 ± 118^{ab}	618 ± 137^{a}	545 ± 143^{b}
PWWT (g/kit)	464 ± 152	442 ± 109	402 ± 90^{b}	504 ± 169^{a}	453 ± 108^{ab}	482 ± 127	424 ± 132

Note: ^{a,b} Means in the same row with different superscripts differ significantly on main factors ($P < 0.05$). LSB = litter size at birth, LWTB = litter weight at birth, AWTB = average weight of kit at birth, LSW = litter size at weaning, LWTW = litter weight at weaning, KWTW = kit weight at weaning (g), PWWT = pre-weaning weight gain.

Table 3 Interactive effect between levels and periods of feed restriction during pregnancy on litter performances of rabbit does

Levels of feed restriction	0%			15%		
Periods of feed restriction	15–19 days	20–24 days	25–29 days	15–19 days	20–24 days	25–29 days
LSB (kit)	5.60 ± 1.07	4.80 ± 1.93	4.70 ± 1.15	5.90 ± 2.02	4.90 ± 1.28	4.90 ± 1.19
LWTB (g)	317 ± 72	279 ± 124	270 ± 76	303 ± 109	248 ± 74	242 ± 62
AWTB (g/kit)	56.56 ± 4.82^{a}	57.70 ± 7.39^{a}	57.11 ± 4.08^{a}	51.18 ± 2.20^{b}	50.34 ± 3.00^{b}	49.25 ± 1.90^{b}
LSW (kit)	5.40 ± 0.96^{a}	4.10 ± 1.59^{b}	4.20 ± 0.78^{ab}	5.40 ± 1.50^{a}	4.50 ± 1.43^{ab}	4.70 ± 1.05^{ab}
LWTW (g)	2,630 ± 427	2,555 ± 601	2,620 ± 360	2,875 ± 564	2,580 ± 469	2,463 ± 541
KWTW (g/kit)	493 ± 80^{c}	671 ± 213^{a}	639 ± 128^{ab}	553 ± 118^{abc}	602 ± 144^{abc}	529 ± 80^{bc}
PWWT (g/kit)	370 ± 65^{b}	532 ± 199^{a}	491 ± 120^{ab}	434 ± 101^{ab}	479 ± 136^{ab}	415 ± 85^{ab}

Note: ^{a,b,c} Means in the same row with different superscripts differ significantly ($P < 0.05$). LSB = litter size at birth, LWTB = litter weight at birth, AWTB = average weight of kit at birth, LSW = litter size at weaning, LWTW = litter weight at weaning, KWTW = kit weight at weaning (g), PWWT = pre-weaning weight gain.

However, comparable mean values were obtained in other dietary treatments. Kit weight at weaning and pre-weaning weight gain was significantly ($P < 0.05$) higher from rabbit does on 0% restriction between 20–24 days of gestation, while the least was obtained at 0% restriction between 15–19 days of gestation. The results obtained in this study are contrary to the work of Brecchia *et al.* (2012), who reported no significant difference in litter weight at weaning for rabbit does fast during pregnancy. Higher pre-weaning weight gain obtained from fed *ad libitum* during pregnancy could be attributed to non-restrictive feeding that helps the litters have a good start off till weaning. This result contrasts with the work of Manal *et al.* (2010), who reported that kit weight gain from birth to weaning was not significantly influenced by the levels and periods of feed restriction.

Table 4 shows the interactive effect between levels of feed restriction and vitamin E inclusion during pregnancy on litter performances of rabbit does. Significant ($P < 0.05$) differences were obtained on litter weight at birth, average weight of kit at birth, and litter size at weaning. Litter weight at birth was higher from rabbit does on 0% restriction with vitamin E inclusion compared to the least value obtained from does on 0 and 15% restriction without vitamin E inclusion. The significant difference obtained in litter weight at birth in this study might be due to vitamin E inclusion in the diet. This result agrees with the work of Abdul-Khalek (2008), who reported heavier litter weight at birth for rabbit does fed vitamin E during pregnancy than the control group. The average weight of the kit at birth increased with vitamin E inclusion with rabbit does on 0% restriction with vitamin E inclusion having the heavier weight of kit weight at birth compared to 15% restricted does without vitamin E inclusion that recorded the least mean value. The significant difference in the average weight of the kit might be attributed to vitamin E inclusion and non-restrictive feeding applied on the does during pregnancy. A lower weight of kits obtained at 15% restriction with or without vitamin E inclusion agrees with the work of Fortun-Lamothe and Lebas (1994), who recorded a significant decrease in the weight of fetuses subjected to feed restriction. The litter size at weaning was higher (5.33 ± 1.39 kits) from rabbit does on 15% restriction with vitamin E inclusion during pregnancy. The least (4.26 ± 1.09 kits) was obtained from 0% restricted does without vitamin E inclusion during pregnancy. The significant difference obtained cannot be attributed to the treatment effect. However, no significant difference ($P > 0.05$) was obtained in litter size at birth, litter weight at weaning, kit weight at weaning, and pre-weaning weight gain, respectively.

Table 4 Interactive effect between levels of feed restriction and vitamin E inclusion during pregnancy on litter performances of rabbit does

Levels of feed restriction	**0%**		**15%**	
Vitamin E inclusion	**+Vit. E**	**-Vit. E**	**+Vit. E**	**-Vit. E**
LSB (kit)	5.40 ± 1.68	4.66 ± 1.11	5.53 ± 1.64	4.93 ± 1.48
LWTB (g)	331 ± 101^{a}	247 ± 60^{b}	289 ± 90^{ab}	239 ± 75^{b}
AWTB (g/kit)	61.32 ± 4.61^{a}	52.93 ± 1.30^{b}	52.16 ± 1.60^{b}	48.35 ± 1.50^{c}
LSW (kit)	4.86 ± 1.40^{ab}	4.26 ± 1.09^{b}	5.33 ± 1.39^{a}	4.40 ± 1.18^{ab}
LWTW (g)	2,553 ± 498	2,650 ± 427	2,756 ± 477	2,521 ± 584
KWTW (g/kit)	553 ± 169	649 ± 153	537 ± 117	585 ± 115
PWWT (g/kit)	417 ± 154	511 ± 138	430 ± 108	453 ± 112

Note: ^{a,b,c} Means in the same row with different superscripts differ significantly ($P < 0.05$). LSB = litter size at birth, LWTB = litter weight at birth, AWTB = average weight of kit at birth, LSW = litter size at weaning, LWTW = litter weight at weaning, KWTW = kit weight at weaning (g), PWWT = pre-weaning weight gain.

The interactive effect between vitamin E inclusion and period of feed restriction during pregnancy significantly (P < 0.05) affected all litter performances of rabbit does (Table 5). Litter size at birth was higher for those on vitamin E inclusion at 15–19 days of gestation, while the least was obtained for those fed without vitamin E inclusion at 20–24 days of gestation. However, comparable mean values were obtained for other dietary treatments. The average weight of the kit at birth was statistically similar and higher for those fed with vitamin E inclusion, which differed significantly (P < 0.05) from rabbit does fed without vitamin E inclusion. The significant effect obtained on the average weight of the kit at birth could be attributed to the inclusion of vitamin E in the diet of the does during pregnancy. This result agrees with the findings of Shaibu (2014), who reported heavier weight in rabbit does fed vitamin E during pregnancy. Litter weight at birth and litter size at weaning increased significantly (P < 0.05) with vitamin E inclusion during pregnancy at 15–19 days of gestation compared to a decrease recorded for rabbit does fed a diet without vitamin E inclusion during pregnancy at 20–24 days of gestation. This could be a result of different mothering abilities exhibited by each doe during the experimentLitter weight at weaning increased (2,955 ± 281 g) significantly (P < 0.05) with vitamin E inclusion during pregnancy at 15–19 days of gestation, while the least (2,385 ± 291 g) was obtained at 25–29 days of gestation with vitamin E inclusion. This could be attributed to heavier litter weight at birth recorded for rabbits in these groups. Kit weight at weaning and pre-weaning weight gain was significantly (P < 0.05) influenced without vitamin E inclusion with rabbit does between 20–24 days of gestation having heavier weight (728 ± 139 g/kit) while comparable mean values were obtained at other dietary treatments. Pre-weaning weight gain of kits was highest from rabbit does without vitamin E inclusion at 20–24 days of gestation, while the least was obtained at 15–19 days of gestation without vitamin E inclusion.

Table 6 shows the interactive effect between levels and periods of feed restriction and vitamin E inclusion during pregnancy on litter performances of rabbit does. Significant (P < 0.05) differences were obtained on litter weight at birth, average weight of kit at birth, litter size at weaning, litter weight at weaning, kit weight at weaning, and pre-weaning weight gain. Rabbit does on 0% restriction at 15–19 days of gestation with vitamin E inclusion produced a significantly heavier litter weight at birth (354 ± 79 g) compared to rabbit does on 15% restriction at 20–24 days of gestation without vitamin E inclusion that had the least litter weight (200 ± 21 g). The result obtained in this study on litter weight at birth and average weight of kit at birth can be attributed to restriction levels and vitamin E inclusion. The results obtained on litter weight at birth in this study is contrary to the work of Mosaad (2001), who reported heavier litter weight at birth from fasted rabbit does than the *ad libitum* fed groups likewise, heavier litter weight was obtained with rabbits does on vitamin E inclusion. This result agrees with the work of Abdul-Khalek (2008) who reported higher litter weight at birth in rabbits with vitamin E inclusion. The average weight of the kit at birth increased significantly (P < 0.05) with vitamin E inclusion. The highest (62.0 ± 8.56 g/kit) weight was obtained for 0% restricted does at 20–24 days of gestation with vitamin E inclusion, while the least (47.77 ± 1.38 g/kit) was obtained from does on 15% restriction at 20–24 days of gestation without vitamin E inclusion. The average weight of the kit at birth obtained in this study agrees with the work of Mosaad (2001), who reported heavier bunny weight at birth for *ad libitum* fed rabbit does than restricted groups. The inclusion of vitamin E coupled with non-restrictive feeding increased the weight of the kit at birth. This coincides with the report of Shaibu (2014) who reported a heavier weight of the kit at birth with vitamin E inclusion compared to the control group.

Table 5 Interactive effect between vitamin E inclusion and periods of feed restriction during pregnancy on litter performances of rabbit does

Vitamin E inclusion	**+Vit. E**			**-Vit. E**		
Period of feed restriction	**15–19 days**	**20–24 days**	**25–29 days**	**15–19 days**	**20–24 days**	**25–29 days**
LSB (kit)	6.10 ± 1.59^{a}	5.50 ± 1.95^{ab}	4.80 ± 1.13^{ab}	5.40 ± 1.57^{ab}	4.20 ± 0.78^{b}	4.80 ± 1.22^{ab}
LWTB (g)	347 ± 89^{a}	314 ± 115^{ab}	269 ± 73^{bc}	273 ± 78^{abc}	212 ± 45^{c}	244 ± 64^{bc}
AWTB (g/kit)	57.08 ± 4.22^{a}	57.47 ± 7.51^{a}	55.66 ± 5.52^{a}	50.66 ± 1.85^{b}	50.57 ± 3.14^{b}	50.70 ± 3.21^{b}
LSW (kit)	5.80 ± 1.13^{a}	5.10 ± 1.72^{ab}	4.41 ± 0.96^{bc}	5.00 ± 1.24^{ab}	3.50 ± 0.52^{c}	4.50 ± 0.97^{bc}
LWTW (g)	$2,955 \pm 281^{a}$	$2,625 \pm 655^{ab}$	$2,385 \pm 291^{b}$	$2,550 \pm 603^{ab}$	$2,510 \pm 231^{ab}$	$2,697 \pm 546^{ab}$
KWTW (g/kit)	526 ± 109^{b}	545 ± 175^{b}	565 ± 149^{b}	519 ± 101^{b}	728 ± 139^{a}	603 ± 79^{b}
PWWT (g/kit)	410 ± 101^{b}	414 ± 159^{b}	447 ± 137^{b}	394 ± 80^{b}	595 ± 128^{a}	458 ± 77^{b}

Note: ^{a,b,c} Means in the same row with different superscripts differ significantly ($P < 0.05$). LSB = litter size at birth, LWTB = litter weight at birth, AWTB = average weight of kit at birth, LSW = litter size at weaning, LWTW = litter weight at weaning, KWTW = kit weight at weaning (g), PWWT = pre-weaning weight gain.

Table 6 Interactive effect between levels and periods of feed restriction and vitamin E inclusion during pregnancy on litter performances of rabbit does

Feed restriction		Vitamin E inclusion	LSB (kit)	LWTB (g)	AWTB (g/kit)	LSW (kit)	LWTW (g)	KWTW (g/kit)	PWWT (g/kit)
Level	Period								
0%	15–19 days	+Vit. E	5.80 ± 1.30	354 ± 79[a]	61.06 ± 0.32[a]	5.60 ± 0.89[ab]	2,740 ± 129[ab]	496 ± 52[b]	372 ± 50[b]
	20–24 days	+Vit. E	5.40 ± 2.50	334 ± 151[ab]	62.03 ± 8.56[a]	4.80 ± 2.04[abcd]	2,440 ± 854[b]	547 ± 236[b]	414 ± 218[b]
	25–29 days	+Vit. E	5.00 ± 1.22	304 ± 74[abc]	60.86 ± 0.34[a]	4.20 ± 0.83[bcd]	2,480 ± 238[ab]	615 ± 180[b]	465 ± 166[b]
	15–19 days	-Vit. E	5.40 ± 0.89	281 ± 45[abc]	52.07 ± 1.33[bc]	5.20 ± 1.09[abc]	2,520 ± 603[ab]	489 ± 107[b]	368 ± 84[b]
	20–24 days	-Vit. E	4.20 ± 1.09	225 ± 62[bc]	53.38 ± 0.81[b]	3.40 ± 0.54[d]	2,670 ± 225[ab]	795 ± 91[a]	651 ± 81[a]
	25–29 days	-Vit. E	4.40 ± 1.14	236 ± 68[abc]	53.36 ± 1.46[b]	4.20 ± 0.83[bcd]	2,760 ± 432[ab]	662 ± 58[ab]	515 ± 60[ab]
15%	15–19 days	+Vit. E	6.40 ± 1.94	340 ± 107[ab]	53.11 ± 0.79[b]	6.00 ± 1.41[a]	3,170 ± 214[a]	555 ± 147[b]	448 ± 130[b]
	20–24 days	+Vit. E	5.60 ± 1.51	295 ± 78[abc]	52.92 ± 1.73[bc]	5.40 ± 1.51[ab]	2,810 ± 388[ab]	542 ± 117[b]	413 ± 97[b]
	25–29 days	+Vit. E	4.60 ± 1.14	232 ± 61[abc]	50.47 ± 1.03[bcd]	4.60 ± 1.14[abcd]	2,290 ± 332[b]	514 ± 107[b]	429 ± 119[b]
	15–19 days	-Vit. E	5.40 ± 2.19	266 ± 108[abc]	49.26 ± 1.01[cd]	4.80 ± 1.48[abcd]	2,580 ± 672[ab]	549 ± 97[b]	420 ± 75[b]
	20–24 days	-Vit. E	4.20 ± 0.44	200 ± 21[c]	47.77 ± 1.38[d]	3.60 ± 0.54[cd]	2,350 ± 461[b]	662 ± 155[ab]	539 ± 150[ab]
	25–29 days	-Vit. E	5.20 ± 1.30	251 ± 68[abc]	48.04 ± 1.85[d]	4.80 ± 1.09[abcd]	2,635 ± 688[ab]	544 ± 45[b]	401 ± 40[b]

Note: [a,b,c d] Means in the same column with different superscripts differ significantly ($P < 0.05$). LSB = litter size at birth, LWTB = litter weight at birth, AWTB = average weight of kit at birth, LSW = litter size at weaning, LWTW = litter weight at weaning, KWTW = kit weight at weaning (g), PWWT = pre-weaning weight gain.

At weaning, litter size and litter weight were significantly ($P < 0.05$) influenced by the interactive effect between levels and periods of feed restriction and vitamin E inclusion. Gestating rabbit does on 15% restriction at 15–19 days of gestation with vitamin E inclusion had higher litter size at weaning (6.00 ± 1.41 kits) and litter weight at weaning (3,170 ± 214 g). Heavier litter weight at weaning obtained from restricted does with vitamin E inclusion could be attributed to catch-up growth that happened to the litters after kindling. This result agrees with the work of Manal *et al.* (2010) who reported heavier litter weight at weaning from the restricted group compared to the control groups. Including vitamin E and restriction levels increased litter weight at weaning. This result agrees with the findings of Shaibu (2014), who reported higher litter weight at weaning in rabbit does fed vitamin E than in the control groups. Significant ($P < 0.05$) differences were obtained for kit weight at weaning and pre-weaning weight gain of kits. The highest kit weight at weaning (795 ± 91 g/kit) and pre-weaning weight gain (651 ± 81 g/kit) were obtained from gestating rabbit does on 0% restriction at 20–24 days of gestation without vitamin E inclusion, while the least (489 ± 107 g/kit and 368 ± 84 g/kit, respectively) were recorded for rabbit does at same level of feed restriction without vitamin E inclusion at 15–19 days of gestation. Pre-weaning weight gain of kits was significantly affected by the dietary treatments. This result is contrary to the work of Manal *et al*. (2010), who reported no significant difference in kit weight gain from birth to weaning in pregnant rabbit does. Pre-weaning weight gain of kits increased from rabbit does without vitamin E inclusion in this study coincides with the report of Shaibu (2014), who reported heavier pre-weaning weight gain of kits in *ad libitum* fed rabbits without vitamin E than does fed with vitamin E.

CONCLUSIONS

It can be concluded that *ad libitum* feeding of rabbit does with vitamin E inclusion during pregnancy resulted in higher litter weight at birth and higher kit weight at birth compared to the restricted group. Thus, for better litter weight at birth and kit weight during kindling, vitamin E should be incorporated into the diet of pregnant rabbits does.

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