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Research Article

Improve Reproductive and Health Status of Rabbit Does Under Heat Stress by Using Phytogenic and Prebiotic Sources

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Abstract | Ninety mature does New-Zealand White rabbits age 6 months and weighting 3.2 kg were assigned randomly into six treatment groups. The treatments were fed basal diet as control (G1), basal diet plus 0.3 % turmeric (G2), 0.05 % MOS® (G3), 0.015 % Biostrong® 510 (G4), 0.05 % MOS +0.3 % turmeric (G5) and 0.05% MOS +0.015 % Biostrong (G6), respectively. Rabbits fed with turmeric, MOS and Biostrong recorded a significant ($P \leq 0.05$) increase in doe weight at mating, prepartum, partum and weaning period, and the rate of feed intake increased in the treated groups, especially the G5 through gestation period and the G3 in lactation stage. The milk yield also increased in the rabbits in treated groups, especially the G5, and it appeared clearly in the third parity. Birth size at birth and at weaning, birth weight and milk production were increased ($P \leq 0.05$) in all treated groups in compared to the control group. Results have also shown that turmeric, MOS and Biostrong led to a significant increase in total protein, globulin, total antioxidant capacity (TAO), glutathione peroxidase (GPx) and superoxide dismutase (SOD), with significant improve in A/G ratio and decrease malondialdehyde (MDA) in the treated groups in compared to the control group. In conclusion, turmeric, MOS and Biostrong supplements had a beneficial effect as natural antioxidant additives, especially the mixture among them, by protecting against oxidative stress factors caused by pregnancy and lactation in female rabbits under heat stress.

Keywords | Antioxidant; Turmeric; MOS; Biostrong; stress; Rabbit does

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INTRODUCTION

One of the main reasons for the low productivity of farm animals, especially rabbits, is climatic changes because they have thick fur and lack of sweat glands, which makes them suffer from excessive heat loss, which affects their productivity. The growth and reproduction rates of adult female rabbits are affected as a result of exposure to severe heat stress (30–31 ºC) (Marai et al., 2001). The consequences of exposure to high temperatures on rabbits were shown in terms of low pregnancy rate, fetal growth, birth size, birth weight and milk production, and mortality before and after weaning increase (Morsy and Abd El-Lateif, 2017).

Rabbits are characterized by critical physiological and hormonal changes during their reproductive cycle, making them more susceptible to these climatic influences (Mady, et al., 2018). The solution was to find effective nutritional supplement alternatives to improve the harmful effects of heat stress (El-Kholy et al., 2018; 2021; Hashem et al., 2021).

Turmeric *(Curcuma longa)* is phytogenic additives, rich in phenolic compounds called curcuminoids, which consists of three main components curcuminoids, curcumin and demethoxycurcumin, they are yellowish turmeric pigments and have antioxidative, anticarcinogenic, anti-inflammatory, antihepatotoxic and hypocholesterolemic activities (Nishiyama et al., 2005). Alsaied et al. (2019) reported that the litter size and kit weight at birth, litter weight and bunny weight at weaning and increased viability percentage in bunnies from birth till weaning were improved by feeding female rabbits diet with curcumin.

Biostrong®510 is a preparation of partially encapsulated essential oils of thyme and anise, dried herbs and dried spices (Aquilina, 2016). One of the functional properties of anise oil and anethole: antibacterial, anti-fungal, anti-oxidant. (Newall, et al., 1996). Also, thymol has capability to work as antioxidant agent by suppressing harmful free radicals from interacting with cellular biological compounds. So, Biostrong-510 optimizes performance, production by increase litter size at birth and weaning as well as viability rates in both at birth and weaning. (Abdelnour et al., 2022).

Mannan-oligosaccharides (MOS) is a component of the structural cell wall in *sacchoromyces cerevisiae*. Mannan-oligosaccharides is an alternative natural product for antibacterial growth factors, known to bind pathogenic microorganisms (*Salmonella* spp. as well as *E. coli*) and make them unable to adhere to the intestinal wall, to reduce cecal PH and increase volatile fatty acid which prevents bacterial stability. MOS protein conjugates are also involved in interactions with the animal's immune system and can enhance immune system activity. Which is reflected on the immunity and health of the doe rabbits, and consequently on the litter size at births, their health, and the mortality rate. (Spring, et al., 2015). Attia et al. (2015) found that productive and reproductive performance of rabbit does was improved by supplemented Mannan-oligosaccharides in diet.

This study aimed to determine the effects of combining turmeric as single raw phytogenic source or Biostrong 510 as purified extracted mixed phytogenic product with MOS as prebiotic in diet of female rabbits exposed to heat environmental conditions.

MATERIAL AND METHODS

Ethical approval

This research belongs to the Animal Production Research Institute (APRI), Agricultural Research Center (ARC). This research is subject to the guidelines of the Animal Production Research Institute Ethical Committee.

Animals and treatments

This study was carried out at Sakha Research Station, Animal Production Research Institute, Agriculture Research Center, Egypt.

A total number of Ninety New-Zealand white rabbits mature does were used in the study at 6 months of age with live body weight of 3.2 kg during a period from August to December 2019. Does were randomly assigned to six homogeneous groups, each with 15 does. The first group was fed a basal diet (G1) while the other five groups received the diet supplement with Turmeric group (G2) at 0.3%, Mannanoligosaccharides (MOS) group (G3) at 0.05%, Biostrong (G4) at 0.015%, combination between Turmeric and MOS (G5) , combination between Biostrong and MOS (G6), respectively. Diets were formulated to meet the NRC (1977) requirements during pregnancy and lactation periods. Ingredients and chemical composition of the pelleted ration are summarized in Table 1. The experimental period included three reproductive cycles (three parity). Feed intake of rabbit does was recorded daily and the weight of doe rabbits was recorded at mating, prepartum (in half of pregnant period), partum and at weaning period.

During the experimental period, ambient temperatures and relative humidity were measured in the rabbitry twice a day at 06:00 AM and 15:00 PM and the temperature humidity index (THI) was calculated according to Marai, et al. (2001):

$$THI = db^{\circ}C-[(0.31-0.31RH) \times (db^{\circ}C-14.4)]$$

Where, db°C = dry bulb temperature in Celsius,
RH= the relative humidity as a percentage.
Then classified as follows:
$<$ 27.8 =absence of heat stress, 27.8–28.9 =moderate heat stress, 28.9–30.0 = severe heat stress

Milk production and composition:

Milk yield (MY, g/d) was determined by calculating the difference in kit´s body weight before and after suckling. Milk composition was determined by Milkoscan® analyzer (130 B, N. Foss Electronic, Denmark) at International Livestock Management Training Center at Sakha, Kafr El-Sheikh governorate.

Plasma constituents

About 3 ml blood was collected from 5 does/treatment from the marginal ear vein in heparinized test tubes at the end of second parity in the morning before feeding. The blood samples were collected in heparinized tubes to collect plasma. Colorimetric determination of plasma (total protein, albumin, creatinine, urea, alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were determined using commercial kits (Diamond Diagnostics, Egypt). Globulin was obtained by subtracting albumin from corresponding values of total protein.

Redox status assessments

For redox status evaluations, total antioxidant capacity (TAC), superoxide dismutase (SOD), glutathione peroxidase (GPx) and malondialdehyde (MDA) in plasma were calorimetrically determined using commercial kits (purchased from Bio-Diagnostic, Cairo, Egypt) according to the manufacturers instructions.

Statistical analysis

Data collected were subjected to two-way analysis of variance to detect the effects of treatment(T) and parity and their interaction using the general linear model (GLM) of (SAS, 2004).

The statistical model used was as follows:

$Y_{ijk} = \mu + T_i + P_j + (TXP)_{ij} + e_{ijk}$

Where: Y_{ijk}= the individual observation, μ = The overall mean, T_i= The effect of the treatments (i= 1,2,3,4,5,6), P_j= the effect of parity (j=1, 2, 3), $(TXP)_{ij}$= Effect of interaction between i^{th} treatments and j^{th} parity (ij =1,……..18), e_{ijk}= Random error associated with the individual.

The collected data of blood samples were subjected to one-way analysis of variance to detect the effect of treatment. The statistical model used was as follows:

$Y_{ij} = \mu + T_i + e_{ij}$

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

RESULTS

Temperature humidity index (THI)

Calculating the temperature humidity index showed that it fluctuates between moderate and severe heat stress and the THI values in August, September, October, November and December were 29.1, 27.1, 29, 28.5 and 27.4, respectively according to Marai, et al. (2001).

Reproductive performance of does

The data in Table 2 illustrate the performance of the rabbits does during the experiment. All rabbits in treated groups were significantly heavier in BW at mating, pre-partum, partum and weaning compared to the control. Rabbits in treated groups consumed significant more feed compared to the control group during pregnancy and lactation. The highest feed intake observed in G5 at pregnant period and G3 in lactation period.

It showed that the rabbits in third parity were heavier in body weight (mating, pre-partum, partum and weaning) and the feed intake (pregnancy and lactation) was higher in this parity. Considered to the interaction between treatments and parities in Table 3, the results obtain for doe weight at mating, pre-partum, partum and weaning in the group 5 in third parity was insignificantly increase than second and first parity. These results were also similar to the feed consumption during pregnancy and lactation period.

Milk yield

The effect of experimental treatments on milk yield is shown in Table 4. The dietary turmeric, MOS and Biostrong had a significant effect on milk yield especially in first and second weeks of lactation; resulting in higher values for rabbit does fed diet with turmeric and MOS (G5) than those fed the control diet throughout the lactation period.

All rabbits in treated groups gave more total milk yield (TMY, g) compared to control group, especially G5, which significantly increased than G1 by 8.4%. Moreover, it could be seen that the combination of turmeric and MOS was more effective in enhancing milk yield as shown in G5 (Table 4) throughout the four lactation weeks by 17.8, 10.3, 4.3 and 6.8%, respectively compared to the control group.

Resulted showed that the rabbits in third parity had the highest milk yield during the 4 weeks (lactation period) compared to the other parities.

From the obtained results in Table 5, it appeared that there were no significant differences in milk yield or total milk yield due to the interaction between treatments and parities.

Milk composition

Table 6 shows that the addition of turmeric, MOS and Biostrong in mixture form to rabbits' diet leads to a significant ($P \leq 0.05$) increase in the percentage of fat present as one of the milk compounds compared with the content of milk in the control group. The highest milk fat content was recorded in G6 (MOS + Biostrong) followed by G5 (turmeric + MOS). On the contrary, the percentage of protein in milk decreased in the mixture group (MOS + Biostrong) as well as the Biostrong group individual form. For the rest of the groups, the increase in protein was not significant compared to the control group.

All treatments increased insignificantly in the milk content of lactose compared to the control group, except for G6, which had a significantly high value compared to the control group. A significant improvement in DM was observed in treatments fed diet with turmeric and MOS (G5)

Table 1: Ingredients and calculated analysis of the basal diet

Ingredient	%	Calculated chemical analysis	
Barley	17.5	Crude protein (%)	18.26
Wheat bran	32.2	Digestible energy (kcal/kg)	2620
Soybean meal (44%)	13.6	Crude fiber (%)	11.14
Clover hay (12%)	17.9	Ether extract (%)	2.75
Corn gluten (60%)	3.5	Calcium (%)	1.23
Yellow corn	11.5	Total phosphorus (%)	0.81
Limestone	1.5	Lysine (%)	0.82
di-Calcium phosphate	1.5	Methionine (%)	0.51
NaCl	0.3	Methionine + cystein	0.84
Vitamins and minerals premix*	0.3	Sodium	0.16
Dl- Methionine	0.2		
Total	100		

*Each 3 kg contain: 6000000 IU Vit. A; 900000 IU Vit. D3; 40000 mg Vit. E; 2000 mg Vit. K3; 2000 mg Vit. B1; 4000 mg Vit. B2; 2000 mg Vit. B6; 10 mg Vit. B12; 50 mg Biotin; 10000 mg Pantothenic acid; 50000 Niacin; 3000 mg Folic acid; 250000 mg Choline; 8500 mg Mn; 50000 mg Zn; 50000 mg Fe; 200 mg I; 100 mg Se, 5000 mg Cu, and 100 mg Co.

Table 2: Effect of treatments and parities on does performance during gestation and lactation periods of NZW rabbits

	Does weight (g) at:				Feed intake (g/d) for	
	Mating	Pre-partum	Partum	Weaning	Pregnant doe	Lactation doe
Treatment						
G1	3057.8^{b}	3301.7^{b}	3044.4^{b}	3548.9^{b}	160.8^{c}	179.4^{c}
G2	3216.9^{a}	3523.1^{a}	3243.1^{a}	3806.7^{a}	160.3^{c}	181.6^{bc}
G3	3343.6^{a}	3571.4^{a}	3290.0^{a}	3882.4^{a}	165.1^{bc}	192.4^{a}
G4	3325.6^{a}	3619.3^{a}	3333.9^{a}	3890.0^{a}	170.8^{ab}	184.8^{abc}
G5	3270.6^{a}	3580.0^{a}	3290.6^{a}	3910.6^{a}	177.3^{a}	188.3^{ab}
G6	3250.0^{a}	3549.2^{a}	3252.8^{a}	3827.7^{a}	171.1^{ab}	181.6^{bc}
S.E	43.1	83.2	49.2	50.5	2.47	2.79
Parity						
1th	3063.8^{c}	3290.8^{c}	3033.3^{c}	3420.8^{c}	137.9^{c}	156.9^{c}
2nd	3165.7^{b}	3471.3^{b}	3182.4^{b}	3660.4^{b}	164.7^{b}	179.9^{b}
3rd	3502.8^{a}	3810.3^{a}	3511.7^{a}	4351.9^{a}	199.9^{a}	217.3^{a}
S.E	30.5	58.8	34.8	35.7	1.74	1.74

^{a,b} and ^{c} Means in the same Column with different superscripts are significantly different at (P<0.05). SE = Standard error of means. G1= control, G2= Tumeric, G3= Mos, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

followed with those fed MOS and Biostrong (G6) compared to the other treatments and control.

Performance of offspring

Data of total kits born, litter size per animal, litter weight at birth, weaning and rate of mortality were presented in Table 7. All rabbits in treated groups had a large litter size and body weight for the kits from birth to weaning compared to control. The number of stillbirth kits did not significantly vary among the different groups.

The mixture of turmeric and MOS (G5) added to the diets of pregnant rabbits caused an increase (P ≤ 0.05) in the total number of birth by 10% compared to the control group. This increase continued at the same rate until the rabbits was weaned. The highest growth of kits, milk yield and the best value of milk conversion ratio were recorded during days 1-28 of bunny life in G5 that received the diet with a combination of turmeric and MOS. While the lowest value was recorded in the control group and no differences were observed between groups.

The interaction between treatments and parities showed no significant effect on litter size from birth to weaning and litter weight in that period, also the weight gained of rabbits from birth to weaning and milk conversion (Table 8).

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Table 3: Effect of inter action between treatments \and parities on does performance during gestation and lactation periods of NZW rabbits

		Does weight (g) at:				Feed intake (g/d) for	
		Mating	Pre-partum	Partum	Weaning	Pregnant doe	Lactation doe
G1	1th	2995.0	3086.7	2859.2	3234.2	133.6	151.0
	2nd	2855.8	3301.7	3043.3	3403.3	156.0	180.7
	3rd	3322.5	3516.7	3230.8	4009.2	192.8	206.7
G2	1th	3066.7	3272.5	3021.7	3367.5	131.0	157.3
	2nd	3119.2	3425.8	3134.2	3713.3	158.8	170.8
	3rd	3465.0	3870.8	3573.3	4339.2	191.0	216.5
G3	1th	3106.7	3310.8	3045.0	3539.7	133.5	165.2
	2nd	3300.8	3546.7	3262.5	3714.2	169.2	183.7
	3rd	3623.3	3856.7	3562.5	4393.3	192.5	228.3
G4	1th	3074.2	3474.7	3223.3	3485.8	134.2	156.7
	2nd	3380.8	3534.2	3237.5	3700.8	168.7	180.0
	3rd	3521.7	3849.2	3540.8	4483.3	209.5	217.8
G5	1th	3060.0	3299.2	3027.5	3479.2	151.0	164.3
	2nd	3179.2	3539.2	3244.2	3752.5	170.5	181.8
	3rd	3572.2	3901.7	3600.0	4500.0	210.3	218.8
G6	1th	3080.0	3300.8	3023.3	3418.3	144.3	146.7
	2nd	3158.3	3480.0	3172.5	3678.3	165.2	182.2
	3rd	3511.7	3866.7	3562.5	4386.3	203.7	215.8
S.E		74.6	86.4	85.3	87.5	4.27	4.84

^{a,b} and ^{c} Means in the same Column with different superscripts are significantly different at (P<0.05). SE = Standard error of means.
G1= control, G2= Tumeric, G3= Mos, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

Table 4: Average of Daily milk yield (DMY,g/d) and total milk yield /doe(g) as influenced by treatments and parities during the four weeks of lactation

	MY1	MY2	MY3	MY4	TMY
Treatment group					
G1	79.7^{d}	180.3^{b}	185.6^{b}	104.8^{b}	3666.4^{c}
G2	85.8^{c}	193.1^{a}	188.6^{ab}	103.6^{b}	3775.3^{b}
G3	89.7^{abc}	193.1^{a}	186.7^{b}	105.1^{b}	3803.3^{b}
G4	89.2^{bc}	195.6^{a}	187.2^{b}	104.4^{b}	3809.6^{b}
G5	93.9^{a}	198.8^{a}	193.6^{a}	111.9^{a}	3973.7^{a}
G6	90.7^{ab}	197.5^{a}	186.9^{b}	107.8^{ab}	3864.8^{b}
S.E	1.52	2.10	1.79	1.62	36.2
Parity					
1st	87.2	191.3	186.3	104.9	3773.8^{b}
2nd	87.6	192.8	189.2	106.8	3822.8^{ab}
3rd	89.7	195.0	188.9	107.2	3850.0^{a}
S.E	1.07	1.48	1.26	1.14	25.6

^{a,b} and ^{c} Means in the same Column with different superscripts are significantly different at (P<0.05). SE = Standard error of means.
G1= control, G2= Tumeric, G3= MOS, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

Blood constituents of rabbit does

The data in Table 9 shows that the plasma total protein and globulin concentration was significantly increased due to feeding with turmeric, MOS and Biostrong compared to the control group. A significant increment were detected in albumin concentration in mixture group MOS and Biostrong compared to the other treatments. The increase in globulin was reflected in a significant improve in A/G

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Table 5: Average of Daily milk yield (DMY,g/d) and total milk yield /doe(g) as influenced by interaction between treatments and parities during the four weeks of lactation

		MY1	MY2	MY3	MY4	TMY
G1	1th	79.2	180.8	185.0	102.0	3630.7
	2nd	77.5	176.7	184.0	106.8	3649.3
	3rd	82.5	183.3	187.5	105.7	3719.3
G2	1th	85.0	192.5	185.0	102.8	3738.0
	2nd	85.8	194.2	193.3	103.5	3808.0
	3rd	86.7	192.5	187.5	104.3	3780.0
G3	1th	90.8	192.5	186.7	106.2	3817.3
	2nd	88.3	192.5	188.3	103.5	3784.7
	3rd	90.0	194.2	185.0	105.7	3808.0
G4	1th	85.8	193.3	184.2	101.8	3733.3
	2nd	89.2	194.2	185.8	105.3	3803.3
	3rd	92.5	199.2	191.7	106.0	3892.0
G5	1th	95.0	194.6	194.2	112.0	3959.7
	2nd	91.7	200.8	193.3	111.0	3962.0
	3rd	95.0	200.8	193.3	112.8	3999.3
G6	1th	87.1	194.2	182.5	104.5	3763.7
	2nd	93.3	198.3	190.0	110.3	3929.3
	3rd	91.7	200.0	188.3	108.5	3901.3
S.E		2.63	3.64	3.09	2.80	62.8

^{a,b} and ^{c} Means in the same Column with different superscripts are significantly different at (P<0.05). SE = Standard error of means. G1= control, G2= Tumeric, G3= MOS, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

Table 6: Effect of treatments on milk composition of NZW does rabbits.

	Fat	Protein	Lactose	DM	Ash
Treatment group					
G1	17.82^{b}	10.11^{a}	3.09^{bc}	34.36^{c}	2.48
G2	15.52^{c}	10.28^{a}	4.12^{ab}	32.56^{d}	2.55
G3	15.44^{c}	10.39^{a}	4.13^{ab}	32.20^{d}	2.48
G4	19.09^{a}	9.81^{b}	3.72^{c}	35.15^{b}	2.58
G5	19.40^{a}	10.22^{a}	4.24^{ab}	38.29^{a}	2.78
G6	20.06^{a}	9.80^{b}	4.36^{a}	38.08^{a}	2.78
S.E	0.36	0.10	0.11	0.21	0.12
Weeks of lactation period					
1st	16.47^{b}	9.69^{c}	3.90^{b}	32.98^{d}	2.51
2nd	17.16^{b}	10.0^{b}	3.94^{b}	34.26^{c}	2.50
3rd	18.54^{a}	10.26^{a}	4.18^{ab}	35.68^{b}	2.64
4th	19.37^{a}	10.45^{a}	4.28^{a}	37.51^{a}	2.78
S.E	0.29	0.08	0.09	0.17	0.10

^{a,b} and ^{c} Means in the same Column with different superscripts are significantly different at (P<0.05). SE = Standard error of means. G1= control, G2= Tumeric, G3= MOS, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

ratio in all supplemental groups.

Table 10 shows the effect of different treatment on ALT, AST, urea and creatinine. The supplemental groups showed insignificant decrease in ALT in compared to the control, while the G5 group (mixture between the turmeric and the MOS) significantly reduced AST in compared to the control. Data from this study showed that urea and creatinine were not significantly affected by different these supplements.

Table 7: Effect of dietary treatments and parities on litter performance of NZW rabbits.

	Total born	Litter size (Birth-weaning)	MR(%) stillbirth kits	Litter weight (g) at: Birth	21 day	Weaning	Weight gain (g/rabbit)	Milk conversion ratio (g milk/g gain)
Treatments								
G1	7.2	6.7^{b}	7.14	257.2^{b}	1734.4^{e}	2615.8^{c}	358.3	2.74
G2	7.6	7.3^{a}	3.16	285.8^{a}	1818.3^{d}	2822.8^{b}	350.2	2.60
G3	7.5	7.2^{a}	3.16	280.8^{a}	1895.0^{c}	2855.3^{b}	358.4	2.64
G4	7.7	7.3^{a}	4.32	286.7^{a}	1945.8^{bc}	2886.4^{b}	356.3	2.63
G5	7.6	7.4^{a}	2.54	289.4^{a}	1990.8^{ab}	2999.4^{a}	367.7	2.59
G6	7.5	7.3^{a}	2.03	296.4^{a}	2038.3^{a}	3034.4^{a}	372.3	2.70
S.E	0.19	0.15	1.87	6.7	22.0	28.3	5.5	0.06
Parity								
1st	7.4	6.9^{b}	4.91	257.8^{b}	2090.7^{a}	2880.6	378.1^{a}	2.8^{a}
2nd	7.6	7.2^{ab}	4.61	289.0^{a}	1770.4^{c}	2879.4	361.5^{b}	2.7^{b}
3er	7.6	7.4^{a}	1.66	301.4^{a}	1850.3^{b}	2847.1	341.9^{c}	2.5^{c}
S.E	0.13	0.10	1.32	4.7	15.6	20.0	3.88	0.04

^{a,b} and ^{c} Means in the same Column with different superscripts are significantly different at (P<0.05). SE = Standard error of means. G1= control, G2= turmeric, G3= MOS, G4= Biostrong, G5= turmeric+ MOS, G6= MOS+ Biostrong, MR= mortality rate

Table 8: Effect of dietary interaction between treatments and parities on litter performance of NZW rabbits.

		Total born	Litter size (Birth-weaning)	MR(%) stillborn kits	Litter weight (g) at: Birth	21 day	weaning	Weight gain (g/rabbit)	Milk conversion ratio (g milk/g gain)
G1	1th	6.8	6.3	6.25	227.5	1800.0	2600.8	378.8	2.93
	2nd	7.2	6.5	8.92	258.3	1694.2	2562.5	358.6	2.78
	3rd	7.7	7.2	6.25	285.8	1709.2	2684.2	337.2	2.53
G2	1th	7.2	7.0	2.08	250.8	1941.7	2796.7	364.9	2.73
	2nd	7.8	7.3	5.55	292.5	1717.5	2870.8	352.7	2.60
	3rd	7.6	7.5	1.85	314.2	1795.8	2800.8	332.7	2.48
G3	1th	7.5	7.2	3.70	264.2	2078.3	2925.8	373.6	2.73
	2nd	7.6	7.2	5.78	384.2	1774.2	2850.0	360.1	2.65
	3rd	7.3	7.3	0	294.2	1832.5	2790.0	341.4	2.51
G4	1th	7.7	7.0	7.93	253.6	2199.3	2897.1	378.6	2.81
	2nd	7.4	7.3	1.58	295.0	1776.4	2940.0	363.7	2.65
	3rd	7.8	7.7	1.58	310.0	1883.6	2870.0	332.8	2.38
G5	1th	7.6	7.4	2.50	277.0	2281.0	3067.0	377.9	2.68
	2nd	8.0	7.4	6.66	297.0	1801.0	3041.0	371.6	2.61
	3rd	7.4	7.4	0	298.0	1887.0	2891.0	351.6	2.46
G6	1th	7.5	7.0	6.08	277.5	2257.5	3024.2	394.3	2.95
	2nd	7.5	7.5	0	307.5	1863.3	3029.2	363.7	2.60
	3rd	7.5	7.5	0	304.2	1994.2	3050.0	358.8	2.57
S.E		0.33	0.25	3.25	11.5	35.5	49.3	9.5	0.10

^{a,b} and ^{c} Means in the same Column with different superscripts are significantly different at (P<0.05). SE = Standard error of means. G1= control, G2= Tumeric, G3= Mos, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

Table 9: Effect of treatments on total protein (TP), albumin (Alb), globulin (Glb) and A/G ratio of NZW does rabbits

	TP (g/dl)	Alb (g/dl)	Glb (g/dl)	A/G ratio
Treatment group				
G1	6.30[b]	4.05[ab]	2.25[c]	1.90[a]
G2	7.40[a]	4.20[a]	3.19[b]	1.32[b]
G3	7.26[a]	4.18[a]	3.08[b]	1.37[b]
G4	7.46[a]	3.70[bc]	3.77[ab]	0.98[bc]
G5	7.20[a]	3.72[b]	3.48[b]	1.08[bc]
G6	7.57[a]	3.53[c]	4.21[a]	0.80[c]
S.E	0.17	0.11	0.22	0.15

[a,b] and [c] Means in the same Column with different superscripts are significantly different at ($P<0.05$). SE = Standard error of means. G1= control, G2= Tumeric, G3= MOS, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

Table 10: Effect of treatments on aspartate aminotransferase (AST), alanine aminotransferase (ALT), urea and Creatinine of NZW does rabbits.

	AST (U/L)	ALT (U/L)	Urea (mg/dl)	Creatinine (mg/dl)
Treatment group				
G1	37.3[a]	55.0	37.3	1.00[ab]
G2	25.7[ab]	40.0	38.7	1.09[a]
G3	25.0[ab]	37.7	34.7	0.86[ab]
G4	32.7[ab]	42.7	42.0	0.96[ab]
G5	18.7[b]	50.3	43.0	0.74[ab]
G6	27.7[ab]	51.0	43.0	0.64[b]
S.E	4.59	7.63	2.83	0.13

[a,b] and [c] Means in the same Column with different superscripts are significantly different at ($P<0.05$). SE = Standard error of means. G1= control, G2= Tumeric, G3= MOS, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

Table 11: Effect of treatments on antioxidant status of NZW rabbits.

	TAO(µmol/mg)	GPx(µmol/mg)	SOD(µmol/mg)	MDA(nmol/ml)
Treatment group				
G1	3.68[c]	1304.3[c]	434.3[c]	6.40[a]
G2	3.63[c]	1345.0[c]	462.0[c]	5.44[b]
G3	4.27[bc]	1448.7[b]	619.7[b]	4.51[c]
G4	4.81[b]	1547.7[a]	675.7[a]	4.54[c]
G4	5.71[a]	1582.7[a]	654.7[a]	4.67[c]
G6	6.44[a]	1597.3[a]	687.7[a]	4.18[c]
S.E	0.24	29.96	10.58	0.18

[a,b] and [c] Means in the same Column with different superscripts are significantly different at ($P<0.05$). SE = Standard error of means. G1= control, G2= Tumeric, G3= MOS, G4= Biostrong, G5=MOS+Tumeric, G6= MOS+Biostrong

Antioxidant enzymes

The effects of different treatments (Turmeric, MOS and Biostrong) individual or mixture form on the antioxidant profile of female rabbits during trial period are illustrated in Table 11. All rabbits in treated groups recorded a significant increased in TAO, GPx and SOD compared to control except G2. The highest value was observed for G6 in TAO, GPx and SOD. In contrast, MDA significantly decreased in rabbits treated groups compared to control group.

DISCUSSION

Stress caused by climate change or pregnancy and lactation in female rabbits increases Reactive Oxygen Species (ROS) formation and had an effect on rabbit productivity by activating cellular oxidative stress. The use of plant as feed additives that are characterized by antioxidants was one of the ways to defense as antioxidants against the formation of ROS. Supplementation with Turmeric, MOS and Biostrong as an addition to the diet of rabbits exposed to heat stress, they mitigate the harmful effect of this stress by positively affecting body weight (from mating to weaning) and feed intake. The improvement in the weight of rabbits fed diets containing Turmeric, MOS or Biostrong may be due to increased feed consumption (Alsaied, et al., 2019). In addition, Turmeric or MOS may have a stimulating effect on digestion and increased digestibility, the combinations supplement increased nutrients absorbed from the small intestine, increased nutrient utilization efficiency and led to more gain (Ibrahim, 2016). From the results obtained, the mixed form of turmeric and MOS had the highest effect on the weights of rabbits and the feed consumption. This effect of the mixture may be due to the synergistic relationship between turmeric and MOS, as turmeric has a phytobiotic activity (Okanlawon, et al., 2020) similar to that of MOS as a prebiotic (Morsy and Abd El-Lateif, 2017), as it acts as a protection against harmful bacteria to improve nutrient absorption and reflection on the health of the doe. The use of turmeric leads to a balanced gut microbial ecosystem by controlling the growth and colonization of many pathogenic species of bacteria in rabbit gut this is reflected in the better feed utilization reflected in live body weight (Al-Mashhadani, 2015). Abdel Magied et al. (2021) found that rabbits fed diet supplement with turmeric decreased the cholesterida spp content, cholestrida prevent weight gain by blocking the intestine ability to absorb fat.

On the other hand, milk yield in this experiment was high in rabbits treated with a mixture of turmeric and MOS, and this increase may be due to the increased litter size from birth to weaning this is in agreement with Okanlawon, et al. (2020) and Ragab et al. (2021) who reported that doe milk yield is positively related to litter size at weaning. The high intake of feed from rabbits treated with turmeric and MOS was reflected in an increase in milk yield (Nour El-Din, 2015; Morsy and Abd El-Lateif, 2017; Amber, et al., 2020).

The results of the study showed that milk yield of does during the first to the third parity was increased until the third lactation (Casado et al., 2006). These phytochemicals can enhance estrogen excretion, stimulating mammogenesis and milk production (Gopalakrishnan et al., 2016).

From this study, we found that milk components in terms of fat, protein and lactose were affected by adding turmeric, MOS and Biostrong to rabbit diets during pregnancy and lactation. The percentage of fat and lactose in the milk components increased, especially in the mixed groups between turmeric and MOS or between MOS and Bostrong, and the protein of the milk components decreased in all treatments this result agreement with Maertens et al. (2006) who reported that the protein content gradually decreased during the lactation weeks with increasing daily milk yield. Rabbits in group 5, especially in the third parity recorded high milk yield, this increase may be due to the interactive effect of turmeric and MOS to stimulate milk production while reducing oxidative stress caused by high temperature or physiological processes of rabbits, and it was evident in the third parity over the second and the first, to highlight the cumulative effect of additives.

Also from this study the results showed that supplementation with Turmeric, MOS or Biostrong in the diet of rabbits improved their performance under heat stress. Where the study indicated an improvement in litter size and kit weight at birth, litter weight at weaning and increased percentage of viability in bunnies from birth till weaning. The effect of turmeric on ovarian cells was reflected in the formation and growth of rabbit follicles, thus increasing the rate of ovulation. This effect was evident in increasing of litter size at birth (Alsaied, et al., 2019). The antioxidant, antimicrobial activity and essential oils in these medicinal plants which were secreted in the milk of their mothers was improved the viability in bunnies from birth to weaning Gupta and Sharma, (2014).

The mixture between Turmeric, MOS and Biostrong were increased the number of rabbits born and weaned due to the medicinal (turmeric and thymol present in Biostrong) or MOS enhance the reproductive efficiency of rabbits by reducing rabbit mortality and also improves the viability of adults (Sirotkin, et al., 2018). The best weight gain was in the group 6, and the best milk conversion ratio was in the group 5. This supports the theory that the mixed groups are more effective than the individual groups, due to the synergistic effect of additives between MOS and turmeric or between MOS and Biostrong, and the improvement was evident in the third parity than in the previous parities this is due to the cumulative effect of additives.

The increase in total Protein in the combinations containing turmeric, MOS and Biostrong may be due to better absorption of proteins from the diet due to extending the absorption surface of the intestinal wall and increased production of digestive enzymes (Bacova et al., 2020). The increase in globulin was reflected in a significant improvement in the A/G ratio in all rabbits in treated groups compared to the control. The improvement of A/G ratio was reflected in the decrease in stress of the rabbits (El-Kholy, et al., 2018), which improved their performance. Decrease in AST and ALT in rabbits in treated groups were considered a positive indicator for feeding does with Turmeric, MOS and Biostrong.

Oxidative stress is due to an imbalance between the formation of cellular free radicals and the antioxidant defense.

The cellular components are vulnerable to attack due to the excessive production of free radicals (Harrison, et al., 2003). Glutathione peroxidase plays an important role in the elimination of hydrogen peroxide, which stops the proliferation of free radicals, and this is the main protection against oxidative stress and cell death in mammals. El-Speiy, et al. (2014) found that the improved antioxidant capacity was due to the increased activity of GSH-Px and SOD (Elkomy, et al., 2021). In this study, the results showed that turmeric, MOS and Biostrong increased the TAO, GPx and SOD activities that promoted the ability of rabbits treated to resist the stress of the biological and environmental. These results were in agreement with the results of (Zeweil, et al., 2016; Abdelnour, et al., 2022).

Harrison, et al. (2003), Zeweil, et al. (2016) and Badr (2019) concluded that Turmeric, MOS and Biostrong have pharmacological antioxidant activities, especially the mixture of their, therefore, it can reduce oxidative damage to lipids and proteins as well as DNA to provide a defense against cellular damage.

Also MDA decreased in rabbits in treated groups in compared to control, especially, rabbits fed diet with MOS and Biostrong (G6), this results is in agreement with Placha et al. (2013) who suggested that thymol (component of Biostrong) contains phenolic OH groups that donate hydrogen to peroxy radicals produced during the lipid peroxidation phase and thus prevent the formation of more peroxide.

CONCLUSION

It can be concluded that the addition of turmeric, MOS and Biostrong in the diets of rabbit does reduced the effect of heat stress. Especially in the treatment with a mixture between turmeric and MOS or a mixture between MOS and biostrong, which led to an improvement in the antioxidant status, which was reflected in an improvement in the performance of rabbits, and these additions succeeded in alleviating the negative effects of heat stress conditions on the productivity and reproductive of rabbits.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

NOVELTY STATEMENT

We found that the addition of a mixture between turmeric and MOS or a mixture between MOS and biostrong can significantly improve the antioxidant status of the doe rabbits to improve the reproductive status that was affected by the stress.

AUTHORS CONTRIBUTION

NMA, HAA, MNG, NAR, EHA, YSH and HHH checked and confirmed the final revised manuscript.

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