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ANTIOXIDANT STATUS AND PRODUCTIVE PERFORMANCE OF PREGNANT RABBIT DOES AS AFFECTED BY ALOE VERA LEAVES POWDER SUPPLEMENTATION

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ABSTRACT: *The current study has been conducted in Rabbit Research Unite in Sakha Station, located in Kafr El-Sheikh governorate. Using 24 of New Zealand White (NZW) rabbit does aged between 8-10 months and their average initial body weight was 3377 ± 36.7g. Divided into four groups, G1 was served as control group and fed on commercial pellets with no any additions. The other three groups, G2, G3 and G4 fed on diets supplemented with Aloe Vera (AV) powder at levels 0.5, 1.0 and 2.0 g/kg diet, respectively.*

The results showed that*, rabbits subjected to severe heat stress during months of July, August and September (THI= 30.5, 31.8 and 29.9, respectively). While, the corresponding value of THI during October and November month value was 27.7 and 24.7, respectively, indicated moderate and no heat stress. The antioxidant status was in overall, higher in TAC levels with lower levels of MDA in supplemented groups with AV than that in the control one. During summer season, litter size at birth and weaning age was lower in G1 (6.2 ± 0.33 and 4.3± 0.33, respectively) compared to supplemented groups. The G3 was the highest group in litter size, recorded 7.0 ± 0.33 at birth vs. 6.8± 0.33 and 6.7± 0.33 in G2 and G4, respectively. Whilst, in autumn litter size was not differed between groups and they almost close to each other. Furthermore, AV, during summer season, especially at level 1g/kg diet (G3), helped rabbit does to deliver their kits with higher body weight (280.8± 12.7 g) than that in other groups. At weaning age, those kits (of G3) recorded the highest body weight, 2450.8± 71.8 than that in G1, G2 and G4. In autumn, no significant differences in kits body weight at birth, day 21 of lactation and weaning age were found among experimental groups. In the same line, no significant differences between groups in kits body weight gain and milk conversion ratio* *in both seasons summer and autumn. Moreover, enhances the antioxidant status of NZW rabbit does (TAC and MDA) especially in G4. Conclusively, the **G4** was the best group in most of the studied parameters (litter weight, milk production, lower mortality rate, with higher TAC and lower MDA) than the other three groups.*

Key words: Aloe Vera, pregnant rabbits, kits performance, milk yield, antioxidant status, heat stress.

INTRODUCTION

During summer season, elevating air temperature considered one of the major constrains that negatively and seriously affect rabbit production. Through, its negative impact on their meat and milk productions, immune system, growth rate and reproduction (Oladimeji *et al.*, 2022). Indeed, thermoregulation in rabbits is poor, because they can regulate their body temperature in narrow range, due to lack of sweet glands and their thick fur (Szendro *et al.,* 2018). There were numerous tries to reduce the harmful effects of heat stress on rabbits. Trying to help them to live in suitable conditions and protect their health and production (Sheiha *et al.,* 2020).

Previous studies (Banakar *et al.*, 2019 and Zhou *et al.*, 2020) proved the positivity of adding phytogenic feed additives on animal performance, without any harmful effects on liver and kidney functions or left residues in animals meat or milk. Moreover, improving antioxidant status in animals body thus helping them to be more resilient to any stress (Banakar *et al.*, 2021).

Aloe Vera (*Cactaceae*, AV) is one of these natural feed additives that containing 75 bioactive components. Such as, vitamins A, C and D that are combating free radical as natural antioxidants. It also, contains many anthraquinones components that act as analgesics and having the powerful to be antifungal, antibacterial and antivirus properties. Besides that, AV is containing minerals, sugars, fatty acids and enzymes that involved in food digestion, cellulase, amylase and carboxypeptase (Yohannes, 2018). In lactating goats, Banakar *et al.* (2021) illustrated that AV has positive impact on antioxidant profile and enhanced fermentation in rumen. In addition, AV enhanced metabolic activity during transition period in dairy cows as confirmed by Mezzetti *et al.* (2020). To the best of our knowledge, fewer researches supplied rabbit diets with AV. El-Kholy *et al*. (2022) found that, supplementing growing rabbit with diets containing AV improved growth performance, immunity and antioxidant profile, especially with the dose of 1 and 2g AV/kg diet. As far as we know, no studies were tested impact of AV on pregnant and lactating rabbits especially during summer season.

Therefore, the current study aimed to test the AV at different levels inclusion in rabbit does diet on their productive performance and antioxidant status during summer and autumn seasons in Egypt.

MATERIALS AND METHODS

This study has been conducted in Rabbit Research Unit, Sakha Research Station. It is located at Kafr El-Shiekh governorate, Egypt and belongs to Animal Production Research Institute (APRI), Agricultural Research Center (ARC). This experiment was lasted continuously for five months. In the beginning of July and continued during August and September (summer season, SS) and directly continued progressively during October till the end of November (autumn season, AS) at 2022. Ethical approval: all the experimental procedure was following the guidelines of the Scientific Committee, the coded number was 01-05-03-37.

Experimental animals and procedures:

Twenty-four mature New Zealand White (NZW) rabbit does were used in this study. Does were aged between 8-10 months with an average body weight (BW) of 3377.1±37.6 g. The rabbits were housed in individual cages in well ventilated indoors clean pens. Does were kept under same managerial conditions and have been divided randomly into four equal groups (6 rabbit does). The first one served as control group (G1), supplied with commercial pellets (Table 1) with no any supplementations. The other three groups, G2, G3 and G4 were fed the same commercial pellets supplied with 0.5, 1.0 and 2.0 g Aloe Vera leaves powder (AVLP) /kg diet. Feeding on AVLP were lasted for the whole experimental months. All experimental does were inseminated then after 12 day of insemination; abdominal palpation has been conducted to diagnose pregnancy that lasted about 30-32 days, throughout two parities in each season. The AVLP was prepared according to description of Mohamed *et al.* (2017). These leaves were purchased from markets, and then are dried in oven, first at 50°C followed by 105°C until getting constant weight. Then it is grinded using a manual mill to obtain fine powder that can be added to diets. Feeding with AVLP started before mating by two weeks. Rabbits were supplied with feed *ad libtium* in the morning at 7 am and 4 pm. The rabbits were fed based on the recommendations of NRC (1977) that satisfied rabbit requirements during pregnancy and lactation, the ingredients and chemical analysis are shown in Table (1).

Table 1. Feed ingredients and chemical analysis of the basal diet (on dry matter basis) provided to the rabbit does during the whole experimental period

Feed Ingredients	**(%)**	***Chemical analysis*****	
Soybean meal (44% CP)	8.50	Dry matter (DM)	89.00
Barley	30.0	Organic matter (OM)	90.88
Yellow corn	9.50		
Wheat bran	23.0	Crud protein (CP)	18.00
Clover hay	16.0	Crud fiber (CF)	10.60
Corn gluten (60%CP)	9.70		
Molasses	0.30		
Limestone	1.50	Ether extract (EE)	2.50
Di- calcium phosphate	0.50	Nitrogen free extract (NFE)	59.78
DL-methionine	0.20	Ash	9.12
Sodium chloride	0.30	Lysine	0.98
Vit.-min. premix*	0.30	Methionine+ cysteine	0.70
Anti-coccidiosis	0.10	Calcium	0.95
Anti-fungi	0.10	Phosphorus	0.64
Total	**100**	Digestible energy(kcal/kgDM)	2850

- **Each 1 kg contains:** 12000 IU Vit.A; 2200 IU Vit. D3; 13.4 mg, Vit E (determined); 2.0 mg Vit. K3; 1.0 mg Vit. B_1; 4.0 mg Vit. B_2; 1.5 mg Vit. B_6; 0.0010 mg Vit B_{12}; 6.7 mg Vit Pantothenic; 6.67 mg Vit. B_5; 0.07 mg B_8; 1.67 mg B_9; 400 mg Choline chloride; 133.4 mg Mg; 25.0 mg Fe; 22.3 mg Zn; 10.0 mg Mn;1 .67 mg Cu; 0.25 mg I and 0.033 mg Se.

**Calculated according to NRC (1977).

Micro-environmental conditions

Ambient temperature (AT, C°) and relative humidity (RH, %) were determined using thermos-hydrometer (Table 2). The readings of these parameters have been taken three times per day at 12.00, 1.00 and 2.00 pm.

These daily values were overaged and were used to calculate weekly and monthly averages. Consequently, the average of these parameters were used to calculate the temperature – humidity index (THI, units) based on the equation of Marai *et al.* (2001) as follows**:**

$$THI = dbC° - [(0.31 – 0.31\ RH\ \%) \times (db\ C° - 14.4)]$$

Where; dbC° is a dried bulb temperature expressed in Celsius (C°), RH = Relative humidity expressed in percentage. The obtained values (units) of calculated THI were classified into: THI = < 27.8 = Absence of heat stress

(HS), THI = 27.8 - < 28.9 = Moderate HS, THI = 28.9 - < 30.0 = Severe HS, THI = 30.0 = Very severe HS.

Bio-security procedures:

Part of this experiment have been carried out during summer season, so does have been spraying with water during the hottest hours of the day. Besides that, good and indirect ventilation was provided through fans. The house was carefully cleaned to get rid of rabbit droppings. Moreover, the floor was completely dried from any water deposits to prevent humidity elevation inside the rabbit house. Disinfectants were placed at the entrance to the rabbit house to prevent the entry of any pollutants into the house. In addition, the entry of any stranger that might cause panic to the pregnant rabbits or the nursing one was prevented. Fresh and clean tap water (with adding ice during the hottest hours of the day) to drink freely during the day was provided. Furthermore, the rabbit does in this experiment were always checked up, to find out if there is any signs of illness, injury or abnormality. All the experimental does were in good health. No signs of illness or abortion cases have been recorded and they kept in the same managerial conditions.

Antioxidant biomarkers

Blood samples (about 3 ml) were collected from marginal ear vein (at the end of each season) in heparinized tubes from each doe and were centrifuged at 3000 r.p.m. to get blood clear plasma that stored under -20°C until analysis. Blood plasma was used to determine both malondialdehyde (MDA), expressed in nmol/mL and total antioxidant capacity (TAC) that expressed in mmol/L. Determination was performed according to the instructions of manufactures, using kits obtained from Bio-Diagnostic Company, Dokki, Giza, Egypt.

Doe performance

Feed intake (FI) of the experimental rabbit does were recorded daily, and their body weight (BW) have been recorded four times at the times of: insemination day, at delivery day, day 21 of lactation and at weaning age of their kits. Litter size (LS) were observed at the days of; birth, 21 of their age and weaning age.

Milk yield (MY, g/d) was determined by calculating the difference in kit´s body weight before and after suckling. The amount of daily milk yield / doe (DMY, g/d) and the average of total milk yield (ATMY) during the whole lactation period (five weeks) were determined.

Kit's performance

Kit's body weight and their weight gain (LWG) were recorded at days of; birth, day 21 of their age and weaning age. In additions, milk conversion ratio were (MCR, grams of litter LWG per grams of the suckled milk) calculated from delivery day up to day 21 of lactation (litter weight gain through the first three weeks of lactation divided by milk intake through the same period) based on El Nagar *et al.* (2014). Besides that, litter pre-weaning mortality rate (MR) was also calculated (dead litters / total litters) during the whole experimental period.

Statistical analysis:

Data collected were subjected to two-way analysis of variance to detect the effects of treatment (T) and season (S) and their interaction (T*S) using the general linear model (GLM) procedure of SAS (SAS, 2004) according to Snedecor and Cochran (1982). The statistical model used was as follows:

$$Y_{ijk}= \mu + T_i + S_j+(T*S)_{ij} + e_{ijk}$$

Where: Y_{ijk}= the individual observation, μ = The overall mean, T_i= The fixed effect of the i^{th} treatments (i= 1,2,3,4). S_j= The fixed effect of the j^{th} season (j=1, 2), $(T*S)_{ij}$= Effect of interaction between i^{th} treatments and j^{th} season (ij =1,…..8), e_{ijk}= Random error associated with the individual.

The differences among treatments, season and their interaction means were separated according Duncan's Multiple Range Test (Duncan, 1955). The significance level was set at 5%.

RESULTS AND DISCUSSION

1. Climatic conditions

As shown in Table (2), during summer season (SS) the AT (C°) ranged between 30.4 in September to 33.0 in August with an average of 31.7. Whereas, the RH (%) ranged from 75.6 in September to 80.9 in August with an average of 78.3. Meanwhile, the THI (units) ranged between 29.9 to 31.8 with an average of 30.7. Its well-known that THI is considered the most practical indicator for assessing the severity of HS. The present observations are based on HS classifications of Marai *et al.* (2001). It is obvious that August month had the highest values of AT, RH and THI which means that, this month is not suitable for rabbit rearing in Egypt unless the modern techniques for alleviating HS are adopted. Accordingly, does during SS were exposed and suffer from severe HS and uncomfortable conditions, which seriously reflected adversely on their

Table 2. Air temperature, relative humidity and temperature-humidity index during experimental period

Experimental months	**Temperature (^{o}C)**	**Relative humidity (%)**	**Temperature humidity index (THI, units)**
Summer season (SS)			
July			
1st week	32.3	79.3	31.1
2nd week	31.4	78.6	30.3
3rd week	31.1	77.9	29.9
4th week	31.5	77.7	30.3
S.E	**0.3**	**0.9**	**0.3**
Overall mean	**31.6^{b}±0.2**	**78.4^{b}±0.6**	**30.5^{b}±0.2**
August			
1st week	32.1	80.0	31.0
2nd week	33.0	82.5	31.9
3rd week	34.0	80.0	32.8
4th week	33.0	81.4	31.8
S.E	**0.3**	**1.1**	**0.3**
Overall mean	**33.0^{a}±0.2**	**80.9^{a}±0.6**	**31.8^{a}±0.2**
September			
1st week	30.1	77.5	31.0
2nd week	30.6	75.0	30.2
3rd week	30.6	75.6	29.8
4th week	30.1	74.3	28.5
S.E	0.3	1.1	0.3
Overall mean	**30.4^{c}±0.2**	**75.6^{c}±0.6**	**29.9^{b}±0.2**
Overall mean of SS	**31.7 ±0.2**	**78.3±0.2**	**30.7±0.2**
Autumn season (AS)			
October			
1st week	29.4	72.5	28.0
2nd week	29.1	70.6	27.7
3rd week	29.0	70.0	27.6
4th week	28.8	68.6	27.4
S.E	**0.3**	**1.1**	**0.3**
Overall mean	**29.1^{d}±0.2**	**70.4^{d}±0.6**	**27.7^{c}±0.2**
November			
1st week	28.1	56.3	26.3
2nd week	27.1	50.6	25.2
3rd week	26.0	45.6	24.0
4th week	**25.0**	**45.0**	**23.2**
S.E	**0.3**	**1.1**	**0.3**
Overall mean	**26.6^{e}±0.2**	**49.4^{e}±0.6**	**24.7^{d}±0.2**
Overall mean of AS	**27.9±0.2**	**59.9±0.2**	**26.2±0.2**

[a] and [b] Means in the same column with different superscripts are significantly different at ($P<0.05$). SE = Standard error of means.

performance and welfare as expected and obtained in the coming results.

In contrast, during autumn season (AS), the AT (C°) ranged between 20.6 – 29.1 with an average of 27.9. The corresponding values of RH (%) where 49.4 to 70.4 and 59.9. Whilst, the THI (units) ranged between 24.7 to 27.7 with an average of 26.2. this means that does during AS were maintained under favorable and comfortable circumstances which actually reflected positively on their performance and welfare as found in the following results. It is interesting to note that, the November month is the favorable and best month for keeping rabbits under Egyptian hot conditions, since it had the lowest values of each of AT, RH and THI.

Based on the aforementioned observations, we expected that does performance during SS will differed markedly than that during AS, as well established in all the previous studies.

1. Antioxidant status:

Treatment with AVLP shown that, G4 was generally having the lower levels of MDA, which was significantly ($P<0.05$) lower than G1 by 27.8% (Table, 3). In addition, this group having higher TAC concentration (0.93 mmol/L) that significantly ($P<0.05$) overpassed G1 by 27.39%. In overall, the received AVLP groups were higher in their TAC levels with lower levels of MDA than that in the control one. This could be attributed to the antioxidant effect of AVLP that resulted in improving antioxidant status. Considering effect of season, The MDA value in SS was higher than its value in AS by 25.1% (Table, 3). On contrary, TAC showed the opposite trend that recorded higher concentration in AS than that in SS, this may due to the need to elevate TAC levels to reduce free radicals that resulted during summer HS.

The interaction between the two seasons and AVLP, also reflected that, values of MDA during SS in the treated groups were almost close to each other. Moreover, MDA values in treated groups with AVLP were higher during SS than that in AS. While in G1, levels of MDA were close to each other in both seasons. The elevating level of MDA during SS may be related to the impact of HS in causing oxidative stress (OS). Especially that, rabbit does in this experiment were suffering from very severe HS as mentioned previously. In addition, in the supplemented groups with AVLP, the insignificant higher levels of TAC with lower MDA levels is indicating to the decrease of OS.

This confirmed by previous studies, Chaiyasitel *et al.* (2007), Abdelnour *et al.* (2021) and Abdel-Rahman *et al.* (2022) who stated that, increasing values of TAC is an important factor that reflect the reduction in OS. The current study is in harmony with Sethi *et al.* (2012), who gave 300 AV mg/kg to Albino

Table 3. Effect of Aloe Vera leaves powder addition on levels of malondialdehyde (MDA) and total antioxidant capacity (TAC) in pregnant NZW rabbits during the whole experimental period

Groups	MDA (nmol/mL)		TAC (mmol/L)	
Effect of treatment (T)				
G1	5.36^{a}		0.73^{b}	
G2	4.17^{b}		0.93^{a}	
G3	4.17^{b}		0.79^{ab}	
G4	3.87^{b}		0.93^{a}	
S.E	0.22		0.06	
Effect of season (S)				
Summer	4.88^{a}		0.79	
Autumn	3.90^{b}		0.89	
S.E	0.15		0.04	
Interaction (T*S)				
	Summer		**Autumn**	
	MDA	**TAO**	**MDA**	**TAO**
G1	5.44	0.61	5.28	0.86
G2	4.84	0.94	3.50	0.93
G3	4.66	0.69	3.68	0.88
G4	4.60	0.96	3.15	0.91
S.E	0.31	0.08	0.31	0.08

[a] and [b] Means in the same column with different superscripts are significantly different at ($P<0.05$). SE = Standard error of means. G1=control group, G2, G3 and G4 = groups that supplemented with 0.5, 1.0 g and 2.0 g AV LP /kg diet, respectively.

rabbits. They found that, AV has a significant role in reducing MDA level and enhancing antioxidant status in rabbits. Furthermore, Abd El-Galil and AlKot (2022) reported positive role of AV in reducing MDA in rats. They cleared that, the antioxidant effect of AV is related to its content of vitamins such as C, A and D, that can combat free radicals in the body, thus improving antioxidant status.

Therefore, the ability of AVLP in relieving OS could be attributed to improve and consequently providing good welfare to animals, so they can produce and reproduce well.

2. *Doe performance:*

2.1. *Body weight and feed intake*:

The addition of AVLP indicated that, G4 recorded the highest BW at partum, 21-day of lactation and weaning age of their kits. This may attribute to the increased their FI than the other experimental groups as shown in Table 4.

Table 4. Effect of Aloe Vera leaf powder on doe performance during the whole experimental period in NZW rabbits

	Doe weight at				Feed intake at	
Effect of treatment (T)						
	Mating	Partum	Peak*	Weaning	Pregnant	Lactation
G1	3412.5[b]	3545.2[b]	4189.6[b]	4398.7[b]	159.7[b]	206.9[b]
G2	3559.6[ab]	3648.7[ab]	4307.9[ab]	4478.7[ab]	167.1[b]	208.3[ab]
G3	3603.7[a]	3677.5[ab]	4321.3[ab]	4490.8[ab]	174.7[b]	209.2[ab]
G4	3521.7[ab]	3717.2[a]	4385.0[a]	4564.6[a]	204.4[a]	220.5[a]
S.E	53.2	53.1	47.6	44.4	5.7	4.3
Effect of season (S)						
Summer	3377.1[b]	3323.6[b]	3952.5[b]	4157.1[b]	158.6[b]	177.8[b]
Autumn	3671.7[a]	3970.7[a]	4649.4[a]	4809.4[a]	194.4[a]	244.7[a]
S.E	37.6	37.5	33.6	31.4	4.0	3.0

*Interaction (T *S)*

	Summer						Autumn					
	Doe weight at				Feed intake at		Doe weight at				Feed intake	
Groups	Mating	Partum	Peak*	Weaning	Pregnant	Lactation	Mating	Partum	Peak*	Weaning	Pregnant	Lactation
G1	3283.3	3229.2	3823.3	4069.2	158.5	173.5	3541.7	3861.2	4555.8	4728.3	161.0	240.3
G2	3429.2	3340.8	3948.3	4138.3	154.0	177.8	3690.0	3956.7	4667.5	4819.2	180.2	238.8
G3	3476.7	3365.0	4000.8	4173.3	164.3	182.5	3730.8	3990.0	4641.7	4808.3	185.2	235.8
G4	3319.2	3359.3	4037.5	4247.5	157.7	177.3	3724.2	4075.0	4732.5	4881.7	251.2	263.7
S.E	75.3	75.0	67.3	62.8	8.1	6.2	75.3	75.0	67.3	62.7	8.1	6.2

[a] and [b] Means in the same column with different superscripts are significantly different at ($P<0.05$).
SE = Standard error of means. G1=control group, G2, G3 and G4 = groups that supplemented with 0.5, 1.0 g and 2.0 g AV LP /kg diet, respectively.

As for effect of season, the overall BW value in AS was significantly ($P<0.05$) overpassed the recorded one in SS. This may due to effect of HS (previously shown in Table 2) and its negative impact on FI that resulting in lowering BW. This previously confirmed via Al-Sagheer *et al.* (2017) who stated that, during SS rabbits are getting off feeding and both voluntary FI and digestion are already dwindled.

On the other side, the interaction between the two factors (season and AV levels). Illustrated that, during SS G3 gained more BW at partum while G4 was the superior one in BW at the peak of lactation (day 21 of lactation) and weaning age of their kits. In AS, G4 also was the highest in BW and this could attribute to the increased their FI. Generally, the supplemented groups with AV were superior in their BW and FI than that of G1in both seasons. This may related to the AV content of enzymes such as cellulase, carboxypeptase and amylase that may improve nutrient digestibility (Yohannes, 2018).

The current results agree with Arif *et al*. (2021) who found that, AVLP in quail diet cause elevation in FI. They attributed their results to antibacterial properties of AVLP. Besides, improving pancreatic and digestive enzymes thus causing higher nutrients absorption leading to FI enhancement.

3.2. Litter size

In general effect of AVLP revealed that, at birth there was no significant difference in LS between all experimental groups. Whilst, at ages of day 21 and weaning, the supplemented groups with AVLP have significantly ($P < 0.05$) different numbers in G1. The higher LS were recorded for G3 (6.6±0.2) and recorded lowest mortality rate (MR) which was 17.7% when compared with the other groups (Table 5). At weaning age, G1 was the lowest group in LS (3.9±0.24) due to their higher MR that reached to 41.1% in comparison with the treated groups with AVLP. That means, AVLP (especially at level 2.0 g/kg) helps the young rabbits in elevating their survival rate due to its enrichment components such as anthraquinones component that act as antifungal, antibacterial and antivirucidal.

Additionally, AVLP containing minerals for example zinc, contributes to the metabolism of proteins, carbohydrates and fats. Also, contains chromium that is necessary for the proper function of insulin, which in turn controls the sugar levels in the blood, besides its content of different vitamins. All these components make AV as a survival factor that supply rabbit kits with their nutritional requirements.

Table 5. Effect of Aloe Vera leaves powder on litter size and mortality rate, during whole experimental period

Items	Litter size at:							
Effect of treatment (T)								
	Birth			**21**		**Weaning**		**MR%**
G1	6.6			5.2^{b}		3.9^{b}		41.1^{a}
G2	6.9			6.2^{a}		5.2^{a}		24.7^{b}
G3	7.1			6.6^{a}		5.8^{a}		17.7^{b}
G4	6.9			6.3^{a}		5.2^{a}		26.1^{b}
S.E	0.23			0.31		0.34		4.64
Effect of season (s)								
Summer	6.7			5.6^{b}		4.5^{b}		33.2^{a}
Autumn	7.1			6.5^{a}		5.5^{a}		21.6^{b}
S.E	0.2			0.2		*0.24*		3.28
Interaction (T*S)								
	Summer				**Autumn**			
	Litter size at:			**MR%**	**Litter size at:**			**MR%**
	Birth	**21**	**Weaning**		**Birth**	**21**	**Weaning**	
G1	6.2	4.3	3.0	51.2	7.0	6.0	4.8	31.0
G2	6.8	5.8	4.8	28.9	7.0	6.5	5.5	20.5
G3	7.0	6.3	5.6	19.2	7.2	6.8	6.0	16.4
G4	6.7	5.8	4.5	33.6	7.2	6.8	5.8	18.6
S.E	0.33	0.43	0.48	6.56	0.33	0.43	0.48	6.56

[a] and [b] Means in the same column with different superscripts are significantly different at ($P<0.05$). SE = Standard error of means. G1=control group G2, G3 and G4 = groups that supplemented with 0.5, 1.0 g and 2.0 g AV LP /kg diet, respectively.

The interaction between AVLP with the season which reflect that, higher LS (during SS) was observed for both G3 followed by G2. In AS, LS for both G3 and G4 were almost equal. General, LS in supplemented groups with AV have higher LS than G1 in both seasons. Also, the data in Table (5) showed that both LS was lower with higher MR (%) during SS. This may due to the effect of HS on LS, as mentioned by Oladimeji *et al.* (2022). They mentioned that environmental HS affect negatively on LS at birth, pre-weaning and weaning age. In the same line, Macro-Jimenez *et al.* (2017) confirmed that rabbit does that exposed to HS during gestation period may deliver litters with lower number and body weight than the unstressed one.

3.3 Milk production

Table (6) illustrated daily milk production (DMP) of NZW rabbits through five weeks of lactation. The AVLP treatment shown that, G4 was the highest milk producer that significantly differed from all the other tested groups in the first and second week of lactation. Also, the results revealed that, all the experimental groups were reached to their peak in the second week of lactation not in the third one as known. This is in harmony with El-Maghawry *et al.* (1993), El-Sayiad *et al* (1994) and Zerrouki *et al*. (2005) who found that, peak of lactation in NZW rabbits was in the second week. They attributed their results to the conditions of HS that does were exposed during lactation period, just as the conditions of the current study that previously discussed.

In addition, the interaction cleared that, AVLP supplementation in the three groups, especially G4 were higher in producing milk than the control one either during SS or AS. This could related to the impact of AVLP on FI (previously discussed in Table 4). Furthermore, the amount of milk production throughout the whole lactation period was higher in AS than that produced in SS during all lactation period. This is related to the negative effects of HS on milk production (Laing *et al.*, 2022).

Some research has been cited for other types of animals to clarify the impact of AV on milk production due to the absence of research on rabbit in this field. For example, Singh *et al.* (2021) fed dairy cows with AV at 20g/kg BW and found that AV succeeded in elevating milk production. In goats, Banakar *et al.* (2021) illustrated that AV at levels 20 g / kg DMI and 40 g / kg DMI improved milk production.

From the present data, it could assume that, the enhancement effect of AVLP on rabbits milk production may be attributed to improvement in antioxidant status in rabbit received AVLP in their diet. Because, it will reflect on rabbit welfare and this may have positive impact on overall produced milk. In addition, the improvement in FI in AVLP groups reflected on their milk production compared to non-supplemented group.

4.Litters performance

4.1. Litter weight:

Concerning litter body weight (LBW), AVLP addition reflected that, at birth both G3 and G4 were close to each other in LBW and were higher than G1 and G2 with no significant differences among the groups. Meanwhile, at the day 21 of age and weaning age, G4 was significantly higher than G1 by 8.34% and 12.93%, respectively. Generally, effect of season showed that, all treated groups

Table 6. Effect of Aloe Vera leaf powder on daily milk yield (DMY) and average of total milk yield (ATMY), during whole lactation period (5 weeks) in NZW rabbits

Effect of treatment (T)

	W1	W2	W3	W4	W5	ATMY
G1	79.2^{c}	196.3^{bc}	191.7^{ab}	166.7^{b}	30.0^{c}	132.7^{c}
G2	84.2^{bc}	193.7^{c}	190.0^{b}	171.3^{b}	31.3^{bc}	134.1^{c}
G3	86.9^{b}	199.2^{b}	198.3^{ab}	180.0^{a}	34.2^{ab}	139.7^{b}
G4	96.7^{a}	205.0^{a}	200.4^{a}	185.0^{a}	36.7^{a}	144.7^{a}
S.E	1.99	1.67	3.02	2.37	1.17	1.44
Effect of season (S)						
Summer	85.8	198.1	192.5	173.9	31.8	136.5
Autumn	87.6	198.9	197.7	177.5	34.2	139.2
S.E	1.41	1.18	2.14	1.67	0.83	1.02

*Interaction (T*S)*

Groups	Summer						Autumn					
	W1	W2	W3	W4	W5	ATMY	W1	W2	W3	W4	W5	ATMY
G1	78.3	193.3	188.3	164.2	29.2	130.7	80.0	199.2	195.0	169.7	30.8	134.8
G2	84.2	195.2	185.8	166.7	30.0	132.5	84.2	191.2	194.2	175.8	32.5	135.7
G3	86.7	199.2	197.5	180.0	31.7	139.0	87.2	199.2	199.2	180.0	36.7	140.5
G4	94.2	204.2	198.3	185.0	36.7	143.7	99.2	205.8	202.5	185.0	36.7	145.8
S.E	2.82	2.36	4.28	3.35	1.66	2.04	2.82	2.36	4.28	3.35	1.66	2.04

^{a} and ^{b} Means in the same column with different superscripts are significantly different at ($P<0.05$).

SE = Standard error of means. G1=control group, G2, G3 and G4 = groups that supplemented with 0.5, 1.0 g and 2.0 g AV LP /kg diet, respectively. W= week were higher in their LBW than G1. Besides that, LBW was lower during SS than the AS (Table 7).

The interaction showed that, there was no significant differences between the tested groups. In both seasons, LBW was at its best values in G2 and G4 in all days (birth, 21 day of age and weaning age) than the control one. Moreover, kits that born in AS have heaver BW than those born in SS. The decrease in LBW during SS especially in G1 may due to the impact of HS. Okab *et al*. (2008) illustrated that, the kits that born from heat-stressed does were suffered from a decrease in post-natal growth during lactation, especially that, rabbits are very sensitive to HS. Additionally, LBW in supplemented groups with AV was better than G1. This could be attributed to the AV contents of minerals, vitamins and antibacterial components, which previously mentioned.

Table 7. Effect of Aloe Vera leaves powder on litter body weight during the whole experimental period

	Litter body weight at:					
Effect of treatment (T)						
	Birth		**21**		**Weaning**	
G1	260.0		1752.1^{b}		2281.3^{b}	
G2	272.5		1815.8^{ab}		2443.3^{a}	
G3	287.1		1812.1^{ab}		2566.6^{a}	
G4	286.3		1898.3^{a}		2576.3^{a}	
S.E	9.0		40.4		50.8	
Effect of season (s)						
Summer	268.1		1558.3^{b}		2330.4^{b}	
Autumn	284.8		2080.8^{a}		2603.3^{a}	
S.E	6.4		28.5		35.9	
Interaction (T*S)						
	Summer			**Autumn**		
	Litter body weight at:			**Litter body weight at:**		
	Birth	**21**	**Weaning**	**Birth**	**21**	**Weaning**
G1	244.2	1534.2	2072.5	275.8	1970.0	2490.0
G2	272.5	1623.3	2441.7	272.5	2008.3	2445.0
G3	280.8	1490.0	2450.8	293.3	2134.2	2682.3
G4	275.0	1585.8	2356.7	297.5	2210.8	2795.8
S.E	12.7	57.1	71.8	12.7	57.1	71.8

[a] and [b] Means in the same column with different superscripts are significantly different at (P<0.05). SE = Standard error of means. G1=control group G2, G3 and G4 = groups that supplemented with 0.5, 1.0 g and 2.0 g AV LP /kg diet, respectively.

In the same context, the increased in LBW could be linked to higher milk produced from dams of G4 followed by G3 with milk conversion ratio (MCR) 0.38 and 0.36, respectively (Table 8). This makes G4 to be higher in LWG than G1 by 7.8%.

The interaction (in Table 8) showed that, the produced milk during SS in all tested groups is lower than that in AS. The dams of G4 succeeded in producing more milk in both seasons thus gained more weight for their kits. The values of MCR that illustrated in Table (8) is fallen with the suggested range by Khalil *et al*. (2004). Who stated that MCR in rabbits is ranged between 0.12 and 2.82, with an average 0.74. Also, these values were close to those recorded by El Nagar *et al.* (2014). They determined MCR in rabbits in the first three weeks of lactation and recorded 0.42 for MCR. Also, the present data were lower than those reported by Abd El-Azeem *et al.* (2022) who found that MCR in rabbits was 2.5. Indeed, as much as we know, there were no studies on the impact of AV on milk production in rabbits or MCR.

Table 8. Effect of Aloe Vera leaves powder on litter weight gain and milk conversion ratio, during the whole experimental period

	MY	LWG	MC
G1	191.7[ab]	71.1[b]	0.37
G2	190.0[b]	73.5[ab]	0.38
G3	198.3[ab]	72.6[ab]	0.36
G4	200.4[a]	76.7[a]	0.38
S.E	3.02	1.70	0.01
Sumer	192.5	61.43[b]	0.32[b]
Autumn	197.7	85.52[a]	0.43[a]
S.E	2.14	1.20	0.007

	Sumer			**Autumn**		
	MY	**LWG**	**MC**	**MY**	**LWG**	**MC**
G1	188.3	61.4	0.33	195.0	80.7	0.42
G2	185.8	64.3	0.35	194.2	82.7	0.43
G3	197.5	57.6	0.29	199.2	87.7	0.44
G4	198.3	62.4	0.32	202.5	91.1	0.45
S.E	4.28	2.41	0.02	4.28	2.41	0.02

[a] and [b] Means in the same column with different superscripts are significantly different at ($P<0.05$). SE = Standard error of means. MY= milk yield , LWG= litter weight gain, MC= milk conversion (g, gain/g, MY). , G2, G3 and G4 = groups that supplemented with 0.5, 1.0 g and 2.0 g AV LP /kg diet, respectively.

In conclusion, the present study revealed the benefits of adding Aloe Vera leaf powder (AV) in rabbit's diets. The AV helped rabbits does during summer season to deliver kits with heaver body weight and less mortality rate in comparison with control group. Moreover, enhances the antioxidant status of NZW rabbit does (TAC and MDA) especially in G4. In should be noticed that, increasing level of AV to 2 g/kg diet did not affect palatability as evidenced by the increasing doe body weight and most of improvement in the recorded data (LS, LWG, LW and MY) was in favor for G4.

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حالة مضادات الأكسدة والأداء الإنتاجي للأرانب الحوامل المتأثرة بإضافة مسحوق أوراق الصبار

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أجريت الدراسة الحالية في مجمع أبحاث الأرانب بمحطة سخا بمحافظة كفر الشيخ. حيث تم استخدام عدد ٢٤ من إناث الأرانب النيوزيلندية تتراوح أعمارهم بين ٨-١٠ أشهر وكان متوسط وزن الجسم في بداية التجربة ٣٣٧٧ ± ٣٦.٧ جم. وتم تقسيمها إلى أربع مجموعات متساوية ، الأولي G1 كمجموعة كنترول ،والتي تم تغذيتها على عليقة المزرعة بدون أي إضافات. وتم تغذية كلا من المجموعات G2 و G3 و G4 على العلائق المحتوية علي مسحوق أوراق الصبار بمستويات ٠.٥ و ١.٠ و ٢.٠ جم / كجم على التوالي.

أظهرت النتائج الي تعرض الأرانب لإجهاد حراري شديد خلال شهور يوليو وأغسطس وسبتمبر (THI = ٣٠,٥ و ٣١.٨ و ٢٩.٩ على التوالي). في حين أثناء شهور أكتوبر ونوفمبر كان THI ٢٧.٧و ٢٤.٧ ، على التوالي. أظهرت تحاليل الدم وجود مستوي عالي من TAC مع مستويات أقل من MDA في المجموعات التي تم تغذيتها علي الصبار مقارنة بالمجموعة الكنترول. وفي خلال فصل الصيف ، كان حجم الخلفات عند الولادة والفطام أقل في المجموعة الأولى (٦.٢ ± ٠.٣٣ و ٤.٣ ± ٠.٣٣ على التوالي) مقارنة بالمجموعات المغذاه علي الصبار. وكانت المجموعة G3 هي الأعلى في عدد الخلفات ، حيث سجلت ٧.٠ ± ٠.٣٣ عند الولادة مقابل ٦.٨ ± ٠.٣٣ و ٦.٧ ± ٠.٣٣ في G2 و G4 على التوالي. بينما لم يكن عدد الخلفات في الخريف مختلفًا بين المجموعات المغذاه علي الصبار وكانوا متقاربين من بعضهم البعض تقريبًا. علاوة على ذلك ، ساعد مسحوق الصبار، خلال موسم الصيف ، خاصة عند المستوى ١ جم / كجم من النظام الغذائي (G3) ، الي الحصول علي مواليد بوزن أعلى (٢٨٠.٨ ± ١٢.٧ جم) مقارنة بالمجموعات الأخرى. وأيضا في عمر الفطام ، سجلت تلك المجموعة (G3) أعلى وزن للجسم ، ٢٤٥٠.٨ ± ٧١.٨ جم من تلك الموجودة في G1 و G2 و G4. أيضا الخلفات خلال فصل الخريف لم تظهر فروق معنوية في وزن الجسم عند الولادة واليوم ٢١ من الرضاعة وعمر الفطام وذلك في كل المجموعات المستخدمة في التجربة. علي نفس السياق لا توجد فروق معنوية بين المجموعات في زيادة وزن الجسم المكتسبة يوميا ونسبة تحويل الحليب وذلك في كلا موسمي الصيف والخريف.

__التوصية:__ حققت المجموعة الرابعة (والتي تم إمدادها بمعدل ٢ جم من الصبار / كجم عليقة) في تحقيق أفضل النتائج في كلا من: وزن الخلفات ومعدلات نفوق الخلفات وكمية اللبن المنتجة، بإضافة الي أن تركيزات TAC كانت اعلي مقارنة بالمجموعات الأخري وإنخفاض تركيز الـــ MDA عن المجموعات الأخري. ولوحظ أيضا أن، زيادة تركيز الصبار في العليقة لم يؤثر علي إستساغة العليقة لدي الأرانب.

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